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Financing Infrastructure in Asia

Capturing Impacts and New Sources

Edited by

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Abbreviations

ADB	Asian Development Bank
ADF	Asian Development Fund
APEC	Asia-Pacific Economic Cooperation
ASEAN	Association of Southeast Asian Nations
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
CBTA	Cross-Border Transport Agreement
CIED	Chinese Industrial Enterprise Database
CIESIN	Center for International Earth Science Information Network
CSIRO	Commonwealth Scientific and Industrial Research Organization
DID	difference-in-difference
EIB	European Investment Bank
EMDEs	emerging markets and developing economies
EOSDIS	Earth Observing System Data and Information System
ERSDAC	Earth Remote Sensing Data Analysis Center, Japan
ETF	exchange-traded fund
ETM	Enhanced Thematic Mapper
GBEs	government business enterprises
GDP	gross domestic product
GMS	Greater Mekong Subregion
GPW	Gridded Population of the World
GRUMP	Global Rural Urban Mapping Project
HAC	heteroscedasticity and autocorrelation consistent
HCMC	Ho Chi Minh City
ICT	information and communication technology
IDA	international development agencies
IPO	initial public offering
ISIC	International Standard Industrial Classification
LAN	luminosity or light at night
LLG	local level government
LNG	liquid natural gas
LP	labor productivity
MDB	multilateral development bank
MLP	master limited partnership
NSO	National Statistics Office
OECD	Organisation for Economic Co-operation and Development

OLS	ordinary least squares
PMGE	pooled mean group estimation
PNG	Papua New Guinea
PNGRIS	Papua New Guinea Resource Information System
PPI	private participation in infrastructure
PPIAF	Public–Private Infrastructure Advisory Facility
PPP	public–private partnership
PPRF	public pension reserve fund
PRC	People's Republic of China
RAMS	Road Asset Management System
RCT	randomized control trials
RIETI	Research Institute of Economy, Trade and Industry, Japan
RMUs	Resource Mapping Units
ROK	Republic of Korea
S&P	Standard and Poor's
STAR	Southern Tagalog Arterial Road
SUR	seemingly unrelated regressions
SWF	sovereign wealth fund
TBK	Toshguzar–Boysun–Kumkurgon
TFP	total factor productivity
UK	United Kingdom
UNESCAP	United Nations Economic and Social Commission for Asia and the Pacific
US	United States
VGF	viability gap funding

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Introduction

Naoyuki Yoshino, Matthias Helble, and Umid Abidhadjaev

Economic growth and investment in infrastructure go hand in hand. A growing economy needs constantly improved infrastructure to ensure that the production and exchange of goods and services happens as smoothly and efficiently as possible. Investment in infrastructure itself contributes to economic growth and can provide ample employment opportunities. Despite this reinforcing mechanism, infrastructure investment is by no means a self-sufficient. Costs typically must be borne upfront, whereas the returns can only be collected in the medium to long term. The benefits of improved infrastructure are also diffuse, in the sense that some economic agents enjoy new opportunities thanks to better infrastructure without contributing to the costs. Another problem is that infrastructure investment is typically a long-term investment carrying risks that are difficult to gauge in advance. Finally, infrastructure investments can be undertaken by the government as well as the private sector, or by both in conjunction. However, the allocation of risks and benefits in these three scenarios can be complicated. It is for all these reasons and more why infrastructure investments are challenging to undertake.

The complexity of infrastructure investment is one of the main reasons why governments in Asia and the Pacific region are investing less in infrastructure than necessary to maintain the present growth momentum. The Asian Development Bank estimated that developing Asia will need to invest $1.5 trillion per year in infrastructure through 2030 to maintain its economic growth momentum and tackle poverty[1]. This number increases to $1.7 trillion per year if one takes into account the efforts needed to tackle climate change, both in terms of mitigation and adaptation. Investment in infrastructure is not only lagging in Asia. McKinsey estimates that total infrastructure financing as a share of gross domestic product (GDP) will need to increase from around 3.8% to 5.6% by 2020 worldwide[2]. Even in advanced economies, such as the United States, plans have been proposed to rebuild and modernize ailing transport infrastructure.

1 Asian Development Bank. 2017. Meeting Asia's Infrastructure Needs. Manila.

2 McKinsey Global Institute. 2012. The future of long-term finance: Backup material. Report for Group of Thirty, November.

This book aims to provide the latest scientific evidence on infrastructure investment, including new ideas as to how to finance infrastructure. The editors thus hope that the book will make an important contribution to help Asia and the Pacific region close their infrastructure gap and continue on the path to prosperity.

The book aims to achieve two specific objectives. First, it presents the latest research on the impact of infrastructure on various economic outcomes, especially economic growth or fiscal revenues. In recent years, new evidence has been gathered on the impact and spillovers of infrastructure investment. The chapters in the first part of the book present the latest scientific research results for several Asian countries. It is hoped that this evidence will help policy makers obtain a better grasp of the full potential impact of infrastructure investment. The second objective of the book is to present an overview of the tools that can be used to finance infrastructure projects in the best possible way. Infrastructure projects can be financed in a myriad of ways. The book attempts to show the advantages and risks of the various models. Furthermore, the book introduces a novel financing method based on the idea that new infrastructure generates positive spillover effects, which can be captured and returned to the investor to increase the rate of return.

Infrastructure can be defined in various ways, but it typically encompasses a wide range of facilities and services such as water supply, sewers, power grids, and telecommunications, as well as transport infrastructure, such as roads, tunnels, and bridges. In addition to hard infrastructure, there is also soft infrastructure, which is mainly based around institutions, such as health care, education, or financial systems. This book focuses on hard infrastructure, especially transport infrastructure, electricity, and telecommunications. The authors will use the word infrastructure to refer to hard infrastructure.

Infrastructure investment has attracted the attention of economists for decades. This book adds to this long literature by studying the impact of infrastructure for various cases in Asia and the Pacific region. The analysis is mainly based on the so-called difference-in-difference (DID) approach, gravity model estimation, trans-log type production function, and other approaches. This book is the first collection of case studies using these approaches to estimate infrastructure's impact in Asia.

The book covers many aspects of infrastructure finance, and provides a very valuable overview of the existing investment tools (these tools have also been described in other publications, most recently by ADB [2017]). The novelty of this book is that it demonstrates the existence of spillover effects across time and regions as well as proposing a new type of financing scheme. The main idea is to return the spillover effects to the investor, thereby increasing the rate of return. We believe that it is worthwhile to explain this innovative solution in detail, and propose a means of putting it into practice.

The book is divided into four parts. Part I is dedicated to empirical studies that measure the impact of transportation infrastructure on economic outcomes. The first chapter attempts to answer the question of how railway infrastructure affects regional GDP in Uzbekistan. The second and third chapters show how improved transportation infrastructure have increased regional tax revenue in Japan and the Philippines.

Part II studies the impact of improved infrastructure on firms and households. Chapter 4 looks at infrastructure's impact on total factor productivity (TFP) in Japan and Thailand. Chapter 5 measures the impact of telecommunications and information and communication technology on firm productivity in the People's Republic of China (PRC). Chapter 6 finds that improved port infrastructure improved household income and educational outcomes in the Philippines. Chapter 7 shows that better roads have led to an increase in average household consumption in Papua New Guinea (PNG), and highlights various data sources that can be used for the purpose of infrastructure analysis.

Part III of the book focuses on the cross-border connectivity effects of infrastructure. Chapter 8 looks at cross-border connectivity effects with an emphasis on trade. Chapters 9 and 10 provides cross-country estimations of the trade effect of improved infrastructure in Asia and the Pacific region.

Finally, Part IV covers all questions related to financing infrastructure. Chapter 11 looks back at history and derives lessons for today. Chapters 12 and 13 review various options and modes for financing infrastructure.

The target audience of this book are policy makers in Asia and the Pacific region who face the challenge of financing increasing infrastructure in their countries. We hope that this book will help them formulate evidence-based infrastructure policies that lead to stable and sustained economic growth. The book should also be of interest for graduate students in development studies. The chapters are written by leading experts in the field of infrastructure analysis. The book uses state-of-the art econometric techniques in various setups and countries. Finally, the authors of the book have worked to ensure that their main research findings can be understood by people with a genuine interest in the topic, but without an expertise in economics. Overall, the book aims to be a reference volume for all questions related to the impact and financing of infrastructure in Asia and the Pacific region.

Chapter Overview

In Chapter 1, Yoshino and Abidhadjaev examine the nature and magnitude of the effects of infrastructure provision on regional economic performance in Uzbekistan. The analysis uses empirical evidence based on DID estimation that links changes in the growth rate of regional-level economic outcomes in affected regions to the Tashguzar–Boysun–Kumkurgon railway connection in southern Uzbekistan, conditioned on the regions' time-invariant individual effects, time-varying covariates, and evolving economic characteristics. To explore the differential nature of infrastructure provision, the authors employ an empirical model that examines the railway connection's regional, spillover, and connectivity effects, as well as its lead, launch, and lag effects. The empirical results suggest that the Tashguzar–Boysun–Kumkurgon railway line in Uzbekistan increased the regional GDP growth rate in affected regions by around 2%, in the frame of connectivity effects. This seems to have been driven by an approximately 5% increase in industry value added and 7% increase in services value added. The positive impact on agricultural output was around 1%, which is consistent with previous literature on the differential impact of public capital. The results and the framework provided may help regulatory bodies comprehensively estimate the impact of infrastructure and formulate promotional and compensatory measures related to or induced by the effects of infrastructure provision.

In Chapter 2, Yoshino and Abidhadjaev analyze the impact of the Kyushu high-speed rail line in Japan on the tax revenues of prefectures. The line began operating partially in 2004, and the entire line was opened in 2011. The authors used the DID method to estimate its impact on the Kyushu region of Japan, and compared the tax revenues of regions along the railway line with those of other regions not affected by the line. As GDP is an aggregate indicator of economic activity while fiscal revenue is directly linked to tax revenues, they focused on total tax revenue and its decomposition into personal and corporate income taxes. Their results show that tax revenues in the region increased significantly during the line's construction (1991–2003), and dropped after the start of operations in 2004. The train also positively impacted the prefectures that neighbor Kyushu, but its impact on tax revenues during 2004–2013 was lower in more distant places. This situation changed when the Kyushu line was connected to the existing high-speed Sanyo line. The study found that the line had a statistically significant and economically growing impact on tax revenue after it was completed and connected to large cities such as Hiroshima and Osaka. Tax revenues are higher in the regions near the train than in adjacent regions. The DID coefficient methods reveal that corporate tax revenue fell below personal income tax revenue during construction; however, corporate tax revenue rose after connectivity with large cities was achieved.

In Chapter 3, Yoshino and Pontines examine the impact of the Southern Tagalog Arterial Road (STAR) Tollway located in the province of Batangas, the Philippines, on the public finance of the cities and municipalities through which it directly passes. To do so, the authors use a unique dataset disaggregated into the tax (property and business taxes) and non-tax (regulatory fees and user charges) revenues of the cities and municipalities in Batangas. Based on two specifications of a modified DID model, the authors found that the STAR Tollway had a robust, statistically significant, and economically growing impact on business taxes. Yoshino and Pontines also found that this so-called "highway effect" extends to municipalities in a province that neighbors Batangas. Moreover, careful inspection and robustness checks reveal that the STAR Tollway significantly impacted not only business taxes, but also property taxes and regulatory fees. These findings support the widely held belief that infrastructure investments matter. Finally, the micro case study suggests that infrastructure investments can indirectly boost both tax and non-tax revenues.

In Chapter 4, Yoshino and Nakahigashi examine the productivity effect of infrastructure in Thailand and Japan. Specifically, they estimate the effect of infrastructure using a production function and TFP regression by industry from the 1970s to the 2010s in Thailand and Japan. In Thailand, growth accounting by industry reveals that TFP growth has increased in the manufacturing and service sectors. Conversely, TFP growth has declined in the agricultural sector, which has the lowest TFP of all considered industries. The production function analysis revealed a productivity effect from infrastructure investment only in the manufacturing sector, and the level of this effect has increased. In other industrial sectors, the productivity effects of infrastructure investment are smaller or do not exist. In Japan, growth accounting by industry and region reveals that TFP growth in secondary and tertiary industry is higher in urban areas than in rural areas. The level of TFP is also higher in urban regions than elsewhere. The authors show that a productivity effect from infrastructure investment exists in secondary and tertiary industry, and that marginal productivity decreases more rapidly in secondary industry than in tertiary industry in Japan. In secondary industry, the amount of production decreased gradually from 1990 to 2010. Hence, this result partly reflects the fact that the utilization of public capital has decreased because of the decrease in production. TFP regressions reveal that transport infrastructure investment has a positive effect on TFP in Japan, especially in secondary industry. However, in Japan, whose population is shrinking, an excess supply of transport infrastructure will appear in the future.

In Chapter 5, Zhan, Wan, and Huang use a panel of more than 44,000 manufacturing firms in the PRC from 2002 to 2007 to estimate a firm-level TFP model with three kinds of infrastructure investments: roads, telecommunications servers, and cable. The authors found that all three investment types affect firm productivity positively, and that infrastructure investments benefit firms in the western and central provinces more than those in the eastern provinces. In addition, a strong spillover effect on firm productivity from infrastructure in neighboring provinces is observed.

In Chapter 6, Helble and Francisco explore the impacts of providing an efficient and affordable transport system within a country by looking at the experience of the Philippines with the Roll-on/Roll-off (Ro-Ro) policy. They offer three analyses that examine the effects at the household and municipality levels. Firstly, the estimates show that agricultural households benefit from Ro-Ro port operation as higher incomes for both agricultural and non-agricultural activities were observed. Additionally, the estimates suggest that the island location of agricultural households relative to Ro-Ro ports does not hinder the gains from the Ro-Ro policy. Meanwhile, estimates from authors' second analysis exhibit higher school attendance in municipalities near the Ro-Ro ports, which were observed for both males and females (this impact is noticed earlier in females than in males). Finally, the third analysis reveals lower household consumption of alcoholic beverages and tobacco in areas near the Ro-Ro ports. Likewise, the authors note higher household income, implying the availability of work opportunities in areas near the Ro-Ro ports. Overall, the chapter demonstrates several unintended effects of strengthening physical linkages among local economies within a country.

In Chapter 7, Edmonds et al. evaluate the impact of road infrastructure on rural development in PNG, detailing the data collection and distillation process that provided the basis for the evaluation. This evaluation of road development in PNG compiles multiple cross-sectional data from national income and expenditure surveys with road quality and other spatial data sources into a two-period panel. The chapter starts by outlining the authors' initial efforts to explore novel data sources (such as light-at-night or luminosity data and satellite imagery) to support road impact evaluation. This review is intended to direct researchers to spatial data sources that are available for data-poor countries such as PNG. In addition, the authors briefly evaluate the usefulness of these sources in an empirical context. Finally, the chapter summarizes the findings of an econometric assessment of the impact of roads on rural development.

Investment in transport infrastructure typically aims to lower trade costs between centers of economic activity, and thereby stimulate economic exchange. In Chapter 8, Helble studies the importance of transport connectivity for international trade using the case of 14 Pacific islands. Countries in the Pacific are confronted with several structural constraints—most importantly their small size and remoteness—that make it difficult for them to integrate into the world economy. The chapter focuses on shipping connectivity and its impact on the trade performance of Pacific island countries. The chapter first introduces a new dataset containing all shipping connections within the Pacific and with the rest of the world. Combining the dataset with the corresponding trade flows allows the author to assess the importance of connectivity for trade performance in the Pacific.

In Chapter 9, Ismail and Mahyideen look at the role of infrastructure as a facilitator of trade, especially since the recent liberalization of trade in Asia has resulted in significant tariff reductions. Their study quantifies the impacts of both hard and soft infrastructure on trade volume for exporters and importers in the region, as well as on various economic growth indicators. The results demonstrate that improvements in transport infrastructure (i.e., the road density network, air transport, railways, ports, and logistics) have resulted in increased trade flows. Information and communication technology infrastructure has also enhanced trade, as increased numbers of telephone lines, mobile phones, broadband access, internet users, and secure internet servers in Asia are found to affect trade positively for both exporters and importers. In relation to soft infrastructure, the study employed three indicators, namely cost to export and import, documents needed to export and import, and time to export and import. The results show that soft infrastructure reforms can improve trade flows by reducing the cost of doing business, the number of documents needed, and the time taken to complete the procedure. The authors conclude that, although hard infrastructure has traditionally received more attention, the impact of soft infrastructure on trade flows must be examined more thoroughly.

The Greater Mekong Subregion, comprising Cambodia, the Lao People's Democratic Republic, Myanmar, Viet Nam, and Thailand, as well as Yunnan Province and Guangxi Zhuang Autonomous Region of the PRC, has recently seen remarkable progress in the development of cross-border transport infrastructure along its "economic corridors." In Chapter 10, Fujimura uses three approaches to evaluate cross-border transport infrastructure in the Greater Mekong Subregion. First, the author presented partial attempts to produce benefit–cost ratios for the North–South, East–West, and Southern Economic Corridors. The estimates indicate that the Southern Corridor is the most economically viable, followed by the North–South, and East–West Corridors. The result for the Southern Corridor fits well with an insight from a gravity model framework, as the corridor includes three large economies—Bangkok, Ho Chi Minh City, and Phnom Penh—along its relatively short length (about 900 kilometers). In contrast, the East–West Corridor includes no large economies (except Da Nang) along its route, which is about 1,450 kilometers long. The East–West Corridor was presumably built with the intention of yielding benefits in the long term, and may do so in 10–20 years.

In Chapter 11, Yoshino and Stillman describes the history of infrastructure financing, with a focus on the experiences of the United States and Japan. In the past, many infrastructure projects with public good character were successfully completed by attracting private finance. Privately-owned railway companies in the United States and Japan would mostly service their massive debt by selling or developing gifted real estate that was either adjacent to the tracks or part of their rightsofway. Yoshino and Stillman, have been able to draw upon useful elements from forgotten experiences and overlooked prototypes to synthesize practical features of infrastructure financing relying on spillover effects estimated in the first part of the book.

In Chapter 12, Regan presents a status report about the methods, strengths, and limitations of infrastructure financing in Asia and the Pacific region as of 2017. Asia and the Pacific region is the world's fastest growing regional economy, a position it has held for over a decade. A major challenge for sustained regional growth and development and greater engagement among national economies is increased investment in economic and social infrastructure. Governments provide the majority of infrastructure as a public good; however, since 2005, private capital has increased to account for around 22% of investment and around 40% of infrastructure finance, mainly in the telecommunications, energy, and transport sectors. The chapter adopts a positivist perspective, examines contemporary supply and demand conditions, and makes several recommendations for future policy development in regional countries.

Similar to Chapter 12, Chapter 13 by Inderst evaluates infrastructure investment and finance in Asia from a global perspective. The chapter provides an overview of infrastructure needs and the various sources of private finance, both globally and within Asia, and creates a "bigger picture" of the demand for and supply of capital for infrastructure by using a simple framework: percentages of GDP. Although the picture is expectedly not uniform across Asia, Inderst reveals some interesting features that emerge from global comparisons. Overall, the private sector still plays a relatively subdued role. Bank loans dominate private infrastructure finance, and there is much scope to develop capital markets further. The volumes of listed and unlisted investment instruments, of project finance, and of public–private partnerships remain small relative to investment needs and well below the global average. However, there are some notable exceptions.

Institutional investors are widely seen as a new financing source for infrastructure. The investment landscape in Asia has some distinctive features, such as the prominence of large pension reserve funds and sovereign wealth funds, and comparatively weak private long-term savings institutions. The current asset allocation to infrastructure by domestic investors is overall very low, and the attractiveness for foreign investors remains subpar. Expectations as to the future involvement of investors in this field should be realistic, and there are barriers and risks that must be worked on. Governments in Asia can take steps to attract more private capital.

PART I

Economic Impact of Infrastructure Investment

1

An Impact Evaluation of Infrastructure Investment: The Case of the Tashguzar–Boysun–Kumkurgon Railway in Uzbekistan

Naoyuki Yoshino and Umid Abidhadjaev

1.1 Introduction

Defined as the basic physical and organizational structures and facilities needed for the successful operation of a society or enterprise, infrastructure affects economic activity in at least three ways. First, the quantity and quality of the infrastructure supply, such as electric power or clean water in a region, directly affect investors' decisions in terms of whether or not to launch a business. This results in variations in household income levels, state tax revenues, and the region's general economic performance.[1] Second, improvements in information and communication technology infrastructure results in more mobile and fixed-line telephone subscribers, and internet users. This significantly and positively affects the rate of economic growth by improving productivity and eliminating information asymmetry. Third, the provision of new infrastructure in the form of paved roads and railway connections creates new opportunities to expand the goods market for firms and the job market for labor, bringing the market closer to economic agents through better accessibility and improved mobility. If

[1] In examining the high-altitude railway connecting the province of Qinghai to the Tibet Autonomous Region as a natural experiment, Wang and Wu (2012) found a 33% increase in GDP per person in counties that were affected by the railway connection relative to those that were not.

resource allocation varies across regions, with and without particular types of infrastructure, underlying systematic differences in many dimensions should cumulatively affect economic outcomes.

This chapter investigates the effect of infrastructure provision on the economic outcomes of regions affected by new infrastructure facilities. The empirical evidence, which was obtained by employing a difference-in-difference (DID) approach to investigate commonly accepted assumptions on timing and the points of impacts, takes advantage of a multitude of perspectives and a unique dataset created for the purposes of the study.

We examine the impact of railway connections on the gross domestic product (GDP) growth rate and sector value added of regions in Uzbekistan, a Central Asian country that—along with other economies in transition—has gradually been reforming and rebuilding its own integrated railway connection system since the collapse of the Soviet Union in 1991. Identifying the causal contexts explains the variation in the growth rates of the economic outcomes according to the regions' exposure to the new railway's positive effects, and allows regions to be classified into three categories based on how they were affected. We address the following questions:

(i) Did the changes driven by the introduction of the new railway connection significantly affect the economic performance of the regions exposed to them relative to those that were not?
(ii) Has the new railway connection caused any spillover or connectivity effects across regions?

Similarly, it is nearly impossible to prove definitively how a railway connection might affect economic outcomes or capture all of the perennial effects derived from such a connection.[2] Yet, this does not lessen the degree of policy relevance in understanding whether and how infrastructure provision influences regional economies within a country. It is important for central governments to understand the performance of infrastructure projects when reviewing the economic viability of future infrastructure projects arising from budgetary

2 Schumpeter (1912: Chapter I) explains that the concept of economic development is an object of economic history that is "only separated from the rest for purposes of exposition," and concludes that "because of this fundamental dependence of the economic aspect of things on everything else, it is not possible to explain economic change by previous economic conditions alone." Consequently, the same is true for subsequent impacts, because "heteronomous elements generally do not affect the social process in any such sector directly...but only through its data and conduct of its inhabitants...the effects only occur in the particular garb with which those primarily concerned dress them" (Schumpeter 1912: 58).

constraints. This is a particularly sensitive issue in developing countries with underdeveloped internal capital markets, because the demand for infrastructure finance in middle- and low-income countries always outweighs the supply of available funds. Thus, multilateral development agencies and donors targeting investment in infrastructure projects in developing countries should evaluate the exact magnitude and significance of the impact of a particular type of infrastructure on economic outcomes.

In summary, the empirical results suggest that the Tashguzar–Boysun–Kumkurgon railway line led to an approximately 2% increase in the GDP growth rate in the examined regions. This effect seems to be driven by an estimated 5% increase in industry value added and 7% increase in services value added. The impact on agricultural output has been moderate relative to the sectors mentioned above (around 1%), which is consistent with previous literature on the differential impact of public capital (Yoshino and Nakahigashi 2000). As well as revealing varying impacts across space and time, and among sectors, this study yielded counterintuitive results concerning the effect of railway line provision on regional economic performance: regions located at the far ends of the within-country railway system seem to experience statistically significant and growth-inducing impacts on their economies relative to the regions where the new railway line is actually located.

1.2 Literature Review

The identification of the relevance of infrastructure to economic activity can be traced back to classic works in economics, such as those by Adam Smith, Karl Marx, and Friedrich Hayek. Although these authors had drastically different core views and paradigms concerning the principles or nature of economic issues, they were united in addressing the importance of infrastructure for economic activity.

Smith unquestionably understood the crucial difference between infrastructure capital and other forms of capital. He classified infrastructure capital into two types, "circulating capital" and "fixed capital," and defined the latter as that used "in erecting engines for drawing out the water, in making roads and wagon-ways, etc." (Smith 1776). Beyond simply describing the role of such capital, Smith provided clear examples of infrastructure's impact on interactions among producers, customers, landowners, and retailers, thus justifying infrastructure financing options. Similarly, Hayek described two kinds of production factors, "economic permanent resources" (a proxy for infrastructure capital), and "non-permanent production goods" (Hayek 1947).

Surprisingly, most later models of economic growth theory that became widely known—including the 1946 Harrod-Domar model, the 1956 Solow-Swan model, the 1965 Ramsey-Cass-Koopmans model, and the 1988 Lucas model—either missed or omitted the notion of infrastructure capital, although their models greatly improved our understanding of the role and interrelationship of capital, labor, human capital spillovers, and technological progress.

Thus, although the question of economic growth and its determinants arose in the 18th century, at the same time that economics became a separate discipline, it was not until 1989 that Aschauer examined core infrastructure capital in his empirical work relating the provision of infrastructure after World War II to variations in economic growth in the United States (US). His provocative findings were considered seminal in empirical work and caused a commotion in the field, followed by both confirmatory (Eisner 1994) and counterfactual (Hulten and Schwab 1991; Harmatuck 1996) arguments. Inspired by the growing debate on the impact of infrastructure initiated by Aschauer (1989), other estimations using proxies for public infrastructure capital were subsequently carried out using data for different countries (Yoshino and Nakahigashi 2000; Arslanalp et al. 2010). Due to data availability, most of these studies dealt with developed countries.

One of the earliest empirical examinations of the economic effects of infrastructure using statistical data for Asian countries was conducted by Yoshino and Nakahigashi (2000), who employed a production function approach to examine the productivity effect of infrastructure for Japan and Thailand, distinguishing social capital stock by region, industry, and sector.[3] They found that the productivity effect of infrastructure is

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[3] They also explained the transformation mechanism of infrastructure investment and economic growth, dividing its effect into so-called direct and indirect effects. A direct effect is defined as an additional output due to an increase in marginal productivity, which occurs due to an increase in infrastructure. An indirect effect is described as an additional output due to increased labor and private capital input based on an increase in infrastructure. In particular, the theoretical framework employed constitutes a trans-log type production function in which infrastructure capital, private capital, and the labor force are included as factor inputs, as follows:

$$Y = f(K_p; L; K_g)$$

where Y denotes output, K_p is the private capital stock, L is the labor input, and K_g is the infrastructure stock. Relating the output to the aforementioned factor inputs, they estimated both the direct and indirect effects from infrastructure provision, expressed as follows:

$$\frac{dY}{dK_g} = \frac{\partial Y}{\partial K_g} + \frac{\partial Y}{\partial K_p}\frac{\partial K_p}{\partial K_g} + \frac{\partial Y}{\partial L}\frac{\partial L}{\partial K_g}$$

greater in tertiary industries than in primary and secondary industries, and their sectoral analysis revealed greater impacts in the information, telecommunications, and environmental sectors. From a regional perspective, the effect of infrastructure provision appears greater in regions with large urban areas.

In addition to the production function approach, economists have used a wide range of different approaches to explore the nature of infrastructure, including dual-cost or profit function and vector autoregression approaches. As Pereira and Andraz (2013) note, most these approaches address issues associated with estimating the magnitude and significance of the contribution of public capital to infrastructure, but cannot account for the possibility of structural change or breaks. Thus, general consensus on the economic impact of infrastructure investment is lacking, possibly due to the methodology chosen, the sample periods covered, or ignorance of the structural breaks that such infrastructure might induce.

Randomized trial or treatment effects methods, which are widely used to evaluate programs in the context of development studies, are helpful in estimating total impact. Assuming a common time path and the availability of pre- and post-treatment data on outcome variables of interest, researchers can estimate the degree of departure from the counterfactual trajectory, which can be attributed to the provision of treatment—in this case, some kind of infrastructure. In particular, in evaluating the impact of the National Trunk Highway System in the People's Republic of China (PRC), Faber (2014) found that the network connections led to a reduction in GDP growth among peripheral counties, which were non-targeted or lay outside the network system. Similarly, Gonzalez-Navarro and Quintana-Domeque (2010) presented evidence of the impact of infrastructure on poverty reduction, where within 2 years of the provision of infrastructure in the form of paved roads, household consumption of durable goods and the purchase of motor vehicles increased. This study uses a similar approach, distinguishing the scope of analysis for Uzbekistan by time frame, sector, and region.

The body of literature covering middle-income countries has been increasing in recent years, particularly studies related to the PRC (Wang and Wu 2012; Ward and Zheng 2013; Faber 2014) and some East Asian countries (Yoshino and Nakahigashi 2000), mainly driven by their remarkable growth and improved data dissemination conditions. However, the empirical literature examining either infrastructure's role or its differential impact on economic outcomes in the context of Central Asian countries remains limited. This chapter attempts to shed light on the performance of infrastructure by focusing on the case of a railway connection in Uzbekistan.

1.3 Background

To understand the current state of the unintegrated railway system in Central Asia, it is necessary to comprehend the history of its creation and how the Central Asian Railway was developed. In 1880, construction began on a railway from Uzun to Ada in the west of present-day Turkmenistan, at Michael Bay in the Caspian Sea. The railway ran in the direction of Kizir-Arvat through Ashgabat, Mary, Chardzhou, Bukhara, and Samarkand, later reaching Khavas, Tashkent, and the Fergana Valley in the east of present-day Uzbekistan. After the fall of the Russian Empire and rise of the Soviet Union, construction of railway lines continued with the aim of facilitating greater connectivity between the outer and central regions.

As the neighboring socialist republics that were part of the Soviet Union were not considered foreign countries at this time, in many cases a railway line in one republic crossed the territory of neighboring republics to reach other parts of its own territory. Consequently, after the Soviet Union collapsed and customs procedures were established, this design created significant obstacles to mobility and connectivity among the newly independent countries. As a result, each post-Soviet republic faced the challenge of adjusting its disjointed railway lines and paved inter-city roads to form a single within-country system.

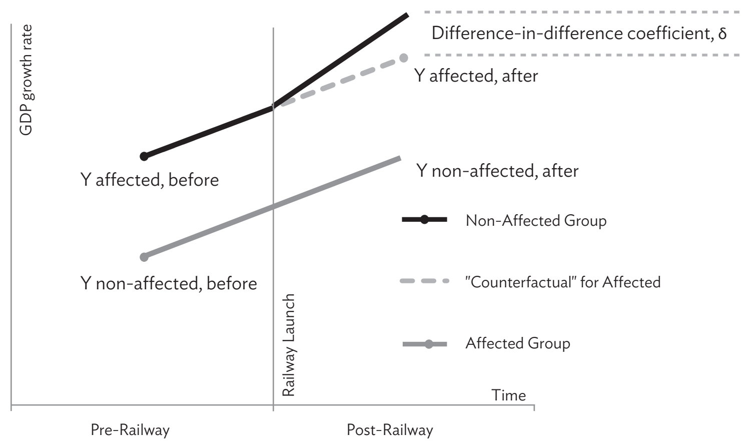
The Government of Uzbekistan has been gradually creating infrastructure to achieve this goal. Of the various government measures intended to improve transportation infrastructure, four major projects should be outlined: (i) the repair and construction of the A-373 Tashkent–Osh highway connecting Tashkent, the capital city, with the Fergana Valley in eastern Uzbekistan; (ii) the construction of the Navoi–Uchkuduk–Sultan Uvaystog–Nukus railway line connecting the north of the country to the center; (iii) the construction of the Toshguzar–Boysun–Kumkurgon (TBK) railway (the project examined in this study), linking the southern Surkhadarya region to the single within-country railway system; and (iv) the construction of the Angren–Pap electrical railway line, which will connect the unintegrated railway system in the eastern regions (in the Fergana Valley) with the Tashkent region, thus providing railway mobility across all regions of the country.

1.4 Methodology

This analysis aims to capture the economic dimensions of infrastructure provision, especially the variations in outcome variables affected by the introduction of a railway connection. To accomplish this, we employ a DID approach that allows us to estimate the difference between the observed "actual" outcome and an alternative "counterfactual" outcome.

To undertake this estimation, it is necessary to divide the data into control and treated groups on the basis of geography and time, making the difference between pre-intervention or baseline data and post-intervention data. Figure 1.1 provides a graphical illustration of the framework. This study differs from others in that it investigates generally accepted assumptions about the division of these groups in the framework, both in cross-sectional terms and based on time series.

Figure 1.1 Illustration of the Difference-in-Difference Method with the Gross Domestic Product Growth Rate Outcome Variable



GDP = gross domestic product.
Source: Authors.

First, with regard to geographical impacts, we estimate regional, spillover, and connectivity effects, and describe the rationale for and definitions of these impacts. After providing the framework for these assumptions, we check for outcome variations due to changed assumptions in terms of timing, and consider the lead, launch, and lag effects of infrastructure provision. These data are used to estimate the impact of the TBK railway line launched in 2007–2008

Table 1.1 Numerical Estimation of the Difference-in-Difference Coefficient Using Regional Data for Uzbekistan, 2005–2008 and 2009–2012

Region Group	Outcome	Pre-Railway Period	Post-Railway Period	Difference
Non-affected group	Average GDP growth rate (%)	8.3	8.5	0.2
Affected group	Average GDP growth rate (%)	7.2	9.4	2.2
				2.0

GDP = gross domestic product.
Notes: The affected group includes the regions of Samarkand, Surkhandarya, Tashkent, and the Republic of Karakalpakstan. The rest of the observations are included in the non-affected group.
Source: Authors' calculations.

in southern Uzbekistan on the economic outcomes of the affected regions during 2009–2012, as represented by regional GDP and its components, including agricultural, industrial, and services value added.

By using the sample analog of the population, the DID coefficient can be easily computed numerically by observing changes in the variable of interest over time in both groups and calculating their differences (Table 1.1).

This allows us to control for time-invariant, region-specific effects to proxy a region's idiosyncratic features proceeding from historical, cultural, and social development, as well as year-specific effects to capture the effect of changes in legislation or the overall business climate. However, a wide range of other factors besides infrastructure provision and these effects can also cause changes in economic performance. If these factors' positive effects are not accounted for, our estimates may be biased upward (downward) by positive (negative) effects generated by other factor inputs. The program evaluation literature mentions and documents this difficulty as an external validity problem (Rodrik 2008; Banerjee and Duflo 2009; Ravallion 2009). To overcome this problem, we must acknowledge the factors behind changes in the economic growth rate and control for time-varying covariates, such as investment share, labor force, terms of trade, and others.

The regression framework allows us to control for the covariates mentioned previously and obtain a less-biased estimate of the DID coefficient. The baseline estimation strategy of the DID specification takes the following form:

$$\Delta Y_{it} = \alpha_i + \varphi_t + \beta X_{it} + \delta D_{gt} + \epsilon_{it}$$

where ΔY is the regional GDP growth rate; X denotes the time-varying covariates (vector of observed controls); D is the binary variable indicating whether or not the observation relates to the affected group after the provision of the railway line; i indexes regions; g indexes groups of regions (1 = affected group, 0 = non-affected group); t indexes treatment before and after ($t = 0$ before the railway, $t = 1$ after the railway); α_i is the sum of autonomous (α) and time-invariant, unobserved, region-specific (γ_i) rates of growth;[4] φ_t is the year-specific growth effect; and ϵ_{it} is the error term, assumed to be independent over time.

The vector of observed controls, X, can be classified into micro- and macro-level factors. Macro-level factors are represented by government spending on education, research and development, and healthcare, with spending on healthcare defined as the sum of expenditure and including the provision of health services (preventive and curative), family planning activities, nutrition activities, and emergency aid designated for health, but excluding the provision of water and sanitation. Micro-level factors comprise the percentage of the working population (the ratio of those aged 16–64 to the total population), the investment share of the state and the private sector (classified as population, enterprises, commercial banks, foreign investors, and off-budget funds), and terms of trade (the ratio of total exports to imports in a given period).

To account for both time-invariant unobserved characteristics (e.g., the advantageous location of a region) and year-specific growth effects (e.g., favorable changes in the business climate), we use a fixed-effects estimator. If we assume that such factors do not determine the nature of changes in the control variables, we can use a random effects estimator; however, this would ignore important information on how the variables change over time when region-specific characteristics are correlated with time-varying covariates.

Following Bertrand, Duflo, and Mullainathan (2004) with regard to possible autocorrelation within a region, we employ heteroscedasticity and autocorrelation consistent (HAC) standard errors, which belong to the class of clustered standard errors. HAC standard errors allow for heteroscedasticity and arbitrary autocorrelation within a region, but treat the errors as uncorrelated across regions, which is consistent with the fixed-effects regression assumption of independent and identical distribution across entities, in our case regions $i = 1,\ldots14$.

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4 This approach requires the assumption of a common time path or parallel trends, accepting the autonomous rate of growth α to be equal in both the affected and non-affected groups.

As part of our sensitivity analysis, we execute non-hierarchical stepwise inclusion of additional variables such as initial services per capita, which is mainly based on the convergence theory and might also explain the magnitude of a region's growth rate. Furthermore, we employ various functional forms, including cubic and quadratic forms, of the state's investment share. Post-estimation diagnostics in the form of testing the exclusion of variables were carried out for year-fixed effects, and the equality of the coefficients of the state investment share with the remaining three types was tested.

1.4.1 Assumptions Concerning the Geographical Impact of Infrastructure Provision

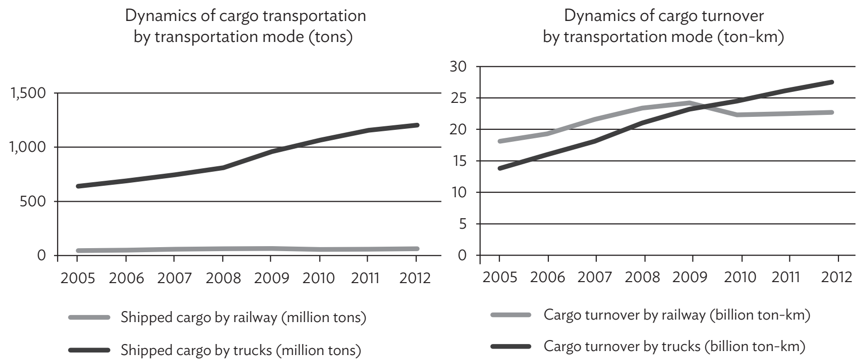
First, with regard to the geographical context, we examine the assumption that infrastructure provision has a regional effect, influencing economic performance in the location where the infrastructure is located, in this case the Surkhandarya and Kashkadarya regions of Uzbekistan. The literature provides empirical evidence from the testing of a similar hypothesis using a production function approach (Yoshino and Nakahigashi 2000; Seung and Kraybill 2001; Stephan 2003; Abidhadjaev and Yoshino 2013), a behavioral approach (Moreno, López-Bazo, and Artís 2003; Cohen and Paul 2004), and vector autoregression approaches (Everaert 2003; Pereira and Andraz 2010), among others.

Second, quasi-experimental methods for evaluating the impact of a particular intervention usually require the affected and non-affected groups to be clearly distinguished (see Duflo, Glennerster, and Kremer [2008]). The inappropriate assignment of observational data into treated or control groups might complicate the objective and comprehensive assessment process. In this respect, the empirical literature can help us explore different combinations of treated or affected groups based on patterns revealed through previously conducted studies. Consequently, proceeding from the analysis of Pereira and Andraz (2013), who revealed a pattern of negative or insignificant effects of infrastructure provision at the regional level (see also Yoshino and Abidhadjaev [2015]), and positive and significant effects at the aggregate level (Pereira and Andraz 2005; Belloc and Vertova 2006), we address the railway connection's spillover effects on neighboring regions. Empirical evidence derived from the analyses conducted by Pereira and Andraz (2003), who used a vector autoregression approach for transport and communications infrastructure, and by Pereira and Roca-Sagales (2007), who used this approach for highways, demonstrates the positive spillover effects of infrastructure provision on neighboring regions.

Third, we looked at empirical evidence obtained from the literature on transportation mode choice (Wang et al. 2013) and connectivity (Faber 2014). Wang et al. (2013) analyzed interstate freight mode choices between truck and rail in Maryland, US, and found that longer distances contribute positively to the use of rail as a means of transportation. The impact of distance on the choice of rail had been demonstrated earlier by Jiang, Johnson, and Calzada (1999), who used data for France, and by Beuthe et al. (2001), who computed the modal elasticity of Belgian freight by employing origin–destination matrices and cost information. Based on these studies, we examine the railway connection's connectivity effect by designating the regions at the far ends of the within-country railway system as potential beneficiaries.

Before proceeding with the third empirical context, it is necessary to confirm that the pattern revealed in these studies also applies to the case of Uzbekistan. This is illustrated in Figure 1.2, which describes two main indicators related to the transportation of goods in Uzbekistan by different modes of transportation. In terms of cargo transportation, which uses payload mass measured in tons, the dynamics of transportation by railway for the period 2000–2013 are lower than those of transportation by truck.

Figure 1.2 Transport Mode Choice in Uzbekistan by Cargo Versus Cargo Turnover, 2005–2012



bln = billion, mln = million, ton-km = ton-kilometer.

Note: Cargo transportation is an indicator that defines the volume of cargo in tons, transferred by means of the transportation of enterprises, the main activity of which is cargo carriage. Cargo turnover is an indicator of the volume of carriage operations of the transport mode, taking into account the distance of transportation by tons per kilometer.

Source: Statistics Committee of the Republic of Uzbekistan (2014).

However, in terms of cargo turnover, which also takes into account the distance of transportation, the indicator for rail for the majority of the period either surpasses or equals that of truck transportation. This demonstrates the positive impact of distance on the choice of rail as a mode of transportation.

The last step to support the distance argument is to compare the length of both the railway lines and paved roads actually available in Uzbekistan to check for the absence of physical constraints on trucks transporting cargo over long distances. Table 1.2 clearly demonstrates that in 2013 the length of paved roads available (42,654 km) was 10 times greater than that of railway lines (4,187 km). This shows that the higher cargo turnover indicator for railway transportation is not due to constraints on truck transportation, but rather the conventional nature of transportation mode choice consistent with previous empirical evidence.

This study examines three possible contexts for evaluating the impacts of infrastructure: (i) regional effects, which capture the direct effect of infrastructure on the regions in which it is located; (ii) spillover effects, which include neighboring affected regions; and (iii) connectivity effects, which examine variations in outcome variables in the regions at the far ends (terminal stations) of the within-country railway system and hub region after the introduction of a new railway line.

Table 1.2 Transport Modes in Uzbekistan, 2005–2013

Transportation Mode	Railway Lines		Main Pipelines	Highways	
Year	Total length (km)	Railway lines with electrification (km)	Total length (km)	Total length (km)	Roads of international importance (km)
2005	4,014	593.9	13,452	42,530	3,626
2006	4,005	593.9	13,144	42,539	3,626
2007	4,230	589.0	13,402	42,558	3,626
2008	4,230	589.0	13,716	42,557	3,626
2009	4,230	589.0	13,716	42,537	3,626
2010	4,227	674.3	14,280	42,654	3,979
2011	4,258	727.4	14,280	42,654	3,979
2012	4,192	702.0	14,325	42,654	3,979
2013	4,187	698.2	14,342	42,654	3,979

km = kilometer.
Source: State Statistics Committee of the Republic of Uzbekistan (2014).

1.4.2 Assumptions about the Timing of the Impact of Infrastructure Provision

Regarding the timing of the impact, we examine launch, lead, and lag effects.

The launch effect captures the impact of infrastructure provision immediately following the commissioning of the railway line. The TBK railway commenced operation in August 2007;[5] however, of the line's five bridges (its vital components), only two were constructed by the end of 2008,[6] and the remaining three were not completed until July 2009.[7] Thus, the launch period is assumed to fall after 2008, covering the period 2009–2012.[8] Within the post-railway or post-treatment period, we differentiate between short-term (2 years), mid-term (3 years), and long-term (4 years) effects. Therefore, our regression framework takes the following form:

$$\Delta Y_{it} = \alpha_i + \varphi_t + X'_{it}\beta + \delta\left(D_{gt\{2010:2009\}}\right) + \epsilon_{it}$$

$$\Delta Y_{it} = \alpha_i + \varphi_t + X'_{it}\beta + \delta\left(D_{gt\{2011:2009\}}\right) + \epsilon_{it}$$

$$\Delta Y_{it} = \alpha_i + \varphi_t + X'_{it}\beta + \delta\left(D_{gt\{2012:2009\}}\right) + \epsilon_{it}$$

where $D_{gt\{2010:2009\}}$ is the binary variable indicating that the observation relates to the group affected by the railway line and corresponds to the period 2009–2010. Conversely, one could conclude that such treatment is endogenous and target a technical solution by choosing a set of instrumental variables. A major subset of the literature queries the feasibility of treating infrastructure provision as a randomized trial, since the design process suggests that economically significant provincial regions may influence railway planning, raising the question of the endogeneity of the treatment itself.

The disjointed railway system in former Soviet Union countries compromised economic outcome levels in connected regions. The fact that Uzbekistan's central government initiated the construction of the

5 http://railway.uz/ru/gazhk/transport/. Website of joint stock company "O'zbekiston temir yo'llari"

6 Gazeta. https://www.gazeta.uz/ru/2008/12/26/bridges/.

7 Gazeta. https://www.gazeta.uz/ru/2009/07/29/bridges/.

8 For a study that uses alternative assumptions, see Yoshino and Abidhadjaev (2017).

railway makes it easier to address the issue of reverse causality and the treatment of endogeneity, assuming that rail routing was assigned randomly and was not influenced by the performance of local economies or the policies of local administrations. Furthermore, the influence of unobserved variables, such as the community's political preferences, on both the dependent variable and the intervention itself, can easily be dealt with using panel data (see Elbers and Gunning [2013]), which we exploit in framing our study. Understanding the background to the examined project and its relationship to the outcome variables may help differentiate between the presence of endogeneity and the occurrence of lead (ex ante) effects, both of which may be revealed as pre-trends in the scope of the analysis. Understanding that expectations may affect the outcome variable of interest makes it possible to assess the projects under consideration more comprehensively.

Anticipation of the infrastructure project might have positive economic effects, serving as positive shocks to the investment climate or trade terms. For example, Rose and Spiegel (2011) found that even unsuccessful bids to host the Olympics positively impacted a country's exports, and concluded that what matters most is what countries signal to international markets when making such a bid.

With a lesser degree of information asymmetry, the existence of forward-looking agents whose responses anticipate future treatment may make it necessary to evaluate impacts that cause changes in outcomes before the implementation of a new program or provision of a railway connection. Malani and Reif (2011) survey the literature and list the frameworks for the paradigm of a policy effect that occurs at time $t + k$, but is announced or adopted during an earlier period, at time t.

After incorporating 1 and 2 years of lead effects into the post-treatment period, the regression framework including lead effects for full short-, mid-, and long-term impact evaluation takes the following form:

With 1 year of lead:

$$\Delta Y_{it} = \alpha_i + \varphi_t + X'_{it}\beta + \delta\left(D_{gt\{2010:2008\}}\right) + \epsilon_{it}$$

$$\Delta Y_{it} = \alpha_i + \varphi_t + X'_{it}\beta + \delta\left(D_{gt\{2011:2008\}}\right) + \epsilon_{it}$$

$$\Delta Y_{it} = \alpha_i + \varphi_t + X'_{it}\beta + \delta\left(D_{gt\{2012:2008\}}\right) + \epsilon_{it}$$

With 2 years of lead:

$$\Delta Y_{it} = \alpha_i + \varphi_t + X'_{it}\beta + \delta\left(D_{gt\{2010:2007\}}\right) + \epsilon_{it}$$

$$\Delta Y_{it} = \alpha_i + \varphi_t + X'_{it}\beta + \delta\left(D_{gt\{2011:2007\}}\right) + \epsilon_{it}$$

$$\Delta Y_{it} = \alpha_i + \varphi_t + X'_{it}\beta + \delta\left(D_{gt\{2012:2007\}}\right) + \epsilon_{it}$$

where $D_{gt\{2010:2008\}}$ is the binary variable indicating that the observation relates to the group affected by the railway line and corresponds to the period 2008–2010.

Similar to lead effects, lag effects from infrastructure provision are also a possibility; that is to say, businesses might respond to the launch of a new railway line with some lag. Similar to the inclusion of lead effects in the full impact evaluation, the same adjustment can be made to incorporate lag effects with 1 and 2 years of lag, as follows:

$$\Delta Y_{it} = \alpha_g + \varphi_t + X'_{it}\beta + \delta\left(D_{gt\{2012:2010\}}\right) + \epsilon_{it}$$

$$\Delta Y_{it} = \alpha_g + \varphi_t + X'_{it}\beta + \delta\left(D_{gt\{2012:2011\}}\right) + \epsilon_{it}$$

where $D_{gt\{2012:2010\}}$ is the binary variable indicating that the observation relates to the group affected by the railway line and corresponds to the period 2010–2012.

The variables of interest in our analysis, besides regional GDP, are the sector components. Sectoral studies of infrastructure investment (Yoshino and Nakahigashi 2000; Pereira and Andraz 2003) indicate that the impact of infrastructure investment might have differential effects on economic sectors. The scope of this analysis covers agricultural, industrial, and services value added.

Data

We created a unique panel dataset containing information on the economic characteristics of regions in Uzbekistan via a compilation of yearly and quarterly data from the State Statistics Committee of the Republic of Uzbekistan (2014), and yearly reports from the Ministry of Finance of Uzbekistan (2014), for the period 2005–2012. Descriptive statistics for all outcome variables for the affected regions are provided in Tables 1.3–1.5.

Regional GDP, which serves as the outcome variable in our analysis, is defined as the part of Uzbekistan's GDP produced in the territory of the corresponding region—the first-order administrative division.

Table 1.3 Summary Statistics for Outcome Variables for Regional Effects

Regional Effects Context

Affected Administrative Divisions:
Kashkadarya and Surkhandarya regions

Di = regional = 0					
Variable: Growth rate (%)	**Number of observations**	**Mean**	**Standard deviation**	**Minimum**	**Maximum**
Regional GDP	96	8.5	2.8	0.6	18.6
Industrial output	96	11.5	8.4	−5.3	36.8
Agricultural output	96	5.7	2.8	0.0	13.7
Services	96	17.6	5.9	4.8	35.4
Di = regional = 1					
Variable: Growth rate (%)	**Number of observations**	**Mean**	**Standard deviation**	**Minimum**	**Maximum**
Regional GDP	16	7.4	2.5	3.1	11.7
Industrial output	16	8.6	6.4	−2.4	18.9
Agricultural output	16	5.3	3.3	0.8	12.8
Services	16	18.0	8.0	7.4	34.1

GDP = gross domestic product.
Source: State Statistics Committee of the Republic of Uzbekistan (2014).

These include 12 regions, the autonomous Republic of Karakalpakstan, and the city of Tashkent. In addition to regional GDP, the State Statistics Committee of the Republic of Uzbekistan (2014) provides consistent data on growth rates for its three essential components: agricultural output, industrial output, and services.

The notion of agricultural output in the context of our analysis consists of the combination of subsectors that constitute agricultural production (crop production and animal husbandry) according to the International Standards of Industrial Classification: forestry, fishery, and hunting.

Similarly, industrial output is considered to be the sum of data on the volume of products of individual industrial enterprises. The Statistics Committee of Uzbekistan defines this stock of output as the cost of all final products produced and the cost of semifinal products realized by enterprises during the period under review, as well as the cost of production-related works carried out by the enterprises during the same period. According to the International Standards of

Industrial Classification, this output includes such sectors as mining, manufacturing, and construction, as well as the output of enterprises that supply electricity, water, and gas. Furthermore, Uzbekistan's social and economic accounts classify the outputs of the mining and manufacturing industries as industrial output.

"Services" corresponds to the real growth rate of the total monetary amount of rendered services, such as communications, transport, retail, wholesale, hotel and restaurant businesses, and warehouses. This indicator also includes enterprises and institutions that render financial, insurance, real estate-related, business, community, and social and private services (education and healthcare).

Table 1.4 Summary Statistics for Outcome Variables for Spillover Effects

Spillover Effects Context

Affected Administrative Divisions:
Bukhara, Kashkadarya, Samarkand, and Surkhandarya regions

Di = spillover = 0					
Variable: Growth rate (%)	**Number of observations**	**Mean**	**Standard deviation**	**Minimum**	**Maximum**
Regional GDP	80	8.4	2.9	0.6	18.6
Industrial output	80	11.5	8.7	–5.3	36.8
Agricultural output	80	5.6	2.9	0.0	13.7
Services	80	17.6	5.8	7.0	35.4
Di = spillover = 1					
Variable: Growth rate (%)	**Number of observations**	**Mean**	**Standard deviation**	**Minimum**	**Maximum**
Regional GDP	32	8.0	2.4	3.1	13.6
Industrial output	32	10.2	6.9	–2.4	24.6
Agricultural output	32	6.0	2.9	0.8	12.8
Services	32	17.6	7.3	4.8	34.1

GDP = gross domestic product.
Source: State Statistics Committee of the Republic of Uzbekistan (2014).

With respect to the explanatory variables in our specification, the report also provides highly detailed information on the dynamics of different types of investment shares in Uzbekistan's regions. Investments are divided into public sector investments (made by the

Table 1.5 Summary Statistics for Outcome Variables for Connectivity Effects

Connectivity Effects Context

Affected Administrative Divisions:
Samarkand, Surkhandarya, and Tashkent regions; the Republic of Karakalpakstan

Variable: Growth rate (%)	Number of observations	Mean	Standard deviation	Minimum	Maximum
Di = connectivity = 0					
Regional GDP	80	8.3	2.9	0.6	18.6
Industrial output	80	11.0	8.8	–5.3	36.8
Agricultural output	80	5.6	2.9	0.0	13.7
Services	80	17.5	6.7	4.8	35.4
Di = connectivity = 1					
Variable: Growth rate (%)	**Number of observations**	**Mean**	**Standard deviation**	**Minimum**	**Maximum**
Regional GDP	32	8.2	2.3	3.0	13.6
Industrial output	32	11.5	6.7	0.3	28.6
Agricultural output	32	6.0	3.0	0.1	12.8
Services	32	17.8	5.1	11.1	33.1

GDP = gross domestic product.
Source: State Statistics Committee of the Republic of Uzbekistan (2014).

state), and private sector investments (made by the public, banks, and foreign companies). The State Statistics Committee of Uzbekistan defines foreign direct investment as a net inflow of investment to acquire a lasting management interest with 10% or more of voting stock in an enterprise operating in an economy other than that of the investor. This is the sum of equity capital, reinvestment of earnings, and short- and long-term capital.

Yearly time-series variables indicating government expenditures on healthcare, education, and research and development are derived from yearly reports by the Ministry of Finance of the Republic of Uzbekistan (2014).

1.6 Empirical results

First, we estimate the model of equation (4) in a specification including the percentage of the labor force and total investment as the only explanatory variables, together with an interaction term that captures the DID coefficient. In their influential paper, Mankiw, Romer, and Weil (1992) found that these factors together with human capital explained more than 80% of the variation in the GDP growth rate. Consequently, our baseline specification is augmented by including government spending on education, healthcare, and research and development. However, it is first necessary to identify the impacts attributed to tax revenue from mineral resources and favorable trade terms on a region's growth rate (see Barro [1996]). Finally, to account for potential nonlinearities where government expenditure as part of a fiscal stimulus might have an ambivalent effect on the economy (Bruckner and Tuladhar 2010), the quadratic term of the state investment share, as well as its reciprocal, are used in the regression model.

Table 1.6 presents the empirical results for nine versions of the model of equation (4). The interaction term reported in the table, *Di = connectivity x Dt = 2012–2009*, compares the trajectory for the counterfactual scenario without infrastructure provision to the actual performance of the regions after the launch of the new railway line in the frame of connectivity effects (for the Republic of Karakalpakstan, and the Samarkand, Surkhandarya, and Tashkent regions) for the 4-year period from 2009 to 2012, defined as "long-term" in the scope of our analysis. Similarly, the scope of regional effects focuses on the Surkhandarya and Kashkadarya regions, the actual geographical location of the new railway line, whereas the hypothesis of spillover effects considers these regions together with the adjacent Bukhara and Samarkand regions.

Regression 1 exhibits the simplest specification form and has a DID coefficient of 1.43, meaning that the introduction of the railway connection in the Surkhandarya and Kashkadarya regions led to higher regional GDP growth (by 1.43%) in the four regions at the far ends of the railway system relative to the counterfactual scenario of the growth trend. However, this regression does not consider year-specific conditions, which might put upward pressure on the economy in these regions, although it does account for region-specific idiosyncratic characteristics. Regression 2 solves this problem by controlling for time-specific characteristics, increasing the coefficient of the interaction term to approximately 1.90. Subsequent F-statistics testing the exclusion of the groups of variables confirm the strong significance of time-specific effects in regional GDP growth as represented in the column for regression 2 in Table 1.6. This suggests that year-specific effects inform changes in overall legislation or that the general business climate in the transition economy might be significantly relevant for the regions' economic performance. This also makes it necessary to consider the issues of heteroscedasticity and autocorrelation.

Table 1.6 Regional Gross Domestic Product Growth Rate and Railway Connection: Estimation Output for the Long-Term Connectivity Effects Context

	Regression 1	Regression 2	Regression 3	Regression 4	Regression 5	Regression 6	Regression 7	Regression 8	Regression 9
Time period	**2005–2012**	**2005–2012**	**2005–2012**	**2005–2012**	**2005–2012**	**2005–2012**	**2005–2012**	**2005–2012**	**2005–2012**
State effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time effects	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Clustered standard errors	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant term	–12.7	11	11	13	15	–39	–40	–32	–35
	(9.0)	(17)	(12)	(12)	(12)	(40)	(41)	(40)	(41)
DI = connectivity x Dt = {2012:2009}	1.43*	1.90**	1.90***	1.73***	1.67***	1.82**	1.83**	2.05***	2.07***
	(0.80)	(0.79)	(0.54)	(0.55)	(0.54)	(0.76)	(0.83)	(0.66)	(0.68)
Percentage of working population	0.36**	-0.08	–0.08	–0.06	–0.07	–0.02	–0.05	–0.01	0.01
	(0.16)	(0.31)	(0.21)	(0.21)	(0.22)	(0.30)	(0.34)	(0.31)	(0.26)
Total investment	–0.00013	-0.00042	-0.00042	–0.00040	–0.00032	0.00091	0.00096	0.00120	0.00114
	(0.00053)	(0.00059)	(0.00059)	(0.00045)	(0.00053)	(0.00070)	(0.00069)	(0.00075)	(0.00077)
Tax revenue from mineral resources				–0.0095	–0.0107	0.050*	0.046	0.043	0.043
				(0.0058)	(0.0065)	(0.025)	(0.027)	(0.025)	(0.026)
Terms of trade (ratio of exports and imports)					–0.052	–0.083	–0.080	–0.065	–0.051
					(0.059)	(0.067)	(0.065)	(0.059)	(0.064)
Investment by population						0.052*	0.050*	0.057**	0.070**
						(0.025)	(0.026)	(0.025)	(0.032)
Investment from bank loans						0.05	0.07	0.10	0.12
						(0.13)	(0.14)	(0.13)	(0.14)

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Table 1.6 *continued*

	Regression 1	Regression 2	Regression 3	Regression 4	Regression 5	Regression 6	Regression 7	Regression 8	Regression 9
Time period	**2005–2012**	**2005–2012**	**2005–2012**	**2005–2012**	**2005–2012**	**2005–2012**	**2005–2012**	**2005–2012**	**2005–2012**
Investment by foreign investors						0.037	0.036	0.052*	0.063**
						(0.033)	(0.031)	(0.028)	(0.025)
Investment from bank loans x treat_dummy						0.16	0.16	0.14	0.13
						(0.16)	(0.17)	(0.15)	(0.16)
Government expenditure: education						0.035	0.038	0.031	0.030
						(0.048)	(0.048)	(0.048)	(0.049)
Government expenditure: healthcare						−0.025	−0.022	−0.029	−0.026
						(0.071)	(0.076)	(0.079)	(0.077)
Government expenditure: research and development						−2.3	−2.5	−1.9	−1.9
						(1.7)	(1.6)	(1.5)	(1.6)
Initial services per capita						−0.00068	−0.00117	−0.00087	−0.00092
						(0.00066)	(0.00094)	(0.00086)	(0.00091)
Investment by state							−0.034	−0.030	−0.029
							(0.023)	(0.025)	(0.025)
Investment by state_ reciprocal								−3.8**	−3.4*
								(1.5)	(1.7)
Investment by state^2									0.00126
									(0.00190)

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Table 1.6 *continued*

	Regression 1	Regression 2	Regression 3	Regression 4	Regression 5	Regression 6	Regression 7	Regression 8	Regression 9
Time period	**2005–2012**	**2005–2012**	**2005–2012**	**2005–2012**	**2005–2012**	**2005–2012**	**2005–2012**	**2005–2012**	**2005–2012**
F-statistics and p-values testing exclusion of group of variables									
Time effects = 0		4.18 (0.0005)	13.72 (0.0000)	16.63 (0.0000)	14.95(0.0000)	17.83 (0.0000)	14.79 (0.0000)	16.55 (0.0000)	19.09 (0.0000)
Investment from state budget = Investment from population							9.49 (0.0088)	11.97 (0.0042)	11.3 (0.0051)
Investment from state budget = Investment from bank loans and others							0.51 (0.4895)	0.97 (0.3426)	1.17 (0.2984)
Investment from state budget = Investments by foreign investors							2.05 (0.1758)	3.35 (0.0903)	4.92 (0.0449)
Investment bank loans and other = Investments by foreign investors						0.01 (0.9069)	0.05 (0.8339)	0.15 (0.7022)	0.19 (0.6741)
Number of observations	112	112	112	112	112	112	112	112	112
R2	0.14558409	0.35879783	0.35879783	0.36092367	0.36234278	0.44656874	0.45200681	0.46666631	0.47036421

Notes: Standard errors are given to two significant digits (in parentheses), and the coefficients are given to the same decimal place as the corresponding standard errors.
* Significant at the 10% level.
** Significant at the 5% level.
*** Significant at the 1% level.
Source: Authors' calculations.

Following discussions on potential autocorrelation within a region (Bertrand, Duflo, and Mullainathan 2004), regression 3 employs HAC standard errors, which allow for heteroscedasticity and arbitrary autocorrelation within entities but treat the errors as uncorrelated across regions. In our analysis, this perspective is consistent with the fixed-effects regression assumption of independent and identical distribution across entities. As a result, although regression 3 reports DID coefficients that are identical in magnitude to those of regression 2, the corresponding standard errors indicate that regression 2 yields a more precise estimate than that from regression 3.

The next step of the analysis, in regressions 4 and 5, examines the hypothesis of the so-called "resource curse", as well as changes in external trade, for which, depending on the country's institutional quality, the nature of the economic growth response to trade changes might be dubious (see Fosu [2011]). To compute an unbiased coefficient of the interaction term in our regression analysis, we partial out the impacts of total tax revenues from mineral resources and trade volatility calculated for each region in the form of an export–import ratio, following Barro (1996). The role played by the added variables in our augmented specification with respect to the DID coefficient confirms our expectations: in regression 4, both the value of the coefficient of interest and its significance is lower than in regression 3, and controlling for terms of trade in regression 5 further decreases this characteristic of the interaction term. The magnitude of the DID coefficient decreases from around 1.90 to 1.73 in regression 4 and to 1.67 in regression 5. However, controlling for tax from mineral resources and terms of trade in both regressions, we obtain a statistically significant impact from the introduction of the railway connection, as demonstrated by the economic performance of the regions at the far ends of the railway system.

The non-hierarchal stepwise inclusion of additional variables provides us with four more specifications of estimation equations, with regression 9 considered the representative regression in the scope of our analysis.[9] Differentiating the investment share by financing source in total investment reverses the trend of obtaining lower coefficients of the interaction term (1.82 in regression 6 and 1.83 in regression 7), but produces less-precise estimates relative to the specifications in regressions 4 and 5. Regressions 8 and 9 address concerns about non-linearity and the dependency of state investments on the level of

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9 This follows from the property of conditional variance, which states that $E[Var(y|x)] \geq E[Var(y|x,z)]$ (see Wooldridge [2010]). If the mean squared error (MSE) for function m is defined as $MSE(y;m) \equiv E\left[\left(y - m(x)\right)^2\right]$, then $MSE\ [y; E(y|x)] \geq MSE[y; E(y|x,z)]$.

government implementation (Bruckner and Tuladhar 2010) by including the squared term of the variable for the share of public investment, as well as its reciprocal. These augmentations further increase the impact of the interaction term on regional GDP growth, increasing the values of the coefficient to 2.05 in regression 8 and 2.07 in regression 9. These point estimates are more precise than those in regressions 6 and 7.

Regarding the nuisance parameters, once we control for nonlinearities, the investment shares by the population and foreign investors are identified as significant factors influencing regional economic performance, based on the nature of government investments reported in the literature. These might be related to the absence of the agency problem and information asymmetry compared with public investment. In this respect, by estimating vector autoregressions for 14 European Union countries, as well as Canada, Japan, and the US, Afonso and Aubyn (2009) found that public investment between 1960 and 2005 had a contractionary effect on output in five cases, namely, GDP growth rates in Belgium, Canada, Ireland, the Netherlands, and the United Kingdom. Furthermore, positive public investment impulses led to a decline in private investment, suggesting potential crowding-out effects. Similar to our results, Afonso and Aubyn (2009) report that private investment impulses were always expansionary in terms of GDP and the effects were higher in terms of statistical significance.

Investigating the assumptions and frameworks for regional scope and timing provides a wide range of specification combinations to estimate.

Given our set of assumptions concerning the geographical location, timing, and timeframe of the impact, our analysis comprises the following steps: first, we estimate all 1,188 versions of the regressions[10] arising from the combinations listed above; then, in Tables 1.7–1.10, we report the coefficients of the interaction term corresponding to the specification adopted for regression 9 in Table 1.6. Each of the four subsequent tables contains 33 coefficients placed in accordance with the chosen assumptions on timing and geographical location, varying by the dependent variable of interest. Our estimate of 2.06 with a standard error of 0.68 is found in Table 1.7, which reports the estimated DID coefficients with the variable of interest set as the regional GDP growth rate. The coefficient is displayed in the corresponding cell at the juxtaposition of the row for long-term launch effects and the column

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10 The 1,188 versions are derived as follows: four dependent variables (GDP growth rate, agricultural value added, industrial value added, and services value added) x three geographical combinations (connectivity, regional, and spillover effects) x 11 assumptions about timing (launching effects: short-, mid-, and long-term; lead effects: 1 year and 2 years, short-, mid-, and long-term; lag effects: 1-year and 2-year lags) x nine specifications of regressions.

for connectivity effects. Similarly, the coefficients of the interaction term linked to the growth rate of sectors are in Tables 4.8 (agriculture), 4.9 (industry), and 4.10 (services).

Table 1.7 presents the empirical results of the DID coefficient for the regional GDP outcome variable. The impact of infrastructure provision after launch in terms of connectivity effects demonstrates a positive and significant effect for railway connection. Regions located at the far ends of the railway system seem to be experiencing increased GDP growth rates of about 2.8% in the short term, 2.5% in the mid-term, and 2.1% in the long term. This result is consistent with previous empirical studies that reveal the positive role of distance in the use of rail as a transportation mode (Jiang, Johnson, and Calzada 1999; Beuthe et al. 2000; Wang et al. 2013). The regional effect of the railway connection appears positive in both the short term (0.4%) and medium term (0.7%).

Table 1.7 Difference-in-Difference Coefficients with the Gross Domestic Product Outcome Variable

			Connectivity Effect	Regional Effect	Spillover Effect
		Di / Dt	Dg = connectivity	Dg = regional	Dg = spillover
Launch Effects					
	Short-term	Dt = 2010:2009	2.83*** (0.63)	0.70 (1.60)	1.30 (1.20)
	Mid-term	Dt = 2011:2009	2.51*** (0.36)	0.40 (1.20)	1.27 (0.87)
	Long-term	Dt = 2012:2009	2.06*** (0.68)	−0.40 (1.40)	2.29** (0.78)
1 year	**Lead Effects**				
	Short-term	Dt = 2010:2008	0.19 (0.57)	0.85 (0.48)	−0.18 (0.90)
	Mid-term	Dt = 2011:2008	0.31 (0.61)	0.64 (0.49)	−0.02 (0.66)
	Long-term	Dt = 2012:2008	0.07 (0.53)	−0.01 (0.60)	0.50 (0.74)
	Lag Effects	Dt = 2012:2010	1.76* (0.90)	−1.50 (2.10)	2.60* (1.30)
2 years	**Lead Effects**				
	Short-term	Dt = 2010:2007	−1.54 (0.93)	1.40 (1.80)	−1.30 (1.40)
	Mid-term	Dt = 2011:2007	0.32 (0.73)	0.84 (0.59)	0.13 (1.01)
	Long-term	Dt = 2012:2007	0.11 (0.73)	0.10 (0.62)	0.87 (0.73)
	Lag Effects	Dt = 2012:2011	−0.14 (0.70)	−1.70 (1.30)	1.05 (0.72)

Notes: Standard errors are given to two significant digits (in parentheses), and the coefficients are given to the same decimal place as the corresponding standard errors.
* Significant at the 10% level.
** Significant at the 5% level.
*** Significant at the 1% level.
Source: Authors' calculations.

The hypothesis of spillover effects documented in regional-level studies by Pereira and Andraz (2003) for states in the US and Pereira and Roca-Sagales (2007) for regions of Spain is also found to hold in the case of Uzbekistan. Assuming launch effects, the magnitude of the long-term impact is around 2.3%. Finally, in the framework of lag effects, whereby we estimate the impact of the railway connection with a 1-year lag, growth rate differences are approximately 1.8% for connectivity effects and 2.6% for spillover effects.

The results for the agricultural sector in relation to connectivity effects provide positive and statistically significant (at the 10% level) coefficients of about 3% for the short term and 2% for the medium term (see Table 1.8). In the long term, comprising a 4-year period in terms of launch effects, this coefficient is approximately 1%. A similar perspective in relation to regional and spillover effects provides coefficients of

Table 1.8 Difference-in-Difference Coefficients with the Agriculture Outcome Variable

			Connectivity Effect	Regional Effect	Spillover Effect
		Di Dt	Dg = connectivity	Dg = regional	Dg = spillover
Launch Effects					
	Short-term	Dt = 2010:2009	3.0* (1.5)	1.4 (1.9)	0.7 (1.3)
	Mid-term	Dt = 2011:2009	2.06* (0.98)	0.10 (2.01)	0.4 (1.3)
	Long-term	Dt = 2012:2009	0.98 (0.66)	−0.7 (1.0)	−0.10 (1.01)
1 year	**Lead Effects**				
	Short-term	Dt = 2010:2008	0.7 (1.1)	0.35 (0.71)	−1.05 (0.81)
	Mid-term	Dt = 2011:2008	0.32 (0.91)	−0.39 (0.69)	−1.05 (0.79)
	Long-term	Dt = 2012:2008	−0.56 (0.69)	−1.25* (0.68)	−1.98** (0.70)
	Lag Effects	Dt = 2012:2010	−1.1 (1.1)	−0.98 (0.75)	0.28 (0.96)
2 years	**Lead Effects**				
	Short-term	Dt = 2010:2007	−1.0 (1.2)	−0.3 (1.9)	−2.0 (1.4)
	Mid-term	Dt = 2011:2007	−1.18 (0.83)	−0.20 (0.74)	−0.87 (0.78)
	Long-term	Dt = 2012:2007	−2.48*** (0.65)	−1.2 (1.9)	−2.0 (1.2)
	Lag Effects	Dt = 2012:2011	−1.7 (1.4)	−3.2** (1.4)	−1.1 (1.1)

Notes: Standard errors are given to two significant digits (in parentheses), and the coefficients are given to the same decimal place as the corresponding standard errors.
* Significant at the 10% level.
** Significant at the 5% level.
*** Significant at the 1% level.
Source: Authors' calculations.

approximately –1.3% and –2.0% in the case of lead effects. This could be because business decisions in the agricultural sector may have been affected by considerations relating to the rail connection from the region in which the infrastructure was located, and its neighboring regions, to the center of the country. Faber (2014) documents a similar result, whereby the provision of the National Trunk Highway System network in the PRC led to reduced output growth among peripheral regions, instead of diffusing production in space.

Table 1.9 shows the results of the estimation of the DID coefficient when the outcome variable is industrial output. Consistent with the findings of Yoshino and Nakahigashi (2000), which reveal the varying impact of infrastructure over sectors, our empirical results indicate the railway connection's positive, long-term impact on industrial output after its launch, with estimates of approximately 5.2% for connectivity,

Table 1.9 Difference-in-Difference Coefficients with the Industry Outcome Variable

			Connectivity Effect	Regional Effect	Spillover Effect
		Di / Dt	Dg = connectivity	Dg = regional	Dg = spillover
Launch Effects					
	Short-term	Dt = 2010:2009	5.3* (2.7)	3.1 (4.6)	2.8 (2.8)
	Mid-term	Dt = 2011:2009	4.5 (2.8)	2.6 (3.2)	2.1 (2.6)
	Long-term	Dt = 2012:2009	5.2 (3.5)	3.2 (4.7)	3.5 (3.8)
1 year	**Lead Effects**				
	Short-term	Dt = 2010:2008	2.5 (1.4)	3.9** (1.5)	4.0** (1.6)
	Mid-term	Dt = 2011:2008	2.5 (1.7)	3.7* (1.8)	3.4* (1.7)
	Long-term	Dt = 2012:2008	3.8 (2.3)	4.6 (3.1)	5.1* (2.8)
	Lag Effects	Dt = 2012:2010	6.1 (3.7)	–0.2 (7.0)	3.9 (4.1)
2 years	**Lead Effects**				
	Short-term	Dt = 2010:2007	–0.8 (3.4)	4.8 (6.8)	4.0 (3.7)
	Mid-term	Dt = 2011:2007	3.9* (2.0)	3.7 (3.0)	5.2** (2.2)
	Long-term	Dt = 2012:2007	5.8** (2.1)	4.6 (3.4)	8.1 (3.3)
	Lag Effects	Dt = 2012:2011	1.6 (3.5)	1.1 (4.3)	0.6 (3.2)

Notes: Standard errors are given to two significant digits (in parentheses), and the coefficients are given to the same decimal place as the corresponding standard errors.
* Significant at the 10% level.
** Significant at the 5% level.
*** Significant at the 1% level.
Source: Authors' calculations.

3.2% for regional effects, and 3.5% for spillover effects. The industrial sector also demonstrates significant and positive short- and mid-term effects in relation to lead effects for regional and spillover effects. The coefficients for the short-term lead effects are approximately 3.9% for regional effects and 4.0% for spillover effects.

The services sector, including tourism hospitality and passenger and cargo transportation, indicates a significant and positive coefficient, achieving the highest magnitude among the analyzed sectors (Table 4.10). In relation to the launch effects, the short-, mid-, and long-term impacts of the railway connection differentiated the growth rate of the services sector in the regions located at the far ends of the railway system by approximately 7.8%, 6.5%, and 6.9%, respectively. The results for the regional and spillover effects appear

Table 1.10 Difference-in-Difference Coefficients with the Services Outcome Variable

		Di / Dt	Connectivity Effect Dg = connectivity	Regional Effect Dg = regional	Spillover Effect Dg = spillover
Launch Effects					
	Short-term	Dt = 2010:2009	7.8** (2.5)	−3.9 (7.4)	0.0 (3.0)
	Mid-term	Dt = 2011:2009	6.5* (2.7)	−1.8 (8.3)	0.4 (4.1)
	Long-term	Dt = 2012:2009	6.9** (2.5)	−1.5 (8.5)	3.1 (4.3)
1 year	**Lead Effects**				
	Short-term	Dt = 2010:2008	4.2 (2.5)	−3.6 (5.1)	−3.0 (3.6)
	Mid-term	Dt = 2011:2008	4.1 (2.9)	−2.3 (6.6)	−2.3 (4.0)
	Long-term	Dt = 2012:2008	5.4 (3.2)	−2.2 (7.0)	−0.9 (4.3)
	Lag Effects	Dt = 2012:2010	0.9 (3.0)	−0.0 (2.0)	3.1 (3.8)
2 years	**Lead Effects**				
	Short-term	Dt = 2010:2007	4.7* (2.1)	0.4 (4.0)	−3.2 (3.9)
	Mid-term	Dt = 2011:2007	4.6 (2.7)	−0.2 (4.8)	−2.6 (3.4)
	Long-term	Dt = 2012:2007	6.6* (2.9)	0.4 (5.4)	−0.9 (3.5)
	Lag Effects	Dt = 2012:2011	1.3 (2.8)	3.0 (5.3)	4.0 (2.6)

Notes: Standard errors are given to two significant digits (in parentheses), and the coefficients are given to the same decimal place as the corresponding standard errors.
* Significant at the 5% level.
** Significant at the 1% level.
Source: Authors' calculations.

negative but statistically insignificant in our analysis. Interestingly, the services sector does not seem to react in lead of the railway connection, possibly because it is unable to accumulate or store services, unlike the industrial sector.

1.7 Conclusions

This study examined the impact of a railway connection in southern Uzbekistan to determine the nature of change in the economic performance of regions affected by the newly provided infrastructure. The empirical evidence derived from DID estimation for regional, spillover, and connectivity effects focused on the regional GDP growth rate, and agricultural, industrial, and services values added.

Our underlying hypothesis was that changes in the growth rates of economic outcomes at the regional level in treated regions would be induced only through the newly built railway connection, conditional on the regions' individual (time-invariant) effects, investment, government spending, natural resource extraction, external trade turnover, and evolving economic characteristics (year effects). Having investigated the impact of the railway connection on economic outcome variables in the regions where the infrastructure is located, as well as neighboring regions, and defining these effects as either regional or spillover, we estimated the connectivity effects, which emphasize the observation of variation in the economic performance of the regions located at the far ends of the within-country railway system. Our empirical results suggest that the TBK railway line encouraged an around 2% increase in regional GDP growth in these regions. The railway connection's regional effects appear positive but smaller in magnitude in the short term (0.4%) and medium term (0.7%).

In the spectrum of economic sectors, the positive effect reflected in regional GDP seems to be driven by approximate increases of 5% in industrial output and of 7% in aggregate services. The effect on agricultural output is moderate relative to other sectors, constituting around 1% for connectivity effects, which is consistent with previous literature on the impacts of public capital.

In particular, as the introduction of the railway line in one part of the country has caused positive changes in the economic performance in other parts, it is important to determine which group of regions has experienced the greatest increase in economic performance based on the provision of the infrastructure within a limited period of time. The findings of this study suggest that the railway connection has not only positively impacted the region in which it is located, but also contributed to economic growth in the most geographically distant parts of the country. However, it is necessary to note that, although our research framework was formulated to constitute a comprehensive evaluation obtained by juxtaposing the aspects of location, time, and sector, the results of the empirical study are open for discussion and are far from final.

Finally, it should be noted that although the current study provides empirical results related to the impact of infrastructure provision using regional data for Uzbekistan, the nature of the effects of the infrastructure provision might be mirrored throughout the transition economies in Central Asia, as well as in other developing countries in Asia that might share common processes that accompany emerging markets.

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2

Impact of Infrastructure Investment on Tax: Estimating the Spillover Effects of the Kyushu High-Speed Rail Line in Japan on Regional Tax Revenues

Naoyuki Yoshino and Umid Abidhadjaev

2.1 Introduction

Infrastructure is important for the economic development of a country, and economists understand well the multiplicative effect of telecommunication and road infrastructure on society and a country's economy. Railways play a particularly significant role in a country's connectivity and interconnectedness (Yoshino and Abidhadjaev 2015a). Better infrastructure facilitates international trade by reducing transportation costs (Ando and Kimura 2013), and infrastructure in the form of mobile and landline phones helps to overcome issues of information asymmetry, thus directly affecting investors' behavior and decisions to invest in a particular region.

Japan has made considerable infrastructure investments based on development plans adopted in the early 1950s and late 1980s and 1990s: in particular, the Five-Year Economic Independence Plan (1956–1960), which aimed to rehabilitate traffic and telecommunication facilities; the New Long-Term Economic Plan (1958–1962), which focused on reinforcing transportation capacity by modernizing roads; and the National Income Doubling Plan (1961–1970), which focused on developing infrastructure to reinforce industrial infrastructure. Two other development plans—Co-Prosperity with the World (1988–1992) and the Five-Year Economic Superpower Plan (1992–1996)—addressed the development of the highway transportation network, with the aim of decentralizing the economy (Yoshino and Nakahigashi 2000).

Using the Kyushu bullet train as an example, we examine the economic impact of infrastructure investment. Taking into account the importance of fiscal balance and infrastructure provision, we use tax revenues by prefecture to compare the economic effects of this rail line. In contrast to gross domestic product (GDP), an aggregate indicator of economic activity, government fiscal revenues are directly linked to tax revenue. Therefore, we focus on the total tax revenues of prefectures, as well as their decomposition into personal and corporate income taxes. Total tax revenues also include property and sales tax, among others.

This chapter focuses on three different time periods with respect to the rail line: (i) construction; (ii) operation before connectivity; and (iii) operation after connectivity. We applied the difference-in-difference (DID) approach to determine the railway connection's impact on the tax revenues of each affected prefecture. We found that, while railways with no connection to large cities boost tax revenues during construction, revenues decline after construction ends while the line operates as an autonomous branch. This situation changes when the line is connected to large cities. Despite the line's positive impact on neighboring prefectures, emerging patterns indicate that the line has a lesser impact on tax revenues in more distant prefectures.

During construction, the DID coefficients for corporate tax revenue were lower than they were for personal income tax revenue, but increased after the railway was connected to large cities.

2.2 Literature Review

Aschauer's seminal 1989 empirical work linking the supply of public infrastructure to economic growth in the United States led to an explosion in the field. His findings were followed by both confirmatory (Eisner 1994) and counterfactual (Hulten and Schwab 1991; Harmatuck 1996) arguments, indicating the statistically significant impact of public infrastructure.

Motivated by the growing debate regarding the impact of infrastructure, corresponding estimations using data for other countries were subsequently carried out (Yoshino and Nakahigashi 2000; Arslanalp et al. 2010). One of the earliest empirical studies on infrastructure's economic effects using data for Asian countries was conducted by Yoshino and Nakahigashi (2000), who employed a translog-type production-function approach to examine infrastructure's productivity effect for Japan and later Thailand, distinguishing social capital stock by region, industry, and sector. They found that infrastructure's productivity effect is greater in tertiary industries than in primary or secondary industries. Their sectoral analysis suggested that the largest impacts occur in the environment and information and telecommunication sectors. From a regional perspective, infrastructure supply appears to have a greater impact in urban areas and those with a relatively large population.

Although most of these frameworks addressed issues related to estimating the magnitude and statistical significance of infrastructure's contribution to economic growth, they did not account for the possibility of structural breaks (Pereira and Andraz 2013). General consensus on the economic effects of infrastructure capital is lacking due to not only the chosen framework, but also the sample periods covered, or because structural breaks brought about by the provision of such infrastructure were not taken into account.

Quasi-experimental methods that assume a common time trend and the availability of pre- and post-treatment data on outcome variables of interest provide an alternative framework for estimating the impact of infrastructure investment. It is possible to estimate the degree of departure from the counterfactual scenario attributable to the provision of treatment, in this case a particular form of infrastructure such as a railway or highway. Estimating the DID coefficients may provide a clearer picture of the net difference resulting from the introduction of an infrastructure facility.

This approach is increasingly being used in infrastructure studies. In particular, Yoshino and Abidhadjaev (2015b) used regional data for Uzbekistan to demonstrate that the introduction of the Tashguzar–Boysun–Kumkurgan (TBK) railway had positive effects during its design and construction, as well as after operations began. They also observed significant variations in outcome variables of interest from regional GDP and sector value added. Their empirical results suggest that the TBK railway induced positive and significant changes in regional GDP growth in the affected regions—those located at the far ends of the railway system—in the frame of so-called "connectivity effects." Consideration of regional GDP in Uzbekistan revealed that these variations were brought about by increases of approximately 5% in industry and 7% in services value added. Similarly, Gonzalez-Navarro and Quintana-Domeque (2010) proved the effect of infrastructure investment on poverty reduction: within 2 years after the provision of infrastructure (paved roads), local households purchased motor vehicles and the consumption of durable goods increased.

Conversely, Faber's 2014 evaluation of the national trunk highway system in the People's Republic of China indicated that network connections might have led to a decline in GDP growth among peripheral counties that were either not targeted or lay outside the network system. Similarly, Donaldson (forthcoming), used archival data from colonial

India to show that, although railroads decreased trade costs and interregional price gaps, they harmed neighboring regions that had no railroad access, leaving the overall magnitude of the net effect under question.

Few studies link infrastructure provision to regional fiscal performance. A notable example is that of Yoshino and Pontines (2015), who linked a newly built infrastructure project, the Southern Tagalog Arterial Roadway highway, to changes in tax revenues by using municipalities' time-invariant individual effects, time-varying covariates, evolving economic characteristics, and the DID estimation strategy. Specifically, they found that the Southern Tagalog Arterial Roadway highway had a robust, statistically significant, and economically growing impact on business taxes, property taxes, and regulatory fees. Similar to Yoshino and Abidhadjaev (2015b), they also supported the hypothesis of spillover effects across territory and time, whereby the positive impact of infrastructure provision extends to neighboring regions and seems to either anticipate or lag behind the project.

Our study also focuses on the fiscal performance of Japanese prefectures and first-order administrative divisions, and links variations in tax revenues to the new Kyushu rail line, distinguishing the spillover impacts by region, adjacency, and connectivity.

2.3 Methodology

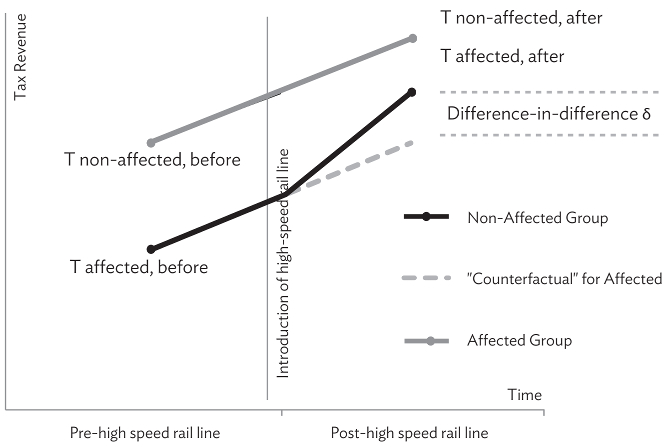
This section describes our empirical strategy based on the DID approach. Our analysis aims to capture the economic dimension of infrastructure provision, in particular by linking the introduction of the Kyushu train to the variations in outcome variables observed in total tax revenue, personal and corporate income tax revenue, and tax revenue from other sources.

To accomplish this, we employ an empirical strategy with a DID approach, distinguishing the degrees of geographic focus as regional and spillover effects. This allows us to estimate the net difference between the observed "actual" outcome, and an alternative "counterfactual" outcome for a given region and time frame.

To carry out this estimation, we divide the data into control and treated groups on the basis of geography and time, distinguishing between pre-intervention or baseline data and post-intervention data (graphically illustrated in Figure 2.1). The novel contribution of this study is its interrogation of generally accepted assumptions about the division of these groups within the framework.

First, we look at the geographic context and estimate three spillover effects by region, adjacency, and connectivity.

Figure 2.1 Illustration of the Difference-in-Difference Method with the Outcome Variable of Tax Revenue



Source: Authors.

The estimation of spillover effects by region includes two subsets (Table 2.1): (i) the Kagoshima and Kumamoto regions, which were affected by the construction and operation of the bullet train; and (ii) these regions plus the Fukuoka prefecture, which is located at one end of the Kyushu rail line. Studies using a similar regional analysis include those of (i) Yoshino and Nakahigashi (2000), Seung and Kraybill (2001), Stephan (2003), and Yoshino and Abidhadjaev (2015a) (who use the production-function approach); (ii) Moreno, López-Bazo, and Artís (2003) and Cohen and Paul (2004) (who use the behavioral approach); and (iii) Everaert (2003) and Pereira and Andraz (2010) (who use vector autoregression approaches). As Pereira and Andraz (2013) demonstrate, evaluations of infrastructure impact have found both negative and positive regional effects. This may be due to the regions' inability to internalize positive externalities fully from public infrastructure provision.

In considering spillover effects due to adjacency, in addition to the three prefectures mentioned above, this analysis also looks at the Oita, Miyazaki, Saga, and Nagasaki prefectures, which may have been affected because of their adjacent location. In general, when using quasi-experimental methods to evaluate the impact of a particular treatment, it is necessary to distinguish clearly between treated and non-treated

Table 2.1 Prefectures Assumed to be Affected by the Construction and Operation of the Kyushu High-Speed Rail Line

Spillover Effects by Region		Spillover Effects by Adjacency		Spillover Effects by Connectivity
Group 1	Group 2	Group 3	Group 4	Group 5
1. Kagoshima	1. Kagoshima	1. Kagoshima	1. Kagoshima	1. Osaka
2. Kumamoto	2. Kumamoto	2. Kumamoto	2. Kumamoto	2. Hyogo
	3. Fukuoka	3. Fukuoka	3. Fukuoka	3. Okayama
		4. Oita	4. Oita	4. Hiroshima
		5. Miyazaki	5. Miyazaki	5. Yamaguchi
			6. Saga	6. Fukuoka
			7. Nagasaki	7. Kumamoto
				8. Kagoshima

Source: Authors' analysis.

groups (Duflo, Glennerster, and Kremer 2008). Distributing observational data inappropriately into treated or control groups might complicate the objective assessment of the treatment. Since studies have revealed patterns of negative or insignificant effects of infrastructure provision at the regional level (Pereira and Andraz 2013), and positive and significant effects at the aggregate level (Pereira and Andraz 2005; Belloc and Vertova 2006), we considered the spillover effects of the bullet train on adjacent or neighboring regions. Earlier empirical evidence—such as that provided by Pereira and Andraz (2003) using a vector autoregression approach for transport and communication infrastructure, and Pereira and Roca-Sagales (2007) for highways—demonstrates that infrastructure provision has positive spillover effects on neighboring regions. Table 2.1 outlines two subsets of the spillover effects analysis.

Most trains along the Kyushu rail line provide a quick and easy transfer to the Sanyo high-speed rail line to Osaka. This allows us to estimate the spillover effect by connectivity. Similarly, Yoshino and Abidhadjaev (2015b) found that the introduction of the TBK railway had an economically growing and statistically significant connectivity impact on regions in Uzbekistan, meaning that regions located at the far ends of the railway system seem to experience larger positive variations in regional GDP growth. Accordingly, we consider spillover effects by connectivity, including prefectures located along the Kyushu and Sanyo lines as those affected by the railway. Table 2.1 lists the prefectures in this group and the other groups mentioned above.

Table 2.2 Construction and Operation Timeline of the Kyushu High-Speed Rail Line

Period	Preconstruction	Construction	Operation phase 1	Operation phase 2
Years	1982–1990	1991–2003	2004–2010	2011–2013

Sources: Authors' analysis; Fujii 2013.

The time comparison is made based on the following framework. The pre-construction period, 1982–1990, covers the absence of the high-speed rail line's construction or operation. The design and construction period, 1991–2003, continues through the first phase of the bullet train's operation between Kagoshima and Kumamoto. The next period, 2004–2010, covers the first phase of operation, and the next period, 2011–2013, covers the second phase of operation when the entire Kyushu line was finished and connected to the Fukuoka station (Table 2.2).

Directly calculating net differences across time and groups of prefectures helps us obtain estimates while accounting for time-invariant, region-specific effects that capture a region's idiosyncratic features stemming from historical and social development, as well as year-specific effects reflecting changes in legislation or overall business climate. At the same time, changes in tax revenue dynamics might be caused by a wide range of other factors, besides the effects mentioned above and the provision of the bullet train. Failure to account for the possibility that either positive or negative effects might result from other evolving factors could bias our estimates accordingly. The program evaluation literature likewise mentions this estimation challenge as an external validity problem (Rodrik 2008; Banerjee and Duflo 2009; Ravallion 2009).

To address this issue, we must acknowledge the factor inputs that may affect the performance of tax revenue in the prefecture and control for time-varying covariates. By incorporating the number of taxpayers in the estimation framework, obtaining a linear projection of tax revenues against the number of taxpayers, and accounting for time-invariant region- and year-specific effects, we obtain the following baseline estimation strategy of the DID specification:

$$\Delta \mathrm{T}_{\mathrm{it}} = \alpha_i + \varphi_{\mathrm{t}} + \beta \mathrm{X}_{\mathrm{it}} + \delta \mathrm{D}_{\mathrm{gt}} + \epsilon_{\mathrm{it}} \quad (1)$$

where ΔT is the prefecture's tax revenue; X denotes time-varying covariates (the vector of observed control variables); D is the binary variable indicating whether the observation relates to the affected group after the provision of the bullet train; i indexes prefectures; g indexes groups of prefectures (1 = affected group, and 0 = non-affected group); t indexes treatment before and after (t = 0 before the bullet train, and t = 1 after the bullet train); α_i is the sum of autonomous (α) and time-invariant, unobserved, region-specific (γ_i) rates of growth;[1] φ_t is the year-specific growth effect; and ϵ_{it} is the error term, assumed to be independent over time.

The vector of observed controls, , constitutes the number of taxpayers in the prefecture. We include the control variables to account for taxpayer demographics, which would be inaccurate if we chose only the "working-age" population (aged 16–64), some of whom may be unemployed or in education, and not contributing to the formation of tax revenues. Assuming that such factors have zero effect would imply that the number of taxpayers in a given region is not determined by location or favorable changes in business climate. Ignoring important information with respect to how variables change over time when region-specific characteristics are correlated with time-varying covariates makes it difficult to choose a random-effects estimator. Thus, we employed a fixed-effects estimator to account for both time-invariant unobserved characteristics, such as a region's advantageous location, and year-specific growth effects similar to favorable changes in the business climate.

With regard to possible autocorrelation within a prefecture (Bertrand, Duflo, and Mullainathan 2004), we employ heteroscedasticity and autocorrelation consistent (HAC) standard errors, which belong to the class of clustered standard errors. These HAC standard errors treat errors as uncorrelated across regions, but allow for heteroscedasticity and arbitrary autocorrelation within a region, consistent with the assumption of the fixed-effects regression with regard to independent and identical distribution across entities, in our case, prefectures, i = 1, 2, ..., 47.

Nearest Neighbor Matching Procedure

The next step of the analysis is the matching of treated and control groups. First, we choose the closest counterpart of the treated prefecture from those in the control group, then carry out a DID analysis in one of two ways: (i) matching the prefectures with the closest number of enterprises during the preconstruction period, accounting for specific regional characteristics such as location or number of enterprises; or

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1 This approach requires the assumption of a common time path or parallel trends, accepting that the autonomous rate of growth is equal in both the affected and non-affected groups.

(ii) focusing on the dependent variable to find the closest match from the pre-high-speed rail-line period by observing the average performance of prefectures in the affected and non-affected groups.

Next, we consider the minimum distance in unit measurement, for which we chose one of three metrics: the Mahalanobis distance, the inverse variance, or the Euclidian distance. In this study, we use Euclidian distance to find the closest match or nearest neighbor for the affected prefectures in the pre-high-speed rail-line period.

By finding the minimum distance between the mean tax revenue amount and standard deviation during the pre-high-speed rail-line period (1982–1990), we can determine the closest counterpart or nearest neighbor of the affected prefecture. These nearest neighbor groups provide a unique dataset for constructing the counterfactual scenario in the absence of treatment (in the form of the Kyushu rail line). In this study, we present empirical results for the case of nearest neighbors calculated by minimum distance between the mean value of tax revenues in the pre-rail-line period (1982–1990). Table 2.3 lists the nearest neighbors for affected prefectures based on the minimum distance from the mean value.

Table 2.3 Affected Prefectures and their Corresponding Nearest Neighbors, by the Minimum Euclidian Distance between the Mean Value of Total Tax Revenues for the Pre-High-Speed Rail-Line Period, 1982–1991 (¥ million)

Prefecture	Mean Tax Revenue	Standard Deviation	Prefecture	Mean Tax Revenue	Standard Deviation
1. Kagoshima	204,108	13,756	1. Wakayama	239,582	22,349
2. Kumamoto	245,181	17,704	2. Shiga	240,466	15,817
3. Fukuoka	1,104,007	77,674	3. Hokkaido	1,109,382	73,606
4. Oita	197,082	12,781	4. Nara	192,948	19,900
5. Miyazaki	138,677	9,054	5. Tokushima	120,935	13,249
6. Saga	120,374	9,258	6. Kochi	113,679	7,138
7. Nagasaki	185,051	12,494	7. Aomori	184,093	11,142
8. Osaka	4,945,666	409,167	8. Aichi	3,054,083	212,024
9. Hyogo	1,561,176	126,463	9. Saitama	1,175,458	120,307
10. Okayama	474,501	34,628	10. Gunma	468,592	31,106
11. Hiroshima	781,393	51,698	11. Kyoto	921,084	67,185
12. Yamaguchi	339,400	29,622	12. Fukushima	311,416	32,678

Source: National Tax Agency Japan.

2.4 Empirical Results

2.4.1 Estimations with a Limited Set of Observations

To avoid bias caused by outliers in the first stage, we exclude observations for the prefectures of Tokyo, Aichi, Kanagawa, and Osaka, which demonstrated superb tax revenue performance during the pre-rail-line period due to the concentration of industrial and commercial conglomerates. The general pattern observed is the occurrence of u-shaped dynamics of net difference in tax revenue performance for all spillover effects. The net difference in tax revenues diminished during the construction period and first operation phase of the Kyushu rail line, whereas the coefficients bounce back during the second operation phase.

Total Tax Revenue

With regard to spillover effects by adjacency, average net differences of ¥110 billion for the fourth treatment group (Group 4) and ¥134 billion for Group 3 in total tax revenues were observed during construction, compared with the counterfactual scenario based on the non-affected group, which includes observations for all other prefectures except Tokyo, Aichi, Kanagawa, and Osaka (Table 2.4a). These impacts diminished after construction, but remained positive during the first operation phase, consisting of ¥76 billion for Group 4 and ¥97 billion for Group 3. From the construction period to the second operation phase, which began in 2011 when the Kyushu and Sanyo high-speed rail lines were connected, the net difference almost doubled to ¥201 billion for Group 4 and ¥229 billion for Group 3. Overall, it appears that the connection of the previously autonomous Kyushu line to the wider high-speed rail network had a statistically significant and economically growing impact on the total tax revenue performance of the Kyushu region as a whole.

In focusing on spillover effects by region, we observe a similar pattern of high net difference in total tax revenue during construction, relatively low but positive coefficients during the first operation phase, and a resurgence during the second operation phase, with coefficients of a magnitude of ¥282 billion and corresponding t-value of 2.56 for Group 2, and ¥169 billion and corresponding t-value of 4.18 for Group 2.

Finally, estimates for spillover effects by connectivity, with a focus on the prefectures adjacent to the Kyushu rail line, further demonstrate the nature of core-periphery links. The coefficient for Group 5 (¥194 billion) is slightly higher than that of Group 2 (¥181 billion) during construction. From the first operation phase to the second, the net difference in total tax revenue increased from a coefficient of ¥118 billion to ¥353 billion

Table 2.4a Difference-in-Difference Empirical Results with the Outcome Variable of Total Tax Revenue (excluding observations for Tokyo, Aichi, Kanagawa, and Osaka prefectures from the control group)

Scale of Focus	Affected Group of Prefectures	Construction Period (1991–2003)	Operation Phase 1 (2004–2010)	Operation Phase 2 (2011–2013)
Spillover Effect by Region	Treatment Group 1	99,949**	60,884**	168,586**
		(6.81)	(5.46)	(4.18)
	Treatment Group 2	181,098*	117,907*	281,933*
		(2.67)	(2.47)	(2.56)
Spillover Effect by Adjacency	Treatment Group 3	134,498**	97,210**	229,224**
		(2.73)	(2.91)	(2.93)
	Treatment Group 4	109,557**	76,310**	200,704**
		(2.86)	(2.81)	(3.11)
Spillover Effect by Connectivity	Treatment Group 5	193,639**	99,830*	352,718**
		(5.22)	(2.25)	(3.49)
Number of Observations		946	731	559

( ) = t-value.
* p < 0.50.
** p < 0.01.
Notes: The tax revenue amount is adjusted for the Consumer Price Index, with 1982 as the base year. The pre-high-speed rail-line construction period covers the years 1982 to 1990. Non-affected groups include the rest of the prefectures. The treated groups are as follows: Group 1: Kagoshima and Kumamoto; Group 2: Kagoshima, Kumamoto, and Fukuoka; Group 3: Kagoshima, Kumamoto, Fukuoka, Oita, and Miyazaki; Group 4: Kagoshima, Kumamoto, Fukuoka, Oita, Miyazaki, Saga, and Nagasaki; and Group 5: Kagoshima, Kumamoto, Fukuoka, Yamaguchi, Hiroshima, Okayama, Hyogo, and Osaka. The t-value measures how many standard errors the coefficient is away from zero.
Source: Authors.

for Group 5, and from ¥100 billion to ¥282 billion for Group 2. The estimates for 2011–2013 are not only the highest compared with the results for other treatment groups, but also constitute the peak of net difference in total tax revenue compared with the others, given the time frames in this analysis.

Personal and Corporate Income Tax Revenue

Tables 2.4b and 2.4c present the empirical results for the structural components of total tax revenue decomposed into personal and corporate income tax revenues. This makes it possible to observe how these types of tax revenues reacted to the construction and operation of the new Kyushu rail line. The evidence in Tables 2.4b and 2.4c reveals a similar pattern: a positive net difference in personal and corporate income tax revenue throughout construction (1990–2003), followed by a decline in the first operation phase (2004–2011), in contrast to that of total tax revenue being negative, giving positive DID coefficients during the second operation phase (2011–2013) for almost all treatment groups.

In magnitude, personal income tax seems to have a higher net difference than corporate income tax during construction, while the opposite is true during the second operation phase, where coefficients are higher for corporate tax revenue than for personal income tax. In the case of spillover effects by adjacency, the net difference

Table 2.4b Difference-in-Difference Empirical Results with the Outcome Variable of Personal Income Tax Revenue (excluding observations for Tokyo, Aichi, Kanagawa, and Osaka prefectures from the control group)

Scale of Focus	Affected Group of Prefectures	Construction Period (1991–2003)	Operation Phase 1 (2004–2010)	Operation Phase 2 (2011–2013)
Spillover Effect by Region	Treatment Group 1	27,371**	−20,204**	43,806**
		(2.17)	(−2.33)	(2.12)
	Treatment Group 2	31,216***	−32,422***	69,743**
		(3.47)	(−2.78)	(2.17)
Spillover Effect by Adjacency	Treatment Group 3	18,346*	−26,311***	54,135**
		(2.01)	(−3.36)	(2.31)
	Treatment Group 4	14,648**	−23,410***	51,064**
		(2.11)	(−3.6)	(2.59)
Spillover Effect by Connectivity	Treatment Group 5	33,660***	−54,830***	100,684**
		(3.45)	(−2.99)	(2.65)
Number of Observations		946	731	559

( ) = t-value.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.
Notes: The tax revenue amount is adjusted for the Consumer Price Index, with 1982 as the base year. The pre-high-speed rail-line construction period covers the years 1982 to 1990. Non-affected groups include the rest of the prefectures. The treated groups are as follows: Group 1: Kagoshima and Kumamoto; Group 2: Kagoshima, Kumamoto, and Fukuoka; Group 3: Kagoshima, Kumamoto, Fukuoka, Oita, and Miyazaki; Group 4: Kagoshima, Kumamoto, Fukuoka, Oita, Miyazaki, Saga, and Nagasaki; and Group 5: Kagoshima, Kumamoto, Fukuoka, Yamaguchi, Hiroshima, Okayama, Hyogo, and Osaka. The t-value measures how many standard errors the coefficient is away from zero.
Source: Authors.

Table 2.4c Difference-in-Difference Empirical Results with the Outcome Variable of Corporate Income Tax Revenue (excluding observations for Tokyo, Aichi, Kanagawa, and Osaka prefectures from the control group)

Scale of Focus	Affected Group of Prefectures	Construction Period (1991–2003)	Operation Phase 1 (2004–2010)	Operation Phase 2 (2011–2013)
Spillover Effect by Region	Treatment Group 1	11,946***	−6,228**	76,216
		(7.71)	(−2.14)	(1.65)
	Treatment Group 2	17,300***	−12,716**	111,579
		(3.81)	(−2.21)	(1.51)
Spillover Effect by Adjacency	Treatment Group 3	13,311***	−8,629*	87,983
		(3.26)	(−1.89)	(1.56)
	Treatment Group 4	10,407***	−6,344*	86,054*
		(3.01)	(−1.73)	(1.69)
Spillover Effect by Connectivity	Treatment Group 5	−57	−14,430	182,127*
		(−0.01)	(−1.63)	(1.71)
Number of Observations		946	731	559

( ) = t-value.
* p < 0.10.
** p < 0.05.
*** p < 0.01.
Notes: The tax revenue amount is adjusted for the Consumer Price Index, with 1982 as the base year. The pre-high-speed rail-line construction period covers the years 1982 to 1990. Non-affected groups include the rest of the prefectures. The treated groups are as follows: Group 1: Kagoshima and Kumamoto; Group 2: Kagoshima, Kumamoto, and Fukuoka; Group 3: Kagoshima, Kumamoto, Fukuoka, Oita, and Miyazaki; Group 4: Kagoshima, Kumamoto, Fukuoka, Oita, Miyazaki, Saga, and Nagasaki; and Group 5: Kagoshima, Kumamoto, Fukuoka, Yamaguchi, Hiroshima, Okayama, Hyogo, and Osaka. The t-value measures how many standard errors the coefficient is away from zero.
Source: Authors.

in personal income tax revenue is equal to ¥15 billion for Group 4 and ¥18 billion for Group 3, while the corresponding figures for corporate tax revenue are ¥10 billion for Group 4 and ¥13 billion for Group 3. However, in the frame of adjacency effects, the estimates during the second operation phase reveal that the net differences for corporate income tax are equal to ¥86 billion for Group 4 and ¥88 billion for Group 3, while the corresponding indicators in personal income tax revenue are ¥51 billion for Group 4 and ¥54 billion for Group 3. A similar pattern is observed in the frame of spillover effects by region, although point estimates appear more statistically significant for personal income tax than for corporate income tax. Turning to spillover effects by connectivity, corporate income tax appears unaffected during construction—with the coefficient of net difference being close to 0 during construction, negative and statistically insignificant during the first operation phase, and ¥182 billion with a t-value of 1.7 during the second operation phase.

2.4.2 Estimation with Full Set of Observations

The next stage of the analysis includes observations for the Tokyo, Aichi, Kanagawa, and Osaka prefectures in a control group. This reveals empirical results that are both similar from and different to those outlined above.

An overall comparison of Tables 5a and 4a reveals the same pattern but lower coefficients, resulting in a lower net difference due to the introduction of the Kyushu line. Thus, the full-set estimate is ¥95 billion for Group 4 and ¥119 billion for Group 3, while the limited-set estimate is ¥110 billion for Group 4 and ¥134 billion for Group 3 (statistically significant in both cases). Other combinations of affected groups with the outcome variable of total tax revenue demonstrate a similar response, except for Groups 1 and 5 for the first operation phase and Group 5 for the second (Table 2.5a).

Divergence emerges when total tax revenue is broken down into personal and corporate income tax revenue. In contrast to Table 2.4b, Table 2.5b shows that almost all of the coefficients of net difference—except for those in spillover effects by region for Group 2 and by connectivity in Group 5—became statistically insignificant during construction. This suggests that the prefectures located along the Kyushu and Sanyo high-speed rail lines are the main beneficiaries in terms of increased personal income tax revenue. Similar dynamics are observed during the first operation phase except in the case of spillover effects by adjacency, which includes all seven prefectures in Kyushu.

When excluding the observations for Tokyo, Aichi, Kanagawa, and Osaka prefectures from the control groups, the following commonality between personal and corporate income tax revenues is observed: DID estimates for the second operation phase remain both positive and statistically significant, although lower in magnitude with respect to estimates with a baseline set of observations (except for Group 5).

Regarding the impact on corporate income tax revenue, in the differences of baseline empirical results, none of the coefficients of net difference were statistically significant during construction or the first operation phase, except for spillover effects by region, which has an estimate of ¥12 billion for Group 2 (including the observations for the Kagoshima, Kumamoto, and Fukuoka prefectures) during 1991–2003 (Table 2.5c). Thus, it appears that the construction of the Kyushu line induced a growing impact on businesses located mostly in these three prefectures.

The DID coefficients for corporate income tax during the second operation phase follow the pattern of personal income tax. We obtained statistically significant and positive coefficients, although of lower magnitudes relative to those obtained in the frame of baseline estimation.

Table 2.5a Periodic Difference-in-Difference Empirical Results with the Outcome Variable of Total Tax Revenue (with observations for Tokyo, Aichi, Kanagawa, and Osaka prefectures included in the control group)

Scale of Focus	Affected Group of Prefectures	Construction Period (1991–2003)	Operation Phase 1 (2004–2010)	Operation Phase 2 (2011–2013)
Spillover Effect by Region	Treatment Group 1	96,603**	64,067	164,542**
		(3.39)	(1.14)	(5.66)
	Treatment Group 2	170,051*	110,832*	273,935**
		(2.65)	(2.04)	(2.77)
Spillover Effect by Adjacency	Treatment Group 3	119,371*	87,089*	223,107**
		(2.36)	(2.13)	(3.22)
	Treatment Group 4	94,896*	75,132*	194,791**
		(2.39)	(2.48)	(3.51)
Spillover Effect by Connectivity	Treatment Group 5	298,403**	271,385	481,536**
		(2.94)	(1.59)	(2.99)
Number of Observations		1,034	799	611

( ) = t-value.
* p < 0.50.
** p < 0.01.
Notes: The tax revenue amount is adjusted for the Consumer Price Index, with 1982 as the base year. The pre-high-speed rail-line construction period covers the years 1982 to 1990. Non-affected groups include the rest of the prefectures. The treated groups are as follows: Group 1: Kagoshima and Kumamoto; Group 2: Kagoshima, Kumamoto, and Fukuoka; Group 3: Kagoshima, Kumamoto, Fukuoka, Oita, and Miyazaki; Group 4: Kagoshima, Kumamoto, Fukuoka, Oita, Miyazaki, Saga, and Nagasaki; and Group 5: Kagoshima, Kumamoto, Fukuoka, Yamaguchi, Hiroshima, Okayama, Hyogo, and Osaka. The t-value measures how many standard errors the coefficient is away from zero.
Source: Authors.

Table 2.5b Difference-in-Difference Empirical Results with the Outcome Variable of Personal Income Tax Revenue

Scale of Focus	Affected Group of Prefectures	Construction Period (1991–2003)	Operation Phase 1 (2004–2010)	Operation Phase 2 (2011–2013)
Spillover Effect by Region	Treatment Group 1	25,724	−19,033	42,035**
		(1.32)	(−0.75)	(2.34)
	Treatment Group 2	25,783*	−35,023	66,498**
		(1.93)	(−1.63)	(2.41)
Spillover Effect by Adjacency	Treatment Group 3	10,915	−30,029**	51,675**
		(0.85)	(−2.18)	(2.59)
	Treatment Group 4	7,448	−23,844**	48,690***
		(0.74)	(−2.13)	(3.01)
Spillover Effect by Connectivity	Treatment Group 5	65,186**	−23761	151,360**
		(2.02)	(−0.55)	(2.59)
Number of Observations		1,034	799	611

( ) = t-value.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.
Notes: The tax revenue amount is adjusted for the Consumer Price Index, with 1982 as the base year. The pre-high-speed rail-line construction period covers the years 1982 to 1990. Non-affected groups include the rest of the prefectures. The treated groups are as follows: Group 1: Kagoshima and Kumamoto; Group 2: Kagoshima, Kumamoto, and Fukuoka; Group 3: Kagoshima, Kumamoto, Fukuoka, Oita, and Miyazaki; Group 4: Kagoshima, Kumamoto, Fukuoka, Oita, Miyazaki, Saga, and Nagasaki; and Group 5: Kagoshima, Kumamoto, Fukuoka, Yamaguchi, Hiroshima, Okayama, Hyogo, and Osaka. The t-value measures how many standard errors the coefficient is away from zero.
Source: Authors.

Table 2.5c Difference-in-Difference Empirical Results with the Outcome Variable of Corporate Income Tax Revenue

Scale of Focus	Affected Group of Prefectures	Construction Period (1991–2003)	Operation Phase 1 (2004–2010)	Operation Phase 2 (2011–2013)
Spillover Effect by Region	Treatment Group 1	10,350	−4,773	72,330**
		(1.26)	(−0.21)	(2.21)
	Treatment Group 2	12,040*	−15,948	104,664*
		(1.88)	(−0.87)	(2.01)

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Table 2.5c *continued*

Scale of Focus	Affected Group of Prefectures	Construction Period (1991–2003)	Operation Phase 1 (2004–2010)	Operation Phase 2 (2011–2013)
Spillover Effect by Adjacency	Treatment Group 3	6,116	–13,250	82,730**
		(0.81)	(–1.06)	(2.10)
	Treatment Group 4	3,436	–6,883	80,998**
		(0.52)	(–0.71)	(2.34)
Spillover Effect by Connectivity	Treatment Group 5	–39,703	–28,031	179,632
		(–0.92)	(–0.65)	(1.58)
Number of Observations		1,034	799	611

( ) = t-value.
* $p < 0.50$.
** $p < 0.01$.
Notes: The tax revenue amount is adjusted for the Consumer Price Index, with 1982 as the base year. The pre-high-speed rail-line construction period covers the years 1982 to 1990. Non-affected groups include rest of the prefectures. The treated groups are as follows: Group 1: Kagoshima and Kumamoto; Group 2: Kagoshima, Kumamoto, and Fukuoka; Group 3: Kagoshima, Kumamoto, Fukuoka, Oita, and Miyazaki; Group 4: Kagoshima, Kumamoto, Fukuoka, Oita, Miyazaki, Saga, and Nagasaki; and Group 5: Kagoshima, Kumamoto, Fukuoka, Yamaguchi, Hiroshima, Okayama, Hyogo, and Osaka. The t-value measures how many standard errors the coefficient is away from zero.
Source: Authors.

2.4.3 Heterogeneity of Responses in Amounts of Income and Income Tax

Next, we build upon the two previous empirical results regarding the negative net difference of income taxes and address the following questions: does the resulting negative net difference in personal and corporate income tax during the first operation phase mean that firm and household income decreased after the introduction of the high-speed rail line? If not, what are the possible causes for the decrease in tax revenue amount relative to the counterfactual scenario without the introduction of the Kyushu line?

Despite the negative DID coefficients for personal and corporate income tax, this is not enough to make logical deductions about personal and corporate income levels. We must also account for the existence of thresholds for progressive taxation or substantial changes in tax revenue (Table 2.6). It is possible that personal and corporate incomes in the region not only were undiminished due to the introduction of a new mode of transportation, but may have even increased, although not enough to translate into a positive net difference in tax revenue.

Table 2.6 Individual Income Tax Rates

Taxable Income Brackets		Tax Rates (%)
NA	Under ¥1,950,000	5
Over ¥1,950,000	but under ¥3,300,000	10
Over ¥3,300,000	but under ¥6,950,000	20
Over ¥6,950,000	but under ¥9,000,000	23
Over ¥9,000,000	but under ¥18,000,000	33
Over ¥18,000,000	but under ¥40,000,000	40
Over ¥40,000,000	NA	45

NA = not applicable.
Source: Japan External Trade Organization.

To address this issue, we turn to the estimation of DID coefficients for personal and corporate income amounts in the Kyushu region, as well as in the regions adjacent to the Sanyo line, which are included in Group 5.

With regard to personal income tax, Japan's tax filing system has two modes of collection: (i) a self-assessed income tax payment, in which individual taxpayers calculate annual income and the corresponding tax amount and file their tax returns; and (ii) a tax withholding system whereby companies collect income tax from their employees on the date of salary payment. Although the mode of payment is determined depending on the type of income and the category of the income recipient, taxation is progressive for both modes. For example, the tax rate is 5% if annual personal income is under ¥2.0 million, and 10% if annual personal income is greater than ¥2.0 million but less than ¥3.3 million.

Conversely, income deductions are regressive. Provided that employment income is equal to or less than approximately ¥1.6 million, an individual is eligible for a ¥650,000 deduction, while the percentage of income deduction is relatively lesser for subsequent employment income thresholds (Table 2.7).

Under Japan's corporate taxation system, tax revenue is based on corporate tax, local corporate tax, corporate inhabitant tax, enterprise tax, and special local corporate tax. Similar to personal income taxation, the applied corporate tax rate is progressive in nature (Table 2.8). This implies that if the construction and operation of the Kyushu line affects companies with relatively lower income levels more positively than it does companies with higher income levels, total corporate tax revenues might decrease despite corporate income experiencing positive net growth.

Table 2.7 Employment Income Deductions

Employment Income	Employment Income Deductions
Up to ¥1,625,000	¥650,000
Over ¥1,625,000 and up to ¥1,800,000	(employment income) x 40%
Over ¥1,800,000 and up to ¥3,600,000	(employment income) x 30% + ¥180,000
Over ¥3,600,000 and up to ¥6,600,000	(employment income) x 20% + ¥540,000
Over ¥6,600,000 and up to ¥10,000,000	(employment income) x 10% + ¥1,200,000
Over ¥10,000,000 and up to ¥15,000,000	(employment income) x 5% + ¥1,700,000
Over ¥15,000,000	¥2,450,000

Source: Japan External Trade Organization.

Table 2.8 Tax Burden on Corporate Income

Taxable Income Brackets	Up to ¥4 million (%)	¥4 million– ¥8 million (%)	Over ¥8 million (%)
Corporate tax	15.00	15.00	25.50
Local corporate tax	0.66	0.66	1.12
Corporate inhabitant taxes			
1. Prefectural	0.48	0.48	0.81
2. Municipal	1.45	1.45	2.47
Enterprise tax	3.40	5.10	6.70
Special local corporate tax	1.46	2.20	2.89
Total tax rate	22.45	24.89	39.49
Effective tax rate	21.42	23.20	36.05

Note: The corporate income tax rate applies for 3 business years from the business year beginning between 1 October 2014 and 31 March 2015. The rates for local taxes may vary depending on the scale of the business and the local government under whose jurisdiction it falls. Applicable tax rates will vary according to the timing.
Source: Japan External Trade Organization.

Tables 2.9a and 2.9b, which contain the estimated amounts for personal and corporate income, support this hypothesis. Compared with Tables 2.5b and 2.5c, the DID coefficients for personal and corporate income are positive for the first operation phase. Thus, although Group 4 representing all seven prefectures in Kyushu experienced a decline in personal income tax revenue during the first phase, expressed as negative and a statistically significant DID coefficient approximately equal to ¥24 billion, the net difference in actual personal income was positive, with a point estimate of about ¥36 billion and a corresponding t-value of 1.98.

Table 2.9a Empirical Results for Personal Income Revenue for Three Periods (with observations for Tokyo, Aichi, Kanagawa, and Osaka prefectures included in the control group)

Scale of Focus	Affected Group of Prefectures	Construction Period (1991–2003)	Operation Phase 1 (2004–2010)	Operation Phase 2 (2011–2013)
Spillover Effect by Region	Treatment Group 1	71,896***	36,139	146,328***
		(3.84)	(0.77)	(4.05)
	Treatment Group 2	105,264***	56,258	257,728**
		(3.44)	(1.59)	(2.53)
Spillover Effect by Adjacency	Treatment Group 3	73,302***	35,527	192,325**
		(2.73)	(1.41)	(2.61)
	Treatment Group 4	63,214***	36,289*	173,304***
		(3.08)	(1.98)	(3.03)
Spillover Effect by Connectivity	Treatment Group 5	175,670***	159,268*	502,215***
		(3.33)	(1.73)	(3.31)
Number of Observations		1,034	799	611

( ) = t-value.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.
Notes: The tax revenue amount is adjusted for the Consumer Price Index, with 1982 as the base year. The pre-high-speed rail-line construction period covers the years 1982 to 1990. Non-affected groups include the rest of the prefectures. The treated groups are as follows: Group 1: Kagoshima and Kumamoto; Group 2: Kagoshima, Kumamoto, and Fukuoka; Group 3: Kagoshima, Kumamoto, Fukuoka, Oita, and Miyazaki; Group 4: Kagoshima, Kumamoto, Fukuoka, Oita, Miyazaki, Saga, and Nagasaki; and Group 5: Kagoshima, Kumamoto, Fukuoka, Yamaguchi, Hiroshima, Okayama, Hyogo, and Osaka. The t-value measures how many standard errors the coefficient is away from zero.
Source: Authors.

Table 2.9b Empirical Results for Personal Income Revenue for Three Periods (with observations for Tokyo, Aichi, Kanagawa, and Osaka prefectures included in the control group)

Scale of Focus	Affected Group of Prefectures	Construction Period (1991–2003)	Operation Phase 1 (2004–2010)	Operation Phase 2 (2011–2013)
Spillover Effect by Region	Treatment Group 1	44,006*	22,435	170,451***
		(2.01)	(0.30)	(3.11)
	Treatment Group 2	80,506**	64,950	291,338**
		(2.31)	(1.05)	(2.37)

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Table 2.9b *continued*

Scale of Focus	Affected Group of Prefectures	Construction Period (1991–2003)	Operation Phase 1 (2004–2010)	Operation Phase 2 (2011–2013)
Spillover Effect by Adjacency	Treatment Group 3	51,345	37,220	222,365**
		(1.65)	(0.83)	(2.49)
	Treatment Group 4	38,021	42,439	208,093***
		(1.49)	(1.32)	(2.89)
Spillover Effect by Connectivity	Treatment Group 5	9,911	149,853	481,490**
		(0.16)	(1.09)	(2.38)
Number of Observations		1,034	799	611

( ) = t-value.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.
Notes: The tax revenue amount is adjusted for the Consumer Price Index, with 1982 as the base year. The pre-high-speed rail-line construction period covers the years 1982 to 1990. Non-affected groups include the rest of the prefectures. The treated groups are as follows: Group 1: Kagoshima and Kumamoto; Group 2: Kagoshima, Kumamoto, and Fukuoka; Group 3: Kagoshima, Kumamoto, Fukuoka, Oita, and Miyazaki; Group 4: Kagoshima, Kumamoto, Fukuoka, Oita, Miyazaki, Saga, and Nagasaki; and Group 5: Kagoshima, Kumamoto, Fukuoka, Yamaguchi, Hiroshima, Okayama, Hyogo, and Osaka. The t-value measures how many standard errors the coefficient is away from zero.
Source: Authors.

Table 2.9c Empirical Results for Personal Income Revenue for 3 Years (with observations for Tokyo, Aichi, Kanagawa, and Osaka prefectures included in the control group)

Scale of Focus	Affected Group of Prefectures	Operation Phase 2 (2011)	Operation Phase 2 (2012)	Operation Phase 2 (2013)
Spillover Effect by Region	Treatment Group 1	205,742**	222,838**	210,253**
		(3.54)	(3.92)	(3.85)
	Treatment Group 2	357,639*	380,186*	362,152*
		(2.52)	(2.63)	(2.62)
Spillover Effect by Adjacency	Treatment Group 3	268,582*	283,948**	272,865**
		(2.63)	(2.69)	(2.74)
	Treatment Group 4	244,461**	258,087**	249,291**
		(3.09)	(3.16)	(3.24)
Spillover Effect by Connectivity	Treatment Group 5	725,690**	750,253**	759,822**
		(2.95)	(3.04)	(3.06)

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Table 2.9c *continued*

Scale of Focus	Affected Group of Prefectures	Operation Phase 2 (2011)	Operation Phase 2 (2012)	Operation Phase 2 (2013)
Number of Observations		517	517	517

( ) = t-value.
* p < 0.50.
** p < 0.01.
Notes: The tax revenue amount is adjusted for the Consumer Price Index, with 1982 as the base year. The pre-high-speed rail-line construction period covers the years 1982 to 1990. Non-affected groups include the rest of the prefectures. The treated groups are as follows: Group 1: Kagoshima and Kumamoto; Group 2: Kagoshima, Kumamoto, and Fukuoka; Group 3: Kagoshima, Kumamoto, Fukuoka, Oita, and Miyazaki; Group 4: Kagoshima, Kumamoto, Fukuoka, Oita, Miyazaki, Saga, and Nagasaki; and Group 5: Kagoshima, Kumamoto, Fukuoka, Yamaguchi, Hiroshima, Okayama, Hyogo, and Osaka. The t-value measures how many standard errors the coefficient is away from zero.
Source: Authors.

Table 2.9d Empirical Results for Corporate Income Revenue for 3 Years

Scale of Focus	Affected Group of Prefectures	Operation Phase 2 (2011)	Operation Phase 2 (2012)	Operation Phase 2 (2013)
Spillover Effect by Region	Treatment Group 1	285,100**	252,629**	234,657**
		(2.28)	(2.47)	(2.36)
	Treatment Group 2	454,240*	421,456**	427,170**
		(1.98)	(2.10)	(2.05)
Spillover Effect by Adjacency	Treatment Group 3	349,486**	322,383**	320,794**
		(2.05)	(2.18)	(2.11)
	Treatment Group 4	328,484**	299,017**	300,348**
		(2.24)	(2.40)	(2.38)
Spillover Effect by Connectivity	Treatment Group 5	809,657*	779,620*	838,416**
		(1.75)	(1.97)	(2.02)
Number of Observations		517	517	517

( ) = t-value.
* p < 0.10.
** p < 0.05.
Notes: The tax revenue amount is adjusted for the Consumer Price Index with 1982 as the base year. The pre-high-speed rail-line construction period covers the years 1982 to 1990. Non-affected groups include rest of the prefectures. The treated groups are as follows: Group 1: Kagoshima and Kumamoto; Group 2: Kagoshima, Kumamoto, and Fukuoka; Group 3: Kagoshima, Kumamoto, Fukuoka, Oita, and Miyazaki; Group 4: Kagoshima, Kumamoto, Fukuoka, Oita, Miyazaki, Saga, and Nagasaki; and Group 5: Kagoshima, Kumamoto, Fukuoka, Yamaguchi, Hiroshima, Okayama, Hyogo, and Osaka. The t-value measures how many standard errors the coefficient is away from zero.
Source: Authors.

Yearly Estimations

Next, we consider the results of the estimation, which show at least two distinguishing aspects of the second operation phase: (i) the trend of net difference in tax revenue is disrupted compared with the previous period, with tax returns diminishing after the end of construction during the first operation phase (the overall tax revenues bounced back during the second operation phase); and (ii) it has exceptionally high estimates relative to the other time frames analyzed in this study.

Tables 2.10a to 2.10c present empirical results for the second operation phase only, providing tax revenue estimates for the years 2011, 2012, and 2013. The net increase in total tax revenue of the Kyushu region attributed to the Kyushu line in 2011 equaled about ¥320 billion, compared with the counterfactual scenario in the absence of the line for Group 4 (Table 2.10a). This statistically significant result is obtained from the estimation with a full set of observations. The corresponding coefficients are equal to ¥308 billion for 2012 and ¥304 billion for 2013 (statistically significant at the 1% level). Thus, the effect of the bullet train is diminishing in nature. This finding aligns with that of Yoshino and Abidhadjaev (2015b), who estimated the impact of the railway connection in Uzbekistan on regional economic performance, and demonstrated diminishing rates of impact over time.

The same pattern of diminishing impact appeared when total tax revenue was broken down into personal income tax revenue, corporate income tax revenue, and estimated yearly impact of the Kyushu line during the second operation phase—expressed by the coefficients for Group 4 and Group 3 in spillover effects by adjacency, and Group 2 in spillover effects by region.

Table 2.10a Yearly Difference-in-Difference Empirical Results with the Outcome Variable of Total Tax Revenue (with observations for Tokyo, Aichi, Kanagawa, and Osaka prefectures included in the control group)

Scale of Focus	Affected Group of Prefectures	Operation Phase 2 (2011)	Operation Phase 2 (2012)	Operation Phase 2 (2013)
Spillover Effect by Region	Treatment Group 1	268,644**	270,263**	253,343**
		(3.05)	(3.37)	(3.15)
	Treatment Group 2	450,497*	438,096*	422,721*
		(2.29)	(2.45)	(2.37)

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Table 2.10a *continued*

Scale of Focus	Affected Group of Prefectures	Operation Phase 2 (2011)	Operation Phase 2 (2012)	Operation Phase 2 (2013)
Spillover Effect by Adjacency	Treatment Group 3	358,183*	346,698*	336,284*
		(2.53)	(2.66)	(2.61)
	Treatment Group 4	319,956**	308,103**	303,789**
		(2.70)	(2.83)	(2.82)
Spillover Effect by Connectivity	Treatment Group 5	869,153*	840,176*	873,185*
		(2.24)	(2.32)	(2.29)
Number of Observations		517	517	517

( ) = t-value.
* $p < 0.05$.
** $p < 0.01$.
Notes: The tax revenue amount is adjusted for the Consumer Price Index, with 1982 as the base year. The pre-high-speed rail-line construction period covers the years 1982 to 1990. Non-affected groups include the rest of the prefectures. The treated groups are as follows: Group 1: Kagoshima and Kumamoto; Group 2: Kagoshima, Kumamoto, and Fukuoka; Group 3: Kagoshima, Kumamoto, Fukuoka, Oita, and Miyazaki; Group 4: Kagoshima, Kumamoto, Fukuoka, Oita, Miyazaki, Saga, and Nagasaki; and Group 5: Kagoshima, Kumamoto, Fukuoka, Yamaguchi, Hiroshima, Okayama, Hyogo, and Osaka. The t-value measures how many standard errors the coefficient is away from zero.
Source: Authors.

Table 2.10b Difference-in-Difference Empirical Results with the Outcome Variable of Personal Income Tax Revenue

Scale of Focus	Affected Group of Prefectures	Operation Phase 2 (2011)	Operation Phase 2 (2012)	Operation Phase 2 (2013)
Spillover Effect by Region	Treatment Group 1	75,583**	80,473**	69,235**
		(2.04)	(2.30)	(2.10)
	Treatment Group 2	127,651*	123,897**	110,807**
		(1.98)	(2.18)	(2.11)
Spillover Effect by Adjacency	Treatment Group 3	97,430**	95,393**	85,923**
		(2.07)	(2.26)	(2.22)
	Treatment Group 4	90,734**	88,516**	82,342**
		(2.29)	(2.47)	(2.49)
Spillover Effect by Connectivity	Treatment Group 5	280,001**	274,942**	277,902**
		(2.03)	(2.15)	(2.15)

continued on next page

Table 2.10b *continued*

Scale of Focus	Affected Group of Prefectures	Operation Phase 2 (2011)	Operation Phase 2 (2012)	Operation Phase 2 (2013)
Number of Observations		517	517	517

( ) = t-value.
* p < 0.10.
** p < 0.05.
Notes: The tax revenue amount is adjusted for the Consumer Price Index, with 1982 as the base year. The pre-high-speed rail-line construction period covers the years 1982 to 1990. Non-affected groups include the rest of the prefectures. The treated groups are as follows: Group 1: Kagoshima and Kumamoto; Group 2: Kagoshima, Kumamoto, and Fukuoka; Group 3: Kagoshima, Kumamoto, Fukuoka, Oita, and Miyazaki; Group 4: Kagoshima, Kumamoto, Fukuoka, Oita, Miyazaki, Saga, and Nagasaki; and Group 5: Kagoshima, Kumamoto, Fukuoka, Yamaguchi, Hiroshima, Okayama, Hyogo, and Osaka. The t-value measures how many standard errors the coefficient is away from zero.
Source: Authors.

Table 2.10c Difference-in-Difference Empirical Results with the Outcome Variable of Corporate Income Tax Revenue

Scale of Focus	Affected Group of Prefectures	Operation Phase 2 (2011)	Operation Phase 2 (2012)	Operation Phase 2 (2013)
Spillover Effect by Region	Treatment Group 1	92,720**	89,083**	76,303*
		(2.05)	(2.09)	(1.82)
	Treatment Group 2	134,314*	133,086*	113,555*
		(1.81)	(1.89)	(1.75)
Spillover Effect by Adjacency	Treatment Group 3	105,830*	104,332*	88,877*
		(1.90)	(1.96)	(1.81)
	Treatment Group 4	102,111**	99,558**	88,615*
		(2.08)	(2.14)	(2.01)
Spillover Effect by Connectivity	Treatment Group 5	234,839	226,902	214,220
		(1.47)	(1.53)	(1.44)
Number of Observations		517	517	517

( ) = t-value.
* p < 0.10.
** p < 0.05.
Notes: The tax revenue amount is adjusted for the Consumer Price Index, with 1982 as base year. The pre-high-speed rail-line construction period covers the years 1982 to 1990. Non-affected groups include the rest of the prefectures. The treated groups are as follows: Group 1: Kagoshima and Kumamoto; Group 2: Kagoshima, Kumamoto, and Fukuoka; Group 3: Kagoshima, Kumamoto, Fukuoka, Oita, and Miyazaki; Group 4: Kagoshima, Kumamoto, Fukuoka, Oita, Miyazaki, Saga, and Nagasaki; and Group 5: Kagoshima, Kumamoto, Fukuoka, Yamaguchi, Hiroshima, Okayama, Hyogo, and Osaka. The t-value measures how many standard errors the coefficient is away from zero.
Source: Authors.

2.4.4 Empirical Results Using the Nearest Neighbor Matching Approach

Total Tax Revenue

Using the nearest neighbor matching approach, we found positive and statistically significant results during construction for all spillover effects. Compared with the counterfactual scenario based on the performance of the non-affected group, during construction the prefectures in Group 4 demonstrated ¥113 billion in higher tax revenue and those in Group 3 demonstrated ¥138 billion in higher tax revenue (Table 2.11). In the same period, Group 1 had a net difference

Table 2.11 Difference-in-Difference Empirical Results with the Outcome Variable of Total Tax Revenue, Using Nearest Neighbor Matching Based on the Euclidian Distance between Mean Tax Revenues, 1982–1990 (¥ million)

Scale of Focus	Affected Group of Prefectures	Construction Period (1991–2003)	Operation Phase 1 (2004–2010)	Operation Phase 2 (2011–2013)
Spillover Effect by Region	Treatment Group 1	101,125***	60,503***	105,773***
		(9.11)	(9.01)	(12.71)
	Number of Observations	88	68	52
	Treatment Group 2	183,783*	116,203*	191,940
		(2.47)	(2.25)	(1.9)
	Number of Observations	132	102	78
Spillover Effect by Adjacency	Treatment Group 3	138,420**	95,595**	156,133**
		(2.75)	(2.73)	(2.54)
	Number of Observations	220	170	130
	Treatment Group 4	113,430**	76,182**	128,318**
		(2.95)	(2.74)	(2.71)
	Number of Observations	308	238	182
Spillover Effect by Connectivity	Treatment Group 5	275,121***	193,207*	454621**
		(3.08)	(1.78)	(2.85)
	Number of Observations	330	255	195

( ) = t-value.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.
Notes: The tax revenue amount is adjusted for the Consumer Price Index with 1982 as the base year. The pre-high-speed rail line construction period covers the years 1982–1990. Non-affected groups include rest of the prefectures. The treated groups are as follows: Group 1: Kagoshima and Kumamoto; Group 2: Kagoshima, Kumamoto, and Fukuoka; Group 3: Kagoshima, Kumamoto, Fukuoka, Oita, and Miyazaki; Group 4: Kagoshima, Kumamoto, Fukuoka, Oita, Miyazaki, Saga, and Nagasaki; and Group 5: Kagoshima, Kumamoto, Fukuoka, Yamaguchi, Hiroshima, Okayama, Hyogo, and Osaka. The t-value measures how many standard errors the coefficient is away from zero.
Source: Authors.

of ¥101 billion with regard to total tax revenue. The highest magnitude of difference during construction is observed in the frames of spillover effects by region for Group 2 and spillover effects by connectivity for Group 5. The higher magnitude of positive net difference during construction was followed by lower although positive and statistically significant coefficients during the first operation phase, which bounced back during the second.

Personal Income Tax

The construction of the Kyushu high-speed rail line positively impacted personal tax revenue. In the case of spillover effects by adjacency, the DID coefficients during construction are equal to ¥15 billion with a corresponding t-value of 2.26 for Group 4, and ¥19 billion with a t-value of 2 for Group 3 (Table 2.12). The spillover effects by region on personal income tax revenue, being higher than those by adjacency, are equal to a net difference of ¥31 billion for Group 2 and ¥28 billion for Group 1, compared with the counterfactual scenario. With regard to spillover effects by connectivity, the construction of the Kyushu bullet train appears to have generated ¥54 billion of net difference, the coefficient of interest being statistically significant at the 5% level. Once the high-speed rail line began operating between Kagoshima and Kumamoto, the impact on personal income tax diminished. This can be observed in the negative net difference compared with the alternative scenario based on the new non-affected group. This also supports the general pattern revealed in the earlier estimations comparing different sets of observations.

Table 2.12 Difference-in-Difference Empirical Results with the Outcome Variable of Personal Income Tax Revenue, Using Nearest Neighbor Matching Based on the Euclidian Distance between Mean Tax Revenues, 1982–1990

Scale of Focus	Affected Group of Prefectures	Construction Period (1991–2003)	Operation Phase 1 (2004–2010)	Operation Phase 2 (2011–2013)
Spillover Effect by Region	Treatment Group 1	27,822.92	−20,139.51	16,721.9
		(2.24)	(−1.81)	(1.42)
	Number of Observations	88	68	52
	Treatment Group 2	31,432.08**	−32,786.25*	51,056.62*
		(3.25)	(−2.32)	(2.42)
	Number of Observations	132	102	78

continued on next page

Table 2.12 *continued*

Scale of Focus	Affected Group of Prefectures	Construction Period (1991–2003)	Operation Phase 1 (2004–2010)	Operation Phase 2 (2011–2013)
Spillover Effect by Adjacency	Treatment Group 3	18,821*	−26,698.04**	37,429.24**
		(2.01)	(−3.03)	(2.88)
	Number of Observations	220	170	130
	Treatment Group 4	15,472.3**	−23,431.25***	31,903.97***
		(2.26)	(−3.39)	(3.07)
	Number of Observations	308	238	182
Spillover Effect by Connectivity	Treatment Group 5	53,576.87**	−50,607.41**	125,253.54**
		(2.29)	(−2.52)	(2.63)
	Number of Observations	330	255	195

( ) = t-value.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.
Notes: The tax revenue amount is adjusted for the Consumer Price Index with 1982 as the base year. The pre-high-speed rail-line construction period covers the years 1982 to 1990. Non-affected groups include the rest of the prefectures. The treated groups are as follows: Group 1: Kagoshima and Kumamoto; Group 2: Kagoshima, Kumamoto, and Fukuoka; Group 3: Kagoshima, Kumamoto, Fukuoka, Oita, and Miyazaki; Group 4: Kagoshima, Kumamoto, Fukuoka, Oita, Miyazaki, Saga, and Nagasaki; and Group 5: Kagoshima, Kumamoto, Fukuoka, Yamaguchi, Hiroshima, Okayama, Hyogo, and Osaka. The t-value measures how many standard errors the coefficient is away from zero.
Source: Authors.

However, the connection of the Kyushu and Sanyo high-speed rail lines in 2011 resulted in a positive net difference in personal income tax revenue. Thus, in the case of spillover effects by adjacency, the net difference constituted ¥32 billion for Group 4 and ¥37 billion for Group 3. In the form of spillover effects by region, the net difference was equal to ¥51 billion for Group 4 and ¥17 billion for Group 3, although the t-value for Group 3 was only around 1.42. Finally, the regions along the Kyushu and Sanyo lines appear to have gained about ¥125 billion with a t-value of 2.63 during the second operation phase.

Corporate Income Tax

The dynamics of corporate income tax revenue were similar to those of personal income tax revenue, but showed lower levels of magnitude (Table 2.13).

The construction period is associated with positive and statistically significant DID coefficients in corporate income tax revenues for

Table 2.13 Difference-in-Difference Empirical Results with the Outcome Variable of Corporate Income Tax Revenue, Using Nearest Neighbor Matching Based on the Euclidian Distance between Mean Tax Revenues, 1982–1990 (¥ million)

Scale of Focus	Affected Group of Prefectures	Construction Period (1991–2003)	Operation Phase 1 (2004–2010)	Operation Phase 2 (2011–2013)
Spillover Effect by Region	Treatment Group 1	12,132.33***	−6,292.71*	6,629.05
		(14.06)	(−2.71)	(2.04)
	Number of Observations	88	68	52
	Treatment Group 2	17,473.79**	−13,261.77	18,730.36**
		(3.56)	(−1.61)	(2.72)
	Number of Observations	132	102	78
Spillover Effect by Adjacency	Treatment Group 3	13,695.24***	−9,138.27	15,128.06**
		(3.37)	(−1.61)	(2.93)
	Number of Observations	220	170	130
	Treatment Group 4	10,902.40***	−6,382.728	15,794.54***
		(3.28)	(−1.54)	(3.84)
	Number of Observations	308	238	182
Spillover Effect by Connectivity	Treatment Group 5	−46,276.71	−46,440.24*	117,806.95**
		(−1.09)	(−1.79)	(2.28)
	Number of Observations	330	255	195

( ) = t-value.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.
Notes: The tax revenue amount is adjusted for the Consumer Price Index with 1982 as the base year. The pre-high-speed rail-line construction period covers the years 1982 to 1990. Non-affected groups include rest of the prefectures. The treated groups are follows: Group 1: Kagoshima and Kumamoto; Group 2: Kagoshima, Kumamoto, and Fukuoka; Group 3: Kagoshima, Kumamoto, Fukuoka, Oita, and Miyazaki; Group 4: Kagoshima, Kumamoto, Fukuoka, Oita, Miyazaki, Saga, and Nagasaki; and Group 5: Kagoshima, Kumamoto, Fukuoka, Yamaguchi, Hiroshima, Okayama, Hyogo, and Osaka. The t-value measures how many standard errors the coefficient is away from zero.
Source: Authors.

almost all scales of focus except for spillover effects by connectivity, which are found to be negative and not statistically significant during construction. Similarly, the net difference turned negative for spillover effects by adjacency and region during the first operation phase, before resurging after the connection of the Kyushu and Sanyo high-speed rail lines.

2.5 Conclusion

This study estimated the impact of infrastructure on regional tax revenue in Japan. We employed the DID approach to examine the effect of the Kyushu high-speed rail line on prefecture-level tax revenues during construction and two periods of subsequent operation. The empirical results suggest that, on average, the total tax revenues of the prefectures affected by the Kyushu line increased during construction and subsequently decreased while it was operating as an autonomous branch. However, once the line was connected to a wider system of rail lines through its linkage with the Sanyo line, the tax revenues rose again with a positive difference.

With regard to spillover effects, this analysis revealed that the Kyushu line positively affected the region in which it was located, adjacent prefectures, and prefectures along the Sanyo line. The empirical results reveal that tax revenues increased more in the actual region of the Kyushu line than in adjacent prefectures, but less than in the prefectures along the Sanyo line. Differentiating tax revenue by types, we found that the DID coefficients for corporate tax revenue were lower than those for personal income tax revenue during construction, but higher during the second phase of operation when the Kyushu line was connected to the wider rail line system. This might suggest that the railway affected the marginal productivity of labor in the short term, and that of capital in the long term, which has important implications for planning and evaluation policies.

This study highlights the need to examine the impact of infrastructure from different angles, conditioning on geography, time frames, and types of outcome variables. Based on these inferences, infrastructure financing can be modified to account for all externalities and variations of the impact of infrastructure over time. Future analyses using a similar approach and focusing on different case studies will create a body of literature that enables us to understand comprehensively the direction and nature of infrastructure impacts.

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3

The "Highway Effect" on Public Finance: The Case of the Southern Tagalog Arterial Road Tollway in the Philippines

Naoyuki Yoshino and Victor Pontines

3.1 Introduction

Transportation infrastructure is widely deemed to have critical development impacts, and public investment in transportation infrastructure constitutes a major portion of spending during sluggish economic activity. According to estimates published in the International Monetary Fund's Government Finance Statistics online database,[1] the Asia and Pacific region spends about $360 billion on transport each year. However, this figure masks the uneven distribution of spending on infrastructure in general, and on transportation in particular. Specifically, in some countries, transportation infrastructure has expanded dramatically, while in others it has increased only modestly, or even contracted (United Nations Economic and Social Commission for Asia and the Pacific 2013). Improving and expanding transportation infrastructure is believed to be synonymous with economic development, particularly in terms of reducing poverty. This is why the Asian Development Bank (ADB) supports this area to such an extent: transport accounted for 27% of ADB's lending during 2005–2009 (ADB 2010).

The need to assess whether development outcomes are being achieved and met on the side of multilateral development donors

[1] International Monetary Fund. IMF Data: Government Finance Statistics at a Glance. https://data.imf.org/?sk=a0867067-d23c-4ebc-ad23-d3b015045405 (accessed 30 May 2017).

has created new demand for evaluations that can accurately measure the impact of assistance. Lending for transportation projects is no exception. This, then, explains the recent proliferation of various impact evaluation tools. From the earlier wide application of the macroeconomic approach in assessing public infrastructure investment to the recent gain in popularity of microeconometric tools to evaluate particular infrastructure projects, including transport, interest in impact evaluation methodologies will continue for years to come.

This chapter provides a microeconomic case study that examines the impact of the Southern Tagalog Arterial Road (STAR) Tollway located in the province of Batangas, the Philippines, on the public finance of the cities and municipalities through which the highway directly passes. Specifically, we employ a modified version of the difference-in-difference (DID) approach, which is typically used in quasi-experimental impact evaluation studies. We then use a unique dataset disaggregated into the tax (property and business taxes) and non-tax (regulatory fees and user charges) revenues of the cities and municipalities in Batangas.

The chapter is structured as follows: Section 3.2 reviews previous studies that use microeconometric impact evaluation tools. Section 3.3 discusses the DID approach and its modification in the present study. Section 3.4 briefly introduces the STAR Tollway and discusses the public finance data used in this study. Section 3.5 discusses the empirical results. The last section concludes.

3.2 Literature Review

Empirical macroeconomic studies that assess the aggregate impact of infrastructure investments have been popular for many years. Recently, counterfactual microeconometric studies that compare what happened to individuals or cities in the presence of an infrastructure project with how they would have fared without it have also gained in popularity (Hansen, Andersen, and White 2011). However, microeconomic studies employing experimental evaluation—such as randomized control trials (RCTs), which have been widely adopted in the impact evaluation of education and health policies—are difficult to implement in the context of large-scale infrastructure projects (Sawada 2015). One obstacle to an RCT-based evaluation is that an infrastructure project's technical nature prevents randomization because the project's engineering design makes it necessary to determine its beneficiary villages (Hansen, Andersen, and White 2011). An exception to this rule can be seen in the study by Gonzalez-Navarro and Quintana-Domeque

(2016), who conducted a randomized street asphalting experiment to measure the impact of infrastructure on poverty.

Nonetheless, the majority of microeconometric evaluation studies have used quasi-experimental approaches that employed different means to match the beneficiary and nonbeneficiary groups (Hansen, Andersen, and White 2011). Recent studies include Duflo and Pande (2007), Dinkelman (2011), and Donaldson (2014). Duflo and Pande (2007) studied the productivity and distributional effects of large irrigation dams in India, using river gradient as an instrumental variable based on the evidence that, in districts located downstream from a dam, agricultural production increases, and vulnerability to rainfall shocks declines. In contrast, agricultural production increases insignificantly in the district where the dam is located, and its volatility increases. Rural poverty declines in downstream districts, but increases where the dam is built, suggesting that neither markets nor state institutions have alleviated the adverse distributional impacts of dam construction.

Dinkelman (2011) used a similar identification strategy by using this time–land gradient to estimate the impact of electrification on employment growth by analyzing South Africa's mass roll-out of electricity to rural households. The study found that electrification significantly raises female employment within 5 years. Electrification also appears to increase work hours for both and women, while reducing women's wages and increasing men's. The study also found evidence suggesting that household electrification increases employment by releasing women from home production and enabling microenterprises. Jensen (2007) studied the introduction of mobile phone service throughout Kerala, an Indian state with a large fishing industry. Using micro-level survey data, the study showed that the adoption of mobile phones by fishermen and wholesalers was associated with a dramatic reduction in price dispersion for sardines, the complete elimination of waste, and near-perfect adherence to the law of one price; further, both consumer and producer welfare increased.

Donaldson (forthcoming) collected colonial-era data to estimate the impact of India's vast railroad network using a general equilibrium trade model. The results showed that railroads decreased trade costs and interregional price gaps, increased interregional and international trade, eliminated the responsiveness of prices to local productivity shocks (but increased the transmission of these shocks between regions), increased the level of real income (but harmed neighboring regions without railroad access), and decreased real income volatility.

3.3 The Difference-In-Difference Method

Through the DID method, the impact of a policy or a project on a certain outcome can be estimated by computing a double difference, i.e., one over time (before and after) and one across individuals or entities (between beneficiaries, the affected or treatment group, and nonbeneficiaries, the non-affected or control group). In its simplest form, when data are available for the beneficiaries and nonbeneficiaries for two time periods (e.g., before and after the operation of an infrastructure project, such as the opening of a highway), the method produces impact estimates as follows: the first difference (e.g., between the before-and-after outcomes for the beneficiaries) is measured to control for factors that are time-invariant. However, it is still necessary to control for time-varying factors. These are captured as followed: first, the second differences between the before-and-after outcomes for the nonbeneficiaries are obtained; next, the second differences are subtracted from the first differences to purge other time-varying factors further. The final result is interpreted as the project's impact.

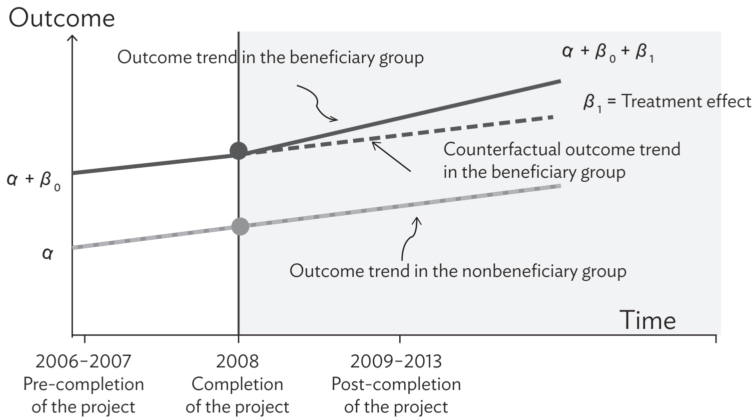
The key assumption of the DID method is that, without the project, the changes in outcomes (i.e., trends) between the beneficiaries and nonbeneficiaries remain the same over time. In effect, the project is the only factor that creates a trend deviation between these two groups. This can be seen in Figure 3.1, where the dotted line represents what would have happened in the beneficiary group in the absence of the project (unobservable or counterfactual). This same dotted line trends parallel to the dashed line, which represents the outcome trend for the nonbeneficiary group. On the other hand, the anomaly in that part of the solid line, i.e., the trend of the beneficiary group, represents the deviation between the beneficiary and nonbeneficiary groups that was assumed to be caused exclusively by the project. In practice, however, it is impossible to test this assumption of the same trend between the beneficiary and nonbeneficiary groups in the project's absence.

To measure the impact of a policy or project, one can also easily use the DID method to estimate the following regression model:

$$Y_{it} = \alpha + \beta_0 A_i + \beta_1 P_t \times A_i + \varepsilon_{it} \quad (1)$$

where Y_{it} is the outcome variable of interest such as gross domestic product (GDP), GDP per capita, or something similar, for the $_i$-th entity in the $_t$-th period; A_i is a binary variable that takes a value of 1 for an entity (e.g., a household, city, or municipality) belonging to the beneficiary group, and a value of 0 for an entity belonging to the nonbeneficiary

Figure 3.1 The Difference-in-Difference Method



Source: Authors.

group; P_t is also a binary variable that takes a value of 1 for the period in which the policy was implemented, or a value of 0 for the period prior to the policy's implementation; $P_t \times A_i$ is the interaction term between the two binary variables; ε_{it} is the error term, which is assumed to be uncorrelated with constant variance σ^2; and α, β_0, and β_1 are the regression parameters to be estimated. The parameter β_1 represents the project's impact. The model can be enriched by including entity and time dummies. The main advantage of working with a regression-based approach to the DID is that other variables can be added to the right side of equation (1) to control for possible violations of the assumption of the same trends between the beneficiary and nonbeneficiary groups.

Our Modified Difference-in-Difference Model

Equation (1) above is a discrete specification and thus does not indicate the dynamics between the infrastructure project and our outcome variable of interest (the logarithm of the respective tax and non-tax categories): how quickly the outcome variable grows from the time that an infrastructure project is constructed, completed, and made operational, and whether this effect accelerates, stabilizes, mean reverts, or shows no effect. To account for these dynamics, equation (1) can be modified by incorporating leads and lags into the specification, and can be expressed as:

$$Y_{it} = \alpha + \beta_0 A_i + \sum_{\tau=t-2}^{t+4} \beta_\tau P_\tau \times A_i + \varepsilon_{it} \qquad (2)$$

The definitions of the variables and regression parameters to be estimated are the same as in equation (1). The only difference between equations (1) and (2) is that equation (2) includes the role of leads and lags of the binary variable P_t before forming its interaction with the other binary variable, A_i. This is to determine whether the infrastructure project caused a significant difference between our beneficiary and nonbeneficiary groups in terms of the outcome variable 1 and 2 years before the project's completion, during the year of its completion, and a few years after its completion. Similar to equation (1), this modified model can be enriched by including entity and time dummies.

3.4 Southern Tagalog Arterial Road Tollway and Regional Public Finance Data

3.4.1 The Southern Tagalog Arterial Road Tollway

The STAR Tollway was built with Japan's Official Development Assistance in an effort to expand the flow of people and goods between the Manila metropolitan area and Batangas City, and thereby contribute to the industrial development of Batangas and the surrounding provinces. This highway is alternatively called the Calabarzon Expressway. The tollway was constructed in two stages. STAR Tollway I is the portion of a four-lane highway, constructed by the Government of the Philippines, that runs from Santo Tomas, Batangas to Lipa City, Batangas (22.16 kilometers). This was opened to traffic in 2001. Its extension, STAR Tollway II, is a two-lane highway from Lipa City to Batangas City (19.74 kilometers) that was constructed as a build–operate–transfer project and opened to traffic in 2008. In June 2013, STAR Tollway II was upgraded to a four-lane asphalt road, which was completed in June 2015. Figure 3.2 shows a map of the province of Batangas[2] and the location of the STAR Tollway within it (highlighted in straight black lines). STAR Tollway I is depicted as two parallel black lines, while STAR Tollway II

2 Batangas is located in Southern Luzon, one of the three main islands in the Philippines.

Figure 3.2 Map of Batangas and the Location of the Southern Tagalog Arterial Road Tollway

Source: Yoshino, Nakahigashi, and Pontines (2017).

is depicted as a single straight black line.

3.4.2 Regional Public Finance Data

As this study's main objective is to ascertain the impact of the STAR Tollway on the public finance of the cities and municipalities through which it directly passes, the outcome variable of interest is the logarithm of the various tax and non-tax revenues of the cities and municipalities in Batangas. In addition to aggregate data on tax and non-tax revenues, we obtained disaggregated data from the Philippine Bureau of Local Government Finance on property and business tax revenues, as well as non-tax revenues covering regulatory fees (e.g., business registration and construction permits) and user charges (e.g., road use fees). These data are compiled annually. When the study began, the most recent year for which data were available from the Bureau of Local Government

Finance website was 2013.[3] Since data are only available from 2001, and the DID method requires before-and-after data on our outcome variable, we are only able to evaluate the impact of STAR Tollway II.[4]

3.5 Empirical Results

STAR Tollway II passes directly through two major cities in Batangas, Lipa City and Batangas City, shown in Figure 3.2 with their municipal boundaries marked in red. Between these two cities, the highway crosses the relatively smaller municipality of Ibaan. For the purposes of this empirical DID analysis, Lipa City, Ibaan, and Batangas City are treated as our group of beneficiaries. The choice of nonbeneficiaries is less straightforward. A natural but arbitrary selection of nonbeneficiaries comprises the adjacent cities and municipalities to the west and east of the beneficiary group. We decided to work with four nonbeneficiary groups (Table 3.1).

Nonbeneficiary groups 1 and 2 are combinations of municipalities

Table 3.1 Municipalities in Batangas that Constitute the Four Nonbeneficiary Groups

Nonbeneficiary Group 1	Nonbeneficiary Group 2	Nonbeneficiary Group 3	Nonbeneficiary Group 4
San Jose	Cuenca	Agoncillo	Nasugbu
San Pascual	Alitagtag	Lemery	Lian
Padre Garcia	Bauan	San Nicolas	Tuy
Rosario	Lobo	Taal	Balayan
Taysan	San Juan	San Luis	Calaca
		Mabini	Calatagan

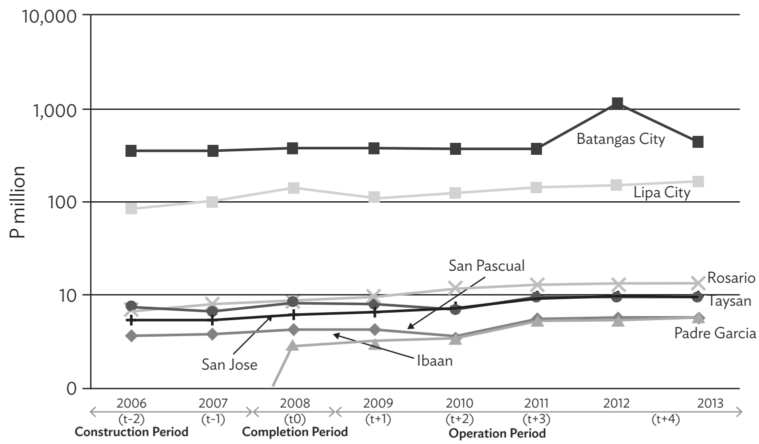
Source: Authors.

that lie to the west and east of the beneficiary group (Figure 3.2). Nonbeneficiary groups 3 and 4 consist entirely of municipalities to the

3 Government of the Philippines, Department of Finance, Bureau of Local Finance. www.blgf.gov.ph (accessed 31 January 2017).

4 To assess the impact of STAR Tollway I using the DID method, data on tax and non-tax revenues prior to 2001 would be required.

Figure 3.3 Business Taxes of the Beneficiary Group versus Nonbeneficiary Group 1



Source: Authors.

west of the beneficiary group; nonbeneficiary group 4 in particular lies directly along Batangas' western edge.

In terms of public finance data, Figure 3.3 presents the trend of business taxes from when the construction of STAR Tollway II began in 2006 using data for the beneficiary group vis-à-vis nonbeneficiary group 1.

Figure 3.3 shows that the two major cities in Batangas, Lipa City and Batangas City, accounted for a large share of business tax revenues from 2006 to 2013. This holds even when we compare the revenues of these two cities with those of the other Batangas municipalities (chart not shown). However, it is unclear whether a deviation exists between these three beneficiary cities or municipalities as opposed to the municipalities of nonbeneficiary group 1, based on our discussion in section 3.3, where the marked trend deviation in the various categories of tax and non-tax data, including business tax revenues, can be assumed to be exclusively caused by STAR Tollway II. It is thus necessary to use an evaluation method such as DID to indicate whether STAR Tollway II indeed significantly impacted the beneficiary group as opposed to the four comparison groups (i.e., the nonbeneficiary groups across the various categories of tax and non-tax revenues).

The empirical results of the modified DID model (equation 2) between our beneficiary and four nonbeneficiary groups are presented in Table 3.2a (property taxes), Table 3.2b (business taxes), Table 3.2c (regulatory fees), and Table 3.2d (usage charges). Each table augments the baseline specification presented in equation (2) by controlling for the level of economic activity in Batangas (denoted as *Construction*, i.e., the number of residential and non-residential constructions).

Tables 3.2a–3.2d show that the interaction terms that incorporate the leads and lags of the P_t binary variable are strongly significant for only one category of tax revenue, i.e., business taxes.[5] This implies that STAR Tollway II, from 2 years before its completion to 4 years after its completion, had an impact on the beneficiary group as opposed to the nonbeneficiaries under this tax revenue category. Specifically, the estimates of the coefficients suggest that the impact of STAR Tollway II on business tax revenues (Table 3.2b) grew gradually from the time of its construction in 2006, reached a peak upon completion in 2008, subsequently slowed, and achieved its largest effect in the last 2 years of its period of observation.

Table 3.2a Modified Difference-in-Difference Regression Results for Property Taxes—Beneficiaries versus Nonbeneficiary Groups 1–4

	Group 1	Group 2	Group 3	Group 4
Impact D	1.5 (1.5)	2.4 (1.5)	2.9* (1.4)	1.5 (1.3)
Impact D × Period_{t-2}	0.10 (0.10)	0.11 (0.10)	0.12 (0.10)	0.061 (0.092)
Impact D × Period_{t-1}	0.25* (0.10)	0.25* (0.10)	0.24* (0.10)	0.201** (0.069)
Impact D × Period_{t}	0.29* (0.13)	0.30* (0.13)	0.30** (0.12)	0.05* (0.16)
Impact D × Period_{t+1}	0.06 (0.16)	0.10 (0.13)	0.13 (0.14)	–0.23 (0.20)
Impact D × Period_{t+2}	0.18 (0.21)	0.22 (0.19)	0.25 (0.20)	–0.07 (0.17)

continued on next page

5 This finding holds even when we use alternative measures of economic activity such as GDP, or a liquidity measure such as the money supply. As this chapter deals with cross-section and time-series data, the reported R-square values are reasonable.

Table 3.2a *continued*

	Group 1	Group 2	Group 3	Group 4
Impact D × $Period_{t+3}$	0.14 (0.14)	0.17 (0.13)	0.19 (0.13)	–0.13 (0.16)
Impact D × $Period_{t+4}$	0.94** (0.35)	0.98** (0.33)	1.01* (0.33)	0.60 (0.39)
Construction	0.71* (0.28)	0.61* (0.15)	0.54* (0.17)	1.33* (0.50)
Constant	10.3** (2.5)	10.3** (1.4)	10.3** (1.4)	5.4 (4.0)
N	90	94	118	104
R^2	0.25	0.42	0.50	0.23

( ) = clustered standard error.
Note: Clustered standard errors are given to two significant digits, and the coefficients are rounded to the same decimal place as the corresponding standard errors.
* Significant at 5%.
** Significant at 1%.
Source: Authors.

Table 3.2b Modified Difference-in-Difference Regression Results for Business Taxes—Beneficiaries versus Nonbeneficiary Groups 1–4

	Group 1	Group 2	Group 3	Group 4
Impact D	0.78 (0.89)	1.08 (0.89)	1.53* (0.79)	0.90 (0.77)
Impact D × $Period_{t-2}$	1.62** (0.63)	1.69*** (0.61)	1.63*** (0.59)	1.59** (0.63)
Impact D × $Period_{t-1}$	1.98*** (0.59)	1.93*** (0.58)	1.97*** (0.57)	1.78*** (0.61)
Impact D × $Period_{t}$	1.10*** (0.62)	2.02*** (0.61)	2.00*** (0.60)	1.81*** (0.65)
Impact D × $Period_{t+1}$	1.54** (0.80)	1.76** (0.72)	1.60** (0.68)	1.62** (0.78)
Impact D × $Period_{t+2}$	1.52* (0.83)	1.72** (0.77)	1.57** (0.73)	1.58** (0.81)
Impact D × $Period_{t+3}$	1.82** (0.69)	1.99*** (0.64)	1.86*** (0.61)	1.83*** (0.69)
Impact D × $Period_{t+4}$	2.36*** (0.57)	2.58*** (0.45)	2.42*** (0.41)	2.35*** (0.78)
Construction	1.09 (0.92)	0.55 (0.41)	0.95** (0.39)	0.60 (0.62)
Constant	6.3 (8.0)	10.3*** (3.6)	6.6** (3.4)	10.2** (4.9)

continued on next page

Table 3.2b *continued*

	Group 1	Group 2	Group 3	Group 4
N	90	94	118	104
R^2	0.37	0.45	0.48	0.36

( ) = clustered standard error.
Note: Clustered standard errors are given to two significant digits, and the coefficients are rounded to the same place as the corresponding standard errors.
* Significant at 10%.
** Significant at 5%.
*** Significant at 1%.
Source: Authors.

Table 3.2c Modified Difference-in-Difference Regression Results for Regulatory Fees—Beneficiaries versus Nonbeneficiary Groups 1–4

	Group 1	Group 2	Group 3	Group 4
Impact D	0.93 (0.78)	1.51* (0.86)	1.95** (0.81)	1.35** (0.69)
Impact D × $Period_{t-2}$	0.16 (0.12)	0.101 (0.111)	0.06 (0.12)	0.21 (0.14)
Impact D × $Period_{t-1}$	0.61*** (0.19)	0.65*** (0.19)	0.68*** (0.19)	0.61*** (0.19)
Impact D × $Period_{t}$	0.64** (0.25)	0.62** (0.25)	0.61** (0.25)	0.55** (0.22)
Impact D × $Period_{t+1}$	0.59 (0.46)	0.40 (0.44)	0.27 (0.45)	0.54 (0.48)
Impact D × $Period_{t+2}$	0.79* (0.41)	0.62 (0.40)	0.50 (0.40)	0.75* (0.45)
Impact D × $Period_{t+3}$	1.04*** (0.28)	0.90*** (0.27)	0.80*** (0.28)	0.99*** (0.24)
Impact D × $Period_{t+4}$	1.37*** (0.27)	1.19*** (0.25)	1.06*** (0.28)	1.26*** (0.11)
Construction	0.57 (0.40)	1.02*** (0.26)	1.34*** (0.39)	0.75*** (0.27)
Constant	10.2*** (3.1)	5.9*** (2.0)	2.1 (3.4)	8.3*** (2.2)
N	90	94	118	104
R^2	0.42	0.47	0.57	0.55

( ) = clustered standard error.
Note: Clustered standard errors are given to two significant digits, and the coefficients are rounded to the same decimal place as the corresponding standard errors.
* Significant at 10%.
** Significant at 5%.
*** Significant at 1%.
Source: Authors.

Table 3.2d Modified Difference-in-Difference Regression Results for User Charges—Beneficiaries versus Nonbeneficiary Groups 1–4

	Group 1	Group 2	Group 3	Group 4
Impact D	0.61 (1.13)	1.08 (1.30)	1.88* (1.15)	1.79* (0.99)
Impact D × Period_{t-2}	0.45*** (0.11)	0.32*** (0.08)	0.29*** (0.08)	0.40*** (0.14)
Impact D × Period_{t-1}	0.33 (0.28)	0.42 (0.27)	0.44* (0.27)	0.47** (0.19)
Impact D × Period_{t}	0.55 (0.29)	0.51 (0.29)	0.50* (0.28)	0.26 (0.23)
Impact D × Period_{t+1}	0.60 (0.47)	0.19 (0.41)	0.10 (0.41)	−0.15 (0.40)
Impact D × Period_{t+2}	0.58 (0.44)	0.20 (0.39)	0.12 (0.39)	−0.08 (0.38)
Impact D × Period_{t+3}	0.80* (0.42)	0.49 (0.39)	0.42 (0.39)	0.19 (0.34)
Impact D × Period_{t+4}	1.09* (0.60)	0.68 (0.57)	0.59 (0.57)	0.27 (0.43)
Construction	0.12 (0.58)	1.12*** (0.19)	1.34*** (0.26)	2.14*** (0.64)
Constant	13.4*** (4.9)	4.8** (1.9)	2.2 (2.3)	−4.2 (5.1)
N	90	94	118	103
R^2	0.21	0.21	0.42	0.44

( ) = clustered standard error.
Note: Clustered standard errors are given to two significant digits, and the coefficients are rounded to the same decimal place as the corresponding standard errors.
* Significant at 10%.
** Significant at 5%.
*** Significant at 1%.
Source: Authors.

Finally, to illustrate the dynamic effects of STAR Tollway II on the business tax revenues of Lipa City, Ibaan, and Batangas City, we calculated the counterfactual increase in business tax revenues for these three beneficiary areas by using the estimated impact coefficients, i.e., the estimated coefficients of the various interaction terms between the leads and lags of the P_t and A_i binary variables reported in the second column of Table 3.2d, as well as the actual business tax revenues for each beneficiary area in a particular period. These calculations are shown in Table 3.3. As emphasized above, the calculated increase in business

Table 3.3 Calculated Increase in Business Tax Revenues for the Beneficiary Group Relative to Nonbeneficiary Group 4 (P million)

	t-2	t-1	t	t+1	t+2	t+3	t+4
Lipa City	134.36	173.50	249.70	184.47	191.81	257.35	371.93
Ibaan	5.84	7.04	7.97	6.80	5.46	10.05	12.94
Batangas City	490.90	622.65	652.83	637.89	599.49	742.28	1,208.61

Note: This represents the average increase in business tax revenues in each province for the period t+4 forward in the case of Lipa City and Batangas City.
Source: Authors.

tax revenues for the three beneficiary areas suggests that the impact of STAR Tollway II grew from the time of its construction in 2006 (refer to the amounts in columns labeled as t-2 and t-1), reached a peak at the time of its completion in 2008 (refer to the amount in the column labeled as t), subsequently slowed down (refer to the amounts in columns labeled as t+1 and t+2), and, in the last 2 years of our period of observation, achieved its largest effect (refer to the amounts in columns labeled as t+3 and t+4).

As government support for the build–operate–transfer portion of the STAR Tollway (i.e., STAR Tollway II) amounted to P0.5 billion, the estimated annual average of the accumulated increase in business tax revenues for the three beneficiary areas is roughly P1 billion. Thus, according to these calculations, STAR Tollway II yielded a net benefit for the government.

3.5.1 Spillover Effect

The next question to arise is whether STAR Tollway II significantly impacted the various categories of tax and non-tax revenues of the municipalities in provinces that neighbor Batangas (referred to as the “spillover effect” in the impact evaluation literature). Figure 3.2 shows these neighboring municipalities, which are located on the eastern edge of Batangas and the STAR Tollway, in hollow white with boundaries marked in discontinuous or broken black lines.[6]

Using municipalities in the neighboring province of Quezon as a test case to examine the spillover effect of STAR Tollway II, we present

6 These municipalities in the province of Quezon are Candelaria, Dolores, San Antonio, and Tiaong.

in Table 3.4 our modified DID empirical results for property taxes (column 1), business taxes (column 2), regulatory fees (column 3), and user charges (column 4). This time, levels of economic activity in the provinces of Batangas and Quezon were used to augment the baseline specification presented in equation (2). As before, economic activity is measured by the number of residential and non-residential constructions (i.e., the variable $Construction_t$).

Table 3.4 Modified Difference-in-Difference Regression Results—Spillover Effect

	(1) Property Tax	(2) Business Tax	(3) Regulatory Fees	(4) User Charges
Impact D	0.74 (0.87)	0.4 (1.4)	0.9 (1.0)	0.4 (1.0)
Impact D × $Period_{t-2}$	–0.08 (0.30)	0.99** (0.45)	–0.02 (0.25)	–0.01 (0.25)
Impact D × $Period_{t-1}$	0.57*** (0.12)	1.50*** (0.54)	0.52*** (0.17)	0.43** (0.17)
Impact D × $Period_t$	0.57** (0.22)	1.64*** (0.48)	0.64*** (0.18)	0.42 (0.16)
Impact D × $Period_{t+1}$	0.39 (0.73)	1.78** (0.47)	0.84* (0.45)	0.20 (0.56)
Impact D × $Period_{t+2}$	0.34 (0.59)	1.80** (0.53)	1.04** (0.41)	0.25 (0.53)
Impact D × $Period_{t+3}$	0.45 (0.58)	2.07*** (0.54)	1.24*** (0.37)	0.68 (0.52)
Impact D × $Period_{t+4}$	1.10 (0.76)	2.56*** (0.35)	1.51*** (0.45)	0.79 (0.75)
Construction	2.3** (1.2)	1.6 (1.2)	1.21 (0.86)	1.9* (1.0)
Constant	–2.5 (8.8)	2.20 (9.10)	4.6 (6.6)	–1.6 (7.0)
N	73	73	73	73
R^2	0.41	0.44	0.50	0.39

( ) = clustered standard error.
Note: Clustered standard errors, corrected for a small number of clusters. These clustered standard errors are given to two significant digits, and the coefficients are rounded to the same decimal place as the corresponding standard errors.
* Significant at 10%.
** Significant at 5%.
*** Significant at 1%.
Source: Authors.

Interestingly, similar to the findings in Tables 3.2a–3.2d, it again appears that all of the interaction terms under the category of business tax revenues remain economically and statistically significant. However, unlike the economic significance of the interaction terms in the empirical results relating to business tax revenues in Tables 3.2a–3.2d, Table 3.4 shows that the impact of STAR Tollway II increased through the last 4 years of our period of analysis.

3.5.2 Robustness Test: Using Continuous Distance

A limitation of our previous strategy for selecting nonbeneficiary groups is that it is impossible to determine whether adjacency to those cities and municipalities through which the highway directly passes can be used to choose a suitable comparison group. Alternatively, in terms of arbitrarily selecting the nonbeneficiary group, the comparison group could be omitted, and the calculated continuous distance from the primary urban center of a municipality to its nearest STAR Tollway II entry point could be used instead. By using the calculated continuous distance, our earlier baseline specification (equation [2]) can now be expressed as

$$\mathrm{Y_{it}} = \alpha + \beta_0 \mathrm{Distance_i} + \sum_{\tau=t-2}^{t+4} \beta_\tau (P_\tau \times \mathrm{Distance_i}) + \varepsilon_{\mathrm{it}} \qquad (3)$$

In equation (3), the binary variable, P_t, is defined as before, including the regression parameters to be estimated. However, the binary variable A_i is replaced with the continuous distance variable, $Distance_i$. As such, the relevant interaction term falls between this continuous distance variable, $Distance_i$ and the binary variable, P_t. Nonetheless, similar to equation (2), we still take into account the dynamics of STAR Tollway II and its impact on the various categories of tax and non-tax revenues by incorporating leads and lags into the specification of equation (3) via the binary variable, P_t. Just as before, this reveals how quickly the different categories of tax and non-tax revenues grew from the time that STAR Tollway II was constructed, completed, and made operational; and whether this effect accelerated, stabilized, mean reverted, or showed no effect. Finally, similar to equations (1) and (2), the model above can be enriched by including entity and time dummies.

Table 3.5 presents the empirical results of equation (3) for property taxes (column 1), business taxes (column 2), regulatory fees (column 3), and user charges (column 4). Controlling for $Construction_t$,

Table 3.5 Regression Results—Using Continuous Distance from the Southern Tagalog Arterial Road Tollway

	(1) Property Tax	(2) Business Tax	(3) Regulatory Fees	(4) User Charges
Impact D	−0.68* (0.22)	−0.72* (0.16)	−0.75* (0.10)	−0.55* (0.12)
Impact D × $Period_{t-2}$	0.0641* (0.0092)	0.117* (0.011)	0.047** (0.019)	0.033** (0.016)
Impact D × $Period_{t-1}$	0.049* (0.018)	0.213* (0.014)	0.173* (0.013)	−0.007 (0.025)
Impact D × $Period_{t}$	0.095* (0.011)	0.222* (0.012)	0.211* (0.019)	0.059** (0.028)
Impact D × $Period_{t+1}$	0.088* (0.024)	0.111* (0.014)	0.241* (0.025)	0.018 (0.027)
Impact D × $Period_{t+2}$	0.130* (0.015)	0.128* (0.018)	0.300* (0.023)	0.042 (0.031)
Impact D × $Period_{t+3}$	0.101* (0.018)	0.168* (0.023)	0.294* (0.024)	0.083* (0.026)
Impact D × $Period_{t+4}$	0.220* (0.023)	0.202* (0.025)	0.377* (0.016)	0.084* (0.027)
Construction	0.03 (0.10)	0.902* (0.059)	0.077 (0.075)	0.50* (0.14)
Constant	19.7* (1.1)	12.26* (0.74)	17.43* (0.75)	12.9* (1.3)
N	886	886	886	886
R^2	0.03	0.07	0.13	0.04

() = clustered standard error.
Note: Clustered standard errors, corrected for a small number of clusters. These clustered standard errors are given to two significant digits, and the coefficients are rounded to the same decimal place as the corresponding standard errors.
* Significant at 1%.
** Significant at 5%.
Source: Authors.

we find that the interaction terms in three of the four categories of tax and non-tax revenues are economically and statistically significant: property and business taxes, and regulatory fees. Furthermore, the economic significance of the interaction terms tends to increase over time for all three categories.

3.6 Conclusions

Given the massive amounts of money that many countries in the Asia region have invested in infrastructure since the 1997 Asian financial crisis, it is important that we evaluate the economic impact and benefits of these investments. Traditional empirical studies on infrastructure have taken the macroeconomic approach of examining the aggregate impact of investment on growth and productivity. However, microeconometric studies have recently gained in popularity. This study aligns with the microeconometric approach of using quasi-experimental methods to examine infrastructure projects.

This study examined the impact of the STAR Tollway located in the province of Batangas, the Philippines, on the public finance of the cities and municipalities through which it directly passes. Specifically, to evaluate the STAR Tollway's impact, we exploit a unique dataset disaggregated into the tax (property and business taxes) and non-tax (regulatory fees and user charges) revenues of the cities and municipalities in Batangas.

Using a modified DID model, we found that STAR Tollway II had a robust, statistically significant, and economically growing impact on business taxes. We also found that the so-called "highway effect" of the STAR Tollway on business taxes also extended to municipalities located in Quezon, a neighboring province of Batangas. These results suggest that certain infrastructure projects may have not only concentrated or "localized" effects, but also wider effects that extend to the regional economy. Further, STAR Tollway II appears to have significantly impacted, not only public finance, but also property taxes and regulatory fees. These findings support the widely held belief that infrastructure investments carry real and significant economic benefits. Given the desire of countries in the region to seek alternative sources of sustainable development financing, boosting tax revenues may not only come from an effective revenue system such as better tax administration and adopting various forms of direct and indirect forms of taxation. The findings of this micro case study suggest that infrastructure investments can play an indirect role in boosting tax and non-tax revenues.

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PART II

Development Impact of Infrastructure

4

The Productivity Effect of Infrastructure Investment in Thailand and Japan

Naoyuki Yoshino and Masaki Nakahigashi

4.1 Introduction

Public investment, such as in infrastructure, is a tool to boost and promote the efficiency of a country's economy. There is a particularly acute demand for infrastructure in Asian countries.[1]

In Thailand, a middle-income country, economic growth has been slowing since the early 2000s, prompting discussion of whether Thailand is a victim of the "middle-income trap" (Jitsuchon 2012; Egawa 2013). Pomlaktong and Ongkittikul (2008) insist that delays in transport infrastructure investment are causing severe problems in Thailand's economy. It is thus necessary to investigate the role of infrastructure in economic development, and determine whether infrastructure supply is adequate to support the economic efficiency in Thailand.

In Japan, a developed country, concerns about inefficient public investment have been raised since 2000, when Prime Minister Koizumi decided to decrease public investment drastically. At the same time, the Japanese government has been increasing social security spending and facing huge levels of public debt. Consequently, spending on public investment and education has been gradually declining. In 2012, the collapse of a ceiling in the Sasago Tunnel drew attention to Japan's aging infrastructure. As a result, the current government's National Resilience Plan promotes additional public investment. Whether such "additional" public investment promotes the efficient use of resources in Japan is an important point to determine.

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1 Bhattacharyay (2010) estimates the demand for infrastructure in Asian countries.

This chapter examines the productivity effect of infrastructure in Thailand and Japan. Specifically, the effect of infrastructure is estimated using a production function and total factor productivity (TFP) regression by industry.

4.2 Economic Growth in Thailand and Japan

This section analyzes changes in economic growth and the level of infrastructure in Thailand and Japan from the 1970s to the 2010s.

4.2.1 Decomposition of Gross Domestic Product Growth

We decompose gross domestic product (GDP) growth into the contribution of input factors and TFP in order to clarify the contribution of technical progress to economic growth.

TFP is defined as the ratio of output to the aggregate inputs. The output is defined as GDP and the two input factors as private capital K_P and labor input L. The aggregate input function is expressed as $X = X(K_P, L)$. The TFP growth rate can be defined using a logarithmic form as follows:

$$\frac{d \ln \mathrm{TFP}}{dt} = \frac{d \ln Y}{dt} - \frac{\partial \ln X}{\partial \ln K_P}\frac{d \ln K_P}{dt} - \frac{\partial \ln X}{\partial \ln L}\frac{d \ln L}{dt} \tag{1}$$

Another expression is shown by:

$$\begin{aligned} \frac{\dot{\mathrm{TFP}}}{\mathrm{TFP}} &= \frac{\dot{Y}}{Y} - \left(\frac{\partial X}{\partial K_P}\frac{K_P}{X}\right)\frac{\dot{K}_P}{K_P} - \left(\frac{\partial X}{\partial L}\frac{L}{X}\right)\frac{\dot{L}}{L} \\ &= \frac{\dot{Y}}{Y} - s_{KP}\frac{\dot{K}_P}{K_P} - s_L\frac{\dot{L}}{L} \end{aligned} \tag{2}$$

where s_j $(j = K_P, L)$ represents the contribution of input j to aggregate input. Equation (2) shows that the TFP growth rate contains various factors that have contributed to output other than K_P and L.

We derived the TFP of industries in Thailand and Japan using the Theil-Törnqvist Index, which is the discrete expression of the Divisia Index. The growth rate of the TFP is expressed as follows:

$$\ln \frac{\mathrm{TFP}_t}{\mathrm{TFP}_{t-1}} = \ln \frac{Y_t}{Y_{t-1}} - \left[\frac{1}{2}\left(s_t^L + s_{t-1}^L\right) \ln \frac{L_t}{L_{t-1}} + \frac{1}{2}\left(s_t^{K_P} + s_{t-1}^{K_P}\right) \ln \frac{K_{P,t}}{K_{P,t-1}}\right] \tag{3}$$

where $s_t^{K_P}$ represents the share of input factor K_P to aggregated input at period t, and s_t^L represents the share of input factor L to aggregated input at period t. In calculating TFP, it is assumed that the output is GDP and the aggregate input function is the constant returns to scale across K_P and L.

To compare TFP among industries and during various years, we calculate the TFP as follows. First, we compute the ratio of TFP to the TFP in the manufacturing sector in the base year. This method is based on Caves, Christensen, and Diewert (1982). The level of TFP in industry compared with that in industry at period j is as follows:

$$\ln \frac{\mathrm{TFP}_j^a}{\mathrm{TFP}_j^m} = \ln \frac{Y_j^a}{Y_j^m} - \ln \frac{K_{P,j}^a}{K_{P,j}^m} - \left[\frac{1}{2}(s_L^a + s_L^m)\left(\ln \frac{L_j^a}{L_j^m} - \ln \frac{K_{P,j}^a}{K_{P,j}^m}\right)\right] \quad (4)$$

where s_L^a is the cost share of labor in industry a. Second, the growth rate of TFP in industry a from period t - 1 to t is calculated as follows:

$$\ln \frac{\mathrm{TFP}_t^a}{\mathrm{TFP}_{t-1}^a} = \ln \frac{Y_t^a}{Y_{t-1}^a} - \ln \frac{K_{P,t}^a}{K_{P,t-1}^a} - \left[\frac{1}{2}(s_{L,t}^a + s_{L,t-1}^a)\left(\ln \frac{L_t^a}{L_{t-1}^a} - \ln \frac{K_{P,t}^a}{K_{P,t-1}^a}\right)\right] \quad (5)$$

where $s_{L,t}^a$ shows the cost share of input factor L at period t. Through these processes, we can compare the level of TFP in each industry to the level of TFP in a sector at a base period.

This analysis uses the level of capital stock as a proxy for the level of capital services. In official stock data, the level of capital stock at period is measured at the end of period . Hence, we assume that the level of capital services at period is a proxy for the level of capital stock at the end of period t - 1.

4.2.2 Growth Accounting in Thailand

East Asian economies performed impressively from the 1960s through the first half of the 1990s. Young (1995) and Collins and Bosworth (1996) insist that the main source of growth in Asian countries in the 1990s was growth in factor inputs as opposed to technical progress, which, they argued, did not contribute to economic growth.[2]

To understand this phenomenon, it is necessary to examine sources of economic growth in Thailand using growth accounting from 1971

2 Bisonyabut (2012) reviews economic growth in Thailand using the results of previous growth accounting.

to 2012.[3] Specifically, we examine the following sectors: (i) agriculture, hunting, forestry, and fishing; (ii) manufacturing; (iii) construction; and (iv) services.[4] The industrial classification in this chapter differs from the International Standard Industrial Classification due to data constraints.

In calculating the level of TFP, 2002 is used as the reference year, and manufacturing is the reference industry. Therefore, the level of TFP is relative to the TFP of the manufacturing sector in 2002. We decompose GDP by industry accordingly (Table 4.1).

Table 4.1 Economic Growth of Thailand by Industry

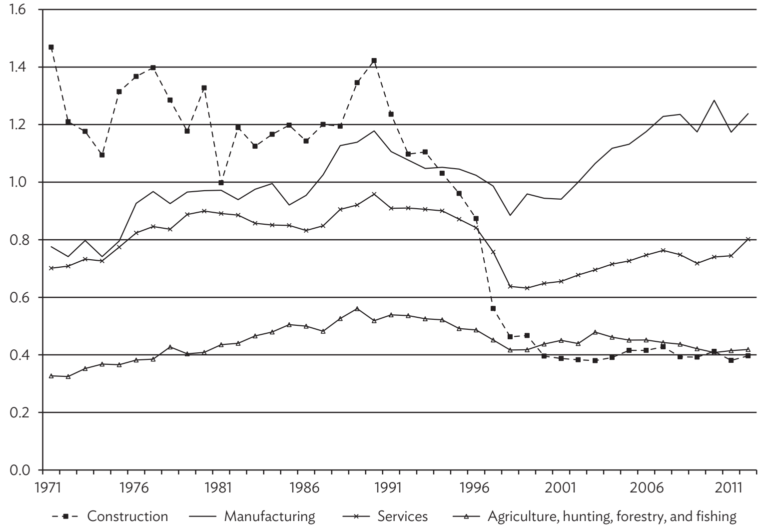
	Growth rate of			
	Output per labor input	Private capital per labor input	Labor input	TFP
Agriculture, hunting, forestry, and fishing				
1976–2012	3.0	3.0	0.3	0.3
1976–1992	0.9	–1.4	2.8	2.1
1992–2002	6.9	10.2	–3.6	–2.0
1986–1996	5.9	6.7	–1.7	–0.3
2002–2012	2.5	3.4	0.3	–0.5
Manufacturing				
1976–2012	2.8	3.2	3.9	0.8
1976–1992	2.4	2.2	6.9	0.9
1992–2002	2.5	5.8	2.3	–0.7
1986–1996	4.8	7.0	6.7	0.7
2002–2012	3.7	2.1	0.8	2.2
Construction				
1976–2012	–1.8	2.0	5.9	–3.4
1976–1992	–1.0	–0.7	11.4	–1.4
1992–2002	–4.9	9.8	–0.1	–10.0
1986–1996	–1.4	1.9	14.7	–2.7
2002–2012	0.1	–1.2	3.4	0.3
Services				
1976–2012	0.9	1.3	4.6	–0.1
1976–1992	1.9	1.8	5.8	0.6
1992–2002	–1.5	1.8	4.6	–2.9
1986–1996	4.2	5.7	4.5	0.1
2002–2012	1.8	0.1	2.6	1.7

TFP = total factor productivity.
Source: Authors' calculations.

[3] The Asian Productivity Organization also measures various productivity indicators every year. See Asian Productivity Organization (2014) for recent data.

[4] The services sector includes the "public administration and defense" sector because of data availability.

Figure 4.1 Level of Total Factor Productivity by Industry in Thailand



Source: Authors' calculation.

It is clear that the TFP growth rate in the manufacturing sector is larger than in other industries. After 2002, the TFP growth rate in the manufacturing and services sectors has increased relative to past levels; however, it has declined in the agricultural sector, and in the construction sector it is negative for almost the entire period. Next, the level of TFP is compared among industries (Figure 4.1).

After 1994, the TFP of manufacturing has exceeded the TFP of any other examined industry. During the 1997–1998 Asian financial crisis, TFP fell for all industries, especially construction. Thus, this chapter focuses on the productivity effect of public capital in industrial sectors other than construction.

4.2.3 Growth Accounting in Japan

Next, we examine sources of economic growth in Japan using growth accounting from 1975 to 2010. Industry in Japan consists of primary, secondary, and tertiary industry. The level of TFP is calculated by industry and region (Table 4.2). The industrial classification system used for Japan in this chapter differs from the International Standard Industrial Classification due to data availability.

Table 4.2 Regional Classification of Japan

Region	Prefectures
Hokkaido	Hokkaido
Tohoku	Aomori, Akita, Iwate, Miyagi, Yamagata, Fukushima
North Kanto	Ibaraki, Tochigi, Gunma, Nagano
South Kanto	Saitama, Chiba, Tokyo, Kanagawa, Yamanashi
Hokuriku	Niigata, Toyama, Ishikawa, Fukui
Tokai	Shizuoka, Gifu, Aichi, Mie
Kinki	Shiga, Kyoto, Osaka, Hyogo, Nara, Wakayama
Chugoku	Tottori, Shimane, Okayama, Hiroshima, Yamaguchi
Shikoku	Kagawa, Tokushima, Ehime, Kochi
North Kyushu	Fukuoka, Saga, Nagasaki, Oita
South Kyushu	Kumamoto, Miyazaki, Kagoshima

Source: Authors.

When calculating the level of TFP in each industry and region, the reference sector is manufacturing in the South Kanto region, and the reference year is 2005. Therefore, the level of TFP in each industry and region is relative to that of the manufacturing sector in the South Kanto region in 2005. Accordingly, the decomposition of GDP in Japan is derived by industry and region (Table 4.3).

The TFP growth rate is highest in secondary industry. Regional disparities in TFP growth rates appear in all industries. For secondary industry, regions containing cities have the highest TFP growth. For tertiary industry, TFP growth is highest in North Kanto, South Kanto, and Tokai.

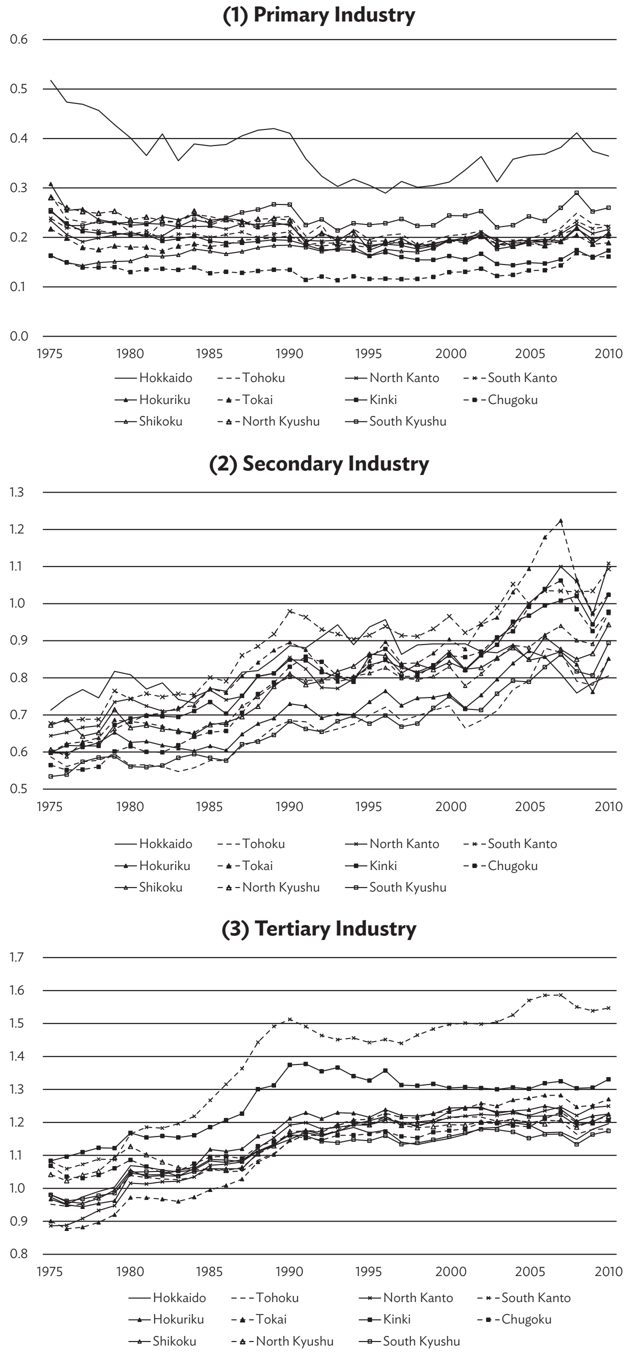
Figure 4.2 shows the changes in the level of TFP in each industry and region. Tertiary industry has the highest TFP. In primary industry, Hokkaido is the region with the highest TFP throughout the period. In tertiary industry, the region with the highest TFP level is South Kanto, followed by Kinki. However, a gap has opened up between these two regions after 1997.

Table 4.3 Economic Growth of Japan by Industry and Region

	Growth rate of			
	Output per labor input	Private capital per labor input	Labor input	TFP
Primary Industry				
Hokkaido	2.5	5.4	−2.6	−1.0
Tohoku	2.1	6.9	−3.9	−0.7
North Kanto	2.4	6.9	−3.7	−0.2
South Kanto	2.7	6.4	−3.4	−0.2
Hokuriku	2.8	7.7	−4.4	−1.2
Tokai	2.7	7.5	−3.7	−0.4
Kinki	2.3	6.8	−3.5	−1.1
Chugoku	2.3	7.0	−3.9	0.0
Shikoku	2.8	6.3	−3.6	0.7
North Kyushu	2.3	6.8	−3.5	−0.8
South Kyushu	3.1	6.4	−3.3	0.1
Secondary Industry				
Hokkaido	1.6	4.2	−1.2	0.3
Tohoku	2.6	5.3	−0.2	1.1
North Kanto	3.5	5.4	−0.2	1.6
South Kanto	2.3	4.3	−1.1	1.4
Hokuriku	2.5	4.8	−0.6	1.0
Tokai	3.2	4.8	−0.4	1.5
Kinki	2.7	4.5	−1.3	1.5
Chugoku	2.8	4.3	−1.0	1.6
Shikoku	2.6	4.7	−1.1	1.0
North Kyushu	2.6	4.4	−0.7	1.4
South Kyushu	2.8	5.2	−0.3	1.5
Tertiary Industry				
Hokkaido	2.2	4.8	0.1	0.6
Tohoku	2.1	4.3	0.4	0.6
North Kanto	2.3	3.7	0.9	1.0
South Kanto	2.6	4.1	0.9	1.0
Hokuriku	2.2	4.1	0.3	0.7
Tokai	2.2	4.0	0.7	1.0
Kinki	2.0	4.0	0.3	0.6
Chugoku	1.9	4.6	0.3	0.3
Shikoku	2.2	5.1	0.2	0.6
North Kyushu	2.1	4.7	0.5	0.4
South Kyushu	2.0	5.0	0.5	0.5

TFP = total factor productivity.
Source: Authors' calculations.

Figure 4.2 Level of Total Factor Productivity by Industry and Region



Source: Authors' calculation.

4.2.4 Comparison of Levels of Infrastructure

Levels of infrastructure in Thailand and Japan are compared using physical indicators (Table 4.4).

Table 4.4 shows that, although Thailand caught up with Japan in electricity production and telecommunications in 2010, Thailand still lags behind Japan in transport infrastructure. Although Japan's transport infrastructure supply may be considered excessive, Thailand's level of transport infrastructure is insufficient.

Table 4.4 Levels of Infrastructure in Thailand and Japan

		Thailand			Japan		
Indicator	Unit	1975	1995	2010	1975	1995	2010
Paved road length	km per 1,000 km^2	34.7	117.9	343.2	895.3	2,224.8	2,575.3
Railway length	km per 1,000 km^2	7.4	7.9	8.7	71.1	72.3	73.6[a]
Fixed line subscribers	per capita	0.005	0.059	0.103	0.272	0.486	0.236
Mobile subscribers	per capita	–	0.022	1.080	–	0.081	0.933
Electricity production	kWh per 1,000 persons	199.4	1,357.7	2,402.3	736.3	1,789.0	2,375.7

km = kilometer, km^2 = square kilometer, kWh = kilowatt-hour.

[a] The 2009 value.

Source: Thailand: Authors' calculations based on Canning (1998); ESCAP Statistical Online Database (United Nations Economic and Social Commission for Asia and Pacific); World Development Indicators (World Bank). Japan: Authors' calculations based on System of Social and Demographic Statistics (SSDS).

4.3 Theory of the Productivity Effect

The main objective of this chapter is to evaluate the productivity effect of infrastructure. To accomplish this, two methods are used: production function analysis and TFP regression. This section describes the theoretical background of our analysis.

4.3.1 Production Function Analysis

The productivity effect of public capital is an important indicator for evaluating infrastructure investment. Several scholars have used the production function approach to determine this effect.[5] In Japan, Yoshino and Nakahigashi (2000) and Miyara and Fukushige (2008) evaluated the productivity effect of public capital by region and sector, and found that regional differences exist among regions and industries. Their work was followed by that of Kameda and Li (2008); Hayashi (2009); and Miyagawa, Kawasaki, and Edamura (2013); who implied that the productivity effect of public capital remedies in Japan can be determined using prefectural panel data.

The production function is the relationship between all input and output. The factor inputs in our analysis are private capital (K_P), labor input (L), and public capital (K_G). The form of the production function is transcendental logarithmic (translog), which is the log-linear approximation around the average.

$$\begin{aligned}\ln Y - \ln \overline{Y} \quad = \quad & \alpha_0 + \alpha_K\left(\ln K_P - \ln \overline{K_P}\right) + \alpha_L\left(\ln L - \ln \overline{L}\right) \\ & +\alpha_G(\ln K_G - \ln \overline{K_G}) \\ & +\beta_{KK}\frac{1}{2}(\ln K_P - \ln \overline{K_P})^2 + \beta_{KL}(\ln K_P - \ln \overline{K_P}) \\ & +\beta_{KG}(\ln K_P - \ln \overline{K_P})(\ln K_G - \ln \overline{K_G}) \\ & +\beta_{LL}\frac{1}{2}(\ln L - \ln \overline{L})^2 + \beta_{LG}(\ln L - \ln \overline{L})(\ln K_G \\ & +\beta_{GG}\frac{1}{2}(\ln K_G - \ln \overline{K_G})^2 + \epsilon\end{aligned}$$

where the variables with an overline denote the average of this variable over an arbitrary period, and ϵ is the error term expressing unexplained factors in this model. To simplify the equation, we use $\ln Y^*$ instead of $\ln Y - \ln \overline{Y}$. Consequently, the new expression of the basic model is as follows:

$$\begin{aligned}\ln Y^* \quad = \quad & \alpha_0 + \alpha_K \ln K_P^* + \alpha_L \ln L^* + \alpha_G \ln K_G^* \\ & +\beta_{KK}\frac{1}{2}(\ln K_P^*)^2 + \beta_{KL} \ln K_P^* \ln L^* + \beta_{KG} \ln K_P^* \ln K_G^* \\ & +\beta_{LL}\frac{1}{2}(\ln L^*)^2 + \beta_{LG} \ln L^* \ln K_G^* \\ & +\beta_{GG}\frac{1}{2}(\ln K_G^*)^2 + \epsilon\end{aligned} \qquad (7)$$

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5 There are many survey papers on the productivity effect of public capital, including Gramlich (1994), Straub (2011), and Pereira and Andraz (2013). Bom and Ligthart (2014) and Melo, Graham, and Brage-Ardao (2013) reviewed previous papers based on a meta-analysis using the estimated results of previous papers on the effect of public investment on productivity.

Although translog is more flexible than other types of functional form, multicollinearity is possible when using this model. To reduce this, we introduce restrictions on the model based on producers' profit maximization, under which the following relationships are fulfilled:

$$\frac{\partial Y}{\partial L} = \frac{w}{p}, \qquad \frac{\partial Y}{\partial K_P} = \frac{r}{p}$$

where is the price of the product, w is the price of labor input, and r is the price of the capital service. Multiplying these two equations by $\frac{L}{Y}$ and $\frac{K_P}{Y}$, respectively, produces the following equations:

$$\frac{\partial Y}{\partial L}\frac{L}{Y}\left(= \frac{\partial \ln Y}{\partial \ln L}\right) = \frac{wL}{pY}, \qquad \frac{\partial Y}{\partial K_P}\frac{K_P}{Y}\left(= \frac{\partial \ln Y}{\partial \ln K_P}\right) = \frac{rK_P}{pY}$$

The left-hand sides of these equations denote the output elasticity of L and K_P, respectively, while the right-hand sides denote the cost share of factor input L and K_P, respectively. Using the marginal productivity principles of factor payments reveals that the cost share of a factor input equals the output elasticity of a factor input.

$$\frac{rK_P}{pY} = \frac{\partial \ln Y}{\partial \ln K_P} = \alpha_K + \beta_{KK} \ln\ K_P + \beta_{KL} \ln\ L + \beta_{KG} \ln\ K_G \qquad (8)$$

$$\frac{wL}{pY} = \frac{\partial \ln Y}{\partial \ln L} = \alpha_L + \beta_{KL} \ln\ K_P + \beta_{LL} \ln\ L + \beta_{LG} \ln\ K_G \qquad (9)$$

In addition, the constant returns to scale across K_P and L are introduced in the production function. To fulfill the constant return to scale, the following sufficient conditions must be added using Euler's theorem:

$$\begin{cases} \alpha_K + \alpha_L = 1 \\ \beta_{KK} + \beta_{KL} = 0 \\ \beta_{KL} + \beta_{LL} = 0 \\ \beta_{KG} + \beta_{LG} = 0 \end{cases} \qquad (10)$$

Consequently, from equations (7), (9), and (10), we derive the following system:

$$
\begin{aligned}
\ln \frac{Y_t^*}{L_t^*} &= \alpha_0 + \alpha_K \ln \frac{K_{P,t}^*}{L_t^*} + \alpha_G \ln K_{G,t}^* \\
&+\beta_{KL}\left(\ln K_{P,t}^* \ln L_t^* - \frac{1}{2}(\ln K_{P,t}^*)^2 - \frac{1}{2}(\ln L_t^*)^2\right) \\
&+\beta_{KG} \ln K_{G,t}^* \ln \frac{K_{P,t}^*}{L_t^*} + \beta_{GG}\frac{1}{2}(\ln K_{G,t}^*)^2 + \epsilon_{P,t} \\
S_{L,t} &= 1 - \alpha_K + \beta_{KL} \ln \frac{K_{P,t}^*}{L_t^*} - \beta_{KG} \ln K_{G,t}^* + \epsilon_{S,t}
\end{aligned}
\tag{11}
$$

where $S_{L,t}$ is the labor cost share, $\epsilon_{P,t}$ is the error term of the production function, and $\epsilon_{S,t}$ is the error term of the labor share function.

In equation (11), we first estimate the labor share function by ordinary least squares (OLS). Second, we estimate the system reconstructed on the basis of the labor share function.[6] Furthermore, we assume that the property of the error vector $\mathrm{u}_t' = (\epsilon_{P,t} \;\; \epsilon_{S,t})$ is $E(\mathrm{u}_t) = 0$ and $V(\mathrm{u}_t) = \Omega$ for all . We introduce this assumption so that the labor share function is derived from the production function. Under this assumption, in order to make efficient parameter estimates, we use the seemingly unrelated regression (SUR) equation to estimate equation (11).

To evaluate the productivity effect of public capital, output elasticity or marginal productivity of public capital is often used. In this chapter, we introduce a "direct effect" and an "indirect effect," as proposed by Yoshino and Nakano (1994) and Yoshino, Nakajima, and Nakahigashi (1999).

The "direct effect" is the same as the so-called marginal productivity of public capital, which is the change in productivity of private capital and labor input through the marginal change of public capital represented by the amount of change of output. The "indirect effect" is the change in output through the change in private capital and labor input aimed at profit maximization caused by the marginal change of public capital.

6 This estimation method is based on the statistical result of Revankar (1974), who revealed the statistical property of estimated parameters when estimating a system where the explanatory variable of one equation is a subset of the explanatory variables of the other equation by SUR. In our system, the explanatory variables of the labor share function are a subset of those of the production function. In this situation, estimates of the labor share function by SUR are identical with estimates of the labor share function by OLS.

To demonstrate these effects clearly, the mathematical expressions of the direct and indirect effects are shown below. The total derivative of the production function with respect to K_G is as follows:

$$dY = \frac{\partial Y}{\partial K_G} dK_G + \frac{\partial Y}{\partial K_P}\frac{dK_P}{dK_G} dK_G + \frac{\partial Y}{\partial L}\frac{dL}{dK_G} dK_G$$

The effect of public capital on output based on equation (7) is expressed as follows:

$$\begin{aligned}\frac{dY}{dK_G} = \eta_{K_G}\frac{Y}{K_G} + \eta_{K_P}\frac{\eta_{K_G}\eta_{K_P} + \beta_{KG}}{\eta_{K_P}(1-\eta_{K_P}) + \beta_{KL}}\frac{Y}{K_G} \\ + \eta_L \frac{\eta_{K_G}\eta_L - \beta_{KG}}{\eta_L(1-\eta_L) + \beta_{KL}}\frac{Y}{K_G}\end{aligned} \tag{12}$$

where η_K represents the output elasticity of private capital, η_L represents that of labor inputs, and η_{K_G} represents that of public capital. The effect of equation (12) is derived under the assumption that all prices are fixed.[7]

The first term of the right-hand side of equation (12) shows the direct effect, which is the impact of output caused by the change in public capital. This indicates the effect of public capital on output when input factors other than public capital are fixed.

The second term of the right-hand side of equation (12) show the indirect effect of private capital, and the third term shows the indirect effect of labor input. These effects are based on the derived demand of factor inputs by the change in the marginal productivity of factor inputs through the increase in public capital. Under the assumption of fixed output and factor prices, producers can increase profit by changing the amount of the factor input. The indirect effect is the change in output generated from the derived demand of factor inputs caused by the marginal increase in public capital.[8]

4.3.2 Total Factor Productivity Analysis

TFP denotes the contribution of factors other than K_P and L. In this respect, this analysis aims to clarify whether infrastructure investment

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7 Yoshino, Nakajima, and Nakahigashi (1999) show the derivation of equation (12).

8 Yoshino, Nakajima, and Nakahigashi (1999) and Yoshino and Nakahigashi (2000, 2004) show a graphical explanation of these effects.

contributes to the level of TFP. The numerous studies that deal with TFP aim to discover accurate measures of technical progress, and essential sources of technical progress. Previous studies designed to discover accurate measures of technical progress eliminated cyclical factors from TFP. The main causes of cyclical changes to TFP are capital utilization, increasing returns to scale, and markup pricing.

Berndt and Fuss (1986) and Hulten (1986) consider the capital utilization under the assumption that capital is quasi-fixed. Capital cannot be adjusted toward an optimized level instantaneously, and capital is observed at a short-term optimized level. Hall (1988) proposed a TFP regression assuming the existence of scale economies and markup pricing. Morrison (1992) used a non-parametric method to consider capital utilization, increasing returns to scale, and markup pricing; and calculated the TFP by eliminating the effect of these.

Many previous studies that aimed to discover the essential sources of technical progress identified infrastructure investment as a source of TFP growth and the TFP level. Aschauer (1989) showed the relationship between the growth rates of TFP and public capital. Nakahigashi (2004) demonstrated the effect of public capital stock on TFP in Japan, Thailand, and Taipei,China. Hulten, Bennathan, and Srinivasan (2006) analyzed the effect of infrastructure on TFP in India's manufacturing sector based on Hall (1988). Straub, Vellutini, and Warlters (2008) and Straub and Terada-Hagiwara (2011) showed the relationship between infrastructure and economic growth using TFP regression and growth regression in Asian countries.

This chapter is based on Hulten, Bennathan, and Srinivasan (2006). The analysis aims to clarify the effect of public capital on TFP while eliminating the effect of scale economies and markup pricing.

Hulten, Bennathan, and Srinivasan (2006) used the following equation based on Hall (1988):

$$\ln \text{TFP} = \ln A + \lambda t + \gamma \ln K_G + (\epsilon - 1) \ln K_P + (\mu - 1) \ln X + u \quad (13)$$

where $\ln K_G$ is the logarithm of the public capital, $\ln K_P$ is the private capital stock, $\ln X$ equals $s_L \ln \frac{L}{K_P}$, and u is the error term.

The coefficient of ϵ in equation (13) is the factor of the extent of a return to scale across K_P and L. If the coefficient is greater (smaller) than zero, then the production function has increasing (decreasing) returns to scale across K_P and L. When the coefficient does not differ from zero, the production function is the constant return to scale across K_P and L. The coefficient of μ in equation (13) represents the extent of markup pricing, which shows the ratio of the marginal cost to the average cost. If the coefficient of $\mu - 1$ is greater than zero, we can evaluate the existence of markup pricing, which represents the situation under imperfect competition.

When estimating TFP regression, we use SUR, which enables us to consider the correlation among industries of unexplained factors expressed by the error term. When error terms among industries correlate, SUR estimators are more efficient than are OLS estimators of each regression.

For example, there are three industries: industry "A", "B", and "C". The estimated system in this chapter is as follows:

$$\begin{cases} \ln \mathrm{TFP}_t^A = \ln A^A + \lambda^A t + \gamma^A \ln K_{G,t}^A + (\epsilon^A - 1) \ln K_{P,t}^A + (\mu^A - 1) X_t^A + u_t^A \\ \ln \mathrm{TFP}_t^B = \ln A^B + \lambda^B t + \gamma^B \ln K_{G,t}^B + (\epsilon^B - 1) \ln K_{P,t}^B + (\mu^Q - 1) X_t^B + u_t^B \\ \ln \mathrm{TFP}_t^C = \ln A^C + \lambda^C t + \gamma^C \ln K_{G,t}^C + (\epsilon^C - 1) \ln K_{P,t}^C + (\mu^C - 1) X_t^C + u_t^C \end{cases} \quad (14)$$

where the subscript t of each variable represents the time and the superscript of each variable shows the industry. The error vector $\mathrm{u}_t' = (u_t^A \, u_t^B \, u_t^C)$ is $E(\mathrm{u}_t) = 0$ and $V(\mathrm{u}_t) = \Omega$ for all t.

4.4 Results for Thailand

This section shows the results of the production function approach and TFP approach in Thailand.

4.4.1 Data

This analysis uses two types of public capital: (i) physical indicators, measured by physical units; and (ii) the real value of public capital. Three kinds of physical indicators are used: (i) "transport," which is the sum of the paved road density (kilometers [km] per 1,000 square km) and railway density (km per 1,000 square km); (ii) "electricity," which is the capacity of electricity (kilowatt-hours per 1,000 persons); and (iii) "telephone," which is the sum of the number of landline subscribers (per capita) and mobile phone users (per capita). Finally, two kinds of real value are used: (i) the gross capital stock of the public sector in the transport, storage, and communications sectors; and (ii) the gross capital stock of the public sector in the electricity, gas, and water supply sectors. The sum of these is used in the production function analysis.

Table 4.5 shows the statistics used in our analysis. The sources of all the data used are in Appendix 4.1.

Table 4.5 Thailand Data

Indicator	Unit	Average	Minimum	Maximum
Agriculture, hunting, forestry, and fishing				
Real GDP	million baht at 1988 prices	382,808	170,286	660,330
Private capital	million baht at 1988 prices	1,311,190	760,425	2,591,257
Employee	1,000 persons	14,345.8	9,141.3	19,725.6
Working hour	hours per week	51.0	42.9	56.5
Labor cost share		0.094	0.037	0.167
Manufacturing				
Real GDP	million baht at 1988 prices	1,097,284	142,262	2,599,334
Private capital	million baht at 1988 prices	2,576,090	354,636	6,003,375
Employee	1,000 persons	3,518.4	852.6	5,619.2
Working hour	hours per week	49.9	47.8	51.2
Labor cost share		0.370	0.249	0.474
Services				
Real GDP	million baht at 1988 prices	1,885,971	429,306	4,087,386
Private capital	million baht at 1988 prices	6,566,049	1,510,243	14,055,567
Employee	1,000 persons	7,749.9	2,493.5	14,819.7
Working hour	hours per week	52.0	49.3	54.3
Labor cost share		0.325	0.256	0.431
Public capital				
Real public capital (electricity)	million baht at 1988 prices	815,750	52,584	2,188,441
Real public capital (transport)	million baht at 1988 prices	1,343,762	287,330	2,935,854
Transport indicator	km per 1,000 km^2	137.5	26.9	353.6
Telephone indicator	subscribers per capita	0.2	0.0	1.3
Electricity indicator	kWh per 1,000 persons	276.1	41.0	728.8

GDP = gross domestic product, km = kilometer, km2 = square kilometer, kWh = kilowatt-hour.
Source: Authors' calculations.

4.4.2 Results of the Production Function Approach

Table 4.6 shows the estimated results of the agricultural, manufacturing, and services sectors based on equation (11). In these estimated results, dummy variables are introduced in the production function because it is necessary to consider the economic recession caused by the Asian financial crisis. Under the assumption that this crisis caused no structural changes in the production function, six intercept dummies were set at 1997, 1998, 1999, 2000, 2001, and 2002.

In describing the estimated results, we focus on the parameters α_G and β_{KG} where public capital is included in the explanatory variables. We find that α_G is positive in the agricultural and manufacturing sectors and zero in the services sector. Positive α_G is the sufficient condition of the positive productivity effect of public capital. Therefore, the productivity effect of public capital is positive in the agricultural and manufacturing sectors. Parameter β_{KG} is negative in all industries. Negative β_{KG} indicates that public capital leads to labor-intensive production since the labor cost share increases with the increase in public capital.

Table 4.6 Estimated Results of the Production Function

(1) Agricultural Sector			(2) Manufacturing Sector		
Parameter	Estimate	(Std. Err.)	Parameter	Estimate	(Std. Err.)
α_0	0.052***	(0.018)	α_0	0.037***	(0.011)
α_K	0.866***	(0.014)	α_K	0.549***	(0.007)
α_G	0.067***	(0.018)	α_G	0.109***	(0.011)
β_{KL}	–		β_{KL}	–	
β_{KG}	−0.066***	(0.013)	β_{KG}	−0.103***	(0.007)
β_{GG}	–		β_{GG}	–	
D_{97}	−0.041	(0.094)	D_{97}	−0.129**	(0.060)
D_{98}	−0.119	(0.094)	D_{98}	−0.242***	(0.060)
D_{99}	−0.102	(0.094)	D_{99}	−0.170****	(0.060)
D_{00}	−0.058	(0.094)	D_{00}	−0.196***	(0.060)
D_{01}	−0.041	(0.094)	D_{01}	−0.206***	(0.060)
D_{02}	−0.074	(0.095)	D_{02}	−0.151***	(0.060)
Coefficient Dummy after 1998			**Coefficient Dummy after 1998**		
α_K	−0.008	(0.045)	α_K	−0.116***	(0.023)
β_{KG}	0.062	(0.068)	β_{KG}	0.390***	(0.034)
R-squared	Production	0.944	R-squared	Production	0.979
	Labor	0.833		Labor	0.905

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Table 4.6 *continued*

(3) Service sector		
Parameter	**Estimate**	**(Std. Err.)**
α_0	0.054***	(0.014)
α_K	0.679***	(0.006)
α_G	−0.007	(0.014)
β_{KL}	–	
β_{KG}	−0.029***	(0.006)
β_{GG}	–	
D_{97}	−0.077	(0.076)
D_{98}	−0.212***	(0.077)
D_{99}	−0.226***	(0.077)
D_{00}	−0.206	(0.077)
D_{01}	−0.193**	(0.077)
D_{02}	−0.160**	(0.077)
Coefficient Dummy after 1998		
α_K	0.063***	(0.021)
β_{KG}	−0.163***	(0.031)
R-squared	Production[a]	0.822
	Labor[b]	0.889

Std. Err. = standard error.
*** Statistically significant at 1%.
** Statistically significant at 5%.
[a] The coefficient of the determination of the production function.
[b] The coefficient of the determination of the labor function.
Source: Authors' calculations.

Table 4.7 shows the point estimate of the productivity effect of public capital. Both the effect on output elasticity and the effect on marginal productivity are shown. These estimates are calculated using coefficients statistically significant at least at the 10% level.

The productivity effect of public capital is decreasing in the agricultural sector, and does not exist in the services sector. However, in the manufacturing sector, the productivity effect of public capital exists and has been increasing after 2001.

In addition, the indirect effect of private capital has shrunk over the estimated period. This result is reflected by the estimate of β_{KG}.

Table 4.7 Point Estimates of the Productivity Effect of Public Capital

(1) Output Elasticity

	Private Capital	Public capital	Direct Effect	Indirect Effect	
			Capital	Capital	Labor
Agriculture, forest, hunting, and fishing					
1971–1980	0.969	1.003	0.090	0.842	0.071
1981–1990	0.914	0.600	0.110	0.407	0.083
1991–2000	0.863	0.161	0.073	0.000	0.088
2001–2012	0.821	−0.135	0.026	−0.247	0.086
Manufacturing					
1971–1980	0.710	0.567	0.201	0.138	0.228
1981–1990	0.623	0.460	0.174	0.016	0.271
1991–2000	0.554	0.442	0.147	0.207	0.089
2001–2012	0.631	0.944	0.184	1.109	−0.350
Services					
1971–1980	0.724	−0.013	0.013	−0.071	0.045
1981–1990	0.700	−0.016	0.010	−0.072	0.046
1991–2000	0.678	−0.168	−0.013	−0.264	0.110
2001–2012	0.610	−0.241	−0.019	−0.524	0.303

(2) Marginal Productivity

	Private Capital	Public capital	Direct Effect	Indirect Effect	
			Capital	Capital	Labor
Agriculture, forest, hunting, and fishing					
1971–1980	0.249	0.465	0.041	0.393	0.032
1981–1990	0.317	0.168	0.030	0.115	0.023
1991–2000	0.282	0.036	0.014	0.005	0.016
2001–2012	0.224	−0.018	0.004	−0.033	0.012
Manufacturing					
1971–1980	0.343	0.288	0.102	0.070	0.116
1981–1990	0.331	0.220	0.083	0.007	0.131
1991–2000	0.232	0.239	0.081	0.085	0.073
2001–2012	0.264	0.468	0.091	0.549	−0.172
Services					
1971–1980	0.241	−0.017	0.017	−0.092	0.058
1981–1990	0.252	−0.017	0.011	−0.078	0.050
1991–2000	0.197	−0.140	−0.010	−0.223	0.093
2001–2012	0.163	−0.179	−0.014	−0.391	0.227

Source: Authors' calculations.

4.4.3 Result of the Total Factor Productivity Regression

Table 4.8 shows the results using physical indicators and Table 4.9 shows the results using real values of public capital. These tables show TFP regressions both with and without a trend.

Table 4.8 Total Factor Productivity Regression—Physical Indicators

(1) With Trend

	Agriculture		Manufacturing		Services	
	Estimate	(Std. Err.)	Estimate	(Std. Err.)	Estimate	(Std. Err.)
Constant	9.720***	(3.227)	2.149	(1.539)	1.959**	(0.800)
Trend	0.024***	(0.006)	0.049***	(0.009)	0.034***	(0.006)
Transport variable	0.029	(0.090)	0.245**	(0.099)	0.214***	(0.071)
Telephone variable	−0.011	(0.055)	−0.107**	(0.044)	−0.113***	(0.027)
Electricity variable	0.121**	(0.057)	−0.263***	(0.076)	−0.135**	(0.052)
Scale variable	−0.845***	(0.209)	−0.224**	(0.094)	−0.220***	(0.042)
Markup variable	0.193	(0.718)	−0.045	(0.117)	0.027	(0.106)
Dummy after 1997	−0.001	(0.038)	−0.023	(0.052)	−0.095***	(0.036)
Dummy after 1998	−0.019	(0.045)	−0.103*	(0.058)	−0.164***	(0.041)
Dummy after 1999	0.039	(0.043)	−0.001	(0.046)	−0.041	(0.033)
R-squared	0.941		0.907		0.931	

(2) Without Trend

	Agriculture		Manufacturing		Services	
	Estimate	(Std. Err.)	Estimate	(Std. Err.)	Estimate	(Std. Err.)
Constant	6.222*	(3.506)	−2.027	(1.281)	−0.402	(0.738)
Trend	–		–		–	
Transport variable	0.089	(0.100)	0.497***	(0.110)	0.383***	(0.081)
Telephone variable	0.025	(0.062)	−0.096*	(0.053)	−0.084**	(0.034)
Electricity variable	0.306***	(0.035)	0.024	(0.074)	0.067	(0.054)
Scale variable	−0.637***	(0.229)	−0.038	(0.083)	−0.137***	(0.044)
Markup variable	1.335*	(0.738)	0.091	(0.104)	−0.018	(0.100)
Dummy after 1997	−0.018	(0.043)	−0.070	(0.064)	−0.142***	(0.045)
Dummy after 1998	−0.010	(0.051)	−0.093	(0.073)	−0.158***	(0.054)
Dummy after 1999	0.070	(0.048)	0.001	(0.058)	−0.039	(0.043)
R-squared	0.924		0.852		0.886	

Std. Err. = standard error.
*** Statistically significant at 1%.
** Statistically significant at 5%.
* Statistically significant at 10%.
Source: Authors' calculations.

Tables 4.8 and 4.9 both show that investments in transport infrastructure have positive effects on the TFP of the manufacturing and services sectors, and that the electricity variable has a positive effect on the TFP of the agricultural sector. In addition, the parameter of the scale variable, which represents the extent of returns to scale, is negative; and the parameter of the markup variable, which represents the extent of competitive competition, is zero. These indicate that a decreasing return to scale exists, and that Thailand's market is competitive.

In the services sector, however, the results of the production function analysis and TFP regression differ in the existence of the productivity effect of public capital. This might be attributed to the misspecification of the production function by the restriction on parameters of equation (10) or omission of important explanatory variables in the services sector.

The results of this analysis show that investment in transport infrastructure has a positive effect on productivity. This result is consistent with the suggestion made by Pomlaktong and Ongkittikul (2008) that the lack of a road network has caused a bottleneck in Thailand's economy. It follows from this result that improving Thailand's transport infrastructure is indispensable for the country's economic development.

Table 4.9 Total Factor Productivity Regression—Total Factor Productivity Based on Gross Domestic Product and Real Value

(1) With Trend

	Agriculture		Manufacturing		Services	
	Estimate	(Std. Err.)	Estimate	(Std. Err.)	Estimate	(Std. Err.)
Constant	9.866 ***	(2.148)	2.812 **	(1.315)	3.376 ***	(0.827)
Trend	0.020 ***	(0.005)	0.035 ***	(0.010)	0.027 ***	(0.005)
Transport variable	0.092	(0.188)	−0.029	(0.295)	0.069	(0.201)
Telephone variable	0.079	(0.071)	0.003	(0.093)	−0.028	(0.069)
Electricity variable	−0.824 ***	(0.164)	−0.234 **	(0.091)	−0.263 ***	(0.057)
Scale variable	−0.249	(0.668)	0.019	(0.120)	0.139	(0.124)
Markup variable	−0.049	(0.046)	−0.076	(0.073)	−0.160 ***	(0.051)
Dummy after 1997	−0.035	(0.045)	−0.123 *	(0.071)	−0.181 ***	(0.050)
Dummy after 1998	0.041	(0.041)	0.001	(0.056)	−0.045	(0.039)
Dummy after 1999	9.866 ***	(2.148)	2.812 **	(1.315)	3.376 ***	(0.827)
R-squared	0.951		0.866		0.917	

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Table 4.9 *continued*

(2) Without Trend

	Agriculture		Manufacturing		Services	
	Estimate	(Std. Err.)	Estimate	(Std. Err.)	Estimate	(Std. Err.)
Constant	5.866 ***	(1.658)	−0.054	(0.870)	1.489	(0.935)
Trend	–		–		–	
Transport variable	0.403 **	(0.202)	0.852***	(0.256)	0.693***	(0.207)
Telephone variable	0.104	(0.080)	−0.079	(0.110)	−0.087	(0.090)
Electricity variable	−0.574 ***	(0.136)	−0.139*	(0.075)	−0.226***	(0.069)
Scale variable	0.266	(0.620)	0.167***	(0.059)	−0.104	(0.096)
Markup variable	−0.138 ***	(0.048)	−0.222***	(0.079)	−0.292***	(0.061)
Dummy after 1997	−0.060	(0.052)	−0.171**	(0.085)	−0.223***	(0.068)
Dummy after 1998	0.086**	(0.043)	0.053	(0.066)	0.015	(0.051)
Dummy after 1999	5.866 ***	(1.658)	−0.054	(0.870)	1.489	(0.935)
R-squared	0.924		0.852		0.886	

Std. Err. = standard error.
*** Statistically significant at 1%.
** Statistically significant at 5%.
* Statistically significant at 10%.
Source: Authors' calculations.

4.5 Results for Japan

This section shows the results of the production function approach and TFP approach in Japan.

4.5.1 Estimated Model

From the early 1970s, the Government of Japan undertook public investment, especially in rural areas, to reduce economic disparities among regions. As a result, the regional allocation of public capital may have been inefficient, and a regional disparity may exist in the utilization of public capital.

In order to consider regional disparities in the utilization of public capital in Japan, this analysis uses regional data and modifies the estimated system equations accordingly.

Using the production function approach, the following system equations based on equation (11) are used:

$$\begin{aligned}
\ln \frac{Y_{it}^*}{L_{it}^*} &= \alpha_0 + \alpha_K \ln \frac{K_{P,it}^*}{L_{it}^*} + \alpha_{G,i} \ln\ K_{G,it}^* \\
&+\beta_{KL}\left(\ln\ K_{P,it}^* \ln\ L_{it}^* - \frac{1}{2}(\ln\ K_{P,it}^*)^2 - \frac{1}{2}(\ln\ L_{it}^*)^2\right) \\
&+\beta_{KG,i} \ln\ K_{G,it}^* \ln \frac{K_{P,it}^*}{L_{it}^*} + \beta_{GG,i}\frac{1}{2}(\ln\ K_{G,it}^*)^2 + \epsilon_{P,it} \qquad (15)\\
S_{L,it} &= 1 - \alpha_K + \beta_{KL} \ln \frac{K_{P,it}^*}{L_{it}^*} - \beta_{KG,i} \ln\ K_{G,it}^* + \epsilon_{S,it}
\end{aligned}$$

where the subscripts of each variable represent the region (i) and time (t). All variables are the deviation from the logarithm of average from 1975 to 1994. Parameters $\alpha_{G,i}$, $\beta_{KG,i}$, and $\beta_{GG,i}$ differ between regions due to regional variations in public infrastructure investments. Parameters α_K and β_{KL} allow for regional disparities. These parameters are needed because, as each industry comprises many subindustries, the technical structures of industries are likely to be different in different regions.

The error term $\epsilon_{P,it}$ is assumed as follows:

$$\epsilon_{P,it} = \mu_{P,i} + u_{P,it}$$

where is the regional fixed effect reflecting regional fixed divergence as an unexplained factor in this model over the estimated period, and is the error term. The property of error vector $\mathrm{u}_{it}' = (u_{P,it}\ \ \epsilon_{P,it})$ is $E(\mathrm{u}_{it}) = 0$ and $V(\mathrm{u}_{it}) = \Omega$ for all t.

In the TFP regression, the estimated model for Japan is as follows:

$$\begin{cases}
\text{Ln TFP}_{it}^A = \ln\ A_i^A + \lambda^A t + \gamma_i^A \ln\ K_{G,it}^A + (\epsilon^A - 1) \ln\ K_{P,it}^A + (\mu^A - 1)X_{it}^A + u_t^A \\
\ln\ \text{TFP}_{it}^B = \ln\ A_i^B + \lambda^B t + \gamma_i^B \ln\ K_{G,it}^B + (\epsilon^B - 1) \ln\ K_{P,it}^B + (\mu^Q - 1)X_{it}^B + u_t^B \\
\ln\ \text{TFP}_{it}^C = \ln\ A_i^C + \lambda^C t + \gamma_i^C \ln\ K_{G,it}^C + (\epsilon^C - 1) \ln\ K_{P,it}^C + (\mu^C - 1)X_{it}^C + u_t^C
\end{cases} \qquad (16)$$

where the subscript of each variable represents the region (i) and time (t), and the superscript of each variable represents the industry. In particular, parameter γ, which is the coefficient of $\ln K_{G,it}^{j}$, is different in each region. This reflects regional differences in the utilization of public capital, as is employed in the analysis using the production function.

4.5.2 Data

As in the analysis for Thailand, two types of public capital are used: physical indicators, and the real value of public capital. This analysis uses three kinds of physical indicators: (i) "road," which is the paved road density (km per 1,000 square km); (ii) "telephone," which is the sum of landline subscribers (per capita) and mobile phone users (per capita); and (iii) "electricity," which is the production of electricity (kilowatt-hours per capita). Finally, this analysis uses two kinds of real value: (i) gross public capital stock in "transport," which is the sum of road, port facilities, and airport facilities; and (ii) gross public capital stock in the "living environment," which is the sum of facilities for sewage, facilities for water services, and city parks. The production function analysis uses the sum of these.

In Table 4.10, which shows the data used in this analysis, 1990/1975 is the ratio of the value at 1990 to that at 1975 for all Japan, and 2010/1990 is the ratio of the value at 2010 to that at 1990. The sources of all data are in Appendix 4.2.

Table 4.10 Japan Data

Indicator	Unit	Average	Minimum	Maximum	1990/1975 (All Japan)	2010/1990 (All Japan)
Primary Industry						
Real GDP	million yen at 2005 prices	607,070	287,915	1,679,990	0.869	0.768
Private capital	million yen at 2005 prices	7,790,147	2,829,177	15,060,606	2.215	1.238
Labor input	1,000 person-hours per month	69,517.0	20,059.2	253,316.9	0.535	0.514
Labor cost share		0.568	0.285	0.853		
Secondary Industry						
Real GDP	million yen at 2005 prices	10,345,817	1,394,274	40,700,843	1.933	0.978
Private capital	million yen at 2005 prices	26,077,894	1,872,154	91,283,827	2.124	1.708
Labor input	1,000 person-hours per month	289,600.7	68,011.4	960,008.1	1.175	0.639
Labor cost share		0.724	0.564	0.886		

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Table 4.10 *continued*

Indicator	Unit	Average	Minimum	Maximum	1990/1975 (All Japan)	2010/1990 (All Japan)
Tertiary Industry						
Real GDP	million yen at 2005 prices	24,269,527	4,018,015	136,571,179	2.093	1.281
Private capital	million yen at 2005 prices	36,273,641	2,723,016	231,360,438	2.723	1.904
Labor input	1,000 person-hours per month	488,713.9	150,580.4	1,761,879.4	1.287	0.948
Labor cost share		0.648	0.514	0.801		
Public Capital						
Real public capital (transport)	million yen at 2005 prices	815,750	52,584	2,188,441	3.195	2.302
Real public capital (Living environment)	million yen at 2005 prices	1,343,762	287,330	2,935,854	4.040	2.319
Road indicator	km per 1,000 km^2	102,708.7	50,260.6	166,080.9	1.039	1.083
Telephone indicator	subscribers per capita	0.6	0.0	1.4	1.531[a]	2.654
Electricity indicator	kWh per capita	1,526.1	589.1	2,646.9	1.952	1.657

GDP = gross domestic product, km = kilometer, km2 = square kilometer, kWh = kilowatt-hour.
[a] the ratio of 1990 to 1976.
Source: Authors' calculations.

4.5.3 Results of the Production Function Approach

Tables 4.11, 4.12, and 4.13 show the results of a system equation of the production function in primary, secondary, and tertiary industry.

Estimates in the upper left-hand side of each table show a parameter estimate common to all regions, and the estimate of a parameter in the coefficient dummy shows the divergence from it.

In describing the estimated results, we especially focus on parameters $\alpha_{G,i}$ and $\beta_{KG,i}$ that represent the marginal effect of public capital ($K_{G,it}$) to production. First, it is found that $\alpha_{G,i}$ is positive in both secondary and tertiary industry. Positive $\alpha_{G,i}$ is a sufficient condition for the productivity effect of public capital to have positive value. Therefore,

Table 4.11 Estimated Results of the Production Function—Primary Industry

Parameter	Estimate	(Std. Err.)	Coefficient Dummy of β_{KL}		
α_K	0.440***	(0.006)	Hokkaido	–	
α_G	–		Tohoku	–	
β_{KL}	–		North Kanto	–	
β_{KG}	–		South Kanto	–	
β_{GG}	–		Hokuriku	–	
Coefficient Dummy of α_K			Tokai	0.080	(0.053)
Hokkaido	0.175***	(0.011)	Kinki	–	
Tohoku	−0.083***	(0.012)	Chugoku	–	
North Kanto	−0.082***	(0.012)	Shikoku	–	
South Kanto	–		North Kyushu	–	
Hokuriku	0.051***	(0.012)	South Kyushu	–	
Tokai	−0.035***	(0.013)	**Coefficient Dummy of β_{KG}**		
Kinki	0.040***	(0.011)	Hokkaido	–	
Chugoku	−0.135***	(0.012)	Tohoku	0.041***	(0.012)
Shikoku	−0.148***	(0.011)	North Kanto	0.089***	(0.012)
North Kyushu	–		South Kanto	0.074***	(0.013)
South Kyushu	–		Hokuriku	0.050***	(0.012)
Coefficient Dummy of α_G			Tokai	0.128**	(0.058)
Hokkaido	−0.116***	(0.019)	Kinki	–	
Tohoku	−0.043**	(0.020)	Chugoku	−0.001	(0.012)
North Kanto	−0.057***	(0.019)	Shikoku	–	
South Kanto	−0.055***	(0.021)	North Kyushu	0.061***	(0.012)
Hokuriku	−0.110***	(0.020)	South Kyushu	–	
Tokai	−0.049	(0.034)	**R-squared**		
Kinki	−0.176***	(0.022)	Production function		0.928
Chugoku	−0.003	(0.019)	Labor share function		0.752
Shikoku	0.131***	(0.018)			
North Kyushu	−0.163***	(0.019)			
South Kyushu	0.070***	(0.018)			

Std. Err. = standard error.
*** Statistically significant at 5%.
** Statistically significant at 1%.
Note: This estimation includes other explanatory variables: the constant dummy variables based on the change in the industrial classification in each region. However, the coefficients of these explanatory variables are omitted in this result.
Source: Authors' calculations.

Table 4.12 Estimated Results of the Production Function—Secondary Industry

Parameter	Estimate	(Std. Err.)
α_K	0.245***	(0.003)
α_G	–	
β_{KL}	–	
β_{KG}	0.019	(0.018)
β_{GG}	–	
Coefficient Dummy of α_K		
Hokkaido	0.032***	(0.007)
Tohoku	–	
North Kanto	0.085***	(0.007)
South Kanto	–	
Hokuriku	0.075***	(0.008)
Tokai	0.056***	(0.008)
Kinki	–	
Chugoku	−0.011	(0.007)
Shikoku	0.086***	(0.008)
North Kyushu	–	
South Kyushu	−0.034***	(0.007)
Coefficient Dummy of α_G		
Hokkaido	0.120***	(0.013)
Tohoku	0.162***	(0.011)
North Kanto	0.150***	(0.012)
South Kanto	0.213***	(0.013)
Hokuriku	0.162***	(0.013)
Tokai	0.250***	(0.015)
Kinki	0.237***	(0.013)
Chugoku	0.267***	(0.012)
Shikoku	0.158***	(0.012)
North Kyushu	0.193***	(0.012)
South Kyushu	0.170***	(0.013)

Coefficient Dummy of β_{KL}		
Hokkaido	–	
Tohoku	–	
North Kanto	–	
South Kanto	0.131***	(0.025)
Hokuriku	–	
Tokai	0.080	(0.053)
Kinki	0.051**	(0.025)
Chugoku	–	
Shikoku	–	
North Kyushu	–	
South Kyushu	–	
Coefficient Dummy of β_{KG}		
Hokkaido	−0.001	(0.020)
Tohoku	0.024	(0.020)
North Kanto	−0.020	(0.022)
South Kanto	–	
Hokuriku	−0.054**	(0.022)
Tokai	0.128**	(0.058)
Kinki	–	
Chugoku	0.044**	(0.020)
Shikoku	−0.027	(0.020)
North Kyushu	0.038	(0.020)
South Kyushu	0.051***	(0.020)
R-squared		
Production function		0.971
Labor share function		0.668

Std. Err. = standard error.
*** Statistically significant at 1%.
** Statistically significant at 5%.
Note: This estimation includes other explanatory variables: fixed effect and constant dummy variables based on the change in the industrial classification in each region. However, the coefficients of these explanatory variables are omitted in this result.
Source: Authors' calculations.

Table 4.13 Estimated Results of the Production Function—Tertiary Industry

Parameter	Estimate	(Std. Err.)
α_K	0.348***	(0.002)
α_G	–	
β_{KL}	–	
β_{KG}	0.094	(0.002)
β_{GG}	–	
Coefficient Dummy of α_K		
Hokkaido	−0.031***	(0.004)
Tohoku	−0.014***	(0.004)
North Kanto	−0.028***	(0.004)
South Kanto	–	
Hokuriku	–	
Tokai	−0.075***	(0.004)
Kinki	−0.027***	(0.004)
Chugoku	–	
Shikoku	−0.049***	(0.004)
North Kyushu	−0.015***	(0.004)
South Kyushu	−0.055***	(0.004)
Coefficient Dummy of α_G		
Hokkaido	0.114***	(0.010)
Tohoku	0.144***	(0.010)
North Kanto	0.176***	(0.009)
South Kanto	0.222***	(0.010)
Hokuriku	0.172***	(0.010)
Tokai	0.215***	(0.010)
Kinki	0.131***	(0.011)
Chugoku	0.073***	(0.009)
Shikoku	0.134***	(0.010)
North Kyushu	0.087***	(0.010)
South Kyushu	0.097***	(0.010)

Coefficient Dummy of β_{KL}		
Hokkaido	–	
Tohoku	–	
North Kanto	–	
South Kanto	–	
Hokuriku	–	
Tokai	0.080	(0.053)
Kinki	–	
Chugoku	0.051***	(0.007)
Shikoku	–	
North Kyushu	–	
South Kyushu	–	
Coefficient Dummy of β_{KG}		
Hokkaido	−0.033***	(0.005)
Tohoku	–	
North Kanto	−0.018***	(0.005)
South Kanto	–	
Hokuriku	–	
Tokai	0.128**	(0.058)
Kinki	−0.031***	(0.006)
Chugoku	–	
Shikoku	–	
North Kyushu	−0.034***	(0.005)
South Kyushu	–	
R-squared		
Production function		0.985
Labor share function		0.908

Std. Err. = standard error.
***Statistically significant at 1%.
** Statistically significant at 5%.
Note: This estimation includes other explanatory variables: fixed effect and constant dummy variables based on the change in the industrial classification in each region. However, the coefficients of these explanatory variables are omitted in this result.
Source: Authors' calculations.

the productivity effect of public capital exists in secondary and tertiary industry. There are also regional differences in parameter $\alpha_{G,i}$, which is larger in urban regions (e.g., North Kanto, South Kanto, Tokai, and Kinki) than in rural regions.

Parameter $\beta_{KG,i}$, which represents the effect of public capital on cost share, is zero in primary and secondary industry and positive in tertiary industry (this differs from the results for Thailand). The positive $\beta_{KG,i}$ shows that a marginal increase in public capital generates a decrease of the labor cost share. Thus, it can be said that in tertiary industry public capital promotes capital-intensive production.

Table 4.14 shows point estimates of the productivity effect of public capital by industry and region in 2010. The productivity effect of public capital is larger in urban regions than in rural regions.

The marginal productivity of public capital in 1990 and 2010 is shown in Figures 4.3 (secondary industry) and 4.4 (tertiary industry). The marginal productivity in each figure is the sum of the "direct effect" and the "indirect effect." These figures show that the marginal productivity of public capital was smaller in 2010 than in 1990.

Table 4.14 Productivity Effect of Public Capital, 2010

(A) Primary Industry

(1) Output Elasticity

	Private Capital	Public Capital	Direct Effect	Indirect Effect	
				Capital	Labor
Hokkaido	0.614	−0.374	−0.116	−0.185	−0.073
Tohoku	0.408	0.012	0.014	0.080	−0.081
North Kanto	0.471	0.185	0.068	0.229	−0.113
South Kanto	0.517	0.136	0.042	0.199	−0.105
Hokuriku	0.551	−0.077	−0.032	0.071	−0.116
Tokai	0.440	0.328	0.147	0.260	−0.079
Kinki	0.479	−0.528	−0.176	−0.162	−0.191
Chugoku	0.304	−0.014	−0.004	−0.003	−0.007
Shikoku	0.292	0.504	0.131	0.054	0.319
North Kyushu	0.512	−0.233	−0.080	0.041	−0.195
South Kyushu	0.440	0.215	0.070	0.055	0.090

(2) Marginal Productivity

	Private Capital	Public Capital	Direct Effect	Indirect Effect	
				Capital	Labor
Hokkaido	0.063	−0.009	−0.003	−0.005	−0.002
Tohoku	0.025	0.000	0.000	0.002	−0.002
North Kanto	0.026	0.004	0.002	0.005	−0.003
South Kanto	0.030	0.001	0.000	0.001	−0.001
Hokuriku	0.022	−0.001	0.000	0.001	−0.001
Tokai	0.017	0.004	0.002	0.003	−0.001
Kinki	0.017	−0.003	−0.001	−0.001	−0.001
Chugoku	0.010	0.000	0.000	0.000	0.000
Shikoku	0.014	0.009	0.002	0.001	0.006
North Kyushu	0.027	−0.004	−0.001	0.001	−0.003
South Kyushu	0.033	0.007	0.002	0.002	0.003

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Table 4.14 *continued*

(B) Secondary Industry

(1) Output Elasticity

	Private Capital	Public Capital	Direct Effect	Indirect Effect	
				Capital	Labor
Hokkaido	0.614	−0.374	−0.116	−0.185	−0.073
Tohoku	0.408	0.012	0.014	0.080	−0.081
North Kanto	0.471	0.185	0.068	0.229	−0.113
South Kanto	0.517	0.136	0.042	0.199	−0.105
Hokuriku	0.551	−0.077	−0.032	0.071	−0.116
Tokai	0.440	0.328	0.147	0.260	−0.079
Kinki	0.479	−0.528	−0.176	−0.162	−0.191
Chugoku	0.304	−0.014	−0.004	−0.003	−0.007
Shikoku	0.292	0.504	0.131	0.054	0.319
North Kyushu	0.512	−0.233	−0.080	0.041	−0.195
South Kyushu	0.440	0.215	0.070	0.055	0.090

(2) Marginal Productivity

	Private Capital	Public Capital	Direct Effect	Indirect Effect	
				Capital	Labor
Hokkaido	0.063	−0.009	−0.003	−0.005	−0.002
Tohoku	0.025	0.000	0.000	0.002	−0.002
North Kanto	0.026	0.004	0.002	0.005	−0.003
South Kanto	0.030	0.001	0.000	0.001	−0.001
Hokuriku	0.022	−0.001	0.000	0.001	−0.001
Tokai	0.017	0.004	0.002	0.003	−0.001
Kinki	0.017	−0.003	−0.001	−0.001	−0.001
Chugoku	0.010	0.000	0.000	0.000	0.000
Shikoku	0.014	0.009	0.002	0.001	0.006
North Kyushu	0.027	−0.004	−0.001	0.001	−0.003
South Kyushu	0.033	0.007	0.002	0.002	0.003

(C) Tertiary Industry

(1) Output Elasticity

	Private Capital	Public Capital	Direct Effect	Indirect Effect	
				Capital	Labor
Hokkaido	0.614	−0.374	−0.116	−0.185	−0.073
Tohoku	0.408	0.012	0.014	0.080	−0.081
North Kanto	0.471	0.185	0.068	0.229	−0.113
South Kanto	0.517	0.136	0.042	0.199	−0.105
Hokuriku	0.551	−0.077	−0.032	0.071	−0.116
Tokai	0.440	0.328	0.147	0.260	−0.079
Kinki	0.479	−0.528	−0.176	−0.162	−0.191
Chugoku	0.304	−0.014	−0.004	−0.003	−0.007
Shikoku	0.292	0.504	0.131	0.054	0.319
North Kyushu	0.512	−0.233	−0.080	0.041	−0.195
South Kyushu	0.440	0.215	0.070	0.055	0.090

(2) Marginal Productivity

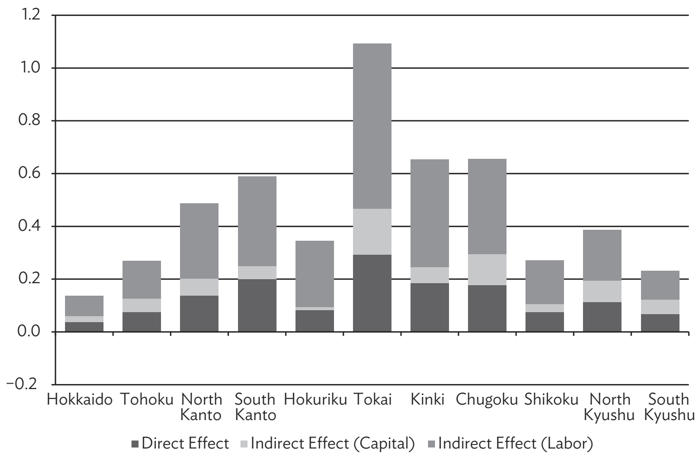
	Private Capital	Public Capital	Direct Effect	Indirect Effect	
				Capital	Labor
Hokkaido	0.063	−0.009	−0.003	−0.005	−0.002
Tohoku	0.025	0.000	0.000	0.002	−0.002
North Kanto	0.026	0.004	0.002	0.005	−0.003
South Kanto	0.030	0.001	0.000	0.001	−0.001
Hokuriku	0.022	−0.001	0.000	0.001	−0.001
Tokai	0.017	0.004	0.002	0.003	−0.001
Kinki	0.017	−0.003	−0.001	−0.001	−0.001
Chugoku	0.010	0.000	0.000	0.000	0.000
Shikoku	0.014	0.009	0.002	0.001	0.006
North Kyushu	0.027	−0.004	−0.001	0.001	−0.003
South Kyushu	0.033	0.007	0.002	0.002	0.003

Source: Authors' calculations.

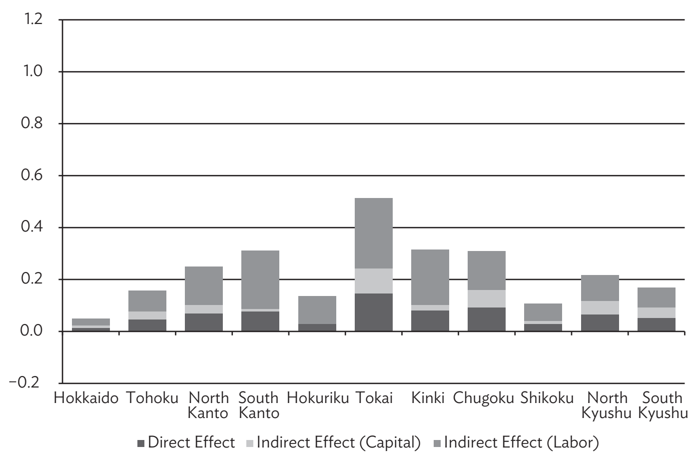
Figures 4.3 and 4.4 show that the marginal productivity of public capital decreases considerably more in secondary industry than in tertiary industry. In secondary industry, the amount of production decreased gradually from 1990 to 2010. This partly reflects the fact that the utilization of public capital decreases because of a decrease in production.

Figure 4.3 Marginal Productivity of Public Capital in Secondary Industry, 1990 and 2010

(1) 1990

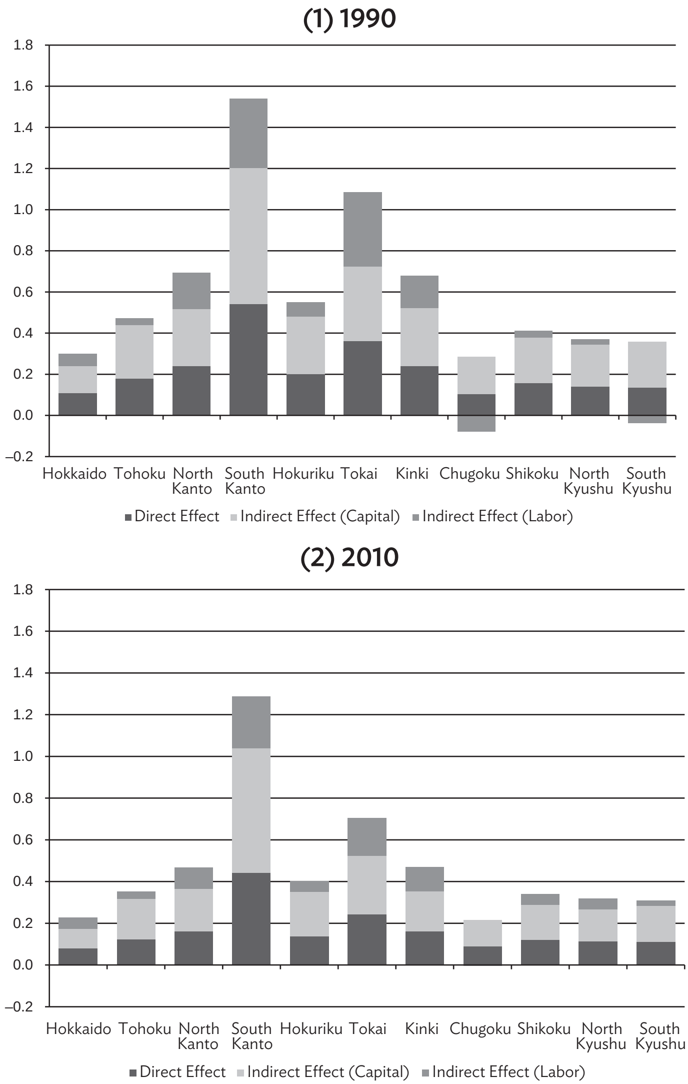


(2) 2010



Source: Authors' calculations.

Figure 4.4 Marginal Productivity of Public Capital in Tertiary Industry, 1990 and 2010



Source: Authors' calculations.

4.5.4 Results of the Total Factor Productivity Regression

Table 4.15 displays the results obtained using physical indicators with trend, and Table 4.16 displays these results without trend.

Tables 4.15 and 4.16 both show the following: (i) the parameters of the telephone variable have a positive effect on TFP in primary industry, (ii) the parameters of the electricity variable have a positive effect on TFP in secondary and tertiary industry, and (iii) the parameters of the road variable have a positive effect in some regions. Furthermore, the parameter of the scale variable, which represents the extent of the returns to scale, is positive in tertiary industry; and the parameter of the markup variable, which represents the extent of competitive competition, is positive in secondary and tertiary industry. Markup pricing appears not only in the imperfect competition but also in the underutilization of private capital and/or labor input. Therefore, in secondary and tertiary industry, these results indicate that private capital and/or labor input are underutilized.

Table 4.15 Total Factor Productivity Regression Based on Physical Indicators with Trend

		Primary Industry		Secondary Industry		Tertiary Industry	
		Estimate	(Std. Err.)	Estimate	(Std. Err.)	Estimate	(Std. Err.)
Trend		0.024***	(0.003)	0.009***	(0.002)	−0.009***	(0.001)
Road variable	Hokkaido	−0.602	(1.017)	0.282	(0.524)	0.893***	(0.338)
	Tohoku	1.619	(1.547)	−1.642*	(0.803)	−1.070*	(0.529)
	North Kanto	−1.247***	(0.468)	0.181	(0.247)	−0.164	(0.159)
	South Kanto	−1.578**	(0.945)	0.169	(0.497)	0.391	(0.322)
	Hokuriku	−1.918*	(0.949)	0.344	(0.502)	−0.810*	(0.323)
	Tokai	−4.342***	(0.972)	0.456	(0.508)	−0.115	(0.327)
	Kinki	−1.802***	(0.556)	0.058	(0.294)	−0.624***	(0.190)
	Chugoku	0.672	(0.719)	−0.871*	(0.379)	−0.150	(0.243)
	Shikoku	−1.574***	(0.537)	−0.093	(0.281)	−0.397*	(0.181)
	North Kyushu	−1.428**	(0.821)	−0.091	(0.419)	0.798***	(0.275)
	South Kyushu	4.472*	(2.023)	−1.894**	(1.060)	1.004	(0.696)
Telephone variable	Hokkaido	0.216***	(0.052)	−0.254***	(0.028)	0.068***	(0.018)
	Tohoku	−0.069	(0.058)	0.014	(0.030)	0.001	(0.019)
	North Kanto	−0.017	(0.051)	0.040	(0.027)	−0.013	(0.017)
	South Kanto	−0.008	(0.053)	0.011	(0.029)	0.020	(0.018)
	Hokuriku	0.113**	(0.059)	−0.052**	(0.031)	−0.022	(0.020)
	Tokai	0.011	(0.050)	0.023	(0.027)	−0.047***	(0.018)
	Kinki	−0.059	(0.058)	0.017	(0.030)	0.017	(0.019)
	Chugoku	0.121*	(0.058)	−0.142***	(0.031)	0.030	(0.019)

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Table 4.15 *continued*

		Primary Industry		Secondary Industry		Tertiary Industry	
		Estimate	(Std. Err.)	Estimate	(Std. Err.)	Estimate	(Std. Err.)
	Shikoku	0.035	(0.060)	−0.026	(0.032)	−0.017	(0.020)
	North Kyushu	0.050	(0.060)	−0.109***	(0.032)	−0.014	(0.020)
	South Kyushu	−0.034	(0.050)	0.061*	(0.026)	−0.038*	(0.018)
Electricity variable	Hokkaido	−1.028***	(0.163)	0.326***	(0.085)	−0.060	(0.056)
	Tohoku	−0.829***	(0.158)	0.592***	(0.101)	0.283***	(0.054)
	North Kanto	−0.682***	(0.102)	0.422***	(0.076)	0.220***	(0.039)
	South Kanto	−0.683***	(0.093)	0.549***	(0.060)	0.215***	(0.039)
	Hokuriku	−0.751***	(0.109)	0.440***	(0.072)	0.293***	(0.040)
	Tokai	−0.331***	(0.090)	0.421***	(0.063)	0.339***	(0.035)
	Kinki	−0.778***	(0.099)	0.492***	(0.059)	0.213***	(0.037)
	Chugoku	−0.799***	(0.100)	0.599***	(0.056)	0.108***	(0.039)
	Shikoku	−0.343***	(0.091)	0.379***	(0.054)	0.196***	(0.038)
	North Kyushu	−0.785***	(0.101)	0.385***	(0.055)	0.057	(0.041)
	South Kyushu	−1.188***	(0.326)	0.589***	(0.171)	−0.044	(0.110)
Scale variable		−0.060	(0.048)	−0.103*	(0.045)	0.250***	(0.019)
Markup variable		0.003	(0.012)	0.226***	(0.010)	0.177***	(0.015)
R-squared		**0.957**		**0.971**		**0.972**	

Std. Err. = standard error.
*** Statistically significant at 1%.
** Statistically significant at 5%.
* Statistically significant at 10%.
Note: This estimation includes fixed effects. However, the estimated coefficients of these effects are omitted.
Source: Authors' calculations.

Table 4.16 Total Factor Productivity Regression Based on Physical Indicators without Trend

		Primary Industry		Secondary Industry		Tertiary Industry	
		Estimate	(Std. Err.)	Estimate	(Std. Err.)	Estimate	(Std. Err.)
Trend		–		–		–	
Road variable	Hokkaido	0.404	(1.094)	0.382	(0.544)	0.563	(0.371)
	Tohoku	3.191***	(1.668)	−1.070	(0.827)	−1.558*	(0.581)
	North Kanto	−0.704	(0.504)	0.434***	(0.254)	−0.394**	(0.173)
	South Kanto	0.395	(0.993)	0.855***	(0.501)	−0.420	(0.342)
	Hokuriku	−0.893	(1.026)	0.837	(0.516)	−1.284*	(0.352)
	Tokai	−2.080**	(1.015)	1.274**	(0.507)	−0.978*	(0.345)
	Kinki	−0.671	(0.589)	0.512***	(0.296)	−1.094*	(0.202)
	Chugoku	1.194	(0.780)	−0.553	(0.391)	−0.341	(0.267)
	Shikoku	−0.950	(0.579)	0.109	(0.289)	−0.592*	(0.198)
	North Kyushu	−0.669	(0.891)	0.239	(0.433)	0.547***	(0.302)
	South Kyushu	4.991**	(2.198)	−2.050***	(1.102)	0.965	(0.769)

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Table 4.16 *continued*

		Primary Industry		Secondary Industry		Tertiary Industry	
		Estimate	(Std. Err.)	Estimate	(Std. Err.)	Estimate	(Std. Err.)
Telephone variable	Hokkaido	0.362*	(0.054)	−0.186*	(0.026)	0.003	(0.018)
	Tohoku	0.024	(0.062)	0.064**	(0.030)	−0.039***	(0.021)
	North Kanto	0.108**	(0.053)	0.089*	(0.027)	−0.055*	(0.018)
	South Kanto	0.122**	(0.055)	0.072[b]	(0.028)	−0.027	(0.019)
	Hokuriku	0.192*	(0.063)	−0.021	(0.032)	−0.044**	(0.022)
	Tokai	0.078	(0.054)	0.047***	(0.027)	−0.060*	(0.019)
	Kinki	0.041	(0.062)	0.053***	(0.031)	−0.015	(0.021)
	Chugoku	0.214*	(0.062)	−0.106*	(0.032)	−0.002	(0.021)
	Shikoku	0.141**	(0.064)	0.017	(0.032)	−0.050**	(0.022)
	North Kyushu	0.141**	(0.064)	−0.078**	(0.032)	−0.052**	(0.022)
	South Kyushu	0.102***	(0.052)	0.114*	(0.026)	−0.077*	(0.019)
Electricity variable	Hokkaido	−0.672*	(0.172)	0.418*	(0.086)	−0.181*	(0.060)
	Tohoku	−0.469*	(0.165)	0.588*	(0.105)	0.162*	(0.057)
	North Kanto	−0.170**	(0.086)	0.487*	(0.077)	0.039	(0.037)
	South Kanto	−0.209*	(0.076)	0.634*	(0.059)	0.063***	(0.038)
	Hokuriku	−0.314*	(0.101)	0.494*	(0.073)	0.148*	(0.041)
	Tokai	0.115	(0.075)	0.477*	(0.063)	0.180*	(0.033)
	Kinki	−0.279*	(0.081)	0.595*	(0.056)	0.034	(0.035)
	Chugoku	−0.280*	(0.080)	0.701*	(0.053)	−0.077**	(0.036)
	Shikoku	0.150**	(0.071)	0.480*	(0.050)	0.022	(0.036)
	North Kyushu	−0.321*	(0.087)	0.482*	(0.052)	−0.107*	(0.040)
	South Kyushu	−0.788**	(0.351)	0.678*	(0.177)	−0.211***	(0.120)
Scale variable		−0.038	(0.052)	−0.011	(0.047)	0.226*	(0.021)
Markup variable		0.015	(0.013)	0.236*	(0.010)	0.142*	(0.016)
R-squared		**0.957**		**0.971**		**0.972**	

Std. Err. = standard error.
*** Statistically significant at 1%.
** Statistically significant at 5%.
* Statistically significant at 10%.
Note: This estimation includes fixed effects. However, the estimated coefficients of these effects are omitted.
Source: Authors' calculations.

Table 4.17 displays the results using real values of public capital with trend, and Table 4.18 displays the results without trend.

Both Tables 4.17 and 4.18 show that the parameters of the transport variable have a positive effect on TFP, especially in secondary industry. However, most of the parameters of the living environment have no effect on TFP. Furthermore, the parameter of the scale variable, which represents the extent of returns to scale, is positive in secondary and tertiary industry, and the parameter of the markup variable, which represents the extent of competitive competition, is positive in secondary and tertiary industry. These results are slightly different in secondary industry, but most of the results are the same as the results of the TFP regression, based on physical indicators.

Finally, it should be emphasized that, despite differences in their development stages, transport infrastructure is indispensable for technical progress in both Thailand and Japan. However, in Japan, where the population is shrinking, an excess supply of transport infrastructure will appear in the future.

Table 4.17 Total Factor Productivity Regression Based on Real Values with Trend

		Primary Industry		Secondary Industry		Tertiary Industry	
		Estimate	(Std. Err.)	Estimate	(Std. Err.)	Estimate	(Std. Err.)
Trend		0.017***	(0.003)	0.011***	(0.001)	−0.004***	(0.001)
Transport	Hokkaido	0.048	(0.182)	−0.700***	(0.090)	−0.253***	(0.074)
	Tohoku	0.481	(0.508)	0.857***	(0.254)	−0.113	(0.170)
	North Kanto	0.847**	(0.420)	−0.329	(0.218)	0.023	(0.145)
	South Kanto	−0.230*	(0.139)	0.246***	(0.070)	−0.411***	(0.064)
	Hokuriku	1.420***	(0.532)	−1.047***	(0.259)	0.354**	(0.181)
	Tokai	0.320	(0.445)	0.186	(0.222)	−0.055	(0.155)
	Kinki	−0.258	(0.281)	0.540***	(0.143)	−0.239**	(0.101)
	Chugoku	−0.441	(0.346)	0.609***	(0.171)	−0.050	(0.116)
	Shikoku	−0.096	(0.205)	0.348***	(0.102)	0.072	(0.072)
	North Kyushu	−0.693***	(0.244)	−0.066	(0.122)	0.031	(0.089)
	South Kyushu	−0.418	(0.400)	0.479**	(0.206)	−0.359***	(0.137)
Living environment	Hokkaido	−0.417***	(0.153)	0.506***	(0.074)	0.020	(0.051)
	Tohoku	−0.612*	(0.371)	−0.687***	(0.181)	−0.060	(0.124)
	North Kanto	−0.846***	(0.296)	0.191	(0.149)	−0.142	(0.099)
	South Kanto	−0.169	(0.136)	−0.138**	(0.067)	0.203***	(0.042)
	Hokuriku	−1.346***	(0.383)	0.741***	(0.190)	−0.385***	(0.134)
	Tokai	−0.559	(0.408)	−0.178	(0.196)	−0.090	(0.143)
	Kinki	−0.269	(0.281)	−0.440***	(0.131)	0.009	(0.086)
	Chugoku	0.137	(0.291)	−0.500***	(0.145)	−0.149	(0.098)
	Shikoku	−0.025	(0.211)	−0.368***	(0.100)	−0.274***	(0.069)
	North Kyushu	0.218	(0.232)	0.001	(0.110)	−0.285***	(0.074)
	South Kyushu	0.151	(0.314)	−0.455***	(0.158)	0.070	(0.105)
Scale variable		0.027	(0.090)	0.254***	(0.039)	0.502***	(0.038)
Markup variable		0.020*	(0.012)	0.239***	(0.010)	0.126***	(0.015)
R-squared		**0.943**		**0.966**		**0.964**	

Std. Err. = standard error.
*** Statistically significant at 1%.
** Statistically significant at 5%.
* Statistically significant at 10%.
Note: This estimation includes fixed effects. However, the estimated coefficients of these effects are omitted.
Source: Authors' calculations.

Table 4.18 Total Factor Productivity Regression Based on Real Values without Trend

		Primary Industry		Secondary Industry		Tertiary Industry	
		Estimate	(Std. Err.)	Estimate	(Std. Err.)	Estimate	(Std. Err.)
Trend		–		–		–	
Transport	Hokkaido	0.385***	(0.171)	−0.275**	(0.089)	−0.451**	(0.059)
	Tohoku	0.737	(0.518)	1.697**	(0.268)	−0.331***	(0.167)
	North Kanto	1.256**	(0.429)	−0.242	(0.245)	−0.083	(0.147)
	South Kanto	0.103	(0.125)	0.557**	(0.071)	−0.579**	(0.052)
	Hokuriku	1.496**	(0.551)	−1.383**	(0.289)	0.504**	(0.182)
	Tokai	0.372	(0.460)	0.670**	(0.243)	−0.112	(0.159)
	Kinki	−0.180	(0.289)	0.896**	(0.157)	−0.408**	(0.095)
	Chugoku	−0.112	(0.355)	0.499**	(0.192)	−0.091	(0.119)
	Shikoku	0.018	(0.212)	0.416**	(0.114)	0.000	(0.072)
	North Kyushu	−0.422*	(0.243)	0.364**	(0.128)	−0.151*	(0.081)
	South Kyushu	0.217	(0.387)	1.222**	(0.213)	−0.610**	(0.129)
Living environment	Hokkaido	−0.349***	(0.158)	0.277**	(0.080)	0.090*	(0.049)
	Tohoku	−0.468	(0.384)	−1.179**	(0.196)	0.017	(0.126)
	North Kanto	−0.792**	(0.306)	0.254	(0.168)	−0.152	(0.102)
	South Kanto	0.045	(0.138)	−0.245**	(0.075)	0.229**	(0.043)
	Hokuriku	−1.053**	(0.392)	1.108**	(0.209)	−0.575**	(0.130)
	Tokai	−0.101	(0.419)	−0.439***	(0.218)	−0.155	(0.146)
	Kinki	0.180	(0.283)	−0.591**	(0.147)	0.045	(0.089)
	Chugoku	0.231	(0.300)	−0.269*	(0.161)	−0.208***	(0.099)
	Shikoku	0.240	(0.213)	−0.285***	(0.112)	−0.307**	(0.070)
	North Kyushu	0.424*	(0.240)	−0.240***	(0.121)	−0.233**	(0.075)
	South Kyushu	−0.009	(0.321)	−0.931**	(0.168)	0.178*	(0.105)
Scale variable		−0.379**	(0.065)	0.271**	(0.044)	0.567**	(0.036)
Markup variable		0.030***	(0.012)	0.246**	(0.012)	0.112**	(0.015)
R-squared		0.943		0.966		0.964	

Std. Err. = standard error.
*** Statistically significant at 1%.
** Statistically significant at 5%.
* Statistically significant at 10%.
Note: This estimation includes fixed effects. However, the estimated coefficients of these effects are omitted.
Source: Authors' calculations.

4.6 Conclusions

This chapter estimated the effect of public investment on productivity using a production function and TFP regression from the 1970s to the 2010s in Thailand and Japan.

In Thailand, growth accounting by industry reveals that TFP growth has increased in the manufacturing and service sectors. Conversely, TFP growth has declined in the agricultural sector, which has the lowest TFP of all considered industries. The production function analysis revealed a productivity effect from infrastructure investment only in the manufacturing sector, and the level of this effect is higher than before. In other industrial sectors, the productivity effects of infrastructure investment are smaller or do not exist. TFP regressions show that investment in transport infrastructure, which is less developed in Thailand than in Japan, has a positive effect on TFP, especially in the manufacturing and services sectors. This implies that investing in transport infrastructure is indispensable for future economic development.

In Japan, growth accounting by industry and region reveals that TFP growth in secondary and tertiary industry is higher in urban areas than in rural areas. The level of TFP is also higher in urban regions than in other regions. Production function analysis shows that a productivity effect from infrastructure investment definitely exists in secondary and tertiary industry, and that marginal productivity decreases more rapidly in secondary industry than in tertiary industry. In secondary industry, the amount of production decreased gradually from 1990 to 2010. Hence, this result partly reflects the fact that the utilization of public capital has decreased because of the decrease in production. TFP regressions revealed that transport infrastructure investment has a positive effect on TFP, especially in secondary industry. However, in Japan, whose population is shrinking, an excess supply of transport infrastructure will appear in the future.

Despite the differences in their development stages, investment in transport infrastructure is indispensable in both Thailand and Japan. In particular, Thailand's transport infrastructure is inadequate, and the insufficient road network has caused a bottleneck in the country's economy. Improving Thailand's transport infrastructure will be indispensable for further economic development in the country.

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Appendix 4.1

Data Sources—Thailand

A4.1.1 Output

The output indicator in this analysis is real gross domestic product (GDP) by industry estimated by the Office of the National Economic and Social Development Board (NESDB). Consistent official estimates after 1990 exist in the National Account in Thailand.

Long-term time-series data are needed to keep this analysis statistically valid. However, there are severe problems with constructing such data. In the National Accounts in Thailand, the official real value estimates are the chain-linked measure, and estimates by industry are based on the new industrial classification since 1990. Old official estimates are the fixed-based measure, and a different industrial classification was used. To overcome these problems, we adopted our own industrial classification and assume the same real GDP growth rate for the chain-linked and fixed-based measures, and estimated data retrospectively using the growth rate from 1990 data.

A4.1.2 Public Capital Stock

This research utilized two indicators of public capital stock: physical indicators and real values. Physical indicators are our original estimates based on Canning (1998), the ESCAP Statistical Online Database (United Nations Economic and Social Commission for Asia and the Pacific), and World Development Indicators (World Bank). Real value is the public capital stock of the public sector at constant prices for which we use the NESDB data. To match the base year of real value for all the data, capital stock is converted into real values at 2002 prices.

A4.1.3 Labor Input

Labor input by industry is the number of employed persons (drawn from Asian Productivity Organization estimates) multiplied by working hours (the authors calculated working hours by industry based on the labor force survey [National Statistical Office of Thailand]).

A4.1.4 Income Share of Labor

The income share of labor in our analysis is defined by the ratio of compensation of employees to nominal GDP. Employee compensation figures are taken from NESDB estimates, and nominal GDP is GDP valued at current factor cost. Since figures for GDP valued at current factor cost did not exist before 1979, we estimate backward from the 1980 data using the GDP growth rate at current market prices.

A4.1.5 User Cost of Capital

Under the assumption that the depreciation rate is constant, we calculated the user cost of capital by industry using the interest rate, the depreciation rate, and the price of capital goods. The interest rate is the lending rate, the depreciation rate is defined by the ratio of depreciation to capital stock, and the price of capital goods is the ratio of the gross capital stock at the current replacement cost to the gross capital stock at constant prices. These data come from the IMF and NESDB.

Appendix 4.2

Data Sources—Japan

Further details of the statistical data used in this analysis can be found in Nakahigashi and Yoshino (2016).

A4.2.1 Output

For output by industry, this analysis uses real gross regional product (GRP). Real GRP is calculated by dividing nominal GRP by a GRP deflator. Nominal GRP is the GRP at producers' prices excluding "taxes on production and imports less subsidies" by the Prefectural Accounts of Japan. Before 2000, the GRP deflator by prefecture did not exist. Consequently, the GRP deflator for prefectures is the same as the GDP deflator classified by economic activities by the National Accounts of Japan.

A4.2.2 Private Capital Stock

For prefectural private capital stock data, we use the Economic and Social Research Institute's 2011 trial estimate of private enterprises' prefectural private capital stock. However, this estimate is inconsistent because privatized public companies were included in the middle of the estimated period. Therefore, we estimate the level of privatized public companies and estimate backward from 2010 using the growth rate of prefectural private capital stock.

A4.2.3 Labor Input

Labor input is derived by multiplying the number of employed persons by the number of working hours. The number of employed persons is counted at the workplace and is estimated using the population census and the labor force survey. It is assumed that working hours by industry is the same among all prefectures and is as estimated by the labor force survey and monthly labor survey.

A4.2.4 Labor Cost Share

The labor cost share is defined by the ratio of workers' income to nominal output. The workers in our analysis included employees, self-employed persons, and workers in family businesses. The Prefectural Account of the Cabinet Office of Japan only records employees' income, which is listed as "compensation of employees." Assuming that the income per worker and employee are the same, the workers' income is estimated using employee compensation, the number of workers, and the number of employees by industry and region.

A4.2.5 Public Capital

For public capital stock by prefecture, we used the prefectural gross capital stock estimated by the Cabinet Office (2012). The public capital stock in this analysis consists of (i) transport public capital, which is the sum of roads, port facilities, and airport facilities; and (ii) public capital for the living environment, which is the sum of sewage facilities, facilities for water services, and city parks. In the production function analysis, the sum of these are used as the public capital.

5

The Effect of Infrastructure on Firm Productivity: Evidence from the Manufacturing Sector in the People's Republic of China

Yan Zhang, Guanghua Wan, and Youxing Huang

5.1 Introduction

Investment in infrastructure in the People's Republic of China (PRC) has been occurring on a large scale since the early 1990s, especially in transportation and telecommunications. In 2013, the PRC launched the Belt and Road Initiative, which will encourage another round of cross-border and domestic infrastructure construction in the regions related to the initiative. In 2015, the total length of the PRC's expressway network reached 123,000 kilometers, surpassing that of the United States to become the longest in the world.[1] It is thus important to consider how infrastructure affects the country's economy.

Many studies have investigated the effects of infrastructure on productivity growth (Cronin et al. 1991; Morrison and Schwartz 1996; Demetriades and Mamuneas 2000; Yoshino and Nakahigashi 2000, 2004). However, these studies tend to consider aggregate-level impacts, for example, on growth at the city or province level. This is potentially problematic because there is usually high demand for infrastructure in areas with high economic growth, making it difficult to ascertain the effect of infrastructure on growth and vice versa.

1 http://www.mot.gov.cn/zhengcejiedu/2015qgsfgltjgb/ (in Chinese) (accessed 16 February 2017).

To circumvent this problem, following Li and Li (2013), we estimate the effect of infrastructure on firm productivity, since firm-level growth would likely not affect the demand for infrastructure construction in a city or province. Another advantage of using micro-level data is that we can estimate the micro-foundation of aggregate-level productivity growth. For example, Haughwout (2002) found that infrastructure influences aggregate welfare via firm productivity and household preferences. Meanwhile, firms in the PRC have exhibited high growth rates since the 1990s. The existing literature tends to attribute this to productivity growth rather than to capital or labor accumulation; however, it is important to consider how public infrastructure investment contributes to firm productivity growth.

Using a panel dataset of more than 44,000 manufacturing firms in the PRC during 2002–2007, this chapter employs a firm-level total factor productivity (TFP) model with three kinds of infrastructure investments: roads, telecommunications servers, and cable. All types of investments were found to affect firm productivity positively. This chapter also compares the effect of infrastructure in different regions in the PRC, namely, the relatively well-developed eastern provinces and the less well-developed western and central provinces. It was found that infrastructure investments benefit firms in the western and central provinces more than those in the eastern provinces.

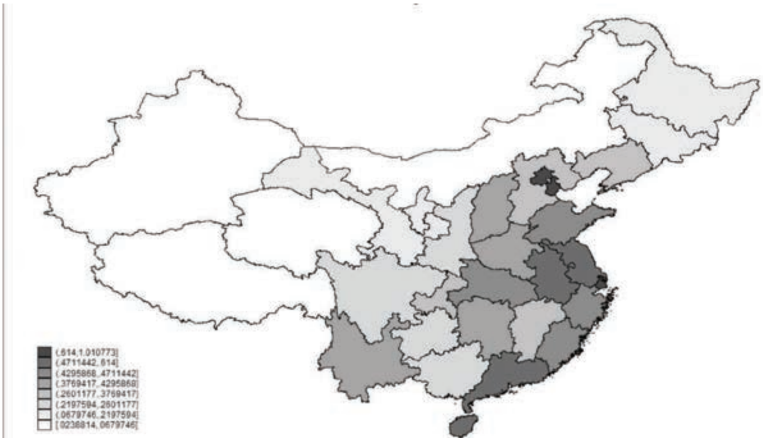
5.2 Background and Methodology

5.2.1 Infrastructure Investment in the People's Republic of China

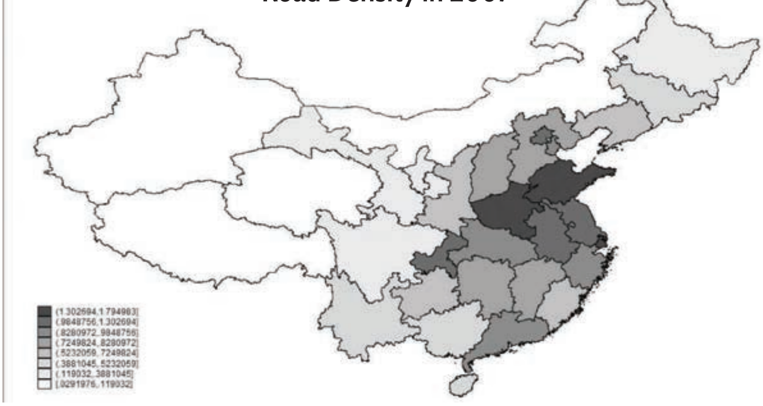
Figure 5.1 depicts the spatial road density from 2002 to 2007, while graphs for telecommunications servers and cable are in Appendix 7A. The measurements are divided by the area of each province to produce the density. These figures depict three main characteristics for several provinces. First, the magnitude of the density scales reveals that all three forms of infrastructure increased rapidly from 2002 to 2007. During this period, road density doubled in every scale, reflecting the magnitude of investment in transportation infrastructure in the PRC. Second, with regard to all three forms of infrastructure, there is significant spatial inequality between the eastern provinces and the western and central provinces. In the coastal provinces, infrastructure density is relatively high, consistent with their rapid economic growth. As discussed above, this could be due to either high infrastructure

Figure 5.1 Spatial Road Density, 2002 and 2007

Road Density in 2002



Road Density in 2007



Source: Authors.

demand or infrastructure's productivity effects. Therefore, it is best to check the firm-level impact instead. Third, infrastructure intensity increased more in the eastern provinces than in the western and central provinces from 2002 to 2007, implying that more infrastructure investment occurs in these regions.

5.2.2 Methodology

Regression Specification

To investigate the relationship between infrastructure and firm productivity, we propose the basic infrastructural effects model:

$$prod_{i,j,k,t} = \alpha_0 + \alpha_1 inf_{k,t} + \beta' X_{i,j,k,t} + \rho_k + \pi_j + \theta_t + \varepsilon_{i,j,k,t} \quad (1)$$

where $prod_{i,j,k,t}$ is the productivity measure for firm *i*, in industry *j*, and province *k* at time *t*. We used the TFP estimated from the Cobb-Douglas production function to proxy firm productivity, and we estimated firm-level TFP using the Levinsohn-Petrin semi-parametric estimation approach (Levinsohn and Petrin 2003) to deal with the simultaneity bias raised by Olley and Pakes (1996).[2] We also used labor productivity as a productivity measure to check robustness (detailed calculations are in Appendix 7C).

$inf_{k,t}$ stands for the three kinds of infrastructure considered in this chapter: road length, the number of telecommunications servers, and cable length. All three are included in the logarithms. $X_{i,j,k,t}$ is a vector of firm-specific control variables investigated in previous studies that may also affect productivity; these include (i) *size*, measured by the total assets (Chen and Guariglia 2013; Edamura et al. 2014); (ii) *capital intensity*, measured by the ratio of the average net value of fixed assets to the number of employees (Abraham, Konings, and Slootmaekers 2010; Chen and Tang 2014); (iii) *export*, measured by the ratio of total revenue from exports to total sales. (Aw, Roberts, and Xi 2008; Chen and Guariglia 2013; Chen and Tang 2014); (iv) *age*, measured by the years since the firm was established (Palangkaraya, Stierwald, and Yong 2009; Chen and Guariglia 2013; Cozza, Rabellotti, and Sanfilippo 2015); (v) *private*, equal to 1 if the firm is privately owned and 0 if otherwise; and (vi) *foreign*, equal to 1 if the firm is foreign-owned and 0 if otherwise. The term ρ_k represents effects for provinces, π_j the effects for industries, and θ_t the effects for years. Finally, $\varepsilon_{i,j,k,and\ t}$ are error terms that are assumed to be independently and identically distributed. The regression variables are more fully defined in Appendix 7B.

$$prod_{i,j,k,t} = \alpha_0 + \alpha_1 inf_{k,t} + \alpha_2 inf_{k,t} * WestCen_{k,t} + \alpha_3 WestCen_{k,t} + \beta' X_{i,j,k,t} + \rho_k + \pi_j + \theta_t + \mu_{i,j,k,t} \quad (2)$$

2 The correlation between error terms and inputs in ordinary least squares might lead to biased TFP estimations.

To test these effects in different regions, we added the region dummy variable *WestCen* (western and central) and its interactive term with infrastructure in equation (2). If a firm is located in the western or central provinces,[3] the value is equal to 1; otherwise it is 0.

We estimated the parameters of equations (1) and (2) using the fixed-effect regression method while controlling for the time effect. We also considered spatial spillover effects between neighboring provinces. This means that an extra unit in one province might affect firm productivity in neighboring provinces. For example, a road connecting two or more provinces could help a firm reach larger markets, and telecommunications servers built in neighboring provinces could improve the speed and quality of communication. We used a spatial model in the following form to control for effects from neighboring provinces:

$$prod_{i,j,k,t} = \alpha_0 + \alpha_1 inf_{k,t} + \gamma SL\_inf_{k,t} + \beta' X_{i,j,k,t} + \rho_k + \pi_j + \theta_t + \mu_{i,j,k,t} \quad (3)$$

$SL\_inf_{k,t}$ represents the spatial-weighted infrastructure from neighboring provinces. It is obtained by the production of two vectors: one containing the infrastructure for all provinces with each component indicating the value of a province (the order of the provinces is fixed); and a spatial vector that presents the neighborhood of province k. If the n-th province is the neighbor of k, the value of the n-th component of the spatial vector is set to 1 and 0 if otherwise.

Data

Our sample set covers the period 2002–2007 and came from two sources. The first is the Chinese Industrial Enterprise Database (CIED), which contains annual information on manufacturing in the PRC taken from a yearly enterprise census conducted by the PRC's National Bureau of Statistics. The CIED covers manufacturing firms, mining firms, and firms that produce and supply electricity, gas, and water. It includes all state-owned enterprises and privately owned enterprises with sales above CNY5 million. The number of firms in our dataset ranged from 181,557 in 2002 to 336,771 in 2007. Our firm-level data for estimating TFP and other firm-level control variables were taken from the CIED. The

[3] The eastern part of the PRC covers 11 provinces and regions: Beijing, Tianjin, Shanghai, Hebei, Liaoning, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, and Hainan. The western and central parts cover 20 provinces and regions: Shanxi, Inner Mongolia, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, Hunan, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Tibet, Ningxia, and Xinjiang. Thus, this study uses data from 31 provinces.

second data source is the PRC's Statistical Yearbook, which provides province-level data for the three forms of infrastructure.

5.3. Results

5.3.1 Descriptive statistics

Table 5.1 summarizes the statistics for the variables in our regression analyses. It is important to note that (i) infrastructure varies significantly among provinces, confirming the inequality of regional infrastructure seen in Figure 5.1; and (ii) the mean of the *WestCen* dummy is 0.23, which implies that most firms in our sample are located in the eastern provinces. This is because the majority of the firms in the CIED database are in developed provinces. However, due to the large number of observations and firms used, this imbalance does not bias our results.

Table 5.1 Summary Statistics for the Regression Variables

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
TFP	1,314,378	6.48	1.13	–3.85	12.93
Labor productivity	1,314,378	4.01	1.10	–7.70	11.58
Roads	186	77,510.58	51,214.44	6,286.00	238,676.00
Telecom	186	1,589.00	1,555.58	31.00	11,365.80
Cable	186	20,241.34	10,900.45	618.00	55,910.00
Size	1,335,926	76,571.59	681,988.60	3.00	1.55E+08
Capital intensity	1,335,926	74.37	109.08	0.98	691.60
Export	1,335,589	0.18	0.35	0.00	1.00
Age	1,335,311	9.69	9.48	1.00	51.00
Private	1,335,926	0.46	0.50	0.00	1.00
Foreign	1,335,926	0.22	0.42	0.00	1.00
WestCen	1,335,926	0.23	0.42	0.00	1.00

Max. = maximum, Min. = minimum, Obs. = observation, Std. Dev. = standard deviation, Telecom = telecommunications, TFP = total factor productivity, WestCen = western and central.
Source: Authors.

5.3.2 Main Results

Table 5.2 presents the ordinary least-squares estimates for the parameters of the basic infrastructural model of equation (1). Columns 1–3 show the TFP results for the three forms of infrastructure, and

Table 5.2 Infrastructure Effects on Firm Productivity

	(1) TFP	(2) TFP	(3) TFP	(4) LP	(5) LP	(6) LP
Roads	0.273***			0.276***		
	(0.000)			(0.000)		
Telecom		0.356***			0.360***	
		(0.000)			(0.000)	
Cable			0.167***			0.186***
			(0.000)			(0.000)
Size	0.386***	0.388***	0.388***	0.098***	0.100***	0.100***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Capital intensity	−0.189***	−0.189***	−0.188***	0.202***	0.203***	0.203***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Export	−0.004	−0.002	−0.003	−0.041***	−0.038***	−0.040***
	(0.397)	(0.686)	(0.512)	(0.000)	(0.000)	(0.000)
Firm age	0.126***	0.126***	0.127***	0.094***	0.094***	0.095***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Private firm	0.022***	0.023***	0.023***	0.027***	0.029***	0.028***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Foreign firm	0.0400***	0.0390***	0.0370***	0.0230*	0.0210*	0.0200
	(0.000)	(0.000)	(0.000)	(0.026)	(0.037)	(0.052)
Constant	0.037	0.139	1.291***	−1.067*	−0.964*	0.069
	(0.940)	(0.774)	(0.006)	(0.015)	(0.029)	(0.873)
Year dummy	Yes	Yes	Yes	Yes	Yes	Yes
Number	1,313,465	1,313,465	1,313,465	1,313,465	1,313,465	1,313,465
Adj. R-sq.	0.211	0.212	0.209	0.164	0.165	0.163

Adj. R-sq. = adjusted r-squared, LP = labor productivity, Telecom = telecommunications, TFP = total factor productivity.
Notes: Firm-level clustered standard errors are in parentheses. Year dummies are controlled for in all columns, but their coefficients are not reported.
* Significant at the 10% level.
** Significant at the 5% level.
*** Significant at the 1% level.
Source: Authors.

columns 4–6 show the labor productivity results. Year-fixed effects were controlled for in all regressions, and the standard errors were robust to firm-level clustering. In all cases, the infrastructural measures had positive coefficients that were statistically significant at the 1% level, and the results are similar to the two different productivity measures. This implies that infrastructure impacts firm-level TFP positively.

The coefficients of the control variables are consistent with existing literature; that is, an increase in the size, age, and share of private and foreign holdings leads to higher firm productivity. However, capital intensity yields opposite results in two productivity measures: when capital intensity is high, it promotes labor productivity but reduces TFP.

Table 5.3 presents the empirical results for the regional infrastructural effects model (equation 2). Columns 1–3 show the results for roads, telecommunications, and cable, while columns 4–6 show the same for labor productivity. The results are generally similar to those in Table 5.2. The estimated coefficients of each of the three infrastructure measures are significant and positive, suggesting that infrastructure positively affects firm productivity. In addition, the *WestCen* coefficients are negative and significant in columns 4 and 6, whereas they are positive but less significant in columns 1 and 2. These results imply that firms in the eastern provinces have relatively high labor productivities. This might be because skilled and educated laborers tend to stay in coastal areas, where the economy is more developed. However, in terms of TFP there are no significant interregional differences. More interestingly, the interactive terms between infrastructure and the region dummy are positive and significant at the 1% level. This indicates that infrastructure investment in the western and central provinces has a greater effect on firm productivity. This may be because infrastructure density in the

Table 5.3 Empirical Results of the Regional Infrastructural Effects Model

	(1) TFP	(2) TFP	(3) TFP	(4) LP	(5) LP	(6) LP
WestCen	−1.68***	−1.25***	−3.66***	−2.21***	−1.73***	−4.56***
	(0.31)	(0.30)	(0.32)	(0.32)	(0.31)	(0.34)
Roads	0.2009***			0.1874***		
	(0.0077)			(0.0079)		
WestCen*× roads	0.1226***			0.1489***		
	(0.0052)			(0.0054)		
Telecom		0.2879***			0.2798***	

continued on next page

Table 5.3 *continued*

	(1) TFP	(2) TFP	(3) TFP	(4) LP	(5) LP	(6) LP
		(0.0072)			(0.0074)	
WestCen× telecom		0.1824***			0.2147***	
		(0.0054)			(0.0055)	
Cable			0.0957***			0.1031***
			(0.0073)			(0.0074)
WestCen× cable			0.343***			0.407***
			(0.012)			(0.012)
Size	0.3860***	0.3877***	0.3885***	0.0987***	0.1003***	0.1012***
	(0.0025)	(0.0025)	(0.0025)	(0.0025)	(0.0025)	(0.0025)
Capital intensity	−0.1889***	−0.1891***	−0.1879***	0.2020***	0.2016***	0.2028***
	(0.0015)	(0.0015)	(0.0015)	(0.0017)	(0.0017)	(0.0017)
Export	−0.0038	−0.0023	−0.0026	−0.0412***	−0.0396***	−0.0397***
	(0.0051)	(0.0051)	(0.0051)	(0.0052)	(0.0052)	(0.0052)
Age	0.1265***	0.1281***	0.1282***	0.0958***	0.0978***	0.0976***
	(0.0027)	(0.0027)	(0.0027)	(0.0027)	(0.0027)	(0.0027)
Private	0.0216***	0.0223***	0.0232***	0.0276***	0.0282***	0.0291***
	(0.0039)	(0.0039)	(0.0039)	(0.0040)	(0.0040)	(0.0040)
Foreign	0.0380***	0.0376***	0.0374***	0.0218**	0.0215**	0.0212**
	(0.0099)	(0.0099)	(0.0099)	(0.010)	(0.010)	(0.010)
Constant	0.0380***	0.0376***	0.0374***	0.0218**	0.0215**	0.0212**
	(0.0099)	(0.0099)	(0.0099)	(0.010)	(0.010)	(0.010)
Year Dummy	Yes	Yes	Yes	Yes	Yes	Yes
Number	1,313,465	1,313,465	1,313,465	1,313,465	1,313,465	1,313,465
Adj. R-sq.	0.211	0.213	0.21	0.165	0.167	0.164

Adj. R-sq. = adjusted r-squared, LP = labor productivity, Telecom = telecommunications, TFP = total factor productivity, WestCen = western and central.
Notes: Firm-level clustered standard errors (in parentheses) are given to two significant digits, and the coefficients are given to the same decimal place as the corresponding standard errors.
Year dummies are controlled for in all columns, but their coefficients are not reported.
* Significant at the 10% level.
** Significant at the 5% level.
*** Significant at the 1% level.
Source: Authors.

eastern provinces is relatively high. Thus, an extra unit of infrastructure construction might not be as effective as in the western and central provinces, where large infrastructure shortages exist.

The empirical estimates for the parameters of the spatial infrastructural effects model (equation 3) are presented in Table 5.4. Again, for every column, the within-province infrastructure impact is significant and positive. Infrastructure in neighboring provinces also has a positive effect on firm productivity. This implies that improvement in neighboring areas helps firms within a given province, indicating an infrastructure network effect in the PRC.

Table 5.4 Empirical Results for the Spatial Infrastructural Effects Model

	(1) TFP	(2) TFP	(3) TFP	(4) LP	(5) LP	(6) LP
Roads	0.1611***			0.1531***		
	(0.0091)			(0.0091)		
Telecom		0.2901***			0.2923***	
		(0.0072)			(0.0071)	
Cable			0.1151***			0.1342***
			(0.0072)			(0.0073)
Roads in neighboring provinces	0.331***			0.358***		
	(0.020)			(0.021)		
Telecom in neighboring provinces		0.403***			0.418***	
		(0.014)			(0.014)	
Cable in neighboring provinces			0.624***			0.644***
			(0.050)			(0.052)
Size	0.3851***	0.3860***	0.3871***	0.0981***	0.0982***	0.1002***
	(0.0023)	(0.0021)	(0.0022)	(0.0030)	(0.0030)	(0.0031)
Capital intensity	−0.1891***	−0.1891***	−0.1882***	0.2022***	0.2022***	0.2031***
	(0.0021)	(0.0023)	(0.0022)	(0.0021)	(0.0022)	(0.0023)

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Table 5.4 *continued*

	(1) TFP	(2) TFP	(3) TFP	(4) LP	(5) LP	(6) LP
Export	−0.0031	−0.0022	−0.0022	−0.0401***	−0.0393***	−0.0391***
	(0.0051)	(0.0052)	(0.0052)	(0.0053)	(0.0051)	(0.0053)
Age	0.1261***	0.1271***	0.1272***	0.0953***	0.0961***	0.0962***
	(0.0032)	(0.0031)	(0.0032)	(0.0033)	(0.0031)	(0.0031)
Private	0.0211***	0.0233***	0.0222***	0.0273***	0.0291***	0.0284***
	(0.0042)	(0.0041)	(0.0041)	(0.0042)	(0.0041)	(0.0041)
Foreign	0.037***	0.037***	0.036***	0.021**	0.021**	0.019*
	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)
Constant	−0.786***	−0.700***	−1.46***	−1.87***	−1.773***	−2.75***
	(0.098)	(0.069)	(0.25)	(0.10)	(0.070)	(0.26)
Year dummy	Yes	Yes	Yes	Yes	Yes	Yes
Number	1,313,465	1,313,465	1,313,465	1,313,465	1,313,465	1,313,465
Adj. R-sq.	0.197	0.198	0.196	0.165	0.167	0.164
Log likelihood	−936578	−935071	−937211	−968490	−967036	−968998

Adj. R-sq. = adjusted r-squared, LP = labor productivity, Telecom = telecommunications, TFP = total factor productivity, WestCen = western and central.
Notes: Firm-level clustered standard errors (in parentheses) are given to two significant digits, and the coefficients are given to the same decimal place as the corresponding standard errors.
Year dummies are controlled for in all columns, but their coefficients are not reported.
* Significant at the 10% level.
** Significant at the 5% level.
*** Significant at the 1% level.
Source: Authors.

5.4. Policy Implications

The results have several policy implications. First, the influence of infrastructure investment on firm-level productivities is significantly positive. Since the manufacturing sector forms a large portion of the PRC's economy, these results highlight the positive impact of infrastructure on aggregate productivity. Second, the infrastructure effect is stronger in the western and central provinces, where there is a shortage of infrastructure facilities. Therefore, these areas require more investment than do more infrastructure-intensive regions. For example, in the western and central provinces, new roads and highways might link two previously unconnected areas, whereas they would only supplement other roads in the eastern provinces. Thus, investment would be more efficacious in the western and central provinces. Third, infrastructure construction can have spillover effects from one province to its neighboring provinces. Thus, infrastructure improvement in one province would help not only firms within that province, but also firms in neighboring provinces.

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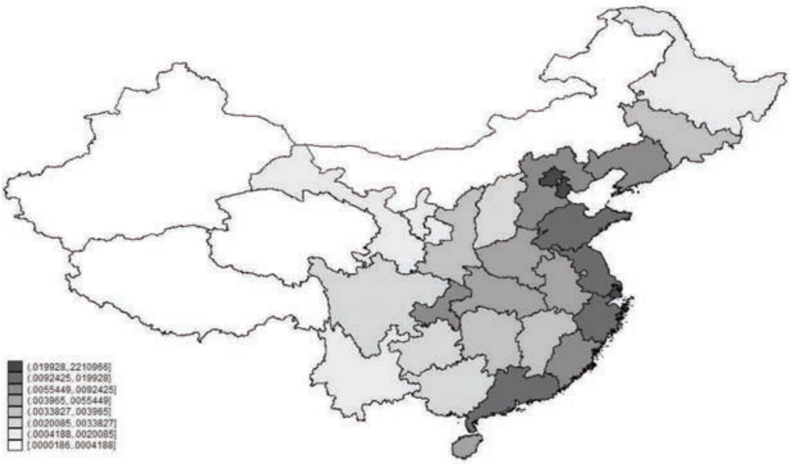
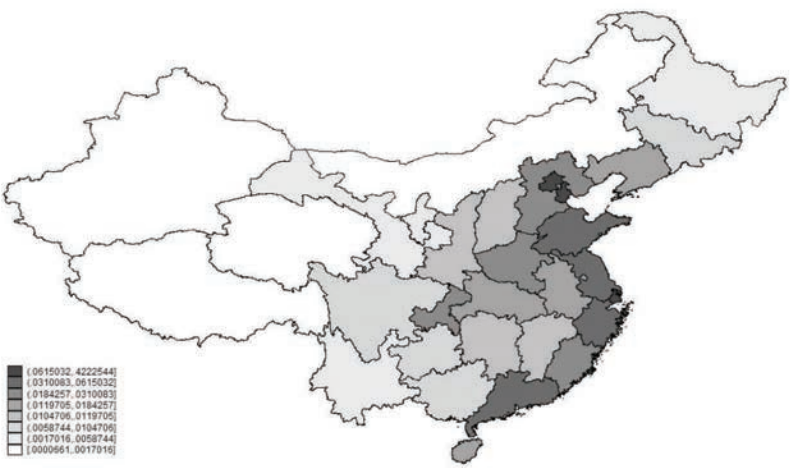
Appendix 5A Changing Spatial Density of Telecommunications and Cable, 2002 and 2007

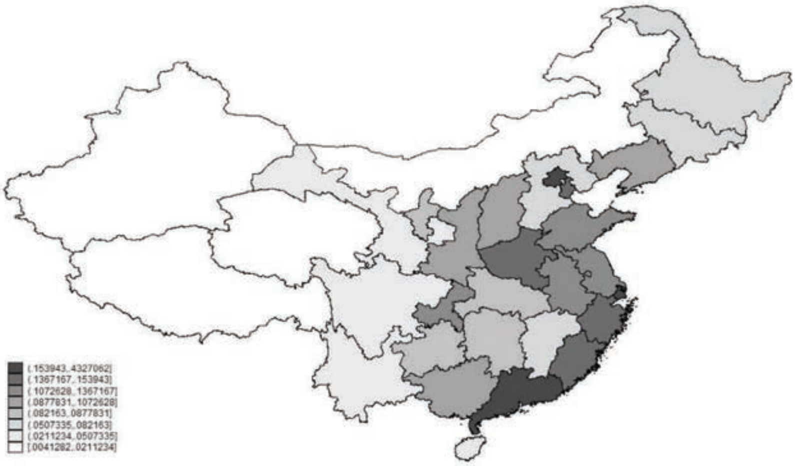
Telecommunications Server Density in 2002



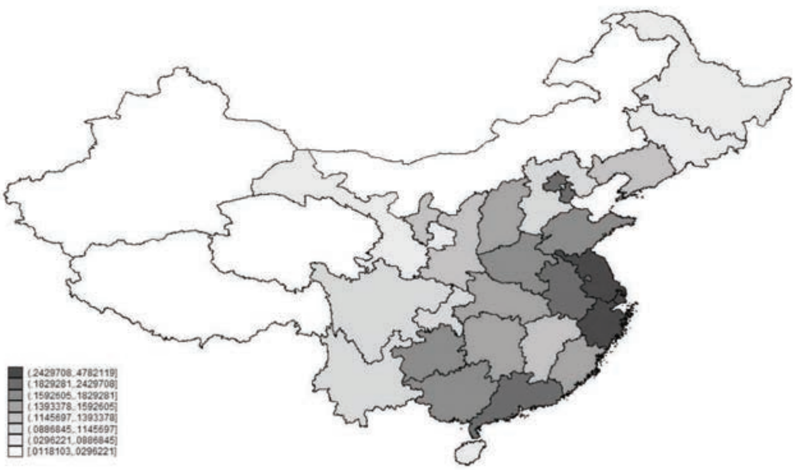
Telecommunications Server Density in 2007



Cable Density in 2002



Cable Density in 2007



Source: Authors.

Appendix 5B Definitions of Covariates

Size: Total assets in a year, in CNY'000, at the firm level, in logarithmic form.

Capital intensity: The average net value of fixed assets divided by the number of employees in each firm.

Export: Total revenue from exports, relative to the firm's total sales.

Age: Number of years since the firm was established.

Private: If a firm is a privately owned enterprise (not including foreign-owned enterprises), the variable is equal to 1; otherwise it is 0.

Foreign: If a firm is a foreign-owned enterprise, the variable is equal to 1; otherwise it is 0.

WestCen: If a firm is located in a western or central province, the variable is equal to 1; otherwise it is 0.

Appendix 5C: Firm-Level Productivity Measures

Labor productivity is defined as follows:

$$Labor_{ijt} = VA_{ijt}/L_{ijt} \qquad \text{(A1)}$$

where i denotes firm, j industry, and t year. Employees (L_{ijt}) is the average number of people employed by the firm per year, in logarithmic form. Value-added (VA_{ijt}) is the industrial value-added, in CNY'000, at the firm level, in logarithmic form.

Total factor productivity (TFP) is estimated using panel data from 2002 to 2007 for two-digit level industries, and is defined as follows:

$$TFP_{ijt} = exp(VA_{ijt} - \ddot{\beta}_K^{LP} K_{ijt} - \ddot{\beta}_L^{LP} L_{ijt} \qquad \text{(A2)}$$

where i denotes firm, j industry, and t year. $\hat{\beta}_K^{LP}$ and $\hat{\beta}_L^{LP}$ denote the estimators of K_{ijt} and L_{ijt} used by Levinsohn and Petrin (2003). VA_{ijt} and L_{ijt} are calculated and deflated as mentioned above. Capital (K_{ijt}) is the average net value of fixed assets, between the beginning and end of the year for a firm, in CNY'000, in logarithmic form. In this chapter, TFP_{ijt} is used in logs.

6

The Impact of Ports Improvement on Education in the Philippines

Kris Francisco and Matthias Helble

6.1 Introduction

The literature recognizes the importance of transport system in a country's development. Several studies show that investment in transport infrastructure leads to economic growth (Easterly and Rebelo 1993), reduced income inequality (Estache 2003, Brenneman and Kerf 2002, Jalan and Ravallion 2002, Galiani et al. 2002, Jacoby 2000, Gannon and Liu 1997, Lee et al. 1997, Lavy et al. 1996, Ferreira 1995, Behrman & Wolfe 1987) and higher productivity (Calderon and Serven 2003, Demetriades and Mamuneas 2000, Canning 1999, Fernald 1999, Baltagi and Pinnoi 1995, Holtz-Eakin 1994, Aschauer 1989). We also know from the economic geography literature (e.g. Fujita et al., 2001) that improved transport system exhibit agglomeration forces that affect the allocation of resources. However, these agglomeration effects are typically mitigated by dispersion forces (such as high wages in cities) which allow the periphery to exist.

In countries with an archipelagic structure such as the Philippines, which consists of about 7,500 islands, building a comprehensive transportation network is a tremendous challenge. Yet, having a reliable and affordable transport system is crucial for facilitating the movement of goods and services within the country and thus spurring economic growth. Moreover, a comprehensive transportation network can play a key role in providing equal growth and development opportunities throughout the country.

The Philippines' transport system is composed of road, railway, air, and water transport. Road transport accounts for about 98% of passenger traffic and 58% of cargo traffic,[1] while water transport remains the predominant mode of inter-island transfer. Since the majority of the country's transport infrastructure is situated in Metro Manila, the capital, much of the country's economic development is concentrated in the National Capital Region, and progress in other regions is slow.[2] The country's transport system is notably characterized by weak connectivity, which is often blamed for the poverty and underdevelopment of small island economies as it limits trade and economic integration (Basilio et al. 2010). Furthermore, a weak logistics network constrains livelihood opportunities, especially in rural areas (Asian Development Bank [ADB] 2012).

To strengthen inter-island linkages, the government implemented the Roll-on/Roll-off (Ro-Ro) policy in 2003. The primary goal of this policy was to create a more efficient and affordable mode of inter-island transfer that would benefit local trade and tourism. The Ro-Ro system was designed to expand the country's transport system by integrating the sea and road networks. The policy allows trucks and other vehicles to board the Ro-Ro vessel directly at the point of embarkation, and roll away from the Ro-Ro vessel directly to the road at the point of destination. By eliminating the need to load and unload cargo, the Ro-Ro system lowered shipping cost by about 30 percentage points. Furthermore, thanks to this policy, many ports were newly integrated into the road network, which enhanced connectivity. Due to this, as well as to faster embarkation and debarkation, transport times were greatly reduced. For example, the travel time between the islands of Mindanao and Luzon was reduced by about 12 hours (ADB 2012).[3]

This chapter aims to provide empirical evidence of the effects of the Ro-Ro policy on various socioeconomic outcomes in the Philippines. First, we investigated the policy's impact on agricultural household income, specifically by observing how Ro-Ro port operations affect entrepreneurial activities. Since one of the policy's main goals is to reduce inter-island transport costs significantly, it can be expected to influence the decisions of agricultural households to engage in certain activities. Second, although the policy was not designed to impact children's education, we evaluated changes in children's school

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1 ADB. (2012). Philippines Transport Sector Assessment, Strategy and Road Map. Manila.

2 Data show that the National Capital Region showcased the highest growth rate in the country (around 35%) in 2012–2014, while that of other regions (except for Calabarzon, Central Luzon, and Central Visayas) fell below 5% around the same period.

3 Luzon, Visayas, and Mindanao are the three main island groups of the Philippines.

attendance in areas near the Ro-Ro ports to identify any transfer of gains from parents to children through human capital investment. Lastly, because improved connectivity can also affect the availability and price of various consumption goods, we checked for possible changes in consumption behavior by studying household expenditure on food, alcohol, and tobacco.

This study will be of use to policy makers and researchers as we demonstrate the benefits of improving a country's transport system. Specific results from each of our three topics also reveal the mechanisms by which households and municipalities are affected by transport policy, such as the Ro-Ro policy in the Philippines.

6.2 Policy Background

The Ro-Ro policy was implemented in the Philippines in 2003 to provide an affordable mode of inter-island transfer by establishing a more efficient Ro-Ro ferry terminal system (RRTS). This policy enabled the government to expand the country's transport system with minimal infrastructure investment by converting pre-existing, private, non-commercial ports into commercial ports under the RRTS. The policy goals were to (i) lower the transport cost of sending products within the country; (ii) enhance inter-island linkages for local tourism and commerce; (iii) facilitate government programs for agriculture, fisheries, and food security; (iv) encourage private sector participation in the RRTS; and (v) promote the development of the RRTS.

The RRTS is composed of a network of terminals linked by Ro-Ro vessels, wherein the Ro-Ro operation is characterized by the process of loading trucks or other vehicles from the road directly to the vessel without offloading the cargo. This system simplified shipping significantly by eliminating the need for portside facilities and equipment, as in the containerization method. As a result, inter-island transport costs were reduced by about 30% for passengers, and 40% for cargo.[4]

The Ro-Ro policy identifies the RRTS as part of the national highway system as it creates a seamless network of connections between nautical highways and national roads. The RRTS is composed of three nautical highways—the Western Nautical Highway, Central Nautical Highway, and Eastern Nautical Highway—along with links provided by the

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4 See The Asia Foundation. 2010. *The Asia Foundation's Roll-on Roll-off Transport: Connecting Maritime Southeast Asia*. https://asiafoundation.org/resources/pdfs/4PagerRoRoPHLetter.pdf (accessed 29 May 2016).

Maharlika or Pan-Philippine Highway (PPH). This system was launched in 2003 with the operation of the Western Nautical Highway, combined with the existing roads and bridges of the PPH. The PPH, the first major highway in the country, was built in the 1960s to connect Luzon, Visayas, and Mindanao, and was intended to stimulate agricultural growth and regional development. Meanwhile, the RRTS was expanded further with the addition of the Central Nautical Highway in 2008 and Eastern Nautical Highway in 2009, completing the interconnections of the country's major island groups.

6.3 Empirical Strategies

To unveil the impacts of the Ro-Ro policy in the Philippines, this chapter evaluates changes in (i) agricultural household income; (ii) children's education; and (iii) household consumption of food, alcohol, and tobacco in areas near the Ro-Ro ports. Due to differences in data availability as well as the nature of the research questions, we utilized different empirical approaches. The models are discussed in the following sections.

6.3.1 Agricultural Household Income

To analyze the effect of the Ro-Ro policy on the income of agricultural households, we constructed a panel-fixed effect model that considers the distance of agricultural households from the nearest Ro-Ro port. Our empirical strategy, which is similar to that of Banerjee et al. (2012) and Atack et al. (2009), enabled us to observe changes in agricultural household income across time while controlling for unobserved heterogeneity. We considered the following model for agricultural household i at time t:

$$y_{it} = \beta_0 + x_{it}'\beta_1 + \beta_2 d_{it} + \beta_3 s_{it} + \beta_4 d_{it} * s_{it} + c_i + e_t + u_{it}$$

where y_{it} is the household income; x_{it}' denotes the transposed K-dimensional vector of control variables; d_{it} represents the geographical distance (straight line) of each household from the nearest Ro-Ro port, which varies with time t; s_{it} is an indicator that is coded 1 if the agricultural household is located on the same island as the Ro-Ro port, or 0 if otherwise; c_i is the household-fixed effect while e_t is the time-fixed effect; and lastly, u_{it} represents the model residual, which we assume to follow a white noise process upon conditioning on our controls.

The strength of this strategy is that it allowed us to incorporate the archipelagic structure of the Philippines in our specification. More particularly, the term $\beta_4 d_{it} * s_{it}$ permitted us to observe the impact of distance from a Ro-Ro port for agricultural households on the same island as the Ro-Ro port against those on different islands. For agricultural households located on the same island as the Ro-Ro port ($s_{it} = 1$), the change in income with respect to the change in distance is given by $\frac{\partial y_{it}}{\partial d_{it}} = \beta_2 + \beta_4$. Conversely, the change in income with respect to the change in distance for agricultural households located on a different island (s_it=0) is given by $\frac{\partial y_{it}}{\partial d_{it}} = \beta_2$.

6.3.2 Children's Education

To investigate the impact of the Ro-Ro policy on children's education, we employed the difference-in-difference (DID) structure based on the seminal work of Ashenfelter and Card (1985). We conducted our analysis at the municipality level and constructed a two-period, fully-interacted model that accounted for age-level and sex variations in school attendance in each municipality. Since the Ro-Ro policy was implemented in 2003, we used 2000 as our pre-treatment period and 2010 as our post-treatment period. Our DID model is specified as:

$$y_{asmt} = \delta_a(D_m \cdot T_t \cdot S_s \cdot A_a) + \theta_a(D_m \cdot T_t \cdot A_a) + \beta_1 D_m + \beta_2 T_t + \beta_{3a} A_a + \beta_4 S_s \\ + \phi_{asmt} + \mu_m + e_{asmt}$$

where

$$\phi_{asmt} = \beta_{5a}(D_m \cdot A_a) + \beta_6(D_m \cdot S_s) + \beta_{7a}(S_s \cdot A_a) + \beta_{8a}(D_m \cdot S_s \cdot A_a) + \beta_9(T_t \cdot S_s) \\ + \beta_{10a}(T_t \cdot A_a) + \beta_{11a}(T_t \cdot S_s \cdot A_a)$$

In this equation, y_{asmt} refers to the school attendance rate in municipality m at period t for children of age a and sex s. As may be noted from our choice of subscripts, our data was stacked by age, sex, municipality, and period. The variable D_m denotes treatment assignment. This was coded 1 if the municipality was considered part of the treatment group, or 0 if otherwise. Time periods are indicated by T_t, which was coded 1 for the post-treatment period or 0 for the pre-treatment period. Age level and sex are represented by A_a and Ss, respectively. S_s is coded 1 if the child is male, or 0 if otherwise.

Meanwhile, the parameters β_1, β_2, β_{3a}, and β_4 denote average differences among treatment groups (D), periods (T), age levels (A), and sex (S), respectively. Additionally, ϕ_{asmt} contains interactions across treatment groups, periods, age levels, and sex, capturing heterogeneity in school attendance. The municipality-level fixed effect is captured by μm, which allowed us to control for time-invariant characteristics that are common within municipalities. Finally, e_{asmt} is the model residual, which we assumed exhibits a white noise process after conditioning on our control variables.

In our specification, the term $\delta a\, S_s + \theta_a$ represents our DID estimator, which showed the impact of Ro-Ro port operations on children's school attendance. We suppressed the interaction term for $\delta\__a$, allowing us to estimate separate DID coefficients $\gamma_{as} = (\delta_a S_s + \theta_a)$ for men and women directly in the same equation.[5]

Treatment Identification

The treatment assignment of municipalities was based on their distances from two groups of ports. This analysis distinguished between Ro-Ro and non-Ro-Ro ports in both the pre-treatment and post-treatment periods. Using the straight-line distance formula $d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$, we computed the distances of each municipality from the nearest Ro-Ro and non-Ro-Ro port, compared these computed distances, and retained the smallest value. If the distance from the nearest Ro-Ro port was smaller than the distance from the nearest non-Ro-Ro port, then we assigned the municipality to the treatment group. On the other hand, if the distance from the nearest Ro-Ro port was larger than the distance from the nearest non-Ro-Ro port, then we assigned the municipality to the control group.

6.3.3 Household Expenditure on Food, Alcoholic Beverages, and Tobacco

To reveal the change in household consumption behavior—particularly expenditure on food, alcohol, and tobacco—after the operation of the Ro-Ro ports, we constructed a 3-year panel spanning 2003–2009. We verified changes in household expenditure on food, alcohol, and tobacco using the following model:

$$Y_{it} = \alpha + \beta_t + \delta I(T_t = 1) + \pi Z_{it} + \gamma_i + \varepsilon_{it}$$

where Y_{it} is the outcome variable for household i at time t; β_t denotes the year-fixed effect; $I(T_t = 1)$ is an indicator function with a value of 1 if the household is treated at year t, or 0 if otherwise; Z_{it} is a vector containing characteristics of household i at year t; γ_i is the household-

5 For a complete discussion of the model, see Francisco (2016: 59–64).

fixed effect; and ε_{it} is the model residual, which we assume to have zero mean and be uncorrelated with our control variables.

To check the consistency of our results, we accounted for differences in household income using the following model:

$$Y_{it} = \alpha + \beta_t + \beta_k + \beta_{kt} + \delta_0 I(T_t = 1) + \delta_k I(T_t = 1) * J(Inc = k) + \pi Z_{it} + \gamma_i + \varepsilon_{it}$$

where we added β_k to capture differences in household income group; β_{kt}, which contains interactions between household income group and year; and δ_k to show the impact of Ro-Ro policy on household expenditure for each income group.

Treatment Identification

Our treatment assignment is likewise based on the geographic distance of households from the nearest Ro-Ro and non-Ro-Ro ports. This study used households near the non-Ro-Ro ports as our counterfactual. With the aid of the straight-line distance formula, we computed the distances of each household from a Ro-Ro and non-Ro-Ro port, then compared these values and retained the smallest. Households nearest a Ro-Ro port were assigned to the treatment group, while households nearest a non-Ro-Ro port were assigned to the control group.

Since our data structure is a 3-year panel for 2003, 2006, and 2009, we matched our treatment assignment with the timing of nautical highway operations. As previously discussed, the RRTS was inaugurated with the operation of the Western Nautical Highway and the PPH in 2003, followed by the opening of the Central Nautical Highway in 2008 and the Eastern Nautical Highway in 2009. Thus, the same sets of households were assigned to the treatment and control groups in 2003 and 2006. Meanwhile, we assigned additional households to the treatment group in 2009 due to the operation of the Central and Eastern Nautical Highways.

6.4 Data

6.4.1 Household Income and Expenditure

The data for our analysis of agricultural household income and expenditure on food, alcohol, and tobacco were mainly sourced from the Family Income and Expenditure Survey (FIES) of the Philippine Statistics Authority (PSA). The FIES collects information on household-level characteristics, consumption, income, and expenditure, and has been conducted every 3 years since 1985. We used the FIES 3-year panel for 2003, 2006, and 2009.

In terms of sample selection, we limited our samples to agricultural households included in the 3-year panel for our analysis of agricultural household income, because agricultural households typically have the lowest income and suffer most from poverty. If their income increases, then poverty levels tend to fall as well. On the other hand, we used all samples for our analysis of education and household expenditure. We deflated income data using region- and year-specific consumer price indexes sourced from the PSA for all commodities.

6.4.2 Children's Education and Related Data

Our primary source of data was the PSA's Census of Population and Housing Survey, a nationally representative survey designed to gather information on the size and distribution of the Philippine population, from which we computed the school attendance rate of individuals aged 5–21[6] in each municipality. The survey includes information about the demographic, social, economic, and cultural characteristics of the population. In particular, we utilized data on sex, date of birth, and school attendance. We also employed the Statement of Income and Expenditure (SIE) of the Department of Finance's Bureau of Local Government Finance to calculate per capita tax revenue in each municipality, which we used as a proxy for household income. The SIE contains financial information on local government units in the Philippines. By using the total employed population to calculate the per capita tax revenue, we obtained a more precise proxy for household income.

1.1.1 Ports and Geographic Data

We obtained our list of Ro-Ro ports from the Philippine Ports Authority, and combined this list with information from the Philippine Ports Inventory provided by the PSA. This document lists all ports in the Philippines with information on their status (i.e., operational or non-operational). We only included public ports in our dataset.

Most Ro-Ro ports are in areas of Luzon, Visayas, and Mindanao that are facing problems of poverty and underdevelopment.

Meanwhile, data on geographic coordinates or specific locations were taken from the PSA's Data Kit of Official Philippine Statistics, which enabled us to compute the distances required in our analyses. Finally, we combined all of our data using the Philippine Standard Geographic

6 The survey question on school attendance is only asked for individuals aged 5 years and above, and the survey question on employment is only asked for individuals aged 15 and above.

Code as an identifier. This code, which is also sourced from the PSA, consists of nine digits corresponding to specific administrative divisions within the Philippines.

6.5 Results

We assessed the impacts of the Ro-Ro policy in the Philippines by performing three separate analyses at the household and municipality levels, and examining changes in agricultural household income, children's education, and household expenditure on food, alcohol, and tobacco. Our estimates are presented in the following sections.

6.5.1 Agricultural Household Income

It is important to analyze agricultural household income because agricultural households comprise the poorest segment of the population. While the causes of poverty may vary depending on location, some attributed factors are a lack of access to finance and non-farm opportunities, especially in rural areas. Thus, understanding how government policies such as the Ro-Ro policy affect agricultural households will benefit future policy decisions.

Our estimates of marginal effects (Table 6.1) revealed that distance from a Ro-Ro port is indeed an important factor for agricultural household income. As demonstrated by our results, agricultural households that are closer to Ro-Ro ports have higher incomes. This finding is consistent even if we allow for variation in island location. In fact, the impact of Ro-Ro ports is relatively higher for agricultural households on different islands. Our results therefore suggest that Ro-Ro port operations bring income opportunities to nearby agricultural households, and these opportunities are not limited by island location.

There are two components of agricultural household income: (i) income from agricultural sources and activities, and (ii) income from nonagricultural sources and activities. Table 6.2 outlines the effect of Ro-Ro port operations on income from agricultural sources and activities. Our marginal effects estimates imply that Ro-Ro port operations stimulated agriculture-related activities on nearby islands. Our results indicate that agricultural households on nearby islands that are geographically closer to a Ro-Ro port have higher income from agricultural sources and activities. This may be because the presence of a Ro-Ro port on a nearby island may stimulate agricultural productivity by improving access to inputs and technology. Bezinger (1996) noted that the use of fertilizer per unit of land

and machinery per work also increases with access to infrastructure and urban markets, leading to higher land and labor productivity. Similarly, Khandker et al. (1994) observed that the use of agricultural input and extension services increases with improved access to infrastructure.

Meanwhile, our estimates (Table 6.3) suggest that agricultural households located on the same island as a Ro-Ro port shifted to non-agriculture-related activities. We view this finding positively

Table 6.1 Log of Total Family Income

Log of distance from nearest Ro-Ro port	−0.209343**
	(0.090491)
Log of distance from nearest Ro-Ro port x Same island as Ro-Ro port	0.179476**
	(0.091062)
HH labor force (above 15 but less than 60 yrs.)	0.059166***
	(0.009992)
With car	0.222654***
	(0.080144)
With motorcycle	0.214667***
	(0.061287)
With access to electricity	0.049596*
	(0.027291)
Sex of Household Head	0.105184
	(0.075442)
Age of Household Head	0.003371
	(0.002581)
Years of education of Household Head	−0.000355
	(0.006920)
Year Fixed-effect	Yes
Marginal effects of distance from nearest Ro-Ro port:	
On same island	−0.029868***
	(0.010198)
On different island	−0.209343**
	(0.090491)
N	3892
R-squared:	
within	0.083
between	0.0039
overall	0.0017

Notes: *, **, *** indicate significance at the 10%, 5%, and 1% alpha levels, respectively. Standard errors reported in parentheses are heteroskedasticity-robust. Marginal effects are computed using Delta-method.
Source: Authors.

Table 6.2 Log of Total Income from Agricultural Sources and Activities

Log of distance from nearest Ro-Ro port	−0.199040**
	(0.084028)
Log of distance from nearest Ro-Ro port x same island as Ro-Ro port	0.178996**
	(0.084694)
Household labor force (those aged 15–60)	0.048616***
	(0.010787)
With car	0.268230***
	0.085638
With motorcycle	0.221301***
	0.068425
With access to electricity	0.057021*
	0.030425
Sex of household head	0.098479
	0.093909
Age of household head	0.001750
	0.002775
Years of education of household head	−0.003052
	0.007437
Year-fixed effect	Yes
Marginal effects of distance from nearest Ro-Ro port:	
On the same island	−0.020045*
	(0.010690)
On a different island	−0.199040***
	(0.084028)
N	3,892
R-squared:	
within	0.0522
between	0.0001
overall	0.0003

Notes: *, **, *** indicate significance at the 10%, 5%, and 1% alpha levels, respectively. Standard errors reported in parentheses are heteroskedasticity-robust. Marginal effects are computed using Delta-method.
Source: Authors.

since one of the factors attributed to rural poverty is the lack of non-farm opportunities for agricultural households. Fan and Chan-Kang (2004) explained that infrastructure and road access often encourage small non-farm businesses, and Fan and Rao (2002) highlighted the importance of non-farm opportunities for agricultural households,

Table 6.3 Log of Total Income from Nonagricultural Sources and Activities

Log of distance from nearest Ro-Ro port	−0.263973
	(0.221448)
Log of distance from nearest Ro-Ro port x same island as Ro-Ro port	0.191621
	(0.222453)
Household labor force (those aged 15–60)	0.106646***
	(0.022470)
With car	−0.056328
	(0.145430)
With motorcycle	0.134804
	(0.131336)
With access to electricity	0.011163
	(0.066439)
Sex of household head	0.038321
	(0.189253)
Age of household head	0.016227**
	(0.007306)
Years of education of household head	0.016914
	(0.014545)
Year-fixed effect	Yes
Marginal effects of distance from nearest Ro-Ro port:	
On the same island	−0.072352***
	(0.020883)
On a different island	−0.263973
	(0.221448)
N	3,891
R-squared:	
within	0.0578
between	0.0396
overall	0.0348

Notes: *, **, *** indicate significance at the 10%, 5%, and 1% alpha levels, respectively. Standard errors reported in parentheses are heteroskedasticity-robust. Marginal effects are computed using Delta-method.
Source: Authors.

as these helped the poor survive during the post-green revolution in many Asian countries.

In summary, we found that Ro-Ro port operations benefits agricultural households in general. Our results are consistent with those of previous studies (e.g., Malmberg et al. 1997; Escobal 2001), which revealed that transport infrastructure provides local populations with opportunities as it boosts the profitability of both farm and non-farm sectors. One important finding is that agricultural households close to Ro-Ro ports gained non-farm opportunities, while the agricultural income of households on nearby islands increased, likely due to better inputs and easier access to markets for their produce.

6.5.2 Children's Education

Education is regarded as a key policy tool in fighting poverty in the Philippines. Despite government efforts to provide free access to primary and secondary education, as mandated by the Constitution, the education sector still faces low enrollment and completion rates in rural and highly disadvantaged areas. In this section, we study the impact of Ro-Ro port operations on children's education by examining changes in municipality-level school attendance.

We observed significant increases in school attendance for both boys and girls in municipalities near the Ro-Ro ports (Table 6.4). This impact occurred earlier for girls, as their enrollment at the pre-primary level increased. As school enrollment at the pre-primary level was not compulsory in the Philippines before 2012, this result implies some improvement in parents' ability to send their children to school. Furthermore, we observed a solid increase in girls' school attendance at the secondary and tertiary levels. Several studies (e.g., Johanson 1999; Orbeta 2003) have mentioned that girls' school attendance and educational attainment is high relative to that boys in the Philippines, since education is believed to increase girls' labor participation (Quisumbing et al. 2004; Sakellariou 2004). In addition, Orbeta (2003) explained that employment opportunities are more readily available for school-age boys than girls, giving boys the option to leave school. However, we also noticed a consistent increase in school attendance for boys aged 6–20. This implies that boys in areas near Ro-Ro ports are being sent to school where they should be. This is important because school-age boys are known to drop out of school easily due to financial problems.

Table 6.4 Estimates for School Attendance

	Male	Female
Pre-primary level		
Age 5	0.01610	0.02016**
	(0.00991)	(0.00977)
Primary level		
Age 6	0.03682***	0.05557***
	(0.00957)	(0.00988)
Age 7	0.03910***	0.02170***
	(0.00715)	(0.00650)
Age 8	0.01809***	0.00910
	(0.00591)	(0.00571)
Age 9	0.01147**	0.00866
	(0.00503)	(0.00544)
Age 10	0.01285**	0.01271**
	(0.00529)	(0.00521)
Age 11	0.01192**	0.00757
	(0.00519)	(0.00535)
Age 12	0.01727***	0.00654
	(0.00543)	(0.00518)
Secondary level		
Age 13	0.01865***	0.01790***
	(0.00644)	(0.00558)
Age 14	0.02185***	0.02040***
	(0.00655)	(0.00582)
Age 15	0.03063***	0.02886***
	(0.00687)	(0.00693)
Age 16	0.02929***	0.02497***
	(0.00765)	(0.00785)
Tertiary level		
Age 17	0.01663**	0.03286***
	(0.00839)	(0.00863)
Age 18	0.02036**	0.02104**
	(0.00839)	(0.00905)
Age 19	0.02854***	0.01820**
	(0.00891)	(0.00901)
Age 20	0.02233***	0.02712***
	(0.00854)	(0.00872)

continued on next page

Table 6.4 *continued*

	Male	Female
Age 21	0.01452	0.02207**
	(0.00903)	(0.00925)
N:		
observations	104,598	
groups	1,539	
R-squared:		
within	0.8491	
between	0.0016	
overall	0.7965	

Notes: *, **, *** indicate significance at the 10%, 5%, and1 % alpha levels, respectively. The model controls for provincial and municipality-level fixed effects. Heteroskedasticity-robust standard errors are reported in parentheses.
Source: Authors.

Using the total population of children in school for each age level, we computed the equivalent increase in school attendance using our beta estimates (Table 6.5). Our results indicate that the highest equivalent increases in school attendance for boys and girls occur at the primary level. We also noticed that the increase in the number of male students at the primary and secondary levels is higher than the increase in the number of female students. Our results are similar to those of a study (Levy 1996) in Morocco, where increased school attendance was observed in areas where roads were improved.

Table 6.5 Equivalent Increases in School Attendance

	Total population (in school)		Beta estimates		Equivalent number of individuals		
Age	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Total**
Pre-primary level[a]							
5	243,731	225,557	0.01610	0.02016	3,923	4,548	8,471
			Subtotals		3,923	4,548	8,471
Primary level							
6	241,516	226,035	0.03682	0.05557	8,892	12,560	21,452
7	239,119	222,901	0.03910	0.02170	9,350	4,836	14,187
8	224,904	212,718	0.01809	0.00910	4,067	1,936	6,003
9	251,031	233,958	0.01147	0.00866	2,880	2,026	4,905

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Table 6.5 *continued*

Age	Total population (in school)		Beta estimates		Equivalent number of individuals		
	Male	Female	Male	Female	Male	Female	Total
10	251,208	230,433	0.01285	0.01271	3,227	2,928	6,155
11	230,498	219,521	0.01192	0.00757	2,747	1,662	4,409
12	245,050	227,684	0.01727	0.00654	4,231	1,488	5,720
			Subtotals		35,395	27,436	62,831
Secondary level							
13	227,768	217,218	0.01865	0.01790	4,248	3,888	8,136
14	237,953	222,833	0.02185	0.02040	5,200	4,545	9,745
15	231,182	216,106	0.03063	0.02886	7,080	6,238	13,318
16	226,494	209,953	0.02929	0.02497	6,635	5,242	11,877
			Subtotals		23,163	19,913	43,076
Tertiary level							
17	221,126	204,314	0.01663	0.03286	3,678	6,713	10,391
18	212,907	197,510	0.02036	0.02104	4,334	4,156	8,490
19	205,122	190,479	0.02854	0.01820	5,854	3,466	9,320
20	191,839	177,356	0.02233	0.02712	4,285	4,809	9,094
21	177,994	162,945	0.01452	0.02207	2,585	3,597	6,181
			Subtotals		20,736	22,741	43,477
Total significant increase					**83,217**	**74,637**	**157,855**

[a] Not compulsory prior to 2012.
Source: Authors.

As discussed in some studies (Orbeta 2003; Maligalig et al. 2010; Albert et al. 2012), income remains a primary consideration for sending children to school in the Philippines. In support of our previous findings, we also examined changes in household income in municipalities near Ro-Ro ports. As a proxy for household income, we used data on the tax revenue of each municipality sourced from the SIE of the Department of Finance (Table 6.6). These data confirmed that household incomes increased in areas near the Ro-Ro ports, which likewise indicates households' increased capacity to send children to school.

Our results therefore suggest that the Ro-Ro policy may have a long-term effect on the economy of municipalities near the Ro-Ro ports. As observed, benefits gained by households are transferred to their children in the form of human capital investment. By sending children to school, households are also improving the quality of the work force in the long run, thus laying the foundation for sustained growth.

Table 6.6 Log Per Capita Tax Revenue

Treatment	–0.1992341***
	(0.0603927)
Year	0.2880480***
	(0.0199620)
Treatment x year	0.0692498**
	(0.0346459)
N:	
observations	2,870
groups	1,435
R-squared:	
within	0.2015
between	0.0041
overall	0.0195

*, **, *** indicate significance at the 10%, 5%, and 1% alpha levels, respectively.
Notes: Heteroskedasticity-robust standard errors, clustered by province and municipality, are reported in parentheses.
Source: Authors.

6.5.3 Expenditure on Food, Alcohol, and Tobacco

Our findings indicate that the implementation of the Ro-Ro policy has brought income opportunities to households near the Ro-Ro ports. Income affects households' access to commodities like alcohol and tobacco (Wagenaar, Salois, and Komro 2009). Several studies note that an individual's health status is affected by different aspects of income, such as the magnitude of change in income over time, duration of exposure to a certain income level, and income instability (McDonough et al. 1997; Duncan et al. 2002; Chen et al. 2007). Typically, alcohol consumption and tobacco use rises with income (Cawley and Ruhm 2012); however, others have argued that alcohol consumption increases during an economic downturn (Pierce et al. 1994). Davalos et al. (2011) use data from the United States to show how state unemployment rates are positively associated with a rise in the probability of excessive drinking. The evidence for tobacco use is also mixed. While some researchers have found that higher income leads to higher rates of smoking (e.g., Ruhm 2005), other studies have shown that economic downturns lead to higher unemployment rates, which are often associated with a higher prevalence of smoking (e.g., Gallus et al. 2015).

In this section, we verify this behavior in the Philippines, by studying changes in household consumption of food, alcohol, and tobacco. Although an ideal demand estimation would have been the best way to answer this research question, the scarcity of price data made it necessary to use a DID strategy, which will also provide useful results.

First, we examined changes in the income of households located near the Ro-Ro ports (Table 6.7). Column (a) shows a general increase in family income of about 4%, but this result disappears when we limit our samples to households with alcohol (column b) and tobacco expenditure (column c).

Table 6.7 Log Per Capita Family Income

	(a)	(b)	(c)
Treatment*Year	**0.0428** **(0.0212)**	**0.0318** **(0.0250)**	**0.0480** **(0.0249)**
Controls:			
Year	Yes	Yes	Yes
Treatment	Yes	Yes	Yes
Urban/Rural			
1 - Urban	0.0313	-0.4176***	0.0100
	(0.1222)	(0.1098)	(0.1610)
Total members employed	0.0157***	0.0185***	0.0144**
	(0.0049)	(0.0058)	(0.0058)
Household class of worker			
Worked for private establishment	-0.0480	0.0067	-0.0167
	(0.0352)	(0.0452)	(0.0441)
Worked for government	0.0613	0.0794	0.1097***
	(0.0435)	(0.0547)	(0.0547)
Self-employed w/o any employee	-0.0761**	-0.0163	-0.0449
	(0.0359)	(0.0464)	(0.0453)
Employer in own f.o.b./farm	0.0022	0.0600	0.0193
	(0.0383)	(0.0490)	(0.0480)
Worked w/ pay in own f.o.b./farm	-0.1792	-0.1066	-0.0550
	(0.1184)	(0.1648)	(0.1695)
Worked w/o pay in own f.o.b./farm	-0.0799	-0.0826	-0.0831
	(0.0633)	(0.0877)	(0.0803)
Household type			
Extended family	-0.1850***	-0.1920***	-0.1972***
	(0.0121)	(0.0147)	(0.0149)
With 2/ more nonrelated members	-0.0257	0.1148	-0.1848
	(0.1245)	(0.1697)	(0.1661)
N	16603	11653	11521
R-squared	0.0451	0.0529	0.0516

Notes: (a) All samples, (b) Includes only those with alcoholic beverages expenditure, (c) Includes only those with tobacco expenditure.
f.o.b. = family-operated business.
*, **, *** indicate significance at the 10%, 5%, and 1% alpha levels, respectively. Standard errors reported in parentheses, are heteroskedasticity robust, clustered by households.
Source: Authors.

Table 6.8 reveals no significant change in household food consumption. This finding remains consistent even when the samples are limited to households with alcohol (column b) and tobacco expenditure (column c). Since we were working with total expenditure data, we could only study changes in aggregate family consumption instead of looking at individual food items. We ran separate regressions for specific groups of food (e.g., starches); however, our results are not reported because we were unable to detect any major change in terms of expenditure shares. Our results suggest that food choices remain unchanged, despite higher incomes. Thus, households are likely spending their additional income on other items.

Table 6.8 Log Per Capita Food Expenditure

Treatment*Year	(a) 0.0042 (0.0143)	(b) 0.0104 (0.0181)	(c) 0.0258 (0.0185)
Controls:			
Year	Yes	Yes	Yes
Treatment	Yes	Yes	Yes
Urban/Rural			
1 -Urban	-0.0941	0.1394	-0.0394
	(0.1032)	(0.1832)	(0.1117)
Per capita National Income Quintile			
Second quintile	0.2630***	0.2694***	0.2637***
	(0.0080)	(0.0098)	(0.0096)
Third quintile	0.4768***	0.4748***	0.4650***
	(0.0102)	(0.0127)	(0.0127)
Fourth quintile	0.6812***	0.6812***	0.6936***
	(0.0124)	(0.0162)	(0.0163)
Fifth quintile	0.9235***	0.9042***	0.9213***
	(0.0160)	(0.0225)	(0.0230)
N	19551	13218	13238
R-squared	0.2528	0.2488	0.2559

Notes: (a) All samples, (b) Includes only those with alcoholic beverages expenditure, (c) Includes only those with tobacco expenditure.
*, **, *** indicate significance at the 10%, 5%, and 1% alpha levels, respectively. Standard errors reported in parentheses, are heteroskedasticity robust, clustered by households.
Source: Authors.

Interestingly, Table 6.9 suggests that household expenditure on alcohol decreased with the operation of the Ro-Ro ports. In column (b), we allowed this effect to vary by income quintile; however, we found no significant differences among income groups. Conversely, the

Table 6.9 Log Per Capita Alcoholic Beverages Expenditure

	(a)	(b)
Treatment*Year	**–0.1959****	**–0.2045****
	(0.0778)	**(0.0962)**
Treatment*year*per capita national income quintile		
Second quintile		0.0002
		(0.0881)
Third quintile		0.0466
		(0.1030)
Fourth quintile		–0.0350
		(0.1262)
Fifth quintile		–0.1349
		(0.1537)
Controls and interactions:		
Year	Yes	Yes
Treatment	Yes	Yes
Per capita national income quintile	Yes	Yes
Per capita national income quintile*year		Yes
Urban or rural		
1 - Urban	–0.2285	–0.1960
	(0.8939)	(0.8716)
N	13218	13218
R-squared	0.0411	0.0414

Notes: (a) Basic model, (b) Model with income variation.
*, **, *** indicate significance at the 10%, 5%, and 1% alpha levels, respectively. Standard errors reported in parentheses, are heteroskedasticity robust, clustered by households.
Source: Authors.

interaction of the treatment and year remains significant and consistent with our estimate in column (a).

It is important to note that, since expenditures were estimated separately, we were unable to ascertain the direction of the relationship between changes in household income and alcohol expenditure. However, the increase in income observed in Table 6.7 may be due to increased access to job opportunities in areas near the Ro-Ro ports, enabling households to use their time more productively.

Meanwhile, tobacco expenditure decreased for households living near a Ro-Ro port (Table 6.10). Although column (b) shows no significant differences in effect among income groups, the interaction of treatment and year remains significant and similar to our result in column (a). As tobacco often complements alcohol consumption, it was not surprising to observe a similar decrease in tobacco expenditure. Several studies (Kenkel and Wang 1999; Auld 2005) have recognized the correlation between the consumption of alcohol and tobacco.

Table 6.10 Log Per Capita Tobacco Expenditure

	(a)	(b)
Treatment*Year	**-0.1477****	**-0.1923****
	(0.0703)	**(0.0809)**
Treatment*Year*Per capita National Income Quintile		
Second quintile		0.0166
		(0.0772)
Third quintile		0.0193
		(0.0942)
Fourth quintile		0.0506
		(0.1187)
Fifth quintile		-0.0422
		(0.1765)
Controls and interactions:		
Year	Yes	Yes
Treatment	Yes	Yes
Per capita National Income Quintile	Yes	Yes
Per capita National Income Quintile*Year		Yes
Urban/Rural		
1 - Urban	0.1377	0.1772
	(0.4844)	(0.4907)
N	13238	13238
R-squared	0.0314	0.0354

Notes: (a) Basic model, (b) Model with income variation.
*, **, *** indicate significance at the 10%, 5%, and 1% alpha levels, respectively. Standard errors reported in parentheses, are heteroskedasticity robust, clustered by households.
Source: Authors.

In summary, we found that Ro-Ro port operations lowered household consumption of alcohol and tobacco in areas near Ro-Ro ports. We took the observed increase in family income as indicating the increased availability of job opportunities near Ro-Ro ports, decreasing households' amount of idle time.

6.6 Conclusion

This study demonstrates how the Ro-Ro policy affects households and municipalities in the Philippines. Our estimates show that the government's efforts to improve the efficiency and affordability of inter-island transport within the country have yielded several opportunities that benefit communities near the Ro-Ro ports.

Our first analysis confirmed that Ro-Ro port operations stimulate both farm and non-farm activities for agricultural households. We also noticed that island location does not hinder the benefits of Ro-Ro port operations. Interestingly, we found indications that Ro-Ro port operations encourage agricultural activities on nearby islands. In contrast, nonagricultural activities flourished on the islands where the Ro-Ro ports are located.

Our second analysis revealed that children's school attendance increased in municipalities near Ro-Ro ports. In particular, our estimates showed that girls' school attendance increased as early as the pre-primary level through the tertiary level. We also noticed a consistent increase in school attendance for boys aged 5–20. Overall, we found that the benefits gained from Ro-Ro port operations are transferred to children in the form of human capital investment, which is expected to benefit local economies in the long term.

Finally, our third analysis revealed that alcohol and tobacco consumption decreased along with an increase in income in areas near the Ro-Ro ports. Since alcohol and tobacco are usually consumed together, a similar decrease in household consumption is unsurprising.

Overall, this chapter underscores the benefit of providing an efficient and affordable mode of transfer within a country. Although the Philippines' archipelagic structure makes it geographically different from most other countries, its experience with the Ro-Ro policy clearly demonstrates that the benefits of such a policy extend beyond reducing transport costs. Our results provide some examples of unintended gains from linking local economies that could be easily overlooked by policymakers. An important takeaway from this chapter is that those located near the infrastructure earn the highest gains from this kind of policy. Thus, the infrastructure's location is an important factor in designing targeted policies. Since we only focused on three topics, this chapter may not have fully unveiled the overall impact of the Ro-Ro policy. Thus, we encourage other researchers to broaden the scope of our analysis in future studies to uncover, not only economic gains, but also losses resulting from this policy.

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7

The Impact of Road Development on Household Welfare in Rural Papua New Guinea

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7.1 Introduction

With a population of over 8.1 million people (in 2016), Papua New Guinea (PNG) is the largest and most populated island state in the Pacific region (Secretariat of the Pacific Community 2017). In 2010, roughly 40% of the population was classified as poor, an increase of about 2 percentage points from 1996 (Gibson 2012). The country also performs poorly on a number of social development indicators. In 2012, ADB and other institutes estimated that only about 6 in 10 people in the country had access to safe drinking water, and roughly the same proportion of the primary school-aged population was enrolled in school in 2008. Health indicators are also poor: the maternal mortality rate stood at 220 per 100,000 live births in 2014, infant mortality was over 48 per 1,000 live births in 2012, and over 18% of children younger than 5 suffer from malnutrition (2005). With regard to these indicators, PNG is lagging behind other countries with similar per capita incomes. PNG did not achieve any of the Millennium Development Goals by 2015, and was ranked 158 out of 188 countries in the United Nations Development Programme Human Development Index in 2014.

Roughly 85% of PNG's inhabitants live semi-subsistence livelihoods in rural areas and rely on selling crops for a cash income. Among urban workers, 78.5% of employed individuals earn wages (PNG National Statistical Office 2013). According to survey results, informal and casual work, small businesses, and agricultural business jobs provide 41% of total employment nationwide and nearly half of all jobs in rural areas.

This highlights the importance of agriculture and agriculture-related employment for rural livelihoods in PNG.

PNG's economy is small, open, and export-oriented; and relies heavily on extracted resource exports—particularly oil, liquefied natural gas (LNG), and minerals or metal ores. Of the total value of exports, mining exports represent about 75%, agricultural products represent about 20%, and forestry products the remaining 5%. Revised national accounts estimates for 2013 show that the three largest sectors of the economy (as a share of estimated gross domestic product [GDP]) were (i) industry, including mining and quarrying (about 38% of GDP); services, such as wholesale and retail trade (around 32%); and (iii) agriculture, forestry, and fishing (about 30%). However, agriculture plays a dominant role as a source of livelihood for a vast majority of the population, roughly three-quarters of whom are estimated to depend on subsistence agriculture.

During the years covered by the data used in this study (1996–2010), PNG's real GDP growth was low (2.2% per year, on average) and highly volatile, reflecting typical cycles of resource boom and bust associated with an export-dependent economy reliant on a small number of exports. High points during this period were in 1996, when an oil export boom boosted per capita growth to 5.0%, and in 2010 when per capita growth reached 5.3% due to stimulus from expenditures to construct an LNG pipeline. However, the economy also experienced a number of recessions triggered by commodity price falls and worsening conditions in key export markets. PNG's GDP declined by more than 3.8% in 1997 and 1998, and by 2.5% in 2000. Between 2010 and 2015 GDP growth accelerated at an average annual rate of nearly 9.0%, and reached a high of more than 13.0% in 2014. This growth was largely driven by the construction of a major overland LNG pipeline and the initiation of LNG exports therefrom. During peak construction, the pipeline project employed approximately 16,000 workers. However, since 2015, growth has slowed to 2%–3% per year due to low export commodity prices, spending cuts, and the aftermath of unfavorable weather conditions caused by the 2015 El Niño.

Despite sporadic periods of high growth driven primarily by mineral resource exploitation, the direct contribution of minerals to poverty reduction and social development has been limited. There are relatively few jobs in resource extraction, few poor households derive livelihoods from mining, and the links between mining and the rest of the economy are weak. Although mining and particularly LNG production contribute to the Government of PNG's revenues, the country's public sector has struggled to translate higher revenue into improved public services.

The effects of growth on employment creation are restricted by PNG's business environment. In 2017, the World Bank ranked the country 119th out of 190 countries for ease of doing business. The formal private sector remains small, employing less than 10% of the economically active population, and is concentrated in a few industries. Issues of law and order as well as poor transport and energy infrastructure represent serious constraints on broad-based job creation. These problems are compounded by weak property rights and a lack of access to credit.

Further, according to available indicators, rising government revenues from higher resource exports have not led to significant improvements in public service delivery, neither in roads nor in other basic government services. Despite a 120% increase in government expenditure since 2002, the quality of service delivery has remained stagnant and in some cases even declined, particularly in rural areas (ADB 2012). Development and maintenance of PNG's road network suffered during the 2 decades following independence in 1975, when funding for road maintenance fell by half (Kwa et al. 2010). Existing roads generally fell into disrepair and there was very little investment in new roads. Government expenditure on infrastructure per capita reached its lowest point in 2001; however, large and sustained increases in funding only began in 2010 (Dornan 2016).

Road access is a key element necessary for economic development, especially in rural areas of PNG. For areas without access to waterways, roads offer the sole means of connecting to markets and public services. Better roads can reduce transport costs for agricultural goods and inputs, enable rural households to engage with labor markets, and permit larger truckloads and more frequent transport options. Improved market access can lead to a greater variety and lower prices of inputs and consumption goods, as well as higher prices and demand for local products. They may also attract financial service providers, facilitating agricultural investments and consumption smoothing (Binswanger et al. 1993). Living close to a road with higher traffic intensity can create demand for local businesses like roadside stalls. Better market access may also boost local productivity and facilitate the transformation from subsistence agriculture to growing cash crops, thus diversifying household income sources. Lastly, better roads may also enhance access to services like schools and hospitals, lower their cost, and improve their quality by making it easier for teachers and doctors as well as materials suppliers to reach the sites.

The distributional effects of better roads are less clear, and the empirical evidence on whether the poor benefit from roads in the same way as do the non-poor remains inconclusive. Consumption gains from better roads may be relatively higher for the poor. For example, if the non-poor are able to compensate better for a lack of good roads because they have a better market position within the village, the poor would experience relatively higher productivity gains from improved roads. However, it could also be that the non-poor profit more from better roads, which enable them to scale up agricultural production more easily, or because transport costs may prevent the poor from using the roads.

During the most recent 2 decades, a number of factors have made it difficult to construct new and maintain existing roads: limited road management capacity in the private sector due to the unsteady provision of maintenance contracts, competition for construction equipment and skilled engineers between resource extraction enterprises and the Department of Works (DOW), and disputes with owners of land adjacent to road works (Lucius 2010). Outright corruption has also adversely affected the quality of road expenditures (Dornan 2016). Lastly, the geography and weather of PNG, which has steep slopes and high seasonal rainfall in many regions (especially the densely populated agricultural heartland of the Highlands), increase road construction and maintenance costs.

This chapter evaluates the impact of road infrastructure on household welfare in PNG. The research is comparatively unique as it integrates an extensive set of spatial data sources with repeated cross-sectional data from national income and expenditure surveys. The project was supported by the ADB subproject Developing Impact Evaluation Methodologies, Approaches, and Capacities in Selected Developing Member Countries, and the authors made considerable efforts to collect and explore a large variety of spatial data sources for the evaluation. The chapter begins by outlining our initial efforts to retrieve and apply novel data sources such as light-at-night (LAN) or luminosity data and satellite imagery. This review is intended to direct other researchers to the spatial data sources available for data-poor countries such as PNG, and thereby reduce the time spent collecting these data in the future. In addition, we briefly evaluate the applicability of these data in the specific context of our analysis. Finally, this chapter summarizes the findings of the econometric analysis of road impact made possible by our data collection efforts.[1]

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[1] Published as The Impact of Road Development on Household Wellbeing in Rural Papua New Guinea. 2017. http:// LINK TO VU working paper when available in August.

7.2 Review of Data Sources Used or Considered for the Evaluation

7.2.1 Road Network Data

A proper description of the road network with reference to changes in its coverage and local conditions is an essential input to any evaluation of its economic impacts. Unfortunately, it was difficult to retrieve these data for PNG. The following data sources were eventually selected for further research: the road asset management system datasets on national and provincial roads in 2000 and 2009.[2]

Road Asset Management System Dataset on National and Provincial Roads in 2000

The original road asset management system (RAMS) datasets describe both national roads (ca. 6,437 kilometers [km] in total) and provincial roads (ca. 7,404 km). The national roads dataset (dated 1999–2001) contains a wide range of road quality variables, including an overall characterization of road conditions (rated as good, fair, or poor) and surface type (recorded as sealed, gravel, or dirt). The dataset referring to provincial roads (dated 2001) contains a similar set of road quality variables but lacks the overall characterization of road conditions. For the latter dataset, we imputed a general road quality assessment based on the relationship between several detailed quality aspects (e.g., severe damage, corrugation, and International Roughness Index) and the overall assessment in the national dataset, using a random forest algorithm. As the resulting out-of-bag classification error is low (3.3%), we consequently treated the imputed classes as actual classes in the preceding analysis.

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2 The DOW made the datasets available. An additional promising source for road network data is the Open Street Map (OSM) dataset, which is maintained by a community of voluntary mapmakers (www.openstreetmap.org). This open source contains many types of datasets (e.g., roads, waterways, places, and points of interest) and is updated continuously. An extract can be created through the BBBike portal (http://BBBike.org). While this road network contains useful attribute information on, for example, road types and road names, it does not describe road quality, which is essential for our study. Furthermore, OSM data rely heavily on the availability of internet access and community activity. OSM data coverage in PNG is thin, and a clear border effect compared to the nearby Indonesian part of the main island can be observed. It is unclear to what extent this relates to community activity or ground truth.

Road Asset Management System Dataset on National and Provincial Roads in 2009

Due to continued underinvestment in the transport sector, certain dimensions of the RAMS—particularly traffic counts, which are vital to estimating a road's value—have not been updated after 2001. However, the provincial works managers of the DOW were given financial support to update data on road conditions, and data collected by DOW provided the basis for our second dataset of road conditions in 2009. The road system was estimated to consist of roughly 26,000 km of roads in 2009. We linked this dataset to the HIES 09/10 and refer to this as the 2009 map.

Building a Complete Road Dataset for 2000 and 2009

Based on interviews with key informants familiar with PNG road data, we assumed that the higher density of roads depicted in the 2009 road map was largely due to an improvement of the information contained in the map, rather than the construction of new roads. This was confirmed by a report of the World Food Programme and Logistics Cluster (World Food Programme 2011), which stated that between 2000 and 2010 road works consisted of maintenance and upgrading, but no new roads were built. Therefore, to create a complete representation of the 2000 network, we matched the road attributes of the 2000 data sources to the 2009 road map.

The road quality attributes for 2000 were linked to the 2009 road map based on the road section identification where available. For the remaining stretches of roads, attributes were matched on spatial proximity (based on the length of the intersection of non-matched national 2009 road stretches with a 200 meter [m] buffer around national roads, and a one-to-many spatial join of the non-matched provincial 2009 roads with the attributes of the provincial roads within a 200 m distance). The spatial joins typically provide matches with multiple road stretches, in which cases we selected the longest overlaps for the match of attributes. This process led to the matching of all information on the national roads from the 2000 data and most of the information from the provincial roads. Only when roads were classified differently, such as national roads in the 2009 data and provincial roads in the 2000 data, did this not seem to work. For these stretches, and the approximately 12,000 km of other roads that exist in the 2009 data, the conditions of 2010 were used as a proxy for the 2000 roads, assuming that road quality was unchanged. Table 7.1 summarizes the classifications of surface type and road conditions in both 2000 and 2009.

Table 7.1 Surface Type and Road Conditions as Described in the Two Road Network Datasets

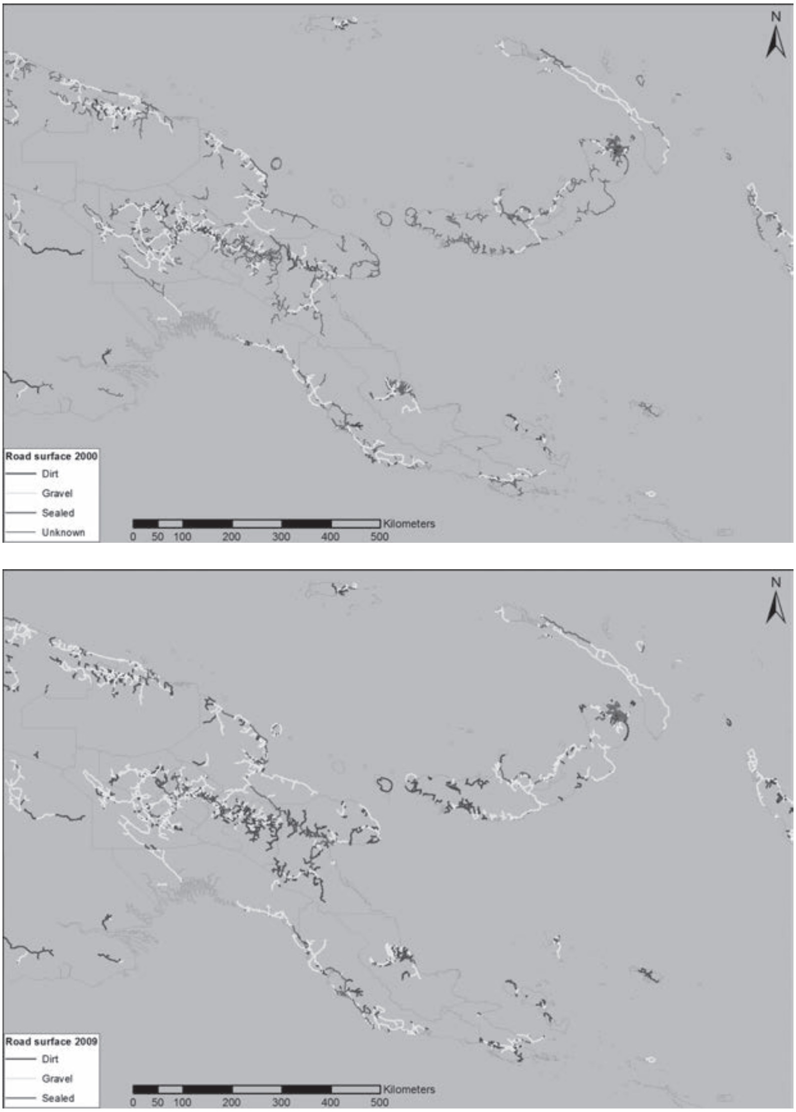
		2009		2000	
Surface	Condition	Total length (km)	%	Total length (km)	%
Sealed	Good	1,799	7.0	911	7.8
Sealed	Fair	1,067	4.2	914	7.8
Sealed	Poor	371	1.5	314	2.7
Gravel	Good	1,096	4.3	2,137	18.3
Gravel	Fair	7,300	28.6	1,649	14.1
Gravel	Poor	5,726	22.4	4,232	36.3
Dirt	Good	166	0.7	223	1.9
Dirt	Fair	3,660	14.3	63	0.5
Dirt	Poor	4,332	17.0	1,230	10.5
Total		**25,517**	**100.0**	**11,672**	**100.0**

km = kilometer.
Source: Authors.

The Development and Maintenance of Papua New Guinea's Road Network

Figure 7.1 provides maps of the roads, distinguished by surface type, comprising identified stretches of the national and provincial networks in 2000 and 2009. Table 7.2 shows the total road lengths by surface type and condition, as depicted in the maps. Comparing the 2000 and 2009 maps reveals large differences in the number of roads captured in the two maps. Reviewing the differences suggests that most of the missing (unknown) road segments in 2000 were classified as earth roads in 2009. This is consistent with the fact that the additional roads on the 2009 map consist almost entirely of provincial roads, which are likely to have earth surfaces. Tables 7.3 and 7.4 show the transitions in surface type and condition between the 2 years for those segments, which are included in both maps. The tables reveal no consistent development trend. Considering changes in surface type, we observed that the length of roads that were upgraded (i.e., from gravel to sealed surfaces) was roughly offset by that of roads that deteriorated (i.e., from gravel to dirt). The road condition characterization captured in the 2000 and 2009 maps shows substantial improvement in road conditions (most notably, from poor to fair) alongside decline (mainly from good to fair).

Figure 7.1 Roads by Surface Type in 2000 and 2009



Source: Authors.

Using data from the road maps, information on the locations of the households included in the surveys, and spatial data on the most important towns in the country, we constructed variables indicating

Table 7.2 Extent, Surface Type, and Condition of the Main Papua New Guinea Road Network

		Roads in 2000		Roads in 2009	
Surface	Condition	Length (km)	Share	Length (km)	Share
Sealed	Good	911	7.8%	1,799	7.0%
Sealed	Fair	914	7.8%	1,067	4.2%
Sealed	Poor	314	2.7%	371	1.5%
Gravel	Good	2,137	18.3%	1,096	4.3%
Gravel	Fair	1,649	14.1%	7,300	28.6%
Gravel	Poor	4,232	36.3%	5,726	22.4%
Dirt	Good	223	1.9%	166	0.7%
Dirt	Fair	63	0.5%	3,660	14.3%
Dirt	Poor	1,230	10.5%	4,332	17.0%
All	All	11,672	100%	25,517	100%

km = kilometer.
Source: Authors.

the length, surface type, and condition of the roads leading to the nearest town for the localities and households included in the sample. Specifically, we considered the shortest route from the stretch of road closest to the household to the nearest town, and calculate the shares of this route by surface type (i.e., sealed, gravel, and dirt) and road condition (i.e., good, fair, and poor). This analysis focused on households no less than 15 km away from a road leading to a town. Furthermore, we only considered towns with more 1,000 inhabitants (according to the 2011 census) that are within 5 km of a road. These two conditions excluded about 20% of the clusters of the two surveys from our analytical dataset. The census units left out are mostly either on small islands (where roads may be of little or no importance anyway), or deep in the western interior of the Momase region or on the coast of the Western Province (both of which have a very low population density).

Roads remain scarce in rural PNG. In 2009, the country had a road density of 56 km per 1,000 square km (km^2), which is very low compared to other countries in the region (Indonesia's road density was 250 km per 1,000 km^2 in 2009 according to ADB statistics). In the same year, only 13% of roads were sealed, while the majority were gravel or dirt roads. This study is significant due to (i) its setting in a country with a relatively large rural population, relatively high poverty, low performance on other development indicators, and limited rural road access; and (ii) the kinds of data used.

We combined the two cross-sectional household surveys discussed in the next section with geographic information system (GIS) maps of the road network around the time that the household surveys were administered. This allowed us to employ a set of road variables directly linked to how ministries monitor their road infrastructure. Most other studies obtain road access variables directly from household surveys and rely on reported travel times and distances to the nearest road, yielding potentially large measurement errors. Our map data contain road quality data for each segment. Combined with household locations, these allowed us to calculate the distance to the nearest road, as well as the quality and length of the entire stretch leading to the nearest town. The types of data used in this analysis are available in many country settings, making this approach both widely applicable and advantageous in terms of data collection costs and time.

Table 7.3 Transition Matrix Comparing Road Segment Surface Types in 2000 and 2009
(kilometers)

	Sealed ’09	Gravel ’09	Dirt ’09	Total
Sealed ’00	1,821	226	93	2,139
Gravel ’00	683	6,502	832	8,017
Dirt ’00	27	304	1,185	1,516
Total	2,531	7,031	2,110	11,672

Notes: Decreasing quality indicated in italics. Statistics only listed for stretches whose surface type was known in 2000.
Source: Authors.

Table 7.4 Transition Matrix Comparing Road Segment Conditions in 2000 and 2009
(kilometers)

	Good ’09	Fair ’09	Poor ’09	Total
Good ’00	1,077	1,531	662	3,270
Fair ’00	925	970	731	2,626
Poor ’00	457	2,994	2,326	5,776
Total	2,458	5,495	3,719	11,672

Notes: Decreasing quality indicated in italics. Statistics only listed for stretches whose condition was known in 2000.
Source: Authors.

7.2.2 Household Survey Data

Our analysis of the impact of road construction in PNG is based on household surveys conducted in 1996 and 2009–2010. The 1996 household survey collected data from 1,144 households in 120 sampling clusters (47 urban and 73 rural). The 2009–2010 survey had a sample size of 4,081 households distributed over 321 census units (196 urban and 125 rural). The sampled census units are of particular importance in this analysis as the variation in road access is between, not within census units.

Table 7.5 provides national averages of some of the variables used in the analysis. In 1996, consumption data were collected via recall and using surveyed regional prices. In 2009–2010, households were asked

Table 7.5 Welfare Indicators Included in the 1996 and 2009–2010 Household Surveys

	PNGHS 1996			HIES 2009/10		
	Mean	Std. Err.	N	Mean	Std. Err.	N
Age	21.81	0.328	8675	22.25	0.189	22718
Going to school (for school-aged children)	0.449	0.032	1836	0.568	0.025	4004
How long to get to school (minutes)	38.510	3.845	1391	27.28	2.581	5282
Ever been to school (if at least 12 years old)	0.627	0.031	5740	0.744	0.015	15478
Literacy (if at least 12 years old)	0.518	0.036	5740	0.528	0.016	15505
Short of food	0.219	0.036	1396	–	–	–
Electricity	0.104	0.026	1396	0.134	0.012	4076
Access to safe drinking water	0.365	0.049	1396	0.409	0.027	3987
Good cooking fuel	0.119	0.026	1396	0.111	0.007	4076
Have own toilet	0.815	0.034	1392	0.803	0.016	3683
Household size	6.014	0.146	1392	5.146	0.067	4081
Number of rooms	3.035	0.108	1392	2.370	0.049	4076
Floor area	40.87	1.746	1392	47.23	1.507	4072
Headcount poverty[a]	0.377	0.025		0.399	0.020	

HIES = Household and Income Expenditure Survey, PNGHS = Papua New Guinea Household Survey, Std. Err. = standard error.

[a] Values from Gibson, J. 2012. Papua New Guinea Poverty Profile. Based on the Household Income and Expenditure Survey. http://www.planning.gov.pg/images/dnpm/pdf/PNG-Poverty-Profile-2012.pdf (accessed 21 December 2016).

Source: Authors.

to keep consumption diaries, including self-reported prices, for 2 weeks (cooperation levels declined over time). We also considered a number of non-pecuniary indicators of well-being, which are relatively easy to compare between survey rounds. These include variables related to education, food shortages (only in 1996), being linked to the electricity grid (with at least 4 hours of electricity per day), access to safe drinking water (from a protected source less than 15 minutes away), use of good quality cooking fuel (i.e., not wood, coconut shells, or charcoal), having a private toilet, number of rooms, and floor area.

Table 7.6 reports variables related to distance and the accessibility of essential services in rural areas. Both surveys included a community questionnaire; the 1996 survey reached urban and rural communities, and the 2009–2010 survey reached rural areas. Both surveys included questions about travel times to the nearest school, market, town, and so on. Some of these questions overlapped, while others were similar. Only the 1996 survey asked about the distance to the nearest road. In the 1996 survey, the questions were answered in four categories (less than 30 minutes, 30–60 minutes, 60–120 minutes, and more than 120 minutes), while in the 2009–2010 survey continuous answers were given. To enable comparability, Table 7.6 includes variables indicating whether the nearest service is less than 60 minutes away.

Table 7.6 Distance and Accessibility Indicators for Rural Areas in the 1996 and 2009–2010 Household Surveys

	PNGHS 1996			HIES 2009/10		
	Mean	Std. Err.	N	Mean	Std. Err.	N
Distance to nearest town (km)				169.83	30.60	105
Nearest town can be reached by road all year round				0.717	0.042	106
It takes less than 60 minutes to reach the nearest:						
Road	0.725	0.063	73			
Community school	0.714	0.065	73	0.703	0.047	106
High school	0.369	0.065	73	0.362	0.048	106
Aid post	0.715	0.070	54	0.483	0.051	106
Health center	0.509	0.067	73	0.483	0.049	106
Child health and nursing service	0.696	0.065	73	0.397	0.048	106
Community health worker				0.495	0.050	106

continued on next page

Table 7.6 *continued*

	PNGHS 1996			HIES 2009/10		
	Mean	Std. Err.	N	Mean	Std. Err.	N
Clinic				0.370	0.048	106
Town or government station	0.449	0.066	73			
Air strip	0.344	0.063	73			
Port	0.121	0.048	65	0.166	0.034	106
Telephone	0.500	0.067	73			
Internet service				0.192	0.037	106
Postal service	0.420	0.066	73	0.235	0.040	106
Daily market				0.573	0.048	106
Weekly market				0.643	0.048	106
Store				0.659	0.047	106
Banking service				0.224	0.040	106
Police station				0.439	0.049	106
Public transport				0.573	0.050	106

HIES = Household and Income Expenditure Survey, PNGHS = Papua New Guinea Household Survey, Std. Err. = standard error.
Note: Accessibility indicators express the fraction of respondents that can reach the nearest service in less than 60 minutes.
Source: Authors.

It is essential to use spatially explicit data at the census unit level in order to analyze the impact of road infrastructure because these add locations to the survey data, as described above. Data on administrative regions at higher aggregation levels may be useful to describe the context in which local developments take place. Spatial delineations of local and more aggregated administrative regions have been collected from various sources, as described below. Figure 7.2 shows the included regional divisions for the Highlands region.

Mapping Household Survey Data Using Additional Data Sources

A spatial representation of the census units (describing point locations in the ArcGIS shapefiles) was obtained from the Pacific Catastrophe Risk Assessment and Financing Initiative portal.[3] These point data were used

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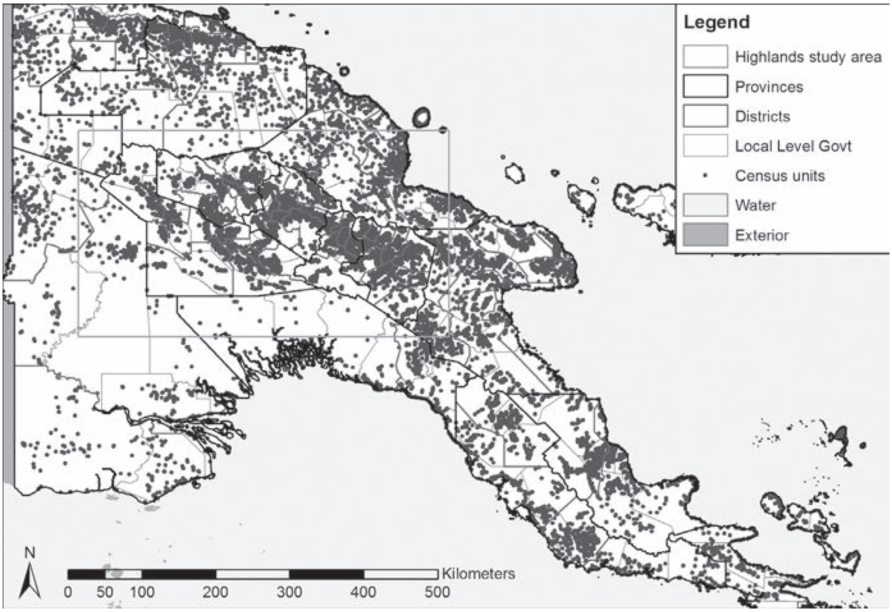
[3] http://pcrafi.sopac.org/layers/geonode:pg_census_unit#more.

Figure 7.2 Regional Divisions and the Highlands Region



Source: www.humanitarianresponse.info.

to georeference the survey data for 1996 and subsequently calculate, for example, the distance to the nearest road.

Shapefiles describing the borders of various regional administration levels have been collected from the Humanitarian Response portal.[4] The initial shapefiles originate from the National Statistics Office of PNG. These spatial delineations are useful for storing region-specific statistical data on themes such as economic development and demography. Many socioeconomic attributes from the 2000 census have been added to the different administration levels, providing a wealth of information related to population number, demographic characteristics, household composition, income, and so on. The data are consistent across the different administrative levels, meaning that population counts in the provinces add up to those of the underlying districts and lower level government regions.

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4 www.humanitarianresponse.info/en/operations/papua-new-guinea/datasets.

Local-level government regions were used as the finest spatial level in the poverty map of PNG created by Gibson et al. (2005). The tabular data of this analysis are available from the Socioeconomic Data and Applications Data Center portal to Environmental and Socioeconomic Data hosted by the Center for International Earth Science Information Network at Columbia University as part of the National Aeronautics and Space Administration's Earth Observing System Data and Information System.[5] Using additional data obtained from two researchers who participated in the poverty mapping study (G. Datt and B. Allen), we were able to reconstruct their maps depicting regional poverty levels in 2000.

7.2.2 Population Density Data

Several globally available, spatially explicit datasets on population density were collected to help characterize spatial patterns in population. These datasets typically downscale regional-level population statistics to the local (grid cell) level following simple assumptions about their spatial distribution. The collected data have been developed by different academic institutions and are freely available to the international community. These data sources were not used in the final econometric analysis, but were included in the initial stages of this analysis to achieve a better understanding of the study area.

The Gridded Population of the World (GPW) is a spatially disaggregated population dataset with a 30 arc-second resolution (equivalent to approximately 1x1 km in PNG) in its newest version. The data are provided by the Socioeconomic Data and Applications Data Center portal and include population counts (number of inhabitants per grid cell) and population density (inhabitants per km2) for 5-year intervals starting in 2000 and including a 2020 projection. Previous version of this dataset also include data for 1990 and 1995. More detailed information on the GPW dataset is provided elsewhere (e.g., Balk et al. 2006).[6] The data were created by distributing regional population counts homogenously over all grid cells in a region. Thus, in the case of PNG, grid cells within a province receive the same hypothetical value, making the data useful for general illustration purposes only.

Some of the limitations of the GPW data are overcome in the Global Rural Urban Mapping Project (GRUMP) dataset, which builds on the GPW approach but incorporates LAN data from satellites to

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5 http://sedac.ciesin.columbia.edu/data/set/povmap-poverty-food-security-case-studies/data-download.

6 http://sedac.ciesin.columbia.edu/data/collection/gpw-v4.

differentiate between urban and rural areas in the spatial reallocation of the population for each census block. These data have the same, relatively high resolution (30 arc-seconds) as do the GPW data, and describe population patterns with more spatial detail, highlighting population concentrations in larger communities and characterizing the surrounding rural areas with lower values. Yet, the data still characterize large areas with uniform hypothetical values that do not match the actual population dispersion. Data are available for 1990, 1995, and 2000 using the same region-specific input data.[7]

A comparable dataset available from the annually updated LandScan Global Population database applies a larger set of ancillary data, such as land cover, transport network, and topographic data to redistribute census data in a gridded format.[8] A limitation of this dataset is that it is not freely available for download, and its assumptions related to input data and spatial distribution methods are not fully disclosed (Gaughan et al. 2013). Instead, the newly available WorldPop data (released in 2015) described below were selected.

The WorldPop project aims to provide an open-access archive of spatial demographic datasets for Central and South America, Africa, and Asia.[9] It was initiated in 2013 to combine earlier mapping efforts for these regions. WorldPop relies on detailed (30 m resolution) Landsat Enhanced Thematic Mapper satellite imagery and additional sources to downscale regional population counts. More extensive descriptions of the applied methodology and incorporated base data are available in several scientific papers (e.g., Gaughan et al. 2013; Stevens et al. 2015). For PNG, data population counts are available for highly detailed grid cells with a resolution of 0.0008333 decimal degrees (around 100x100 m) for 2010 and 2015. An initial visual inspection reveals a highly disaggregated pattern with much more detail than the GRUMP data. However, it is unclear how realistic these simulated patterns are.

7.2.3 Biophysical Characteristics

Elevation Data

Elevation data were obtained from the Global Digital Elevation Model Version 2, and collected with the Advanced Spaceborne Thermal

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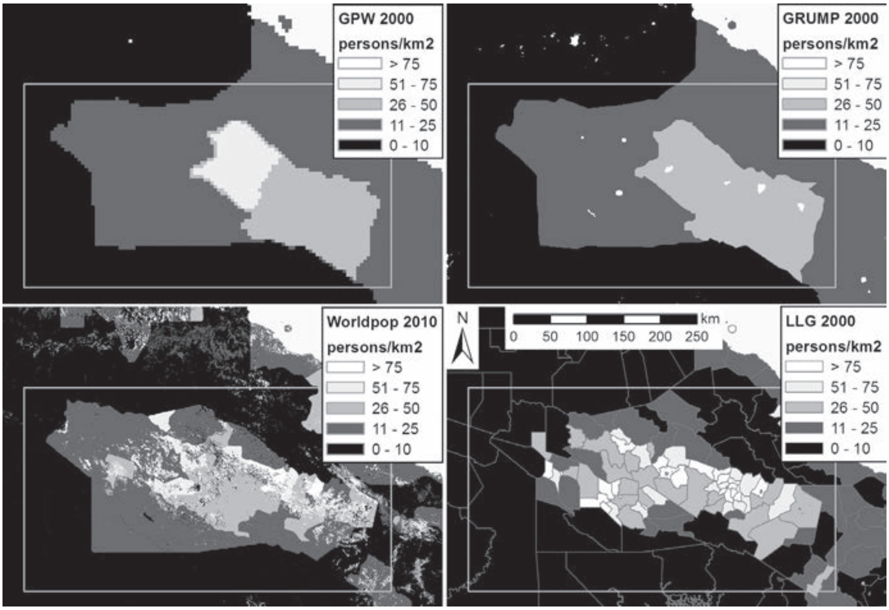
7 See Balk et al. (2006) for more details, or consult the download page at http://sedac.ciesin.columbia.edu/data/set/grump-v1-population-count/data-download.

8 See Bhaduri et al. 2007, or http://web.ornl.gov/sci/landscan/.

9 http://www.worldpop.org.uk/.

Figure 7.3 Different Gridded Population Density Datasets Compared with Census 2000 Data Describing Population per Lower Level Government Level (Bottom Right)



GPW = Gridded Population of the World, GRUMP = Global Rural Urban Mapping Project, LLG = lower level government.

Note: Grid cell size differs per dataset.

Source: Census data derived from the Humanitarian Response portal (www.humanitarianresponse.info). GPW 2000 data taken from version 3 of this dataset.

Emission and Reflection Radiometer sensor as part of a joint American-Japanese remote sensing mission. Due to their global availability and relatively high resolution and accuracy, these data are often used in spatial analyses when more detailed local data sources are lacking. The initial data have a resolution of 30x30 m and an average absolute vertical accuracy of 0.2 m (Meyer 2011). In mountainous and forested areas (such as the PNG Highlands) the data has an offset (consistent error) of circa +7 m with a standard deviation of around 13 m (Meyer 2011). Due to the large range of elevation values in the study area

(0–4500 m), this minor error does not hamper its inclusion in our analysis.

In total, 24 individual map sheets were downloaded from the Earth Remote Sensing Data Analysis Center of Japan.[10] These sheets were first clipped to match the boundaries of the Highlands area (on which we initially intended to focus), then mosaicked into one dataset. Unlikely values in the resulting composite (elevations below sea level and above the highest peak at 4,510 m) were replaced by average elevation values of neighborhood grid cells in an iterative process. During this process, the elevation data are aggregated to a 90x90 m resolution to limit file size and facilitate faster representation. This resolution is deemed sufficient for further analysis.

The elevation data can be used to create control variables (e.g., specifying specific elevation ranges or slope classes) for our statistical estimations of road impact on income levels. However, these were not used in the final analysis as it was found that control variables from another source explained regional variation sufficiently.

Papua New Guinea Resource Information System

The PNG Resource Information System is a valuable resource for spatially explicit information on the country's physical characteristics. This extensive spatial database is the outcome of many land system studies in PNG that the Australian Commonwealth Scientific and Industrial Research Organisation have carried out since 1953 (Vovola and Allen 2001). It contains information variables that may play a strong role in agricultural yields or accessibility, such as land form, rock type, soil type, altitude, relief, and rainfall for each of the 4,566 unique resource mapping units distinguished for the country. A resource mapping unit is a relatively complex area of land characterized by a unique set of natural resource attributes (Bellamy 1986). Information from this database can be used to control for differences in local physical characteristics that make some regions more productive and hence less poor than others.[11] For example, Figure 7.4 shows mean annual rainfall for most of PNG using data from the PNG Resource Information System.

7.2.4 Exploring the Potential of Other Spatial Data Sources

In addition to the classic data sources listed above, we also explored the potential of two more novel data sources that seem to hold potential for

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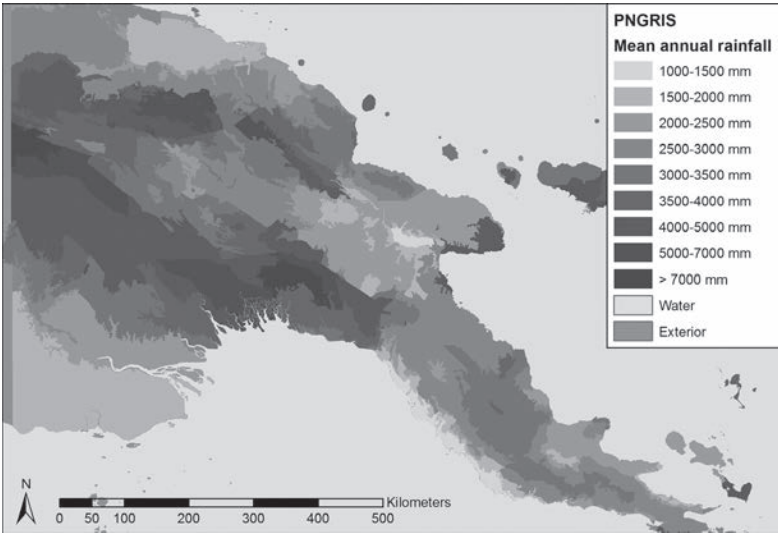
10 http://gdem.ersdac.jspacesystems.or.jp/download.jsp.

11 The spatial datasets in this database have been kindly made available by B. Allen from the Australian National University in Canberra.

Figure 7.4 Mean Annual Rainfall in Papua New Guinea



mm = millimeter, PNGRIS = Papua New Guinea Resource Information System.
Source: PNGRIS.

data-poor environments such as PNG. These are luminosity data and satellite imagery datasets.[12]

Luminosity

Luminosity or LAN data are used extensively to map socioeconomic features. Early examples include the analysis of urban energy consumption (Welch 1980) and the mapping of urban areas (Imhoff et al. 1997) and population densities around the globe (Elvidge et al. 1997; Dobson et al. 2000). Various studies have indicated a strong correlation between total national emittance of light, population density, and especially economic activity (Doll et al. 2000; Elvidge et al. 2001). On a

12 Remotely sensed imagery has produced several derivatives such as the Hansen dataset on annual forest cover loss (https://earthenginepartners.appspot.com/science-2013-global-forest/download_v1.2.html), the Brauer air pollution dataset (http://pubs.acs.org/doi/abs/10.1021/acs.est.5b03709), the van Donkelaar air pollution dataset (http://fizz.phys.dal.ca/~atmos/martin/?page_id=140), and several other air quality measures (the most important datasets are found at http://fizz.phys.dal.ca/~atmos/martin/?page_id=183#). For this general discussion we focused on the raw censored data.

national scale, the relationship between light emittance and economic activity appears stronger due to the direct link between prosperity and usage of electricity, such as for the outdoor lighting of buildings, towns, and roads. More recent studies have focused on mapping economic activity at a more regional and local scale (e.g., Doll et al. 2006; Sutton et al. 2007; Ghosh et al. 2010; Levin and Duke 2012), or on analyzing the differences between light emittance and population density to study phenomena such as poverty (Elvidge et al. 2009), access to electricity in rural areas in developing countries (Doll and Pachauri 2010), and the size of the informal economy in Mexican states (Ghosh et al. 2009).

Elvidge et al. (2001) found that population densities in rural areas are difficult to map with LAN data—even in the prosperous United States rural towns are only consistently detected when they have more than 200 inhabitants—and they expect that these detection limits are substantially higher in less developed areas of the world. Doll and Pachauri (2010) later confirmed this assumption when they compared the percentage of illuminated pixels with local population density for different continents. In Europe and the United States, 90% of locations with a density of 50 or more persons per km^2 were found to be lit, while in developing countries in Asia only 10% of such locations, and only 50% of locations with a density of 250 persons per km^2 were lit. Although this discrepancy may be partly caused by the poor quality of the GRUMP data used to describe population density, it also indicates that rural populations in developing countries produce too little light to be consistently detected. According to Doll and Pachauri (2010), 99.1% of PNG's rural population was unlit in 2000.

LAN data were initially obtained with the Operational Linescan System (OLS) on board satellites launched as part of the United States Defense Meteorological Satellite Program (DMSP). Images for 1992–2013 are available from a range of different satellites.[13] Recently, the Visible Infrared Imaging Radiometer Suite (VIIRS) instrument has made available nighttime light data that are expected to provide more information on low-population areas and economic density than the stable lights data generated by the DMSP-OLS system (Chen and Nordhaus 2015). VIIRS data from 2014 onwards are available from the Earth Observation Group, National Oceanic and Atmospheric Administration National Geophysical Data Center.[14] The images express observed luminosity values averaged per month based on the number of cloud-free days. This approach corrects for the fact that some locations

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13 http://ngdc.noaa.gov/eog/dmsp/downloadV4composites.html.

14 http://ngdc.noaa.gov/eog/viirs/download_monthly.html

will have lower luminosity because they are more often covered by clouds. Obviously, these images do not capture luminosity for those locations covered by clouds on all observation days.

To test the relevance of LAN data for socioeconomic research in PNG, we obtained the OLS and VIIRS datasets and compared these with available data on population density. To provide the best possible match, OLS data were collected for the most recently available year (2013), while VIIRS data were collected for the oldest possible year (2014).[15] OLS data are available in two forms: an average luminosity value per year, and a so-called stable lights version that excludes erratic light occurrences (e.g., related to wildfires, gas flares, and so on) from the calculation of those averages. We selected the stable lights version as it excludes background noise that may obscure actual settlements. For the VIIRS data a temporal composite was created by combining images from different months (weighing the monthly images by the number of cloud-free days to give more weight to more reliable estimates). This operation resulted in an average observed luminosity per cloud-free day for the year 2014. The VIIRS images have a resolution of 15 arc-seconds (around 500x500 m), while the OLS data have a resolution of 30 arc-seconds (around 1x1 km). The finer resolution and different sensor allow more detail to be depicted in in the observed amount of LAN. However, this increased resolution comes at a price as the images also show more noise and oversaturation (dispersion of light into neighboring grid cells).

Visual inspection of the LAN data revealed that major centers such as Port Moresby and Mount Hagen are well captured in the images, and smaller settlements, which have much lower luminosity values, are still observable. However, the most striking features were mining and oil production sites. In the Highlands, the Porgera and Ok Tedi mines and Kutubu-Iagifu, Agogo, and Hides oil and gas production sites with their related infrastructure stand out as high luminosity areas. To assess the potential of LAN data in mapping poverty and welfare in Highlands communities, we excluded these mining sites from our further analysis as they seem to bear little relation to the distribution of settlements (represented as census unit sites) across the region.

To assess the potential of luminosity data for capturing concentrations of people, population density and luminosity values were compared at the level of local-level government regions, the lowest spatial aggregation level at which population data are

15 Standard average luminosity data were used instead of the version including the stray-light corrected data, as this set mainly has added values toward the poles and is of reduced quality (for more information on this issue, see http://ngdc.noaa.gov/eog/viirs/download_monthly.html and Mills et al. 2013).

available. The analysis was performed for the PNG mainland, an area covering about 432,000 km^2 and comprising 249 local-level government regions that range in size from 1 km^2 to 23,000 km^2. Population density (for 2,000 persons/km^2) and average luminosity values per area unit were found to have a fairly strong and positive linear correlation.[16] This correlation is stronger for VIIRS luminosity (r-squared [R2] = 0.43) than for OLS luminosity (R2 = 0.34), indicating that the former dataset is indeed better equipped to map population distribution. Figure 7.5 also suggests that this relationship is stronger for higher population densities. This was confirmed when we ran separate regressions explaining VIIRS luminosity from population density for observations with density values below 25 persons/km^2 (R2 = 0.01) and above that value (R2 = 0.52). The variation in luminosity for low population densities is thus caused by other factors, and may be linked to noise in measurements (e.g., caused by wildfires or measurement errors), proximity to larger towns (whose light may pollute neighboring rural areas), or the presence of specific facilities (e.g., airports and harbors). The figure also indicates that both sources of luminosity data capture fairly similar patterns, as reflected by the strong correlation in luminosity values on both datasets (R2 = 0.72). It is not possible to compare the economic performance of these regions directly, as most economic statistics are only available at the national level.[17]

Luminosity data are available from 1992 and may be useful to discern development trends. To test this, we built a time series of luminosity data. Table 7.7 provides an overview of national GDP, total amount of observed light, and resulting economic intensity values for the years in which luminosity data were collected.

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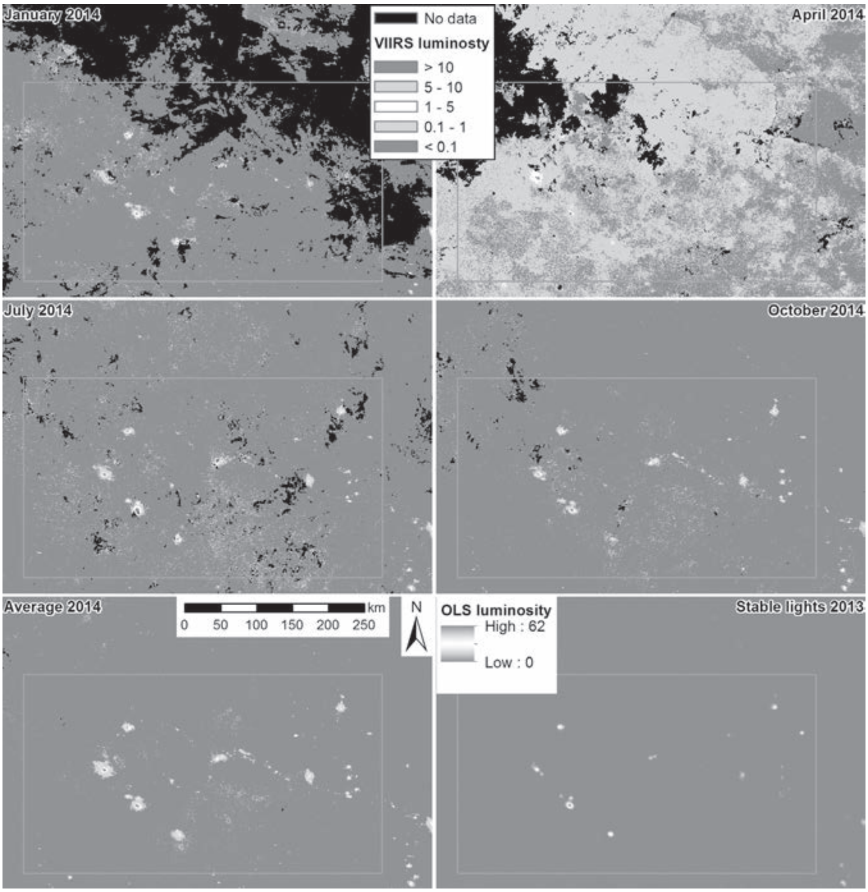
16 VIIRS luminosity values are expressed in nanowatts per square centimeter and multiplied by 1E9 to obtain readable figures. OLS luminosity is described with dimensionless digital numbers ranging from 0 to 63. In this analysis, we sum all luminosity values for a region and divide these sums by the size of the area (in square decimal degrees). We focus on densities of people and luminosity (rather than aggregate, total values) as the regions differ significantly in size. Many of the smaller regions represent densely populated areas with high luminosity values for similar numbers of people as opposed to the much larger, sparsely populated regions characterized by very low or absent luminosity values.

17 An attempt was made to downscale this data to the grid cell level using the method used to create the Geographically Based Economic Data database on gridded output (Nordhaus et al. 2006). This study is not included here as its main input is gridded population density data that do not provide a trustworthy representation of reality. A brief report describing this effort is available for download at the VU-SPINlab website (https://spinlab.vu.nl/wp-content/uploads/2016/09/Using_LAN_data_as_proxy_for_economic_activity.pdf).

Figure 7.5 Luminosity Data from the Visible Infrared Imaging Radiometer Suite Dataset Compared to the Operational Linescan System Stable Lights Dataset (Bottom Right)



km = kilometer, OLS = Operational Linescan System, VIIRS = Visible Infrared Imaging Radiometer Suite.

Note: VIIRS were collected for 4 months in 2014 and subsequently averaged to obtain an image representing the Highlands region without data values (bottom left).

Source: http://ngdc.noaa.gov.

In the collected time series, the southernmost oil field was not yet present in 1992, while the other main mines and oil fields are visible in all years. However, for our analysis of household poverty status we felt that the luminosity data provided no additional value to the detailed household level surveys that were available.

Table 7.7 Key Statistics of the Collected Operational Linescan System Stable Lights Data

Year	Satellite	GDP (billion kina)	Change (%/year)	Total Luminosity	Economic Intensity (million kina/ light unit)
1992	F10	6.2	N/A	23376	0.2642
2000	F14	7.8	3%	43482	0.1783
2000	F15	7.8	N/A	50048	0.1549
2010	F18	11.5	5%	45683	0.2522
2013	F18	14.5	9%	40074	0.3629

GDP = gross domestic product, N/A = not applicable.
Note: GDP is reported in constant prices, showing the values in market prices of the base year (1998) to adjust for the impact of inflation.
Source: Data were collected from World Economic Outlook Database of the International Monetary Fund (http://www.imf.org/external/pubs/ft/weo/2015/01/weodata/index.aspx). The original source of the GDP data is the Papua New Guinea National Statistical Office and Ministry of Finance.

Satellite Imagery Datasets

An inventory was made of open-access sources of satellite imagery that can be helpful in mapping various aspects of land use in PNG. These data may be a useful addition to the land cover maps discussed above to highlight specific features of the landscape. We also discuss the possibilities of a specific application to use remote sensing data to map road quality.

The extensive Landsat archive, containing data from the family of satellites that have been used to map the earth since 1972, is the most widely used repository of satellite imagery. This data collection is the best available source for time series analysis of relatively long periods. Individual, georeferenced images can be downloaded from the United States Geological Survey earth explorer website.[18] Several images were downloaded for the Highlands region to explore their usefulness for the current study in mapping relevant spatial features (such as roads). The datasets were selected for having relatively low cloud coverage and approximating the most relevant years in our analysis (2000 and 2010). For PNG, fully cloud-free images are virtually absent.

Figure 7.6 provides a natural color representation of three visible light bands (red, green, and blue) of one of the included images, and

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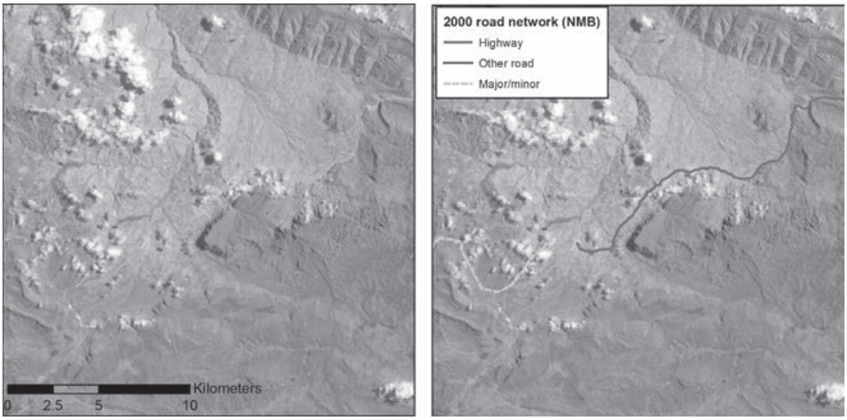
[18] http://earthexplorer.usgs.gov/

Figure 7.6 LandsatLook Image (1997) Comparing the Roads Classified by NMB around the Porgera Gold Mine



NMB = National Mapping Bureau.

Notes: Comparing the images reveals that the resolution is too limited to recognize roads properly, let alone classify their type and quality. Appendix 7.1 discusses this topic in more detail.

Source: Authors.

shows the level of detail (30 m) available in these datasets. Specific operations exist to enhance the level of detail in the most recent Landsat images (Landsat 7 [1999] and Landsat 8 [2013]) by including the 15 m panchromatic band that represents the red, green, and blue portions of the electromagnetic spectrum in a grey scale. Unfortunately, this is only possible for the Landsat8 images as its predecessor suffered from problems with its sensor since 2003, after which it produced striped images. Thus, panchromatic sharpening is only possible for 1999–2003 and from 2013 onwards. In combination with the limited availability of cloud-free images this implies that establishing full coverage of PNG with these sharpened images is most likely impossible.

We also considered the application of Linear Imaging Self Scanning Sensor III data originating from the Indian Remote Sensing Satellite (IRS). Its latest mission (IRS-P6) is also known as ResourceSat-1.[19] After many trials and requests, it became clear that only a limited dataset is available for some locations in Europe through the EOLI-SA application

19 https://earth.esa.int/web/guest/missions/3rd-party-missions/current-missions/irs-p6

distributed by the European Space Agency. The Government of India only distributes images for its own territory.[20] The lack of access to this data source did not hamper our analysis as the resolution of the Linear Imaging Self Scanning Sensor III satellite images (24 m) is comparable to that of the Landsat images (30 m).

Further discussion on obtaining road quality data from remote sensing is provided in the Appendix, while an even more detailed description of methods that can be applied to recognize roads from satellite imagery is currently being prepared for further dissemination.

7.2.5 Assessing the Impact of Road Maintenance and Upgrades on Development

A number of recent papers have rigorously assessed the impact of road system development in less developed economies. Dercon et al. (2009) found that investments in all-weather roads in rural Ethiopia reduced poverty by 6.9 percentage points. Furthermore, they found no evidence that this effect was heterogeneous with regard to household characteristics like size of landholdings, livestock holdings, or household head literacy. However, their estimates showed that the effect on consumption growth was larger for households with landholdings of at least a hectare and a literate household head. Dercon et al. (2012) obtained a complementary estimation result, finding that remoteness from towns and poor roads are some of the factors most associated with chronic poverty. Khandker et al. (2009) investigated how households in Bangladesh profited from road improvement projects, and found that villages next to an improved road experienced poverty reduction of 5 percentage points. The impact on household expenditure is higher for lower expenditure quintiles in this study, suggesting that road investments are pro-poor. However, using a larger dataset and controlling for other investment programs, Khandker and Koolwal (2010) found the opposite pattern. Mu and van de Walle (2011) found positive and significant average effects of rural road rehabilitation on local (commune-level) market development in Viet Nam using double difference and matching methods to address potential selection bias in identifying impacts. These authors note a tendency for poorer localities to have higher impacts due to lower levels of initial market development. A replication study by Nguyen (2016) confirmed these results.

A key challenge in assessing road maintenance and development impacts is the possible endogeneity of road placement with observed outcomes. Existing research in road development impacts has used a

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20 http://bhuvan.nrsc.gov.in/data/ download/index.php?c=s&s=L3&p=&g=.

variety of approaches to address this problem. One such approach is instrumental variable estimation, which requires an exogenous variable that affects road development but has no direct effect on the outcome variable of interest. For example, the straight line approach pioneered by Banerjee et al. (2012, 2004) uses the distance between the sampled household and the nearest straight line between major cities as an instrument for assessing road access. The location of the major cities is assumed to be exogenous, as are the straight lines between them. Where panel data are available, an alternative approach to address potential endogeneity in road placement is to use time-invariant village- or household-fixed effects (Khandker et al. 2009; Khandker and Koolwal 2010) to assess the impact of road investments over the period covered by the panel. The fixed effects remove endogeneity caused by time-invariant characteristics of the location. The availability of multiple time periods further allows instrumentation using lagged outcomes (Dercon et al. 2009; Khandker and Koolwal 2011). Another technique often used when the road variable is binary (project road or not) is difference-in-differences estimation, often with propensity matching to allow the common trend assumption to hold conditional on covariates (Lokshin and Yemtsov 2005; Mu and van de Walle 2011). Estimation using regression discontinuity to study road impacts is rare. Casaburi et al. (2013) provide one example in their study of road development impacts in Sierra Leone, where the roads ranked highest on a priority ranking were selected for improvement.

Gibson and Rozelle (2003) examined the impact of road development on poverty in PNG by using data from the 1996 PNG Household Survey to estimate the impact of travel time to the nearest road on household welfare. To correct for potential endogeneity, the authors used the year in which PNG's national highway system first entered each district as an instrument for calculating travel time to the nearest road. Their rationale was that highway construction happened mainly according to geographical necessities (such as the need to start construction at the coast and proceed inland), and was therefore independent of local characteristics like productivity and average income levels. As rural feeder road networks follow highway construction, higher road density is expected in districts where the highway entered early. The estimates produced by this study showed that reducing travel times to the nearest road to a maximum of 2 hours reduced poverty by 5.8–11.8 percentage points overall. The present study revisits this earlier analysis, applying correlated random effect (CRE) estimation to address endogeneity in the location of road improvements, and using a new round of household surveys and road maps covering the period in between both household surveys (1996–2009) to obtain richer and more robust results.

New Estimates of Road System Development Impacts

Next it is necessary to summarize and discuss the impact evaluation model of road quality on household welfare in rural PNG between 1996 and 2010. Estimating the effects of road development and maintenance is complicated by the fact that government decisions about where to construct new roads or whether to rehabilitate or upgrade existing roads may be endogenous with the growth of areas and other development achievements. Road works may be driven by decisions based on unobserved factors like expected traffic volume, local productivity, investment cost, and the political benefits of placing roads in particular areas—all factors that may also affect household welfare directly.

To assess the causal relationship between the state of road infrastructure and the material well-being of rural households, we estimated a linear model in which outcome variables that measure welfare are a function of various measures of road infrastructure, a number of exogenous control variables at the level of both households and census units, and regional- and time-fixed effects. Road infrastructure was measured by distance and quality variables. The distance variables are time-invariant and include the logarithm of the Euclidean distance to the nearest road (from the surveyed household) and the logarithm of the distance on that road leading to the closest town.[21] The quality variables are time-varying and include the shares of different surface types on the route between surveyed households and the nearest town.

The estimation model takes the linear form

$$y_{ijt} = \beta R_{jt} + \gamma D_j + \delta X_{ijt} + \mu_j + \tau_t + \varepsilon_{ijt} \qquad (1)$$

where y_{ijt} is a measure of material well-being of individual or household i in census unit j at time t; R_{jt} and D_j are vectors of variables related to road infrastructure; X_{ijt} is a vector of exogenous control variables (at the household or census unit level, some varying over time and others time-invariant); μ_j denotes unobserved, time-invariant heterogeneity at the province- and census-unit level, respectively; τ_t is a time-fixed effect; and ε_{ijt} is an independent disturbance term.

The primary outcome variable used in the estimations is the logarithm of real yearly consumption per adult-equivalent, but the model was also estimated for other development indicators, including poverty status, having a good roof (as a proxy for housing quality), whether someone in the household has a wage job, whether someone in

[21] The details of how the shortest route to the nearest town was determined can be found in the appendix.

the household engages in subsistence farming, and the ratio of school-aged children going to school.

A number of location-specific control variables were included in the estimation, such as the following geoclimatic variables: altitude, a dummy for whether the slope is above 10 degrees, a dummy indicating that the land is subject to flooding, a dummy indicating that rainfall deficits are rare, and annual rainfall. To control for differences in the economic importance of the nearest town, the logarithm of its population as measured in the census closest to the survey year was included. The estimation model also includes a parsimonious set of variables describing the composition and education level of adults in the household. These variables include household size, the ratio of household members under 15, the ratio of household members above 50, the age of the household head, a dummy indicating a female household head, a dummy indicating a literate household head, average years of schooling of adults in the household, and the ratio of primary school-aged children. The coefficients of these control variables were not reported because we did not attribute causality to them.

Since the two surveys did not cover the same census units, it was impossible to use first differences to eliminate village-level heterogeneity. Instead, we used the CRE approach introduced by Chamberlain (1982, 1984), who projected potentially endogenous variables measured at multiple points in time on the model disturbance terms. The resulting projection errors are by construction uncorrelated with the variables in question. The specific variables available in both 1996 and 2010 were the shares of road quality and the population of the nearest towns. As the road network itself remained almost entirely unchanged during this period, the distance to the nearest road and the length of the route to the nearest town cannot be used in the same way and are assumed to be conditionally exogenous.[22] Our estimations of the model above were carried out using ordinary least squares for all outcome variables. All regressions were weighted using sampling weights included in both surveys, with person-specific weights for regressions on consumption and poverty, and household-specific weights for the remaining outcome variables. Standard errors were adjusted for census unit-level clustering.

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[22] We let Z_{jt} be the vector of potentially endogenous variables in equation (1). When Z_{jt} is available for both years, we can substitute μ_j with its linear projection and an independent random census unit-effect: $\omega_j : \mu_j = \alpha_{00} Z_{j,00} + \alpha_{09} Z_{j,09}) + \omega_j$. This makes Z_{jt} independent of the combined disturbance term, $\omega_j + \varepsilon_{ijt}$. Since the road type share variables R_{jt} are available for both years, we included them in equation (2). Note that since distance variables D_j are time-invariant, they cannot be included in the model of μ_j and are assumed to be conditionally exogenous.

The results of the estimations generally confirmed the positive effects of maintaining and upgrading rural roads. Table 7.8 shows results from the model specification that includes CRE terms and all control variables. As shown in the first column, upgrading 1% of the route leading to the nearest town from dirt to a sealed road surface increased average consumption per household member by about 0.55%. The same upgrade was also estimated to raise the chance that households live in a house with a high-quality roof by about 0.19 percentage points, and to decrease the probability that a household engages in subsistence farming by 0.14 percentage points.

Analyzing road quality impacts on consumption across different subgroups revealed that the effects on consumption are at least twice as high for households with less than 4 years of education, on average, an illiterate household head, or a female household head, when compared to their respective opposite subgroups (Table 7.9). The effects of upgrading a gravel road to a sealed road are of similar magnitude. The differences between dirt and gravel roads are not significant for most outcomes, which may be due to the relatively low number of dirt roads in the data.

To investigate whether the effects of surface type on log consumption vary across the consumption distribution, we used a generalized quantile regression (Powell 2016), which is an extension to quantile regression that allowed us to control for covariates without altering the conditional distribution of interest. Standard errors were obtained via bootstrapping. Table 7.10 shows our estimates for the 10th, 30th, 50th, 70th, and 90th percentile, respectively. It appears that sealing gravel roads has a consistently positive effect across the consumption distribution, and that these effects are modestly higher for disadvantaged households. This is in line with Gibson and Rozelle (2003) who argued that, due to the sparse road network and the remoteness of many poor households in PNG, infrastructure spending may be one of the few feasible targeted antipoverty measures.

The estimation results are discussed in more detail in the companion paper. One achievement of our analysis is that it demonstrates that by constructing panel data from both survey and administrative sources it is possible to correct impact estimates to account for the endogenous placement of road infrastructure based on time-invariant, location-specific factors using the CRE approach. This approach corrects for correlations of road surface type with unobserved location-specific effects, and can be applied as long as road access variables from different time periods are available for households covered in different cross-sections.

Table 7.8 Impact of Road Type on Indicators of Household Welfare

	Log (Real Consumption PAE)	Poverty Status	Good Roof on Home	Subsistence Farming	Holds Wage Job	Ratio of Children in School
Dirt to sealed	0.5516[a]	−0.1670	0.1872[b]	−0.1409	0.1653	0.0103
	(0.201)	(0.131)	(0.092)	(0.091)	(0.120)	(0.114)
Dirt to gravel	0.1909	−0.0049	0.0808	0.0142	0.0952	−0.2045[b]
	(0.161)	(0.112)	(0.082)	(0.082)	(0.107)	(0.090)
Gravel to sealed[d]	0.3607[b]	−0.1621	0.1063	−0.1551[a]	0.0701	0.2149[b]
	(0.165)	(0.105)	(0.074)	(0.057)	(0.097)	(0.094)
Log total distance to nearest town	−0.1341[a]	0.0753[a]	−0.0224	0.0087	−0.0359[c]	−0.0076
	(0.029)	(0.016)	(0.018)	(0.009)	(0.020)	(0.016)
Log distance to nearest road	0.0114	−0.0087	−0.0170[a]	−0.0030	−0.0137	−0.0172[b]
	(0.015)	(0.009)	(0.006)	(0.004)	(0.008)	(0.008)
R-squared	0.296	0.204	0.469	0.193	0.190	0.206
Census units	155	155	155	155	155	155
Households	2,148	2,148	2,312	2,312	2,306	1,530
P-value CRE	0.000	0.018	0.023	0.002	0.154	0.564

CRE = correlated random effect, PAE = planned aggregate expenditure.
[a] p<0.01.
[b] p<0.05.
[c] p<0.010.
[d] The coefficient for "gravel to sealed" is not actually part of the model and comes about by subtracting "dirt to gravel" from "dirt to sealed".
Note: Standard errors in parentheses, clustered at the census unit level. All regressions are weighted using sampling weights from both surveys. The category "dirt roads" is excluded for the share variables. Road sections observed in the 2009 maps but not in 2000 are assumed to remain the same over time. All specifications also include location-specific control variables, province- and time-fixed effects, and CRE terms.
Source: Authors.

Table 7.9 Impact of Road Type and Distances on Log Real per Adult-Equivalent Consumption by Subgroups

	Average years of schooling ≤ 4	Average years of schooling > 4	Household head illiterate	Household head literate	Household head male	Household head female	Household members above 50 ≤ 30%	Household members above 50 > 30%
Dirt to sealed	0.7081[a]	0.0992	0.6732[b]	0.3244[c]	0.5004[b]	0.9986[b]	0.5371[a]	0.7231
	(0.224)	(0.214)	(0.264)	(0.192)	(0.202)	(0.395)	(0.203)	(0.449)
Dirt to gravel	0.1558	0.3296	0.0908	0.2563	0.2287	−0.4195	0.1880	0.5507
	(0.163)	(0.220)	(0.184)	(0.203)	(0.168)	(0.318)	(0.159)	(0.411)
Gravel to sealed[d]	0.5524[a]	−0.2304	0.5824[b]	0.0681	0.2717[c]	1.4182[a]	0.3491[b]	0.1724
	(0.185)	(0.172)	(0.246)	(0.155)	(0.154)	(0.381)	(0.168)	(0.424)
Log distance to	−0.1236[a]	−0.1812[a]	−0.0863[b]	−0.1693[a]	−0.1393[a]	−0.0626	−0.1348[a]	−0.1185[b]
nearest town	(0.035)	(0.031)	(0.036)	(0.029)	(0.028)	(0.051)	(0.029)	(0.051)
Log distance to nearest road	0.0150 (0.018)	−0.0072 (0.016)	0.0152 (0.018)	−0.0031 (0.016)	0.0117 (0.015)	0.0035 (0.027)	0.0071 (0.015)	0.0422 (0.033)
R-squared	0.330	0.296	0.324	0.296	0.309	0.398	0.312	0.367
Census units	146	144	148	151	154	106	154	123
Households	1,249	899	1,041	1,107	1,873	275	1,836	312

[a] $p<0.01$.
[b] $p<0.05$.
[c] $p<0.010$.
[d] The coefficient for "gravel to sealed" is not actually part of the model and comes about by subtracting "dirt to gravel" from "dirt to sealed".
Note: Standard errors in parentheses, clustered at the census unit level. All regressions are weighted using sampling weights from both surveys. The category "dirt roads" is excluded for the share variables. Road sections observed in the 2009 maps but not in 2000 are assumed to remain the same over time. All specifications include location- and household-specific control variables (see Table 7.4), correlated random effect terms, and province- and time-fixed effects.
Source: Authors.

6.4 Conclusions

This chapter provides a detailed review of the sources of data used in the impact estimates. This is intended to guide future researchers and encourage similar studies. Using administrative road inventory

Table 7.10 Generalized Quantile Regressions of Consumption on Road Type

	Log (real per adult-equivalent consumption)				
Quantile	10%	30%	50%	70%	90%
Dirt to gravel	−0.060	0.020	−0.061	−0.015	0.080
	(−0.378, 0.387)	(−0.165, 0.371)	(−0.241, 0.187)	(−0.150, 0.234)	(−0.053, 0.462)
Gravel to sealed	0.373a	0.244b	0.234c	0.318a	0.330a
	(0.143, 0.803)	(0.076, 0.497)	(−0.004, 0.548)	(0.138, 0.602)	(0.145, 0.754)
Census units	155	155	155	155	155
Households	2,153	2,153	2,153	2,153	2,153

[a] p<0.01.
[b] p<0.05.
[c] p<0.010.
Note: Parentheses indicate 95% bootstrap confidence intervals obtained using a cluster bootstrap at the census unit level with 999 replications. All regressions are weighted using sampling weights from both surveys. All regressions use log distance to nearest town, log distance to nearest road, location- and household-specific variables, correlated random effect terms, province dummies, and time dummies as proneness variables.
Source: Authors.

data combined with repeated cross-sectional household survey data (including the geographical coordinates of surveyed households) appears promising as an avenue for impact evaluation analysis.

These data made it possible to estimate a model akin to a model with village-fixed effects. We used this model to examine the impact of changes in the road quality of PNG's national and provincial road networks on rural household welfare over a 13-year period. New estimates provide clear evidence that investing in sealing roads improves household welfare in rural areas of PNG. The positive effects of road upgrades are proportionately greater for households with lower education levels. Results also suggest that sealing roads supports the transformation of households toward market participation and commercial farming activity. The new estimates do not provide clear evidence for the effects of road quality on access to education services, or of effect heterogeneity across consumption.

The kinds of data used in this study are available in many other countries at relatively low costs (compared to the costs of collecting new data to measure impacts). Thus, the method lends itself for replication in other countries, as well as in PNG when another household survey is conducted.

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Appendix 7.1 Mapping Road Quality and Road-Based Distances

Part of this research aimed to investigate the possibility of supplementing road quality data obtained from surveys with data obtained from satellite imagery. This appendix describes remote sensing techniques applicable for automated road condition mapping. We explain the techniques commonly involved in such analyses, review some successful applications, and summarize data requirements and challenges related to current state-of-the-art methods. A subsequent section concludes regarding the feasibility of automated road condition mapping using satellite imagery.

A7.1.1 Remote Sensing Techniques for Automated Road Condition Mapping

Current practice in mapping road quality involves extensive field observations of experts who index local road quality based on a number of physical parameters, including cracking, raveling, and rutting (Herold et al. 2008). Other technologies, such as photographic and video logs of road quality coupled with geographic information system technology, are rapidly evolving. However, such operations are tedious and costly, and advances in remote sensing techniques could be of potential importance in supporting these infrastructure surveys (Brecher et al. 2004). While physical and chemical properties have been derived successfully on a detailed level from hyperspectral imagery (Clark 1999), it is still challenging to map road quality from satellite imagery depending on the goals and data available.

We distinguish different degrees in recognizable distress signals that categorize the severity of road deterioration. Each category links to a certain spatial resolution of the imagery data. On large spatial scales (low resolution), structural damages such as washouts, bridge collapses, and flooding damages have been successfully recognized by the visual interpretation of satellite data and vector change analysis (Emery and Singh 2013). Algorithms based on vector change analysis subtract two images of an area and categorize the amount of change to recognize large structural changes.

Most research at lower spatial scales (high resolution) is directed at paved roads. Distress signals such as cracking can be recognized through image-processing techniques combined with a variety of image-recognition techniques (Cheng et al. 1991; Cheng et al. 2001; Chambon et al. 2009).[23] However, most of the images used in typical studies are obtained at the ground level, and emerging technologies focus on deploying unmanned airborne vehicles (UAVs) (see e.g., Brecher et al. 2004; Zhang 2010; Mei et al. 2014). Generally, aging and physical parameters of surface differentiation can be obtained from satellite imagery (Herold and Roberts 2005; Mei et al. 2014), but the detail of imagery should be of at least sub-meter resolution with high detail in spectral bands. When imagery is somewhat less detailed (around 4-meter resolution) general categories of road quality and general indicators for condition have still been derived (Mohammadi 2012), although other studies note that efforts to link spectral reflectance and physical characteristics at this resolution do not yield sensible results (Zhang and Elaksher 2012). Some efforts to extract road quality from imagery has focused on unpaved roads, but these studies rely on low-altitude UAVs (Zhang 2008a, 2008b, 2010).

The general procedure in the efforts at different scale levels sketched above is similar. Aerial images are supplemented with highly detailed road quality surveys or in situ measures, and spectral characteristics from the images are related to indicators or measures of road quality. After fitting a certain model that can link road conditions with spectral characteristics, the model can be used to make out-of-sample predictions based on new image data.

A7.1.2 Feasibility

Although technological advances in the past decades have made automated road quality mapping by combining image-processing and image-recognition techniques a real option, state-of-the-art techniques require both highly detailed satellite imagery, low-altitude UAV or ground-level imagery, and road survey data, or a wealth of in situ measures. As far as we know, none of these data sources is currently available for Papua New Guinea or can only be obtained at very high costs. Sub-meter resolution imagery is available through the Satellite Imaging Corporation or Landinfo (e.g., Quickbird, Worldview 1 and 3, and Ikonos), with typical prices of around \$15–\$60 per square kilometer, depending on the resolution.[24] Highly detailed road quality surveys or ground measurements, such as georeferenced road condition information for 10-meter road segments, are also unavailable. Taking

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23 Recognition techniques include, for example, Support Vector Machines, Fuzzy Set Theory, Markov Methods and Neural Networks.

24 For prices, see http://www.landinfo.com/satellite-imagery-pricing.html.

ground measurements is a very tedious process and the study area is too large to obtain full coverage with UAVs. Moreover, performing such an incidental survey will only provide insight in the current status of the road network and not yield a time series of road quality surveys that can be used to link changes in household income over the past 20 years to changes in road quality.

Supplementary information is available from the authors who documented some of our exploratory efforts to determine the usefulness of freely available Landsat imagery. We conclude that the data are not suitable for automated procedures that extract vectorized road data or assign quality variables to known roads. Lack of detail, coverage, and availability play an important role. However, Landsat imagery—if processed properly—can in some cases be interpreted by the human eye and be informative regarding ground-level developments in the road network.

Appendix 7.2 Network Analysis

Figure A7.2.1 provides a simple example of the network-based distances used in the impact analysis by showing the shortest routes (thick green line) over the road network (thin line) linking census units and towns. In this analysis, we recorded not only the total length of the route in meters, but also the total length traveled on different types of roads, distinguishing unique combinations of surface type (sealed, gravel, and dirt) and road condition (good, fair, and poor) in both 2000 and 2009 (3x3x2 = 18 attributes).[25] These values only include distances over the network. Overland distances are added to distances based on simpler geographic information system-based calculations that look for the nearest road from each sampled census unit.

After this initial analysis, a few unrealistically long routes and unconnected census units were found that were related to obvious data gaps (e.g., roads missing in larger towns that were not part of the road asset management system data). These missing links were added to the network, as were the major roads for Port Moresby to allow census units in the surrounding rural areas to link to this major town. The final results present a convincing representation of the routes that villagers would take to travel to town. Although the current analysis may still overestimate travel distance due to network inconsistencies (e.g., when existing connections are missed), we are confident that the most important connections are now included. In fact, the difficulty of travel may be underestimated as some road stretches may not always be passable due to seasonal conditions or incidental road failure.

Some key statistics of the current analysis are as follows: 47 out of 50 towns are linked to the road network; and 297 of the 313 sampled census units from the 2009–2010 survey are linked to a road. All remaining locations are either along the coast or deep in the interior, and appear to be too far from a road to be connected. Some additional census units lack a link to a town because the roads on which they are located do not reach a town (e.g., due to water bodies). In some cases, ferry services may provide a connection; however, as we lack such information, we must assume that these are missing (or at least much poorer) connections. Of course, this may have some impact on the results for the islands, although roads may be less important here due to the prevalence of water traffic. Figure A7.2.2 shows non-connected census units and towns in a lighter

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25 We created more attributes as we also distinguished between known road conditions in 2000 and assumed ones (where missing quality information was filled in using the 2009 conditions). These different distance calculations are used as alternative specifications in our paper describing the statistical analysis.

color with a question mark, and the shortest routes between connected census units and towns as purple lines.

It is also possible to create a full origin–destination matrix linking each census unit to all towns reachable over the road network starting from the census unit. This yields a large origin–destination matrix of 3,309 cells (not all origins link to all towns). Figure A7.2.3 depicts all established connections as straight lines and clearly shows the disconnected larger regions of the country. This distance calculations analysis can be used to add second-nearest destinations to the analysis, or, for example, to include the distances to specific (larger) towns, such as provincial capitals. These variables were not used in the final statistical analysis of this project.

Figure A7.2.1 Example of Network-Based Distance Calculation between a Sampled Household (Indicated by Number) and Nearest Town (Wapenamanda)

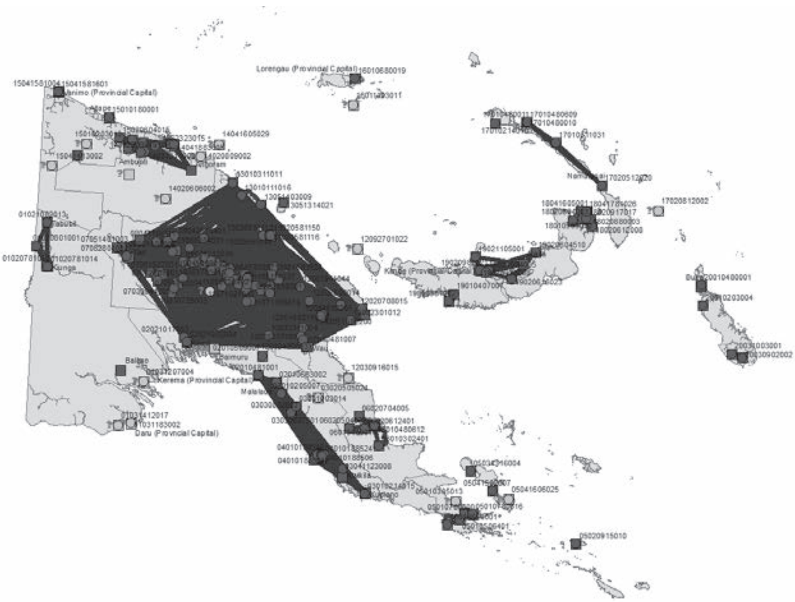
Source: Authors.

Figure A7.2.2 Network Analysis for Papua New Guinea

Note: Sampled census units are shown as squares, towns as circles, and the shortest routes between them as purple lines. Question marks denote census units or towns that could not be linked to a road stretch within the specified search distances.

Source: Authors.

Figure A7.2.3 Schematic Representation of All Possible Connections between Sampled Census Units and Towns



Source: Authors.

PART III

Connectivity and Cross-border Infrastructure

8

The Impact of Shipping Connectivity on Trade Performance: The Case of the Pacific

Matthias Helble

8.1 Introduction

Transport infrastructure investment typically aims to improve connectivity between economic centers. Earlier chapter of this book examined the positive spillover effects of improved transport infrastructure on economic activity along newly established corridors. This chapter focuses on how improved connectivity will increase economic exchanges between countries. Specifically, we study the transport connectivity of 14 Pacific islands, for which shipping is the main means of exchanging goods with the rest of the world.

Pacific economies face a number of structural constraints that make it difficult for them to participate in the world economy. Geographical disadvantages are among the foremost of these constraints. Most of these countries are small in terms of geographical area and spread across many islands. One such example is Kiribati, which consists of 33 islands spread over 3.5 million square kilometers of water, an area larger than India. Second, many Pacific economies are located far from major economic centers. For example, the shipping distance between Suva, Fiji and Shanghai, in the People's Republic of China is 8,907 kilometers (km) and takes on average 14 days and 7 hours. The shipping distance between Suva and San Francisco in the United States (US) is barely shorter at 9,225 km and requires almost the same shipping time (14 days and 19 hours).[1] Finally, many Pacific economies are located in a

1 SeaRates. http://www.searates.com/reference/portdistance/ (accessed 15 May 2017).

zone with a high risk of natural disasters such as cyclones, tsunamis, and earthquakes.

These structural constraints have multiple implications for the integration of Pacific economies into the global economy. First, and most obviously, remoteness equals high transportation costs, both in absolute terms and in terms of delays. Both are considerable disadvantages when competing in global markets where profit margins are low and fast delivery is critical (e.g., Evans and Harrigan [2005]).[2] Second, remoteness combined with a small economic size translates into lower connectivity in terms of frequency as well as direct connections. Given the considerable economies of scale in the transportation sector, small economies are typically served less frequently and from fewer destinations (e.g., Hummels and Skiba [2004], or Winters and Martins [2004]).[3] This lower connectivity means higher costs, not only for the shipping of physical goods, but also for the delivery of services across borders. Finally, as Pacific economies are located in areas at high risk of natural disasters, shipping can be subject to considerable variance. Again, in a world where just-in-time production is critical, Pacific economies face a heavy burden that is difficult to mitigate.

Despite these difficulties, trade in the Pacific has been developing very dynamically since 2000. Exports and imports of Pacific developing member countries (DMCs) increased from less than $5 billion in 2000 to around $36 billion in 2016. From Figure 8.1, which shows the exports of the Pacific DMCs to Asia and the Pacific region as well as to the rest of the world, it is interesting to observe that the share of exports to Asia and the Pacific region is increasing. Papua New Guinea (PNG) and Fiji account for more than 80% of all of the 14 Pacific DMCs' trade during the time period under study. Another important observation is the Pacific DMCs' large and increasing trade deficit. The total trade deficit of all Pacific DMCs surged from less than $2 billion in 2006 to around $12 billion in 2016, mainly financed by remittances and official development aid.

The Pacific DMCs' trade in goods mainly consists of primary commodities. Pacific DMCs with rich fishing grounds typically export mainly fish and fish products, while those with natural resources concentrate on exporting those resources. Exports of manufactured

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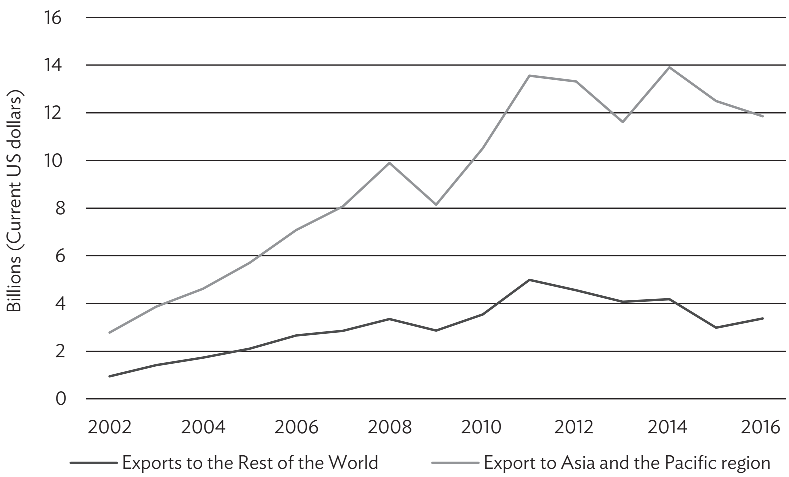
2 Evans and Harrigan (2005) demonstrated the importance of delivery times for the production of clothing.

3 Using US trade data, Hummels and Skiba (2004) showed that a 10% increase in product weight or value results in a 4%–6% increase in shipping costs. Winters and Martins (2004) found that transportation costs by ship fall by 0.31% when shipping volumes increase by 1%.

Figure 8.1 Trade (Export) of Pacific Developing Member Countries, 2002–2016



US = United States.

Source: United Nations International Trade Statistics Database; author's calculations.

goods have declined over the past decade in the Pacific, as Asia has emerged as a world center for manufacturing. A key factor in this success is that Asia has been able to build up or join global and regional value chains and production networks. Conversely, physical remoteness and small manufacturing bases have made it difficult for Pacific DMCs to join regional production networks, and have even forced them to scale down manufacturing.

This chapter examines how the shipping connectivity of Pacific economies affects their trade performance. The subjects of this study are the 14 Pacific DMCs of the Asian Development Bank: the Cook Islands, Fiji, Kiribati, the Marshall Islands, the Federated States of Micronesia, Nauru, Palau, PNG, Samoa, Solomon Islands, Timor-Leste, Tonga, Tuvalu, and Vanuatu.

The chapter is structured as follows: first, we introduce a new database containing the shipping connections and frequencies among the Pacific DMCs and with other countries in the world. The database was constructed using records generated by automatic identification system (AIS) equipment installed on all major ships that sail in national waters. This equipment automatically reports positions and arrival and departure times to the port authorities. We then combine the shipping connectivity data and the corresponding data for trade in goods. Using simple node diagrams, we illustrate how the connectedness of the Pacific DMCs contrasts with the exchange of goods. That is to say, although trade in goods takes place between many economies, connectedness is limited, requiring passage through trading hubs. In the econometric section of the chapter, we apply a gravity model to estimate the importance of direct connections and shipping frequency for trade. We find that direct shipping connections and high shipping frequency imply statistically significant higher trade volumes compared to country pairs with no direct connection. Using an instrumental variable approach to control for endogeneity confirms these results.

8.2 Data

8.2.1 Trade in Goods Data

The trade in goods data come from the United Nations International Trade Statistics Database.[4] For the gravity equation approach (see next section), several explanatory variables are only available for 2012 and 2013. Therefore, we created a 3-year simple average of trade for 2011–2013. A 3-year average has the advantage of leveling out infrequent trade flows, which are not uncommon in our sample of several small economies.

Following common practice, we first downloaded all bilateral trade flows in terms of imports from Pacific DMCs for 2011–2013. We used imports instead of exports because import flows are typically recorded with greater scrutiny than exports (statistics on imports are typically more complete than those on exports as imports are often subject to import tariffs or other measures). For 2011–2013, 180 economies (including the 14 Pacific DMCs) reported imports from at least one of the 14 Pacific DMCs. These importing economies reported 2,304 positive trade flows out of 7,560 possible observations.

Trade statistics based on imports can be complemented by those based on exports. This method, known as mirror statistics, compares the bilateral flows reported by the importer with the trade statistics of the exporting economy. In theory, the value and volume of trade reported by both the exporter and importer should be identical; however, considerable discrepancies exist. The reasons for this are manifold and

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4 United Nations International Trade Statistics Database. [URL] (accessed 10 May 2017).

not yet fully understood. We also find cases in which the exporter records a bilateral trade flow, but not the importer. Thus, mirror statistics can be a useful tool to complement and complete trade statistics.

Using the mirror-statistics approach, we downloaded all exports from the Pacific economies to the rest of the world in 2011–2013 (771 export flows). Next, we combined the database on the bilateral import flows reported by the rest of the world and the bilateral export flows reported by the Pacific DMCs, obtaining 3,075 observations in 2011–2013. Of these, 2,583 were unique observations reported by either importers or exporters, and 492 were reported by both the exporting Pacific DMCs and the importing economies. To remove these duplicates, we calculated a simple average of the two entries and kept one. This allowed us to avoid deciding which entry (by the importing or exporting economy) is correct. After eliminating all flows going to economies that are either obsolete or classified as "unspecified," and taking the 3-year average, we ended up with a sample of 1,126 positive observations. In the gravity equation below, we also made use of all zero observations between the 14 Pacific DMCs towards the 180 economies (including the Pacific DMCs), resulting in 2,520 observations.

8.2.2 Shipping Connectivity Data

As all the Pacific DMCs are island economies and share no land border with other countries (except for PNG and Timor-Leste, which have a land border with Indonesia), most can only be reached by ship or by air. Thus, we have tried to find detailed data that describe the connectivity of the Pacific DMCs by these two means of transportation.

The first dataset describes the connectivity of the Pacific DMCs in terms of the maritime network. To this end, we used a database called Sea-web. Since 2001, major ships and ports worldwide have used AIS equipment that automatically reports arrival and departure times to port authorities, mainly to avoid collisions. Today, all major ports (around 11,000 ports and terminals) and bigger ships (above 100 gross tonnage) have AIS devices installed. The resulting arrival and departure records are collected by the Lloyd's Registry Fairplay and made available online on the Sea-web website.[5] The database, which is generated by AIS signals, covers the vast majority of international ship traffic. Information on the movement of ships is refreshed and updated every 3 minutes.

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5 The information is accessible at www.sea-web.com for a fee. In addition, Lloyd's Registry Fairplay manages the International Maritime Organization Ship and Company Numbering Schemes on behalf of the International Maritime Organization providing unique identifiers for ships and ship owners.

Table 8.1 Overview of the Maritime Network Connections of Pacific Developing Member Countries in 2013
(number of active connections between origin and destination ports)

		Origin			
		Pacific DMC	Other Pacific	Asia	ROW
Destination	Pacific DMC	196 (821)	126 (428)	210 (428)	140 (21)
	Other Pacific	126 (474)			
	Asia	210 (426)			
	ROW	140 (45)			

( ) = frequency of voyages, DMC = developing member country, ROW = rest of the world.
Source: Sea-web (accessed 12 February 2017); author's calculations.

Using this database, we first looked at all connections between ports in the Pacific DMCs and with the rest of the world from 1 January 2013 to 31 December 2013. We were thus able to establish a matrix covering all maritime connections between ports in the 14 Pacific DMCs and with 34 other economies in the world (see Table 8.1). Overall, we counted 1,148 direct links.

In addition to direct links between economies, we tried to measure the frequency of connections between ports. Recent literature shows that the frequency of shipping connections reveals information about freight rates. In the case of the Caribbean islands, higher frequency means lower freight rates due to increased competition (Wilmsmeier and Hoffmann 2008). To obtain a frequency estimate, we downloaded the last 50 observations of each ship (as of 1 July 2014) that traveled through a port in a Pacific DMC in 2013. Using this information, we were able to estimate the frequency for each link. The total number of voyages was 2,643; however, the total frequency of connections may have been higher in 2013 because the last 50 observations reported by each ship do not necessarily cover the entire year. Nonetheless, we believe that our sample is representative of the shipping links over the full period.

The Sea-web website also holds information on the type of ship. We excluded all ship types that appear unrelated to international trade, such as research ships or cable layer ships. Our final sample includes eight ship types: bulk cargo, chemical tanker, container, fishing and trawler, general and refrigerated cargo, oil and gas tanker, product tanker, and passenger ships. For all ships we collected the ship name, gross weight, port and country of call, and arrival and sailing dates.

Table 8.2 Descriptive Statistics of Shipping Data

				Gross Weight (tons)			
No.	**Type of Ship**	**Number of Observations**	**Percent**	**Mean**	**Std. Dev.**	**Min**	**Max**
1	Bulk	158	6.10	17,835.80	17,777.95	2,551.00	106,367.00
2	Cargo	970	37.47	6,424.50	5,072.66	1,211.00	25,483.00
3	Chemical	199	7.69	14,119.18	16,568.96	1,997.00	50,672.00
4	Container	684	26.42	12,460.59	6,043.74	5,234.00	35,887.00
5	Fishing	299	11.55	1,616.17	608.01	349.00	3,415.00
6	Oil and gas	78	3.01	19,439.54	36,839.65	3,409.00	162,863.00
7	Passenger	153	5.91	60,295.03	33,035.25	235.00	90,090.00
8	Product tanker	48	1.85	25,009.58	23,879.61	1,584.00	65,162.00
	Total	**2,589**	**100.00**				

Max = maximum, Min = minimum, No. = number, Std. Dev. = standard deviation.
Source: Sea-web (accessed 12 February 2017); author's calculations.

We calculated voyage times in terms of the number of days between two ports in two different countries.[6] The descriptive statistics are presented in Table 8.2.

8.2.3 Flight Connectivity Data

As explained below, we used flight connectivity as the instrumental variable for shipping connectivity. Recently, more databases of international flight connections have emerged, and are being used by economic researchers, such as Arvis and Shepherd (2011), Yilmazkuday and Yilmazkuday (2014), and Helble and Mutuc (2014). We used the freely available database Openflights, which contains all flight routes worldwide as of January 2012 as well as the airline companies operating the routes (several companies can operate a single route).[7] We downloaded all routes with a Pacific DMC as either the origin or destination. Overall, we found 57 direct flight connections: 22 between Pacific DMCs and 35 between Pacific DMCs and other world economies.

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6 We excluded all movements of ships between ports within one economy.

7 Openflights. http://openflights.org/data.html (accessed 22 March 2017).

The geographical spread is as follows: 19 direct connections to other economies in the Pacifica, 11 direct connections to Asia, and 4 direct connections to the US.

In contrast to the shipping data, the route data are symmetric, as flights travel back and forth between two points. In the case of shipping, a single ship commonly travels not only between two ports, but continues to various additional destinations before returning to the port of origin.

Several of the 57 direct routes to the Pacific DMCs were maintained by more than one company. Openflights listed 117 connections to the Pacific DMCs as reported by the airlines; however, several of the flights were co-shared. To estimate the connection frequency, we counted the number of flights by all airlines (excluding co-shared flights) per week for each of the direct routes. As the Openflights website does not provide information on frequency, we researched this on the corresponding airline websites and found that 294 flights operated weekly on the 57 connections.

8.2.4 All Other Economy-Specific and Bilateral Data

For our gravity model analysis below, additional information on both economies and bilateral relationships is needed (see Appendix). The corresponding data were downloaded from the website of the Centre d'Etudes Prospectives et d'Informations Internationales, a leading French international economics research institute.[8]

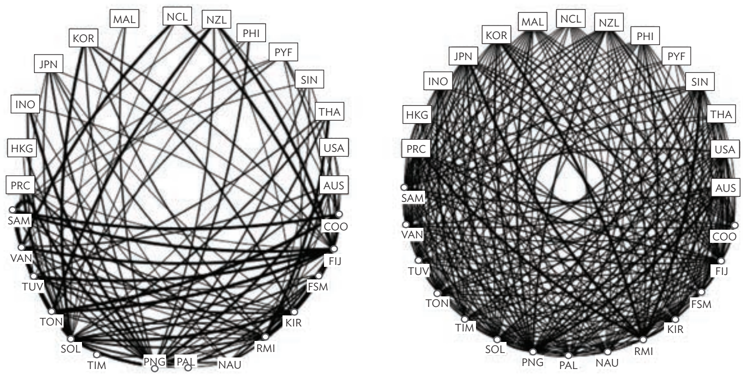
We used the following variables: (i) geographical distance between two economies, (ii) the use of a common official language or ethnic language spoken between trading partners, (iii) whether trading partners have been in a colonial relationship, and (iv) whether trading partners share a common colonizer. We excluded other dummy variables (such as contingency) for the Pacific DMCs as they only apply to a few cases. The variables used are described in detail in the Appendix.

8.3 Nodes Diagrams

One way to illustrate our datasets is to use node diagrams depicting all possible connections between nodes as well as the intensity of the connection. In Figure 8.2, direct shipping connections between Pacific DMCS and major partners are shown on the left. To increase readability, we ignored direct shipping links with weaker intensities (fewer than 20 entries in our sample). The thickness of the lines illustrates the

8 Centre d'Etudes Prospectives et d'Informations Internationales. www.cepii.fr (accessed 2nd April 2017).

Figure 8.2 Node Diagrams of Direct Shipping Connections and Trade Flows between Asia and the Pacific Region and within the Pacific



Ships Traveling To and Within the Pacific DMCs, 2013
(Thicker lines = more ships)

Average Trade Flows (Imports)
To and Within the Pacific DMCs, 2010–2012
(Thicker lines = more trade)

DMC = developing member country.
Note: Only those 14 economies with the most shipping connections to the Pacific DMCs are included.
Source: Author.

intensity of the shipping connection. The busiest connections within the Pacific DMCs were between PNG and Solomon Islands, while the busiest connections between the Pacific DMCs and other Pacific countries were between PNG and Australia, and Fiji and New Zealand. Outside the Pacific, the route between the People's Republic of China and PNG appears to be the busiest by far.

The right side of Figure 8.3 depicts the trade connections among the Pacific DMCs as well as between the Pacific DMCs and economies with major direct shipping links (the same list of countries as the left side). The trade web is very dense, as the Pacific DMCs export to many of the economies included in the graph. Compared to the trade graph, the shipping graph on the left appears very sparsely populated. This indicates that trade linkages are much more frequent than shipping connections, implying that a substantive amount of trade is not shipped directly but routed through one or more economies. It is well known that world trade is organized in a hub-and-spoke system (see, for example, Wilmsmeier and Notteboom [2009]). Although this architecture has been established partly following economic rationale, it often implies substantially higher trade costs for spoke economies compared to hub economies.

8.3 Methodology: The Gravity Equation

Over 50 years ago, the late Nobel Laureate Jan Tinbergen (1962) used a gravity model to predict bilateral trade flows. Like gravitational forces in physics, Tinbergen stipulated that the volume of trade between two countries would be a function of their distance as well as their masses. He found that, compared to other trade models such as that of Ricardo or Heckscher–Ohlin, the gravity model predicted actual trade flows much better. However, for many years the gravity model lacked a theoretical backing from economic theory.

In 1979, Anderson provided the first theoretical underpinning for this model. Over time, more trade models were developed from which a gravity equation could be derived. This literature was revived at the beginning of the 2000s by the seminal contributions of Eaton and Kortum (2002), and Anderson and van Wincoop (2003), who showed that neither the assumption of increasing return nor imperfect competition was needed to formulate a micro-founded gravity equation. After Melitz (2003) introduced the so-called "new-new" trade theory with heterogeneous firms, a corresponding gravity approach was soon developed, such as by Chaney (2008). Given the gravity model's success in predicting international trade flows and its strong theoretical backing, it has maintained its high popularity as a workhorse among trade economists.

The modeling of the gravity equation used in this chapter closely follows the presentation of Head and Mayer (2014). The general gravity model can be formulated as follows:

$$X_{ni} = GS_i M_n \emptyset_{ni} \qquad (1)$$

where X_{ni} stands for the trade flows to the destination market n from i, S_i measures the ability of country i to export to all destinations, M_n captures all characteristics of the destination market n, and bilateral trade costs and their impact on trade flows between n and i are captured by $\emptyset_{ni}$ where $0 \leq \emptyset_{ni} \leq 1$. G is the constant and ε_{ni} is the error term.

When taking logs of equation (1), we obtain the following equation:

$$\ln X_{ni} = \ln G + \ln S_i + \ln M_n + \ln \emptyset_{ni} + \varepsilon_{ni} \qquad (2)$$

The logs of the gross domestic product (GDP) of the exporting and importing countries were traditionally used as proxies for S_i and M_n. To observe the impact of capital and labor endowments on trade flows, the logs of GDP per capita and population have also been used in place of GDP. However, since the influential contribution by Anderson and van

Wincoop (2003), fixed effects for importer and exporter are commonly used instead. We followed this practice and used both importer and exporter fixed effects.

Our two datasets on trade in goods and services contain a substantive number of zero entries. In the trade literature we found an extensive discussion of how best to handle zero entries in empirical estimations (see, for example, Helpman et al. [2008]). In recent years, the approach that has gained the most popularity is that suggested by Santos Silva and Tenreyro (2006), who showed that the most appropriate approach is to use a (pseudo) Poisson maximum likelihood estimator. This method estimates the gravity equation in levels and takes care of the possible presence of heteroskedasticity. Following this study, we use a Poisson maximum likelihood estimator in our econometric approach, in addition to a traditional ordinary least squares approach.

8.4 Research Results

The gravity estimation results for goods trade are listed in Table 8.3. The first three columns were estimated using traditional ordinary least squares estimation, neglecting possible zero trade flows. The first column shows the results when we run a standard gravity equation excluding any variable for connectivity.

Our first observation is that the distance coefficient is substantially higher than usual. Many empirical studies find a distance coefficient of around –1.0 for goods trade (e.g., Kimura and Lee [2006]). For the Pacific economies, we observe a higher distance coefficient (–1.36). The distance variable in our estimation controls for the geographical remoteness of Pacific countries. The bigger magnitude compared to other empirical trade studies seems to indicate that Pacific economies face additional trade costs that make their integration into the global market particularly difficult. The other bilateral control variables yield several interesting results. First, a common official language has a positive effect on trade, whereas sharing any other language appears to have a negative effect on Pacific trade (both effects almost neutralize each other). Furthermore, Pacific economies seem to export more to economies with the same colonizer. Finally, the value of R-squared indicates that our model predicts about 60% of all export flows.

In column (2) we add the dummy variable measuring whether we observe a direct connection in a bilateral pair. The dummy variable is highly statistically significant at a magnitude of 1.52. As expected, a direct shipping connection is highly important for economies' export performance. Interestingly, the distance coefficient in column (2) falls to –0.85, compared to –1.36 in column (1). Thus, direct connectivity

Table 8.3 Gravity Estimation Results of Pacific Developing Member Country Exports (2011–2013 average)

Variables	(1) Log (Trade)	(2) Log (Trade)	(3) Log (Trade)	(4) Trade	(5) Trade
Log (Distance)	–1.36[a]	–0.85[b]	–0.39	–1.94[a]	–1.46[b]
	(0.343)	(0.350)	(0.339)	(0.616)	(0.741)
Common official language	0.73[c]	0.75[c]	0.61	–0.08	–0.05
	(0.422)	(0.426)	(0.424)	(1.234)	(1.274)
Common other language	–0.78[b]	–0.81[b]	–0.69[c]	–0.35	–0.39
	(0.355)	(0.360)	(0.355)	(1.054)	(1.079)
Ever in colonial relationship	0.68	0.56	0.43	1.57[a]	1.44[a]
	(0.535)	(0.545)	(0.522)	(0.347)	(0.340)
Common colonizer	0.56[c]	0.42	0.38	0.18	0.06
	(0.302)	(0.300)	(0.294)	(0.475)	(0.468)
Direct shipping connection		1.52[a]		0.37	
		(0.341)		(0.353)	
Log (Frequency)			1.11[a]		0.33[b]
			(0.137)		(0.153)
Observations	1,126	1,126	1,126	2,520	2,520
R-squared	0.60	0.61	0.62	–	–
Origin and Destination FE	Yes	Yes	Yes	Yes	Yes
Estimation Technique	OLS	OLS	OLS	Poisson	Poisson

( ) = robust standard errors, FE = fixed effects , OLS = ordinary least squares.
[a] $p<0.01$.
[b] $p<0.05$.
[c] $p<0.1$.
Source: Author's estimation.

appears to explain partly the high trade costs for some Pacific DMCs. In column (3), the variable measuring the connection frequency is introduced (given the collinearity between the dummy variable for direct connections and frequency we are unable to introduce the two variables simultaneously). The coefficient is again highly statistically significant. Higher shipping frequency increases trade, but less than having a direct connection. Once again, the distance coefficient falls and becomes statistically insignificant. Thus, shipping frequency appears to constitute another important element of trade costs.

In columns (4) and (5) we take zero trade flows into account. The distance coefficient is now even larger. The economic intuition is that the remoteness of the Pacific economies cuts them off from otherwise positive trade links. The Poisson estimation technique reveals that trade costs become an even heavier impediment for international trade. The coefficient of the dummy variable measuring direct connectivity decreases to 0.37, and the coefficient measuring frequency falls to 0.33. The coefficients may be smaller because both connectivity variables are correlated with distance, especially when we include zero trade flows. Finally, the Poisson regression results show the important role of colonial links.

Overall, we find that trade costs play a key role in shaping the trade of Pacific economies. However, as several of the Pacific economies are very small, establishing new shipping links or increasing the frequency of existing connections might not be economically feasible or desirable. The Pacific economies lend themselves to a hub-and-spoke arrangement for shipping, which should be coordinated at the regional level.

8.5 Robustness Checks

The existence of shipping links cannot be assumed to be fully exogenously determined, but rather the opposite. The connectivity of an economy is in most cases a function of the demand for the transportation of goods and services. To control for endogeneity we apply an instrumental variable approach, a method based on the idea of having an additional variable uncorrelated to the error term in equation (2), but partially correlated to the variable that suffers from endogeneity. In our case, the connectivity variables (direct connection as well as frequency) suffer from endogeneity. To control for the latter, we propose using flight connections and frequency as instruments for measuring shipping connectivity. These instruments yield the results in Table 8.5.

The robustness checks for the trade in goods equations confirm our previous results. In column (1) the dummy variable for direct connection remains highly statistically significant, and even increases in magnitude. The distance coefficient turns positive, probably related to the fact that the direct flight connection is also a function of distance, which is suboptimal for the instrumental variable method. The results of the instrumental variable estimation for the frequency yield very similar results. The coefficient measuring the shipping connection frequency is again highly statistically significant and large in magnitude. The endogeneity tests in columns (1) and (2) show that endogeneity is indeed a concern.

Table 8.5 Gravity Estimation Results Using an Instrumental Variable Approach

Variables	(1) Log (Trade)	(2) Log (Trade)
Log (Distance)	1.22[a]	0.39
	(0.582)	(0.388)
Common official language	0.77	0.59
	(0.477)	(0.394)
Common other language	−0.86[a]	−0.69[a]
	(0.418)	(0.346)
Ever in colonial relationship	0.08	0.23
	(0.609)	(0.495)
Common colonizer	−0.16	0.19
	(0.329)	(0.256)
Direct connection	7.75[b]	
	(1.456)	
Log (Frequency)		1.96[b]
		(0.310)
Endogeneity test	0.000	0.002
Observations	1,126	1,095
R-squared	0.42	0.61
Origin and destination FE	Yes	Yes
Estimation technique	IV	IV

( ) = robust standard errors, FE = fixed effects , IV = instrumental variable.
[a] $p<0.05$.
[b] $p<0.01$.
Source: Author's estimation.

The stability of our results can also be tested by changing the distance measure. Our model measures the distance between trading partners by the geographical distance; however, this is only a rough approximation, especially for smaller economies with few direct shipping or flight connections that rely on their connections to a hub. To account for this, we calculated the minimum distance between trading partners given the underlying connectivity architecture. For example, if A is connected to B only through C, we calculated the sum of geographical distances from A to C, and B to C. The estimation results are in Table 8.6.

Table 8.6 Gravity Estimation Results of Trade Flows Using Full Distance

	(1)	(2)	(3)
Variables	**Log (Trade)**	**Log (Trade)**	**Log (Trade)**
Log (Full distance)	–1.79[a]	–1.13[b]	–0.25
	(0.382)	(0.487)	(0.497)
Common official language	2.06[b]	2.28[b]	2.16[b]
	(0.864)	(0.881)	(0.878)
Common other language	–1.76[a]	–1.86[a]	–1.71[a]
	(0.557)	(0.567)	(0.535)
Ever in colonial relationship	1.32[c]	1.23[c]	0.97[c]
	(0.680)	(0.686)	(0.582)
Common colonizer	0.76[c]	0.63	0.51
	(0.432)	(0.421)	(0.399)
Direct connection		0.92[b]	
		(0.424)	
Log (Frequency)			0.97[a]
			(0.182)
Observations	338	338	338
R-squared	0.68	0.69	0.71
Origin and destination FE	Yes	Yes	Yes
Estimation technique	OLS	OLS	OLS

() = robust standard errors, FE = fixed effects, OLS = ordinary least squares.
[a] $p<0.01$.
[b] $p<0.05$.
[c] $p<0.1$.
Source: Author's estimation.

The sample size for goods trade flows is now smaller, as we only included countries with either a shipping or flight connection to the Pacific. However, the results found earlier (Table 8.5) are very stable. As expected, the distance coefficient increases significantly. In the other columns all connectivity variables are highly statistically significant and of similar magnitude to the previous results. In summary, using a different distance measure confirms the results found earlier (Table 8.5).

8.6 Discussion and Conclusion

8.6.1 Discussion

This chapter highlights the potential of increased connectivity for the Pacific DMCs. However, several words of caution are in order.

First, we face certain data limitations with regard to our dependent variables. For goods exports, it would be ideal to estimate the total volume of trade (in tons) instead of the value (in current US dollars), as we are primarily interested in assessing the effect of physical shipping connectivity. However, in international trade statistics, apart from the goods' value, products are measured by different units (e.g., weight in kilograms or liters), making it very difficult to estimate the total volume of bilateral trade flows. The value of a bilateral trade flow is often a good proxy for the volume. However, in some cases this might overestimate or underestimate the trade volume. For example, certain Pacific DMCs export large amounts of precious raw materials, such as gold, whose weight is relatively low compared to their value in the trade statistics.

Second, certain caveats about our econometric estimations should be mentioned. Although we have tried to control for the problem of endogeneity, the instruments used thus far might not be perfect, and future researchers should try to control for this more effectively. Moreover, our econometric model estimates average marginal effects; however, not every new connection or increase in the frequency of connections will have the same effect.

8.6.2 Conclusion

In this chapter we outlined strong evidence that the connectivity of Pacific economies is an important determinant of their integration into the world economy. Applying a gravity model to goods flows yields several new insights. First, the remoteness of Pacific DMCs (measured by their geographical distance from their trading partners) acts as major barrier to trade. On average, Pacific DMCs face substantially higher trade costs compared to world averages for trade in goods. Second, the gravity equation shows that direct transportation links with trading partners more than double trade flows. Finally, higher transportation frequency is another important determinant of trade performance.

The contributions of this chapter are twofold. First, we exploited a database on shipping connections for the first time and combined it with international trade flows. The initial results of this exercise are promising. We now better understand how the shipping network in the

Pacific compares to the trade network. In the future, it will be important to access comprehensive historical shipping data, which will allow us to assess various policy interventions. For example, several Pacific economies are currently upgrading the physical infrastructure of their ports. We could exploit the database to measure the impact of these major port infrastructure investments. Furthermore, it would be highly interesting to study which port infrastructure would be economically optimal for the region. Given the small size of many Pacific economies not every port can operate efficiently as a hub. By combining trade and shipping data, one could calculate the optimal hub-and-spoke arrangement for the region. Another application would be to measure the economic integration within and between regions in real time. Finally, compared to international trade data, shipping data are recorded in real time and could therefore also be used as proxies for swings in international trade.

Finally, it must be noted that more needs to be done to increase the connectivity of the Pacific beyond upgrading physical infrastructure. For example, it may be helpful to introduce and ensure competition in the transportation sector, or lower bureaucratic or other burdens related to connectivity. Whether improved connectivity will help stimulate economic growth in the medium- to long-term will depend crucially on the capacity of the Pacific DMCs to respond to growing demand. Ideally, increasing connectivity will go hand in hand with an increase in supply and demand.

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Appendix

Summary of Variables

Variable	Unit	Description
Imports	Current United States dollars	Imports of economy i to economy j in year t
Exports	Current United States dollars	Exports of economy i to economy j in year t
Distance	Kilometers	Geographical distance between the two economies' most populated cities
Contingency	0;1	Unity if two economies share a land border, zero otherwise.
Common official language	0;1	Unity if two economies share an official or primary language, zero otherwise.
Common ethnic language	0;1	Unity if a common language is spoken by at least 9% of the population in both economies, zero otherwise.
Colony	0;1	Unity if the economy pair has ever been in a colonial relationship, zero otherwise.
Common colonizer	0;1	Unity if the two economies share a common colonizer, zero otherwise.
Flight connection	0;1	Unity if a flight route exists between two economies, zero otherwise.
Flight frequency	0–7	Number of flight connections between two economies per week.
Shipping connection	0;1	Unity if at least one ship traveled from the economy of origin to the economy of destination in 2013, zero otherwise.
Shipping frequency	Number of ships	Total number of ships that travelled from the economy of origin to the economy of destination in 2013.

Source: Author.

9

The Impact of Infrastructure on Trade and Economic Growth in Selected Economies in Asia

Normaz Wana Ismail and Jamilah Mohd Mahyideen

9.1. Background

Many economies in Asia have exhibited a bandwagon effect by signing trade integration agreements and lowering tariff barriers to increase trade. For example, members of the Association of Southeast Asian Nations (ASEAN) now enjoy tariff import rates as low as 0%, and ASEAN has also recently expanded to include the People's Republic of China (PRC), India, Japan, and the Republic of Korea. Extensive evidence has also shown that improving international transport, such as through tariff liberalization, fosters international trade (Andriamananjara, Dean, Feinberg, Ferrantino, Ludema, and Tsigas 2004; Baier and Bergstrand 2007). Facilitating trade is necessary to minimize the cost of trade and to provide access to markets.

In Asia, the trade pattern has also recently shifted from finished products to intermediate and processing products. Economies that specialize in different tasks have added value to parts and components, which are imported for processing and assembly into semi-finished or finished products and then re-exported to the global supply chain before reaching end-users.

Table 9.1 shows the performance of exports and imports in Asia. The PRC, India, Singapore, Thailand, and Viet Nam increased their ratio of exports to gross domestic product (GDP) from 16% in 2000 to 60% in 2012. The agricultural export ratio further increased by 42% in Viet Nam (from 1.9% in 2000 to 2.7% in 2012), 49% in Thailand, 52% in the Philippines, 55% in India, and 63% in Indonesia. Intra-Asian trade increased by more 200% from 2003 to 2013.

With such increased trade, trade cost has become a major concern. According to Anderson and Van Wincoop (2003), trade cost was estimated

Table 9.1 Trade Performance in Asia, 2000 and 2012

	Hong Kong, China	India	Indonesia	Malaysia	PRC	Philippines	Republic of Korea	Singapore	Thailand	Viet Nam	East Asia	OECD
2000												
Agricultural exports (% of exports)	0.4	1.3	3.6	2.6	1.1	0.6	1.0	0.5	3.3	1.9	1.7	1.9
Agricultural imports (% of imports)	1.2	3.5	7.2	1.3	4.8	1.4	3.2	0.4	3.0	2.9	4.2	2.0
Exports of goods and services (% of GDP)	141.8	12.8	41.0	119.8	20.7	51.4	35.0	189.2	66.8	50.0	31.2	22.6
Imports of goods and services (% of GDP)	137.4	13.7	30.5	100.6	18.7	53.4	32.9	176.9	58.1	53.3	27.6	23.2
Manufacturing exports (% of exports)	95.3	77.8	57.1	80.4	88.2	91.7	90.7	85.6	75.4	42.7	82.4	78.5
Manufacturing imports (% of imports)	90.5	46.7	60.9	84.8	75.1	78.0	62.2	81.8	76.7	72.7	75.3	73.4

continued on next page

Table 9.1 *continued*

	2012											
Agricultural exports (% of exports)	3.4	2.0	5.9	2.4	0.5	0.8	1.1	0.3	4.9	2.7	1.6	1.6
Agricultural imports (% of imports)	0.6	1.8	2.6	2.5	3.9	0.6	1.6	0.4	1.8	3.3	3.2	1.3
Exports of goods and services (% of GDP)	225.6	24.4	24.6	85.3	24.2	30.8	56.3	195.4	75.0	80.0	31.2	27.2
Imports of goods and services (% of GDP)	224.4	31.1	25.0	73.7	21.5	33.9	53.5	172.8	73.8	76.5	28.7	27.8
Manufacturing exports (% of exports)	68.6	64.8	36.2	61.7	93.9	82.6	85.1	69.8	73.8	69.4	82.6	71.4
Manufacturing imports (% of imports)	89.8	43.2	62.4	69.0	55.2	63.9	50.0	60.2	68.7	73.7	59.8	64.9

GDP = gross domestic product, OECD = Organisation for Economic Co-operation and Development, PRC = People's Republic of China.
Source: World Bank. World Development Indicators.

at 170% (in terms of ad valorem equivalent) for industrialized countries. The major categories of trade cost were transport (21%), border-related trade barriers (44%), and retail and wholesale distribution (55%). Trade cost is even larger in developing countries, many of which are found in Asia; thus, infrastructure is relevant to trade facilitation, particularly in minimizing trade cost and further enhancing competitiveness.

Infrastructure is vital to economic development, as it is key to achieving higher and stable economic growth. Although most economies in Asia have already developed their basic infrastructure, the focus of development is usually on quantity rather than quality. According to the World Economic Forum (2014), well-developed infrastructure not only reduces the distance between regions but also integrates national markets and connects them to other economies at a low cost.

Trade facilitation is partially defined as the systematic rationalization of customs procedures and documents; it further encompasses all measures that affect the movement of goods between buyers and sellers along the entire international supply chain (Asian Development Bank 2009; United Nations Economic and Social Commission for Asia and the Pacific 2009). Trade facilitation encompasses both hard and soft infrastructure (Portugal-Perez and Wilson 2012). Hard infrastructure, often referred to as physical infrastructure, refers to roads, airports, ports, and rail; indicators include quality and quantity. The information and communication technology (ICT) sector is also regarded as physical infrastructure, comprising the following indicators: use, availability, absorption, and government prioritization of ICT.

Soft infrastructure refers to matters related to border and transport efficiency, and indicators measure the level of customs efficiency and domestic transport signified in the time taken for, cost of, and number of documents needed for export and import procedures. It also includes the business and regulatory environment, and indicators include regulations, transparency, irregular payments, favoritism, and measures to combat corruption.

This study examines whether the type of infrastructure plays an important role in promoting trade and enhancing economic growth.[1] It seeks to identify the role of infrastructure in reducing trade costs, thus raising the volume and value of trade. In addition, it aims to provide empirical evidence to identify the importance of infrastructure quality for growth enhancement.

The specific objectives of this study are to (i) examine the impact of hard and soft infrastructure on exports, (ii) investigate whether hard and

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[1] Asian economies included in the sample are the PRC; Hong Kong, China; India; Indonesia; the Republic of Korea; Malaysia; the Philippines; Singapore; Thailand; and Viet Nam.

soft infrastructure matter for manufacturing and agricultural exports, and (iii) investigate the effects of quantity and quality of infrastructure on economic growth.

9.2 Infrastructure Development in Asia

Table 9.2 shows the overall performance, improvement (with 7 as the best performance), and rank of infrastructure in Asia from 2006 to 2013. A sizable gap in terms of index and rank still exists, especially in Southeast Asia, with the exception of Singapore.

In terms of the quality of infrastructure index reported by the Global Competitiveness Index for 2013, Hong Kong, China and Singapore were among the best-performing economies in the world. The Republic of Korea was also in the top 20 due to the quality of its roads, rail, and other transport infrastructure. However, the ranks of India, the Philippines, and Viet Nam reveal a large quality gap in the region (Table 9.3).

Table 9.2 Infrastructure Performance—Selected Economies in Asia, 2006, 2010, 2013

	2006		2010		2013	
	Value	Rank	Value	Rank	Value	Rank
People's Republic of China	3.73	52	4.31	46	4.46	48
Hong Kong, China	6.22	4	6.54	2	6.72	1
India	3.39	62	3.47	76	3.60	84
Indonesia	2.81	78	3.20	84	3.75	78
Republic of Korea	5.21	23	5.60	17	5.92	9
Malaysia	5.34	20	5.05	26	5.09	32
Philippines	2.64	88	2.91	98	3.19	98
Singapore	6.35	3	6.35	4	6.50	2
Thailand	4.68	29	4.57	40	4.62	46
Viet Nam	2.61	90	3.00	94	3.34	95
Low-income	1.59		2.00		2.32	
Lower middle-income	1.87		2.53		2.87	
Upper middle-income	2.54		2.93		3.53	
High-income: OECD	5.20		5.23		5.47	
High-income: Non-OECD	3.44		4.79		4.98	

OECD = Organisation for Economic Co-operation and Development.
Source: World Economic Forum. Global Competitiveness Index. http://www.weforum.org/reports (accessed 31 January 2017).

Table 9.3 Selected Quality of Infrastructure Indicators, 2013

Series	Attribute	People's Republic of China	Hong Kong, China	India	Indonesia	Republic of Korea	Malaysia	Philippines	Singapore	Thailand	Viet Nam
Quality of overall infrastructure, 1–7	Value	4.27	6.55	3.89	4.00	5.62	5.52	3.73	6.36	4.53	3.41
	Rank	74	2	85	82	23	25	98	5	61	110
Quality of roads, 1–7	Value	4.50	6.24	3.65	3.74	5.82	5.44	3.56	6.22	4.88	3.08
	Rank	54	5	84	78	15	23	87	7	42	102
Quality of rail infrastructure, 1–7	Value	4.70	6.45	4.76	3.53	5.68	4.78	2.06	5.64	2.55	2.97
	Rank	20	3	19	44	8	18	89	10	72	58
Quality of port infrastructure, 1–7	Value	4.48	6.59	4.19	3.88	5.53	5.42	3.35	6.75	4.50	3.68
	Rank	59	3	70	89	21	24	116	2	56	98
Quality of air transport infrastructure, 1–7	Value	4.54	6.74	4.76	4.51	5.75	5.77	3.54	6.75	5.53	4.04
	Rank	65	2	61	68	22	20	113	1	34	92
Transport infrastructure	Value	4.92	6.60	4.71	4.44	5.86	5.40	3.33	6.45	4.83	3.35
	Rank	26	2	34	40	9	15	84	3	30	81

Note: 1 represents the worst, and 7 the best.
Source: World Economic Forum. Global Competitiveness Index. http://www.weforum.org/reports (accessed 31 January 2017).

Table 9.4 Information and Communication Technology in Asia, 2013

Series	Attribute	People's Republic of China	Hong Kong, China	India	Indonesia	Republic of Korea	Malaysia	Philippines	Singapore	Thailand	Viet Nam
Fixed telephone lines per 100 people	Value	20.6	60.6	2.5	15.5	61.9	15.7	4.1	37.8	9.1	11.4
	Rank	58	5	118	82	2	79	109	29	96	88
Mobile phone subscriptions per 100 people	Value	81.3	227.9	68.7	115.2	110.4	140.9	106.8	153.4	120.3	149.4
	Rank	116	1	123	62	70	27	81	18	49	21
Population using the internet, %	Value	42	73	13	15	84	66	36	74	27	39
	Rank	78	33	120	113	15	39	87	29	97	83
Fixed broadband internet subscriptions per 100 people	Value	13.0	31.6	1.1	1.2	37.6	8.4	2.2	26.1	6.2	5.0
	Rank	49	15	106	105	5	66	97	20	75	79
International internet bandwidth, kilobytes per second per user	Value	4.165	1,239.000	5.200	17.200	26.000	16.400	14.300	391.100	25.000	13.500
	Rank	118	2	113	74	60	77	85	4	62	87
Mobile broadband subscriptions per 100 people	Value	17.24	73.48	4.90	31.86	106.04	13.52	3.82	123.29	0.14	18.99
	Rank	71	10	99	53	4	79	104	1	131	69
Information and communication technology use	Value	2.34	6.22	1.36	2.26	5.76	2.85	2.01	6.06	2.17	2.41
	Rank	79	8	124	84	16	71	93	11	89	78

Source: World Economic Forum. Global Competitiveness Index. http://www.weforum.org/reports (accessed 31 January 2017).

In addition to physical infrastructure, ICT is vital to trade and economic growth. ICT costs have been decreasing in Asia due to investment in ICT infrastructure. Table 9.4 shows that Hong Kong, China and Singapore were among the top 30 economies in the world in terms of ICT infrastructure, but India and Indonesia were underdeveloped, especially with respect to broadband internet and percentage of individuals using the internet.

9.3. Literature Review

9.3.1 Infrastructure and Trade

One approach used to measure the impact of trade facilitation on trade flows is the gravity model, which assesses the impact of trade facilitation reforms on bilateral trade flows. Substantial evidence links improved trade facilitation with improved trade flows. For example, in a study by Wilson, Mann, and Otsuki (2005) of 75 economies, it was noted that improved trade facilitation could increase trade by 10%. This study supported an earlier study by Wilson, Mann, and Otsuki (2003) of Asia and the Pacific region, which demonstrated that improving trade facilitation increased intra-Asia-Pacific Economic Cooperation (APEC) trade by 21%. Moreover, Hertel and Mirza (2009) examined the impact of trade facilitation reforms in South Asia, finding that such reforms resulted in a 75% increase in intraregional trade and a 22% increase in trade with other regions. Shepherd and Wilson (2009) reported that trade in Southeast Asia increased by 7.5% thanks to trade facilitation reforms, such as increasing port quality.

Portugal-Perez and Wilson (2012) assessed the impact of four indicators related to trade facilitation—physical infrastructure, ICT, border and transport efficiency, and the business and regulatory environment—on the export performance of 101 developing economies. Unlike previous studies that used principal component analysis, this study used factor analysis to derive the aggregate indicator. Accordingly, physical infrastructure was found to have the greatest impact on exports. In addition, utilizing a gravity model approach, Hernandez and Taningco (2010) addressed behind-the-border measures that influenced bilateral trade flows in East Asia, such as telecommunications services, quality of port infrastructure, time delays in trade, and depth of credit information. They noted that their impacts varied across sectors or product groups.

Other studies that have applied the gravity model also emphasized the crucial role of infrastructure on trade. Shepherd and Wilson (2009) discovered that bilateral trade flows in Southeast Asia were affected by transport infrastructure, mainly ports and ICT. Hoekman and Nicita (2008) found that poor roads and ports, poorly performing customs agencies and procedures, weak regulatory capacity, and limited access to finance and business services affected trade. Wilson, Mann, and Otsuki (2005) extended the gravity model to trade facilitation measures and to a larger sample of 75 economies, positing that port efficiency and the proxies for infrastructure quality for the services sector, such as the use, speed, and cost of the internet, significantly affected trade flows. Wilson, Mann, and Otsuki (2003) also found that improving port and airport efficiency could positively impact intra-APEC trade.

Bougheas, Demetriades, and Morgenroth (1999) developed a gravity model to analyze the effect of infrastructure on trade volume via its influence on transport costs; they found that infrastructure had a significant and positive relationship to the level of infrastructure and trade volume. As a result, differences in transport costs among economies may highlight differences in their ability to compete in international markets. Furthermore, differences in the volume and quality of infrastructure may account for differences in transport costs and, hence, variations in competitiveness. Better transport services and infrastructure improve international market access and increase trade.

Limao and Venables (2001) employed a gravity model similar to that developed by Bougheas, Demetriades, and Morgenroth (1999), which included dummy variables representing possibilities of transit. Infrastructure was measured by variables including paved and unpaved roads, railways, and telephone lines. Infrastructure was found to be an important factor in determining transport costs, especially for landlocked countries. Limao and Venables (2001) estimated that differences in infrastructure accounted for 40% of transport costs for coastal countries and 60% for landlocked countries.

Adopting the study by Limao and Venables (2001), Nordas and Piermartini (2004) investigated the role of infrastructure on trade in the clothing, automotive, and textile sectors. Indicators included the quality of airports, roads, ports, and telecommunications, and the time required for customs clearance. It also incorporated bilateral tariffs. Their study proved that trade performance was significantly affected by infrastructure quality, especially port efficiency. Timeliness was more significant for export competitiveness in the clothing sector, while access to telecommunications in the automotive sector was more significant. It also concluded that, even after the quality of infrastructure was included, distance remained a significant factor.

Djankov, Freund, and Pham (2010) claimed that infrastructure directly affected transport costs by influencing the type of transport used and delivery time of the goods. By using data on time to export and import, they estimated the impact of delays on trade, showing that trade decreased by at least 1% for every extra day taken to move goods from the warehouse to the ship, comparable to an increase in the distance of an economy from its trading partner by 70 kilometers.

Anderson and Van Wincoop (2004) demonstrated that trade costs were equivalent to a 170% ad valorem tax for industrial economies. They estimated that transport costs represented 21% of 170% total trade in industrialized economies, while border-related barriers represented 44%, and distribution costs represented 55%. Time cost was particularly significant for perishable or other time-sensitive goods. Hummels (2001) discovered that the time cost of 1 day in transit for United States imports was equivalent to an ad valorem tariff rate of 0.8%, indicating a corresponding 16.0% tariff rate on an average trans-Pacific shipment of 20 days. Thus, improvements in infrastructure services that reduce delays in transit times, border-crossing procedures, or ports affect an economy's propensity to trade.

While few studies have investigated ICT's effect on trade flows, Fink et al. (2005) revealed that that the high cost of making a telephone call had a significant negative effect on bilateral trade flows. Further, ICT had a greater impact on the trade of differentiated products than on that of homogenous products. Nicoletti et al. (2003) found that ICT was particularly important for trade-in services due to its high dependence on well-developed infrastructure in both exporting and importing economies.

By using principal components to construct two indicators on infrastructure and institutional quality, Francois and Manchin (2007) found that institutional quality, along with transport and communications infrastructure, was a significant determinant of an economy's export levels as well as prospective exports. The results of this study support the belief that export performance depends on institutional quality and access to communications and transport infrastructure. In addition, Méon and Sekkat (2006) observed a positive relationship between poor institutional quality and low-quality manufacturing exports. Compared to government effectiveness or the rule of law, control of corruption was the most significant factor related to manufacturing exports. Another study by Anderson and Marcoullier (2002), who used data on contractual enforcement and corruption, discovered that lower institutional quality was associated with a negative effect on trade. Other similar empirical evidence is found in Depken and Sonora (2005) and Levchenko (2007).

Several studies have highlighted the significance of other forms of institutional quality, such as contract enforcement procedures, investor protection, and the rule of law on international trade. Ranjan and Lee (2007) employed a gravity model to examine the link between trade volumes and contract enforcement, suggesting that trade volumes were affected by the efficiency of contract enforcement. This finding was consistent with that of Duval and Utoktham (2009), who pointed out that if domestic contract enforcement procedures were shortened and simplified to that of the average of the member countries of the Organisation for Economic Co-operation and Development (OECD), it could raise merchandise exports by up to 27%. The impact of investor protection on trade was also studied by Hur, Raj, and Riyanto (2006), who noted that improved investor protection could stimulate economies' export and trade balances with relatively more intangible assets.

Several studies have tested the effect of transparency in customs administration and trade policy. Helble, Shepherd, and Wilson (2009), with their study on transparency in the trading environment for APEC members, used predictability and simplification measures to develop a new measurement of transparency, concluding that improving transparency in trade policy could reduce trade costs and subsequently boost intraregional trade. Using a sample of 126 economies, Sadikov (2007) showed that troublesome business registration procedures and export signature requirements could negatively affect exports, and the impact was worse for differentiated products than for homogeneous goods.

Some studies have also examined the link between trading time and trade flows. Djankov, Freund, and Pham (2010), in a sample of 126 economies on the length of time needed to transfer products from the factory to the ship, found that a delay of 1 day reduced trade by 1%, and the impact was larger for time-sensitive products such as agricultural goods. Duval and Utoktham (2009) showed a negative relationship between delivery cost and exports, in which a 5% decrease in the cost of delivering a good to the closest port could increase exports by at least 4%.

9.3.2 Infrastructure and Growth

The theoretical analysis of the effect of infrastructure on growth lies at the root of growth theory. Arrow and Kurz (1970) incorporated infrastructure into the theory of growth literature. Infrastructure, as measured by public capital, was treated as an additional input in the aggregate production function in the framework of Ramsey-type exogenous growth models. Barro (1990) analyzed the impact of public capital in the framework of the endogenous growth model, and Futagami, Morita, and Shibata (1993) extended the study by adding private capital stock.

Empirical literature supports the role of infrastructure in promoting growth, such as in Aschauer (1989), Easterly and Rebelo (1993), and the World Bank (1994). The World Bank (1994) reviewed the importance of infrastructure on productivity growth and pointed out that infrastructure might influence economic development through its impacts on economic growth, poverty alleviation, and the environment. Economies with adequate and efficient infrastructure services had higher productivity growth than those with lower and inefficient infrastructure services. In addition, Canning (1998) provided a dataset on physical infrastructure stocks such as roads, paved roads, rail lines, electricity-generating capacity, telephones, and telephone lines for 152 economies for 1950–1995. This dataset contained descriptions of physical infrastructure constructed from the annual database. Telephones and paved roads significantly impacted growth, while the other forms of infrastructure did not.

A few studies have focused specifically on the relevance of infrastructure to growth in East Asia. Seethepalli, Bramati, and Veredas (2008) looked at infrastructure subsectors, such as energy, sanitation, water supply, transport, and telecommunications, by applying standard growth regressions to 16 economies in East Asia. By controlling for the level of investment and human capital, the study showed a significant positive relationship between infrastructure and economic growth in all infrastructure indicators. It also examined whether the relationship between infrastructure and growth was influenced by five variables: the degree of private participation in infrastructure, quality of governance, extent of rural–urban inequality in access to infrastructure, income levels, and geography. Only telecommunications and sanitation supported an a priori hypothesis, while a contradictory result was found for roads.

In a similar study, Straub (2008) examined the impact of infrastructure investment on East Asia's economic growth using a growth-accounting framework and cross-country regression. Although the study used a set of economies similar to that used by Seethepalli, Bramati, and Veredas (2008), the findings showed no significant impact of infrastructure on growth, contradicting the results of Seethepalli, Bramati, and Veredas (2008) when using a production function. When using cross-country growth regressions, the results were much weaker than those of Seethepalli, Bramati, and Veredas (2008), despite the use of infrastructure stocks rather than flows to lessen the problem of reverse causation.

Straub and Terada-Hagiwara (2011) extended this study using physical infrastructure indicators across four sectors: telecommunications, energy, transport, and water. Growth regressions and growth accounting were used, showing that the growth rate of stocks had a positive and significant impact on the growth rate of economies in the East Asia and Pacific region and South Asia for most infrastructure indicators. However, the results of the growth-accounting exercise revealed that positive and significant effects of infrastructure on total factor productivity growth were only observed in the PRC, the Republic of Korea, and Thailand for the telecommunications and energy indicators.

Calderón and Chong (2009) provided a comprehensive assessment of the impact of infrastructure development on economic growth in Africa by using physical indicators in the telecommunications, power, and transport sectors. Data for 136 countries for 1960–2005 were regressed by using non-overlapping 5-year period observations. To address econometric issues such as unobserved country- and time-specific effects as well as potential reverse causality, an instrumental variable technique was employed. The study evaluated the impact on per capita growth of faster accumulation of infrastructure stocks and of enhanced quality of infrastructure services. The findings showed that growth was positively affected by rapidly accumulated infrastructure stocks and better-quality infrastructure services. The study also found that Africa is likely to gain greater benefits from larger stocks of infrastructure than from improving the quality of the existing infrastructure.

Calderón and Servén (2008) assessed the effects of infrastructure on economic growth and inequality, with a specific focus on sub-Saharan Africa. Their empirical results were based on a dataset of infrastructure quantity and quality indicators involving more than 100 economies covering 1960–2005. They demonstrated that an increase in the volume of infrastructure stocks and improved infrastructure quality positively impacted long-term growth and negatively impacted income inequality.

9.4 Empirical Strategy

9.4.1 Impact of Infrastructure on Trade

The first objective of this study is to examine the effects of infrastructure on trade flows in selected economies in Asia. Following the literature, an augmented gravity model was used to analyze the different types of infrastructure on bilateral trade flows in Asia. The estimation was made using the following equation:

$$lnX_{ijt} = \beta_0 + \beta_1 lnGDP_{jt} + \beta_2 lnGDP_{jt} + \beta_3 lnEndow_{tijt} + \beta_4 lnDist_{ij}$$
$$+\beta_5 Lang_{ij} + \beta_6 INFRA_{it} + \beta_7 INFRA_{jt} + \beta_8 HI_i + \beta_9 HI_j + \varepsilon_{ijt} \quad (1)$$

where

i	denotes	economies in Asia;
j	denotes	Asian trading partner (i.e., Asia is among its 20 export destinations);
Xijt	denotes	the level of exports from the i-th economy to the j-th economy in year t;
GDP_{it}	denotes	exporters' real GDP in year t;
GDP_{jt}	denotes	importers' real GDP in year t;
$Dist_{ij}$	denotes	distance in kilometers between capitals of economies i and j;
$Endow_{ijt}$	denotes	relative endowment in absolute difference of GDP per capita between economies i and j in year t;
$Lang_{ij}$	denotes	the dummy for common language is 1 when economies i and j have the same language, or generally share the same linguistic heritage;
$INFRA_{it}$	denotes	exporters' infrastructure in year t;
$INFRA_{jt}$	denotes	importers' infrastructure in year t;
HI_i	denotes	the dummy for high-income exporters is 1 when economy i is high-income;
HI_j	denotes	the dummy for high-income importers is 1 when economy j is high-income

The GDP of both exporters and importers was a proxy for the market size, and expected to correlate positively with exports, as the bigger the market size, the greater the likelihood of having more trade links. The relative endowment referred to the absolute difference of GDP per capita between exporters and importers to capture the level of development. The expected result was ambiguous, because the sample economies were mixed. The closer the income gap, the more likely the economy was to trade with similar-income economies and was expected to have a negative result. Transport costs were captured by a measure of distance between the two economies. This distance was negatively related to the trade volume between them; more trade occurs between economies within a short distance of each other. A common language to capture the information cost was a dummy variable, which took the value of 1 if the two economies shared a common language, and 0 otherwise.

Infrastructure (*INFRA*) was divided into two categories, hard and soft. Hard infrastructure was divided into (i) transport infrastructure (air, road, railway, and port); and (ii) ICT infrastructure (telephone, mobile, broadband, internet user, and internet security). Meanwhile, the variables used for soft infrastructure include documentation, cost to import and export, and time to import and export. To understand the impact better, the estimation was carried out by testing the type of infrastructure for both exporters and importers.

The model also included a dummy variable equal to 1 if exporters and importers were high-income economies, and 0 otherwise. The variables were used to control in the case of bias estimation with mixed sample economies. The dummy variables should have had more potential to trade with economies in Asia and thus have had positive and significant results. This study also estimated the impact of both hard and soft infrastructure on exports in the agriculture and manufacturing sectors. The same model was applied to the variables AX (agricultural exports) and MX (manufacturing exports). Agriculture should have impacted transport infrastructure rather than ICT infrastructure, but both sectors should have had the same impact on soft infrastructure.

The econometric issues of using a random-effect or fixed-effect model were considered. A random-effect model is a more appropriate approach for estimating typical trade flows through a randomly drawn sample of trading partners, particularly from a larger population. However, the fixed-effect model is a better choice for estimating trade between ex-ante predetermined selections of economies (Egger 2000). In the case of the absence of any correlation between observable and panel-specific error terms, the random-effect approach is preferred. Implicitly, the fixed-effect model assumes that all explanatory variables are correlated with the unobserved effects or the specific error term that eliminates this correlation within the transformation. Yet, the fixed-effect model wipes off all time-invariant variables, such as distance and language. Therefore, to allow distance and language as proxies for transactions and information cost, respectively, the random-effect model was used.

Data Source

Export data for aggregate, agriculture, and manufacturing were assessed from the United Nations Commodity Trade Statistics Database, Standard International Trade Classification 3 at 1 digit for 2003 to 2013.[2] Distance and language were taken from the Centre d'Études Prospectives et d'Informations Internationales database.[3] Other indicators such as GDP and GDP per capita are from the World Bank's World Development Indicators.[4]

9.4.2 Impact of Infrastructure on Economic Growth

The second objective of this study is to investigate the effects of the quality and quantity of infrastructure on economic growth. For the growth model, a pooled mean group estimation (PMGE) was carried out, using the following equation:

$$lnY_{it} = \alpha_0 + \alpha_1 lnPOPG_{it} + \alpha_2 lnK_{it} + \alpha_3 lnOpen_{it} + \alpha_4 lnHC_{it} + \alpha_5 lnINFRA_{it} + \varepsilon_{it} \qquad (2)$$

where

Y	denotes	real GDP per capita (in 2000 purchasing power parity [PPP] terms);
$POPG$	denotes	population growth;
K	denotes	physical capital as measured by gross fixed capital formation relative to GDP;
$OPEN$	denotes	trade openness (i.e., real value of exports and imports as a percentage of GDP);
HC	denotes	human capital (i.e., school enrollment at the secondary level);
$INFRA$	denotes	infrastructure; and
Ln	denotes	logarithm.

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2 United Nations Commodity Trade Statistics Database. http://comtrade.un.org/db/ (accessed 31 January 2017).

3 Centre d'Études Prospectives et d'Informations Internationales. http://www.cepii.fr/CEPII/en/welcome.asp (accessed 31 January 2017).

4 World Bank. World Development Indicators. http://data.worldbank.org/data-catalog/world-development-indicators (accessed 31 January 2017).

The dependent variable used was the economic growth proxy by real GDP per capita Y at constant terms. A standard set of control variables, including population growth, was expected to have a negative relationship with economic growth. Investment k was measured by gross fixed capital formation relative to GDP, and was expected to have a positive effect on growth. Additional variables included trade openness and human capital proxy, which were interpolated from Barro and Lee (2010) as control variables and expected to have positive effects on economic growth.

Following Calderón and Chong (2009) and Sahoo, Dash, and Nataraj (2010), the indicators used to represent infrastructure quantity-related measures for the transport sector were freight air transport, air transport passengers carried, and the length of the total roads network. For quality measures of infrastructure, paved roads were used as a proxy. Two ICT indicators were used to measure the quantity of infrastructure and number of telephone lines and mobile phone subscribers, which were expected to have positive effects on economic growth. For the quality of infrastructure, the number of internet users was identified as a proxy, because the greater this number, the more that users are connected and benefit through the transfer of communication and knowledge, leading to higher productivity and economic growth.

Finally, the energy sector was represented by power consumption per capita. The use of energy consumption could be value added to output, because energy was one of the input sources in the production function. This benefit could be seen if use was shifted from less efficient energy consumption to more efficient consumption to stimulate economic growth. Thus, the quality of energy infrastructure, such as alternative and nuclear energy (percentage of total energy) and electric power transmission and distribution losses (percentage of total output) were used to capture the effects on economic growth. Electric power transmission and distribution losses should have had negative effects on economic growth, while alternative and nuclear energy should have contributed positively to growth.

With respect to Asia's long-run growth, the PMGE developed by Pesaran, Shin, and Smith (1999) was deemed to be an appropriate approach, because it allowed for heterogeneity in the short-run coefficients but restricted the long-term coefficients to be the same for all economies. The Hausman test (Hausman 1978) was used to test the null hypothesis of homogeneity in the long-run parameters. The PMGE equation for estimation is the following:

$$\Delta lny_{it} = -\emptyset_i\left(lny_{i,t-1} - \theta_1 lnK_{i,t} - \theta_2 lHC_{i,t} + \theta_3 nPOPG_{i,t} - \sum_j^m \theta_j\, lnINFRA_{i,t}^j\right)$$

$$+b_{1,i}\Delta lnK_{it} + b_{2,i}\Delta lnHC_{i,t} + b_{3,i}\Delta POPG_{i,t} + \sum_j^m b_{j,i}\,\Delta lnINFRA_{i,t}^j + \varepsilon_{i,t} \quad (3)$$

where $\emptyset_i$ was the error-correction term coefficient measuring the speed of adjustment toward the long-run equilibrium. The PMGE method allowed short-run coefficients, intercepts, and error variances to vary across countries and areas but constrained the long-run coefficients to be equal. This implied that $\theta_i = \theta$ for all i. To estimate short-run coefficients and the common long-run coefficients, Pesaran, Shin, and Smith (1999) adopted the pooled maximum likelihood estimation approach by assuming that the disturbances $\varepsilon_{i,t}$ were normally distributed.

Data Sources

The data for physical infrastructure indicators were taken from Canning (1998), and extended by using data from the World Bank (2014). ICT data were taken from the International Telecommunication Union World Telecommunication/ICT Indicators database. Other variables, such as GDP per capita, openness, population growth, and gross capital formation, were taken from the World Bank (2014). The dataset covered the PRC; Hong Kong, China; India; Indonesia; the Republic of Korea; Malaysia; the Philippines; Singapore; Thailand; and Viet Nam from 1971 to 2013.

9.5 Results and Discussion

9.5.1 Transport Infrastructure and Trade Flows

Table 9.5 shows the effects of transport infrastructure on trade flows. The study used various indicators to represent airports, ports, rail, and roads. The four selected indicators were air traffic freight, container port traffic, rail networks, and paved roads.

The basic line of the gravity model shows that the coefficients for the market size for both exporters and importers are positive and statistically significant. This suggests that a larger market size implies higher trade flows. The coefficient for relative endowment is positive but insignificant. As expected, distance exerts a strong negative impact on trade flows, consistent with the theory that, the shorter the distance, the lower the transaction costs and the greater the trade volume. The coefficient of common language is also positive and statistically significant, as expected. The coefficients of the high-income dummies are

Table 9.5 Transport Infrastructure Effects on Exports in Asia

	Basic Model	Airport Infrastructure		Road Infrastructure		Railway Infrastructure		Port Infrastructure		Full Model	
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
GDP, exports	0.869^{c}	0.640^{c}	0.604^{c}	0.563^{c}	0.547^{c}	0.836^{c}	0.776^{c}	0.56^{c}	0.545^{c}	0.715^{c}	0.626^{c}
	(0.059)	(0.027)	(0.019)	(0.023)	(0.026)	(0.033)	(0.039)	(0.20)	(0.020)	(0.029)	(0.039)
GDP, imports	0.451^{c}	0.462^{c}	0.462^{c}	0.455^{c}	0.442^{c}	0.490^{c}	0.649^{c}	0.475^{c}	0.432^{c}	0.447^{c}	0.507^{c}
	(0.016)	(0.017)	(0.019)	(0.022)	(0.025)	(0.021)	(0.038)	(0.019)	(0.020)	(0.020)	(0.047)
Endowment	0.0006	−0.0020	−0.0040	−0.005	−0.0070	0.157^{c}	0.136^{c}	0.0020	0.001	−0.0097	−0.008
	(0.0067)	(0.0052)	(0.0063)	(0.0086)	(0.010)	(0.022)	0.026)	(0.0080)	(0.072)	(0.0089)	(0.010)
Distance	−0.798^{c}	−0.812^{c}	−0.823^{c}	−0.824^{c}	−0.754^{c}	−0.898^{c}	−0.738^{c}	−0.840^{c}	−0.763^{c}	−0.817^{c}	−0.651^{c}
	(0.032)	(0.034)	(0.037)	(0.043)	(0.048)	(0.042)	(0.065)	(0.037)	(0.039)	(0.040)	(0.067)
Language	0.214^{c}	0.262^{c}	0.343^{c}	0.398^{c}	0.455^{c}	0.035	−0.37^{c}	0.288^{c}	0.223^{c}	0.333^{c}	0.196^{a}
	(0.063)	(0.064)	(0.067)	(0.075)	(0.084)	(0.093)	(0.13)	(0.066)	(0.068)	(0.071)	(0.099)
Exporters, high-income	0.43^{a}	0.431^{c}	0.422^{c}	0.271^{c}	0.225^{c}	−0.282^{c}	−0.29^{c}	0.409^{c}	0.404^{c}	−0.059	−0.091
	(0.23)	(0.075)	(0.049)	(0.060)	(0.069)	(0.086)	(0.10)	(0.052)	0.052)	(0.069)	(0.093)
Importers, high-income	0.267^{c}	0.273^{c}	0.293^{c}	0.310^{c}	0.248^{c}	−0.016	−0.55^{c}	0.290^{c}	0.266^{c}	0.319^{c}	−0.5
	(0.048)	(0.052)	(0.058)	(0.066)	(0.075)	(0.077)	(0.12)	(0.058)	(0.059)	(0.062)	(1.2)
Air transport, exports		0.0050	0.0020							0.033^{c}	0.38^{c}
		(0.0077)	(0.0071)							(0.010)	(0.12)
Air transport, imports			0.023^{b}								0.059^{c}
			(0.011)								(0.019)
Road density, exports				0.109^{c}	0.097^{c}					0.142^{c}	−0.126^{c}
				(0.022)	(0.026)					(0.014)	(0.019)

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Table 9.5 *continued*

	Basic Model	Airport Infrastructure		Road Infrastructure		Railway Infrastructure		Port Infrastructure		Full Model	
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Road density, imports					0.070[c]						−0.009
					(0.023)						(0.015)
Railway, exports						−0.082[c]	−0.089[c]				Dropped
						(0.015)	(0.018)				
Railway, imports							−0.007				0.0007
							(0.019)				(0.025)
Container port traffic, exports								0.145[c]	0.154[c]	0.158[c]	0.173[c]
								(0.017)	(0.017)	(0.017)	(0.024)
Container port traffic, imports									0.165[c]		0.117[c]
									(0.021)		(0.029)
Constant	−6.6[c]	−0.73	0.13	1.17	1.200	−6.45[c]	−10.0[c]	−1.17[a]	−3.03[c]	−3.32[c]	−6.6[c]
	(1.6)	(0.84)	(0.69)	(0.83)		(0.91)	(1.4)	(0.70)	(0.75)	(0.88)	(1.7)
Wald Chi^2	1,342.66	1,539.27	1,539.27	1,227.93	908.60	2,065.12	1,555.94	1,956.41	2,031.94	1,569.85	1,007.20
No. of observations	1,972	1,972	1,932	1,472	1,157	1,112	726	1,774	1,670	1,436	826

( ) = standard error, GDP = gross domestic product, No. = number.
a Significant at 10%.
b Significant at 5%.
c Significant at 1%.
Note: Standard errors are given to two significant digits.
Source: Authors.

also positive and significant, as trade increases 1.5 times (for exporters) and 1.3 times (for importers)[5] if the economies are high-income.

Air traffic freight was used as a proxy for airport infrastructure for exporters; the result is positive but insignificant. However, the airport infrastructure for importers is positive and significant. For other types of infrastructure, the results reveal that both road and port infrastructure plays a significant role in trade in both exporting and importing economies. For example, a 10% increase in road density results in a 1% increase in trade. As revealed in much of the literature, port infrastructure is equally important in determining trade volumes in Asian economies.

9.5.2 Information and Communication Technology Infrastructure and Trade Flows

Table 9.6 demonstrates the results of the estimation of ICT infrastructure variables on trade flows. Five indicators were chosen as proxies for ICT infrastructure: the numbers of telephone lines, fixed mobile phones, mobile phone subscriptions, broadband and internet users, and secure internet servers. The GDPs of exporters and importers are positive and significant, with the estimated coefficient ranging from 0.5 to 0.9 for exporters, and from 0.4 to 0.6 for importers. All ICT infrastructure variables are statistically significant and positively related to trade, except for the number of internet users for exporters in column 7; however, when the number of internet users for importer economies is included, the result is positive and significant.

These results are in line with the findings of Nicoletti et al. (2003); Fink, Mattoo, and Neagu (2005); Li and Wilson (2009); and Shepherd and Wilson (2009). These studies revealed that ICT plays an important role in international trade, and confirmed that two-way communications between exporters and importers with good ICT facilities benefit both trading partners. For instance, a 10% increase in the number of fixed and mobile phone subscribers boosts trade by 2.6% (for exporters) and 2.2% (for importers). Although some countries such as India, Indonesia, and Viet Nam are still underdeveloped in terms of internet security, the results indicate a positive significance for both exporters and importers, as a 10% increase in internet security will increase trade by 0.65% (for exporters) and 0.67% (for importers). Columns 9 and 10 provide a full model including all forms of infrastructure in the equation. The results confirm that air transport and port facilities, such as the availability of containers, are significantly important to both exporters and importers.

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5 The exponential (0.425) = 1.5, and the exponential (0.267) = 1.3.

Table 9.6 Effects of Information and Communication Technology Infrastructure on Exports in Asia

	Telephone Lines		Mobile Phones		Fixed Broadband		Internet Users		Security Internet		Full Model	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
GDP, exports	0.651[c]	0.608[c]	0.593[c]	0.620[c]	0.570[c]	0.562[c]	0.930[c]	0.599[c]	0.627[c]	0.605[c]	0.5660[c]	0.589[c]
	(0.032)	(0.018)	(0.056)	(0.019)	(0.029)	(0.018)	(0.066)	(0.019)	(0.025)	(0.019)	(0.043)	(0.043)
GDP, imports	0.454[c]	0.439[c]	0.444[c]	0.458[c]	0.443[c]	0.419[c]	0.449[c]	0.455[c]	0.456[c]	0.4490[c]	0.4380[c]	0.374[c]
	(0.017)	(0.018)	(0.016)	(0.018)	(0.017)	(0.018)	(0.016)	(0.019)	(0.017)	(0.018)	(0.018)	(0.036)
Endowment	0.0050	0.0040	0.0080	0.0050	0.0100	0.0160[c]	0.0010	0.0009	0.0003	−0.0005	0.0150[c]	0.0100
	(0.0065)	(0.0057)	(0.0068)	(0.0068)	(0.0066)	(0.0068)	(0.0063)	(0.0069)	(0.0069)	(0.0069)	(0.0070)	(0.0071)
Distance	−0.803[c]	−0.792[c]	−0.788[c]	−0.768[c]	−0.784[c]	−0.758[c]	−0.796[c]	−0.805[c]	−0.806[c]	−0.821[c]	−0.776[c]	−0.779[c]
	(0.033)	(0.036)	(0.032)	(0.036)	(0.033)	(0.035)	(0.032)	(0.037)	(−0.037)	(0.036)	(0.035)	(0.037)
Language	0.251[c]	0.361[c]	0.213[c]	0.328[c]	0.265[c]	0.355[c]	0.211[c]	0.335[c]	0.278[c]	0.316[c]	0.376[c]	0.342[c]
	(0.063)	(0.063)	(0.062)	(0.063)	(0.063)	(0.062)	(0.063)	(0.065)	(0.064)	(0.065)	(0.063)	(0.064)
Exporters, high-income	0.09	−0.12[c]	0.26	0.214[c]	0.022	−0.046	0.42	0.334[c]	0.245[c]	0.172[c]	−0.062	−0.032
	(0.11)	(0.69)	(0.17)	(0.052)	(0.085)	(0.058)	(0.30)	(0.050)	(0.074)	(0.057)	(0.070)	(0.071)
Importers, high-income	0.260[c]	0.039	0.255[c]	0.096	0.251[c]	0.002	0.267[c]	0.205[c]	0.269[c]	0.036	0.245[c]	−0.012
	(0.051)	(0.069)	(0.049)	(0.062)	(0.050)	(0.050)	(0.049)	(0.059)	(0.052)	(0.064)	(0.054)	(0.078)
Telephone lines, exports	0.249[c]	0.396[c]									0.215[c]	0.263[c]
	(0.048)	(0.032)									(0.041)	(0.042)
Telephone lines, imports		0.189[c]										0.017
		(0.037)										(0.049)
Mobile, exports			0.231[c]	0.266[c]							0.132[c]	0.111[a]
			(0.031)	(0.028)							(0.058)	(0.058)

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Table 9.6 *continued*

	Telephone Lines		Mobile Phones		Fixed Broadband		Internet Users		Security Internet		Full Model	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Mobile, imports				0.210[c]								0.121[c]
				(0.036)								(0.056)
Broadband, exports					0.153[c]	0.176[c]					0.052[b]	0.032
					(0.016)	(0.013)					(0.026)	(0.026)
Broadband, imports						0.107[c]						0.022
						(0.016)						(0.028)
Internet users, exports							0.0010	0.087[c]			0.066[c]	0.042[a]
							(0.0063)	(0.012)			(0.024)	(0.025)
Internet users, imports								0.066[c]				0.064[c]
								(0.017)				(0.027)
Secure internet server, exports									0.0480[c]	0.0650[c]	−0.010	−0.029
									(0.0084)	(0.0079)	(0.022)	(0.023)
Secure internet server, imports										0.067[c]		0.052[c]
										(0.010)		(0.022)
Constant	−1.52	−0.97	−0.2	−2.41[c]	1.28	1.77[c]	−8.1[c]	0.02	0.351	0.35	−0.5	−0.3
	(0.93)	(0.66)	(1.5)	(0.68)	(0.87)	(0.65)	(4.7)	(0.63)	(0.78)	(0.66)	(1.0)	(1.3)
Wald Chi^2	1,501.07	2,159.36	1,447.90	2,208.24	1,681.45	2,378.20	1,339.69	1,992.92	1,661.12	2,094.86	2,218.46	2,289.17
No. of observations	1,954	1,945	1,972	1,972	1,972	1,962	1,972	1,952	1,972	1,962	1,954	1,905

( ) = standard error, GDP = gross domestic product, No. = number.
a Significant at 10%.
b Significant at 5%.
c Significant at 1%.
Note: Standard errors are given to two significant digits.
Source: Authors.

9.5.3 Soft Infrastructure and Trade Flows

Table 9.7 shows the results of soft infrastructure for both exporters and importers on trade. The three indicators of soft infrastructure were cost to export and import, documents needed to export and import, and time to export and import. GDP and other control variables (i.e., distance, common language, and the dummy) for high-income economies have results similar to those of the hard infrastructure model. The coefficients for the costs of imports and exports are negative with trade, which indicates that when the cost of doing business is lower for exporters or importers, the potential trade is higher. These results are similar to those of Sadikov (2007); Duval and Utoktham (2009); and Djankov, Freund, and Pham (2010), who also found a negative relationship between the cost of exports and international trade.

Another indicator of soft infrastructure—documents needed for export and import—has a negative impact on trade. A 10% increase in the number of documents required for export and import reduces trade by at least 5.5%. According to the World Bank (2013), among selected Asian economies, the number of documents required to export has been reduced to three in Hong Kong, China; the Republic of Korea; and Singapore; and eight in the PRC. Time to export and import is based on the number of days from the beginning of a procedure until the end. The results of this study support the hypothesis that the fewer the days required to complete the export procedure the more trade increases. Specifically, a 10% reduction in the time taken to export is estimated to increase trade by 5%; whereas a decrease in the time taken to import is estimated to increase trade by 4%. This result supports the study of Djankov, Freund, and Pham (2010), which also confirmed a negative relationship between time and trade.

9.5.4. Effects of Infrastructure on Agricultural and Manufacturing Exports

Table 9.8 reveals that air transport and container port traffic are among the indicators that positively and significantly affect export manufacturing. Aggregate export data indicate that air transport and port traffic are equally important in Asian economies. Similar results are found for agricultural exports. In addition, road density still matters for agricultural exports, because heavy products must be transported via roads.

Table 9.9 shows that telephone lines and internet security indicators are positive and statistically significant for both agricultural and manufacturing exports. Communication infrastructure is important for businesses because it not only facilitates communication to finalize a contract but also ensures security, especially for internet banking that allows transactions to be wired throughout the world.

Table 9.7 Effects of Soft Infrastructure on Exports in Asia

	Cost to Export or Import		Documents Needed to Export or Import		Time to Export or Import		Full Model for Export	Full Model for Import
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
GDP, exports	0.658[b]	0.722[b]	0.704[b]	0.691[b]	0.674[b]	0.709[b]	0.7190[b]	0.722[b]
	(0.084)	(0.023)	(0.024)	(0.026)	(0.022)	(0.023)	(0.026)	(0.024)
GDP, imports	0.440[b]	0.47[b]	0.454[b]	0.449[b]	0.452[b]	0.498[b]	0.442[b]	0.438[b]
	(0.018)	(0.21)	(0.020)	(0.023)	(0.020)	(0.022)	(0.019)	(0.020)
Endowment	0.0070	0.0040	−0.0010	−0.0040	0.0060	−0.013	0.009	0.006
	(0.0091)	(0.0093)	(0.0056)	(0.0095)	(0.0091)	(0.010)	(0.010)	(0.010)
Distance	−0.791[b]	−0.797[b]	−0.83[b]	−0.845[b]	−0.823[b]	−0.778[b]	−0.808[b]	−0.809[b]
	(0.035)	(0.043)	(0.40)	(0.042)	(0.039)	(0.042)	(0.038)	(0.038)
Language	0.189[b]	0.098	0.321[b]	0.281[b]	0.258[b]	0.119[a]	0.156[b]	0.162[b]
	(0.069)	(0.073)	(0.070)	(0.074)	(0.069)	(0.072)	(0.070)	(0.070)
Exporters, high-income	0.43	0.479[b]	0.179	0.179[b]	0.081	−0.024	0.314[b]	0.310[b]
	(0.32)	(0.053)	(0.067)	(0.070)	(0.072)	(0.073)	(0.070)	(0.069)
Importers, high-income	0.239[b]	0.301[b]	0.270[b]	0.332[b]	0.255[b]	−0.165[b]	0.261[b]	0.265[b]
	(0.054)	(0.064)	(0.062)	(0.070)	(0.061)	(0.080)	(0.059)	(0.060)
Cost, exports	0.43[b]	−1.290[b]					−1.20[b]	
	(0.17)	(0.023)					(0.10)	
Cost, imports		−0.159[b]						−0.825[b]
		(0.051)						(0.093)
Documents, exports			−0.617[b]	−0.58[b]			0.33[b]	
			(0.094)	(0.10)			(0.15)	

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Table 9.7 *continued*

	Cost to Export or Import		Documents Needed to Export or Import		Time to Export or Import		Full Model for Export	Full Model for Import
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Documents, imports				0.125[b]				−0.21[a]
				(0.057)				(0.12)
Time, exports					−0.515[b]	−0.508[b]	−0.413[b]	
					(0.066)	(0.069)	(0.089)	
Time, imports						−0.486[b]		0.001
		6.13[b]				(0.057)		(0.082)
Constant	−3.5		−1.00	−0.62	0.13	−0.73		
	(2.1)	(0.83)	(0.74)	(0.79)	(0.74)	(0.77)		
Wald Chi^2	988.47	1,743.81	1,689.62	1,522.50	1,681.28	1,739.21	1,871.93	1,807.19
No. of observations	1,597	1,488	1,648	1,504	1,647	1,355	1,596	1,580

( ) = standard error, GDP = gross domestic product, No. = number.
a Significant at 10%.
b Significant at 1%.
Note: Standard errors are given to two significant digits.
Source: Authors.

Table 9.8 Transport Infrastructure Effects on Agricultural and Manufacturing Exports

	Manufacturing Exports		Agricultural Exports	
	(1)	(2)	(3)	(4) FEM
GDP, exports	1.029[c]	0.992[c]	0.27[c]	0.45
	(0.029)	(0.031)	(0.10)	(0.32)
GDP, imports	0.447[c]	0.488[c]	0.529[c]	0.494[c]
	(0.020)	(0.025)	(0.038)	(0.059)
Endowment	0.0230[c]	0.0310[c]	−0.064[a]	−0.351[c]
	(0.0087)	(0.0090)	(0.034)	(0.042)
Distance	−1.070[c]	−0.965[c]	−1.117[c]	
	(0.039)	(0.043)	(0.076)	
Language	−0.222[c]	−0.158[c]	0.30[c]	
	(0.070)	(0.073)	(0.16)	
Exporters, high-income	−0.275[c]	−0.340[c]		
	(0.068)	(0.073)		
Importers, high-income	−0.034	−0.243[c]		
	(0.061)	(0.070)		
Air transport, exports	0.048[c]	0.038[c]	0.099[c]	−0.014
	(0.010)	(0.011)	(0.022)	(0.041)
Road density, exports	−0.118[c]	−0.121	0.39[c]	−0.23
	(0.014)	(0.016)	(0.10)	(0.42)
Railways, exports	Dropped	Dropped	−0.063	−0.89
			(0.088)	(0.55)
Container port traffic, exports	0.102[c]	0.109[c]	−0.144[c]	0.96
	(0.017)	(0.019)	(0.032)	(0.51)
Air transport, imports		0.055[c]		0.098[c]
		(0.012)		(0.029)
Road density, imports		−0.0080		0.044[b]
		(0.0097)		(0.024)
Railways, imports		Dropped		−0.104 [c]
				(0.034)
Container port traffic, imports		0.135[c]		0.327[c]
		(0.023)		(0.046)
Constant		−14.8[c]	5.2[a]	−12.2[a]
		(1.0)	(3.0)	(7.2)
Wald Chi^2	2,770.25	2,603.37	500.56	27.83
No. of observations	1,439	1,105	899	508

( ) = standard error, FEM = Fixed Effect Model, GDP = gross domestic product, No. = number.
a Significant at 10%.
b Significant at 5%.
c Significant at 1%.
Note: Standard errors are given to two significant digits.
Source: Authors.

Table 9.9 Information and Communication Technology Infrastructure Effects on Agricultural and Manufacturing Exports

	Manufacturing Exports			Agricultural Exports	
	(1)	(2) FEM	(3)	(4)	(5)
GDP, exports	0.956[b]	0.04	0.956[b]	0.325[b]	0.345[b]
	(0.042)	(0.23)	(0.043)	(0.063)	(0.064)
GDP, imports	0.464[b]	0.135[b]	0.503[b]	0.569[b]	0.361[b]
	(0.017)	(0.017)	(0.034)	(0.027)	(0.054)
Endowment	0.0350[b]	−0.0035	0.0355[b]	0.045[b]	0.045[b]
	(0.0068)	(0.0088)	(0.0071)	(0.010)	(0.011)
Distance	−1.080[b]		−1.042[b]	−1.000[b]	−0.988[b]
	(0.032)		(0.036)	(0.052)	(0.055)
Language	−0.201[b]		−0.177[b]	−0.073	−0.061
	(0.061)		(0.062)	(0.094)	(0.095)
Exporters, high-income	Dropped			−1.66[b]	−1.62[b]
				(0.10)	(0.11)
Importers, high-income	Dropped			−0.521[b]	−0.39[b]
				(0.080)	(0.12)
Telephone lines, exports	0.208[b]	−0.24[b]	0.239[b]	0.203[b]	0.266[b]
	(0.034)	(0.11)	(0.035)	(0.061)	(0.062)
Mobile phones, exports	0.118[b]	−0.3	0.088	−0.042	−0.100
	(0.056)	(1.4)	(0.057)	(0.086)	(0.086)
Broadband, exports	0.007	0.116	0.003	0.057	0.046
	(0.025)	(0.072)	(0.025)	(0.038)	(0.038)
Internet users, exports	−0.008	0.166[b]	−0.017	0.049	0.026
	(0.024)	(0.062)	(0.024)	(0.036)	(0.036)
Secure internet servers, exports	−0.033	0.155[b]	−0.040[a]	0.086[b]	0.054
	(0.020)	(0.039)	(0.021)	(0.033)	(0.034)
Telephone lines, imports			−0.153[b]		−0.271[b]
			(0.042)		(0.072)
Mobile phones, imports			0.211		−0.054
			(0.052)		(0.082)
Broadband, imports			0.006		0.222[b]
			(0.025)		(0.041)
Internet users, imports			−0.029		0.238[b]
			(0.025)		(0.039)
Secure internet servers, imports			−0.021		−0.023
			(0.021)		(0.032)
Constant	−10.05[b]	12.9[b]	−11.7[b]		4.7[b]
	(0.99)	(2.4)	(1.2)		(1.8)
Wald Chi²	4,044.41	34.18	4,001.46	1,288.77	1,360.37
No. of observations	1,961	1,961	1,912	1,958	1,909

( ) = standard error, FEM =Fixed Effect Model, GDP = gross domestic product, No. = number.
a Significant at 10%.
b Significant at 1%.
Note: Standard errors are given to two significant digits.
Source: Authors.

Table 9.10 reports the effects of soft infrastructure on agricultural and manufacturing exports. The negative relationship between cost to export and time to export for manufacturing exports implies that economies in Asia export more manufacturing products if the cost is reduced and the time is shorter. The number of documents needed to export is negative but insignificant. In practice, agricultural products require more documents than manufacturing products because some agricultural products are sensitive and require chemical tests.

Table 9.10 Soft Infrastructure Effects on Agricultural and Manufacturing Exports

	Manufacturing Exports		Agricultural Exports	
	(1)	(2)	(3)	(4)
GDP, exports	1.012[c]	0.976[c]	0.625[c]	0.511[c]
	(0.026)	(0.024)	(0.038)	(0.036)
GDP, imports	0.462[c]	0.463	0.563	0.567[c]
	(0.020)	(0.020)	(0.029)	(0.029)
Endowment	0.026[c]	0.029[c]	0.021	0.039[c]
	(0.010)	(0.010)	(0.015)	(0.015)
Distance	–1.045[c]	–1.050[c]	–0.985[c]	–0.993[c]
	(0.038)	(0.039)	(0.056)	(0.057)
Language	–0.251[c]	–0.275[c]	–0.07	–0.17
	(0.071)	(0.071)	(0.10)	(0.11)
Exporters, high-income	–0.043	0.038	–1.64[c]	–1.37[c]
	(0.070)	(0.068)	(0.10)	(0.10)
Importers, high-income	–0.118[b]	–0.122[c]	–0.512[c]	–0.543[c]
	(0.059)	(0.061)	(0.087)	(0.089)
Cost, exports	–0.51[c]		–0.05	
	(0.10)		(0.15)	
Documents, exports	–0.26		–1.48[c]	
	(0.14)		(0.21)	
Time, exports	–0.162[a]		0.22	
	(0.089)		(0.13)	
Cost, imports		–0.364[c]		–0.26[b]
		(0.094)		(0.14)
Documents, imports		0.002		0.50[c]
		(0.10)		(0.18)

continued on next page

Table 9.10 *continued*

	Manufacturing Exports		Agricultural Exports	
	(1)	(2)	(3)	(4)
Time, imports		−0.115		−0.44[c]
		(0.083)		(0.12)
Constant	−6.55[c]	−7.02[c]	−1.4	1.3
	(0.89)	(0.81)	(1.3)	(1.2)
Wald Chi^2	3,128.53	2,987.73	1,097.72	986.73
No. of observations	1,600	1,584	1,599	1,583

( ) = standard error, GDP = gross domestic product, No. = number.
[a] Significant at 10%.
[b] Significant at 5%.
[c] Significant at 1%.
Note: Standard errors are given to two significant digits.
Source: Authors.

9.5.5 Impact of Infrastructure on Economic Growth

This section discusses the study results for growth quantity-related infrastructure, and employs the PMGE developed by Pesaran, Shin, and Smith (1999). Prior to the analysis, the PMGE and mean group were regressed, and the Hausman test was applied. Because the *p*-value was greater than 0.05, the PMGE was preferred and considered more appropriate. Table 9.11 reports transport infrastructure, and Table 9.12 reports ICT and energy infrastructure.

Different regression estimations were undertaken for all types of transport infrastructure. Only four types of infrastructure were found to be positive and significant. The findings show that all indicators of quantity-related transport infrastructure—total road network, air transport for passengers, and registered freight—have a positive and significant coefficient at least at the 5% significance level. The results align with many studies that emphasize the development of infrastructure such as roads and air transport. Long total road networks eases access to the workplace, thus increasing productivity and encouraging economic growth.

Column 2 reports the result for the quality of transport infrastructure, that is, paved roads. A 10% increase in paved roads increases economic growth more than 5%. Quality, such as paved roads, reduces the cost of vehicle maintenance, thus increasing worker productivity. The results confirm that the quality of infrastructure matters, as economies perform better in periods of economic growth. However, the quantity of infrastructure may not be sufficient for Asia, which mainly focuses on the manufacturing sectors.

For ICT infrastructure, it follows from Table 9.12 that a 10% increase in the numbers of telephone lines and mobile phones is estimated to increase economic growth by about 2.5% and 1.1%, respectively. In the era of globalization, information spreads faster through the internet. Thus, quality ICT infrastructure enables consumers, producers, businesses, and politicians to obtain knowledge and information, which

Table 9.11 Transport Infrastructure Effects on Economic Growth

	Total Road	Paved Road (Quality)	Air Transport Passengers	Air Transport Registered Freight	Full Model
	(1)	(2)	(3)	(4)	(5)
Population growth	−0.17	−0.005	−0.100[c]	−0.121	−0.70[c]
	(0.13)	(0.029)	(0.043)	(0.076)	(0.16)
Investment	1.77[c]	−0.275[c]	−0.015	−0.150	0.375[c]
	(0.28)	(0.069)	(0.047)	(0.094)	(0.074)
Trade openness	0.526[c]	1.039[c]	0.530[c]	0.76[c]	0.129[c]
	(0.084)	(0.092)	(0.070)	(0.12)	(0.052)
Road total network	0.422[c]				0.245[c]
	(0.077)				(0.071)
Paved road		0.55[a]			0.242[c]
		(0.31)			(0.088)
Air transport, passengers			0.375[c]		0.092[c]
			(0.030)		(0.033)
Air transport, registered freight				0.369[c]	
				(0.066)	−0.121[c]
Error-correction term	−0.039[c]	−0.054[c]	−0.088[b]	−0.045[b]	
	(0.016)	(0.019)	(0.039)	(0.023)	(0.059)
No. of observations	297	280	302	308	293

( ) = standard error, No. = number.
a Significant at 10%.
b Significant at 5%.
c Significant at 1%.
Note: Standard errors are given to two significant digits.
Source: Authors.

Table 9.12 Infrastructure Effects on Economic Growth

	Information and Communication Technology Infrastructure			Energy Infrastructure		
	(1)	(2)	(3)	(4)	(5)	(6)
Population growth	0.017	−0.24	1.14	0.19	−0.50[a]	−0.01
	(0.025)	(0.15)	(0.74)	(0.26)	(0.12)	(0.10)
Investment	−0.19	0.81[a]	1.24[a]	1.26[a]	0.244[b]	−1.41
	(0.15)	(0.19)	(0.57)	(0.60)	(0.130)	(0.39)
Trade openness	0.804[a]	0.39[a]	1.06[a]	0.44[a]	0.49[a]	0.70
	(0.069)	(0.13)	(0.48)	(0.20)	(0.11)	(0.18)
Human capital		0.77[a]	1.03[a]	−0.5		
		(0.23)	(0.23)	(4.8)		
Telephones	0.257[a]					
	(0.029)					
Mobile phones		0.113[a]				
		(0.025)				
Internet users			0.218[a]			
			(0.045)			
Electric power consumption				0.75[a]		
				(0.19)		
Alternative and nuclear energy					−0.014	
					(0.023)	
Electric power transmission and distribution losses						−1.12[a]
						(0.21)
Error-correction term	−0.038	−0.079[b]	−0.013	−0.020	−0.108[a]	0.002
	(0.037)	(0.042)	(0.025)	(0.024)	(0.046)	(0.015)
No. of observations	295	145	145	145	146	299

( ) = standard error, No. = number.
a Significant at 1%.
b Significant at 5%.
Note: Standard errors are given to two significant digits.
Source: Authors.

can be referred to as growth enhancement. From the results in column 3, a 10% increase in the number of internet users is estimated to increase economic growth by 2.1%.

Columns 4, 5, and 6 report the results of infrastructure in the energy sector. Power consumption has a positive relationship with economic growth. For quality, an electric power transmission and distribution loss is negative and statistically significant. Reducing transmission and distribution losses by 1% would increase growth by 1.1%. The importance of electricity for economic growth has been widely discussed since Kraft and Kraft (1978). Having a reliable electricity supply is crucial for growth, because electricity is an essential input, and any shortages or deficits can significantly reduce output. Another proxy for energy infrastructure (e.g., the use of alternative or nuclear energy) is positive, but the result is insignificant.

9.6 Summary and Conclusion

Facilitating trade requires not only efficient hard infrastructure, but also soft infrastructure elements such as a good business and regulatory environment, transparency, and customs management. This study shows that improvement in all transport infrastructure sectors results in increased trade flows. ICT infrastructure also plays a vital role in trade enhancement; this applies to both exporters and importers. Further, although more attention has been given to hard infrastructure, it is necessary to examine the key impact of soft infrastructure on trade flows. This study identifies air transport, road transport, and port and container facilities in agricultural and manufacturing exports as confirming the results from aggregate trade data. For ICT infrastructure, telephone lines and internet security are found to be significant. Finally, reducing the number of documents required is important for agricultural exports, and reductions in cost and time to export are vital to boost manufacturing exports.

The quality of infrastructure is as important as its quantity, as inadequate or poorly performing infrastructure may create obstacles for economies working to meet their full growth potential. The study results confirm that the quantity of infrastructure is important for enhancing economic growth; however, quality infrastructure creates more benefits by producing productive and efficient output, thus greatly impacting sustainable economic growth. As markets integrate further, infrastructure will play an ever more important role. Economies that score low with regard to physical infrastructure should invest more in road density, rail, and port facilities to facilitate doing business. ICT infrastructure, especially basic infrastructure such as telephone lines, broadband access, and internet security, should also be emphasized to yield communication benefits and to ease financial transactions between trading partners.

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10

Evaluating the Impacts of Cross-Border Transport Infrastructure in the Greater Mekong Subregion: Three Approaches

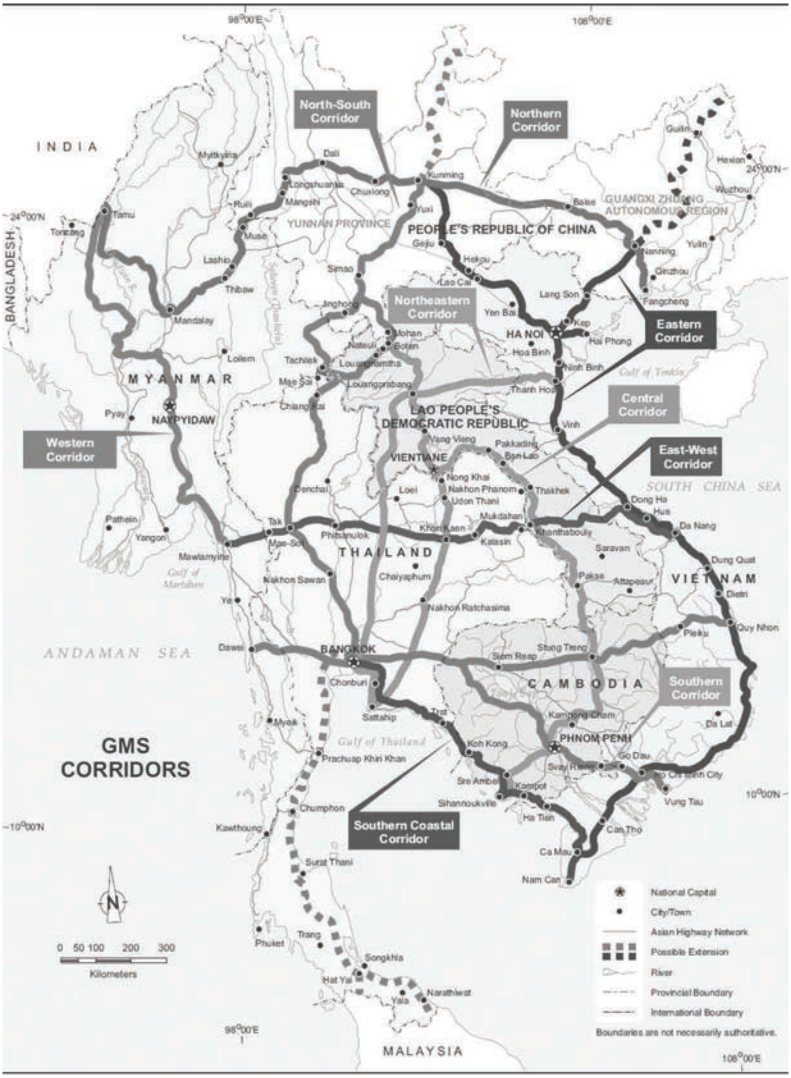
Manabu Fujimura

10.1 Introduction

The Greater Mekong Subregion (GMS), comprising Cambodia, the Lao People's Democratic Republic (Lao PDR), Myanmar, Viet Nam, and Thailand, as well as Yunnan Province and Guangxi Autonomous Region of the People's Republic of China (PRC), has recently seen remarkable progress in the development of cross-border transport infrastructure along its "economic corridors" (Figure 10.1). The significance of this development lies in the corridors' contribution to higher regional economic growth through the promotion of intra-regional trade and investments than would be possible through the independent efforts of national investment projects alone. The evaluation, both ex ante and ex post, of such cross-border infrastructure projects requires two main analytical viewpoints in addition to those required for national projects: (i) economic net impacts beyond national infrastructure developments, and (ii) the laying out of their benefit–cost distributions (Fujimura and Adhikarhi 2012).

The first point can be seen as a concept parallel to that of economic externalities in that it represents additional economic benefits or costs accruing to cross-border infrastructure projects that would not occur through national projects alone. Positive additionality includes the growth impact of enhancing intra-regional trade and facilitating border

Figure 10.1 Economic Corridors in the Greater Mekong Subregion



GMS = Greater Mekong Subregion.
Source: Asian Development Bank. 2012. *GMS Economic Cooperation Program: Overview*. Manila. p. 11.

transactions (especially customs and inspections at land borders in the GMS) that would not arise through individual national efforts alone. Negative additionality includes induced illicit trades in timber, illegal drugs, humans, wild animals, and arms due to lower costs of cross-border transport, and the consequent expansion of underground economies in the region, which would not arise if regional connectivity were not advanced (Fujimura 2014).[1]

The second point, benefit–cost distribution, must be made as transparent as possible for the evaluation of national projects, and this is even more critical for cross-border projects (Fujimura 2012). Making such distributional aspects transparent would help identify areas where third parties (e.g., the Asian Development Bank [ADB] and the Government of Japan) can help fill any gaps. In the context of the GMS, in particular, analytical efforts with regard to distributional aspects would support policy discussions among less and more endowed members of the GMS as well as with external players, and help all parties create win–win outcomes.

This chapter is based on these motives and presents three different approaches to quantifying the additionalities and border transport infrastructure developments in GMS economic corridors.

10.2 Benefit–Cost Comparison for Greater Mekong Subregion Economic Corridors

The author collected publicly available data on the construction of cross-border transport infrastructure and economic data at the subnational level, and used these to compare benefits roughly against costs for selected segments of the main GMS economic corridors. This analysis aims to compare the cumulative incremental income reflected in local gross domestic product (GDP) measures along economic corridors with the cumulative economic cost of transport infrastructure development.

The Yunnan and Lao PDR segments of the North–South Economic Corridor are examined first (Table 10.1). The Thai segment of the corridor is omitted due to the difficulty of finding data on transport infrastructure costs in this segment.

The Yunnan segment of the corridor—particularly the region's capital city, Kunming—experienced accelerated income growth in the late 2000s. As much of Kunming's economic growth is attributable to various urban investments other than the corridor investment (such

[1] These negative aspects are difficult to evaluate quantitatively due to the informal nature of these activities, and are therefore beyond the scope of this chapter.

Table 10.1 Benefit–Cost Comparison for the North–South Corridor ($ million)

Administrative Unit	2008–2011 Cumulative GDP Increase	Cumulative Cost of Road Development	Benefit–Cost Ratio
Yunnan segment			
Kunming City	21,216	4,027	2.97 (excludes Kunming)
Yuxi City	7,438		
Pu'er City	2,773		
Xishuangbana region	1,732		
Lao PDR segment			
Luangnamtha Province	111	137	1.55
Bokeo Province	102		

GDP = gross domestic product, Lao PDR = Lao People's Democratic Republic.
Notes:
- 1. A compound rate of 12% (a standard discount rate used by the Asian Development Bank [ADB] in evaluating projects) is applied to both road construction and maintenance costs and incremental GDP to calculate present values in 2011 prices.
- 2. Cost data for the Yunnan segment are derived from documents relating to ADB support for the construction of the Yuxi–Pu'er expressway.
- 3. Cost data for the Lao PDR segment are derived from documents relating to ADB support for the construction of the Boten–Houayxai road.

Source: Author.

as the new airport, office buildings and condominiums, and subway construction), Kunming's GDP growth is excluded from the benefit side. Consequently, both the Yunnan and Lao PDR segments of the corridor's development show positive net benefits, with the Yunnan segment having a greater benefit–cost ratio. As the Lao PDR segment does not include a large city, the agglomeration effects are limited. However, road construction in the Lao PDR segment was financed by concessional loans from ADB and the governments of the PRC and Thailand, making the benefit–cost ratio for the Lao PDR somewhat greater than the indicated figure. This makes sense because economic corridors encompassing more than two countries should bring about net benefits for all participants—a win–win outcome.

However, several shortcomings make this analysis far from exact. First, it ignores income growth after 2011, spillover effects beyond the areas through which the corridor route passes, and other external benefits facilitated by easier transport such as education and health. To the extent that these benefits are greater, the analysis underestimates the benefit–cost ratio. Second, the analysis ignores many contributing factors to income growth other than the corridor investments, and consequently overestimates the benefit–cost ratio with regard to these missing variables. Third, the cost of road construction is based on estimates produced at project completion. Since the actual cost of road maintenance usually exceeds such estimates, the analysis overestimates the benefit–cost ratio with regard to this tendency.

The Fourth Mekong Friendship Bridge completed in December 2013 between the Lao PDR and Thailand is expected to accelerate corridor traffic. Thus, the corridor's impact, including trade and investment effects among the three countries against the cost of the bridge, should be reassessed in the future.

Next, the Viet Nam and Lao PDR segments of the East–West Economic Corridor are examined (Table 10.2). The analysis does not consider the Thai segment of the corridor because it is difficult to find reliable data on road construction and maintenance in Thailand. Due to incomplete data on road construction in both the Lao PDR and Viet Nam segments, the analysis does not attempt to separate benefits and costs between the two countries.

The cost side of the corridor's impact is derived from available data concerning road development between Da Nang (Viet Nam) and Mukdahan (Thailand), the Second Mekong Friendship Bridge between Savannakhet (Lao PDR) and Mukdahan (Thailand), and the improvement of the Hai Van Tunnel (Viet Nam) and Da Nang Port (Viet Nam). As it is difficult to attribute the growth impact of each infrastructure component to specific geographical areas, three different estimates for the benefit–cost ratio are examined: very conservative, moderately conservative, and moderately optimistic. As Da Nang and Hue in Viet Nam are large economies, to whose growth many variables other than the corridor development contribute, their GDP increases are excluded from the benefit side.

The very conservative estimate, which includes all infrastructure components mentioned above, yields a benefit–cost ratio of 0.69, that is, negative net benefits. The moderately conservative estimate, which excludes the cost of the Da Nang Port improvement, yields a benefit–cost ratio of 1.46. The moderately optimistic estimate, which excludes the Hai Van Tunnel development as well, yields a much-improved benefit–cost ratio of 2.44.

Since this corridor does not connect large cities such as Bangkok or Ho Chi Minh City, it was expected at the outset that its main impact would be poverty reduction in the low-income areas along its route. This analysis confirms this expectation to some extent. Again, the shortcomings of the analysis include (i) the possible underestimation of benefits for (a) post-2011 income growth, (b) spillover effects beyond

Table 10.2 Benefit–Cost Comparison for the East–West Corridor ($ million)

Administrative Unit	2008–2011 Cumulative GDP Increase	Comment
Viet Nam segment		
Da Nang City	808.20	Da Nang is a port city.
Thua Thien-Hue	437.10	The Hai Van Pass used to separate the economies of Hue and Da Nang.
Quang Tri	233.40	Borders with the Lao PDR on the NR9 route
Lao PDR segment		
Savannakhet	274.10	Borders with Viet Nam on the NR9 route
Cumulative costs		
Road development for NR1 in Viet Nam, and NR9 in Viet Nam and the Lao PDR	135.10	The Viet Nam section is supported by JICA; the Lao PDR section is supported by ADB and JICA.
Road maintenance for NR9 in the Lao PDR	39.90	Supported by JICA (but excluding O&M costs)
Second Mekong Friendship Bridge	73.30	Supported by JICA
Hai Van Tunnel construction	139.20	Supported by JICA
Da Nang Port improvement	87.10	Supported by JICA (but excluding O&M costs)
Benefit–cost ratio (excludes Da Nang and Hue in the benefit side)		
All cost items included	0.69	Very conservative estimate
Excluding the Da Nang Port improvement	1.46	Moderately conservative estimate
Also excluding the Hai Van Tunnel construction	2.44	Moderately optimistic estimate

ADB = Asian Development Bank, JICA = Japan International Cooperation Agency, Lao PDR = Lao People's Democratic Republic, O&M = operations and maintenance.

Notes:

- 1. A compound rate of 12% (a standard discount rate used by the Asian Development Bank [ADB] in evaluating projects) is applied to both road construction and maintenance costs and incremental GDP to calculate present values in 2011 prices.
- 2. Road development is divided among the Da Nang–Dong Ha (NR1), Dong Ha–Phin (NR9), and Phin–Savannakhet (NR9) roads. The economic costs of this development are approximated using data in ADB and JICA loan documents.
- 3. Costs for the Second Mekong Friendship Bridge and Hai Van Tunnel are derived from JICA's post-evaluation documents.

Source: Author.

the direct route, (c) and other external benefits; and (ii) the possible overestimation of benefits not attributable to the corridor development.

Next, the Cambodia and Viet Nam segments of the Southern Economic Corridor are examined (Table 10.3). Once again, the analysis

Table 10.3 Benefit–Cost Comparison for the Southern Corridor ($ million)

Administrative Unit	2008–2011 Cumulative GDP Increase	Comment
Cambodia segment		
Banteay Meanchay	242.1	Borders Thailand to the west
Battambang	363.8	NR5 runs south of Ton Le Sap Lake.
Pursat	128.7	
Kampong Chhnang	160.9	
Phnom Penh	817.5	Possesses a river port
Kandal	207.5	The Neak Luong Bridge was opened in April 2015 but this analysis excludes this cost. Completed.
Prey Veng	264.4	
Svay Rieng	134.4	Borders Viet Nam to the southeast
Viet Nam segment		
Tay Ninh	423.2	Borders Cambodia to the northwest
HCMC	5,529.8	The Cai Mep–Chi Vai ports are being expanded between HCMC and the Vuntau ports, but are excluded from this analysis.
Ba Ria Vuntau	519.2	
Road development cumulative costs		
Poipet–Sisophone	16.5	Excludes O&M costs
Sisophone–Neak Luong	41.0	Rehabilitation of this road section ignores sunk costs, and underestimates total costs.
Neak Luong–HCMC	475.5	Excludes time costs for Mekong River ferry transport
Aggregate benefit–cost ratio	4.1	Moderately optimistic estimate

GDP = gross domestic product, HCMC = Ho Chi Minh City, O&M = operations and maintenance.
Notes:

1. A compound rate of 12% (a standard discount rate used by the Asian Development Bank [ADB] in evaluating projects) is applied to both road construction and maintenance costs and incremental GDP to calculate present values in 2011 prices.
2. Costs for the analyzed section are approximated by using data included in documents for three Asian Development Bank-assisted projects: the Phnom Penh–Ho Chi Minh highway, the development of the Poipet–Siem Reap road, and the development of Cambodia's national road network.

Source: Author.

does not consider the Thai segment of the corridor due to the difficulty of obtaining data, and does not attempt to separate benefits and costs between the two countries due to inadequate data on road construction in both segments.

The cost side of the corridor's impact is derived from available data concerning road development between the Aranyaprathet (Thailand)–Poipet (Cambodia) border and Ho Chi Minh City (Viet Nam) via Phnom Penh (Cambodia). As Phnom Penh, Ho Chi Minh City, and Ba Ria Vuntau Province are large port-based economies, to whose growth which many variables other than the corridor development contribute, their GDP increases are excluded from the benefit side.

As a result, the benefit–cost ratio is calculated as 4.1, revealing the corridor's strong economic viability. However, shortcomings of the analysis include (i) the possible underestimation of benefits for (a) post-2011 income growth, (b) spillover effects beyond the direct route, and (c) other external benefits; and (ii) the possible overestimation of benefits not attributable to the corridor development.

As the new Mekong bridge in Cambodia (at Neak Luong), completed in April 2015, is expected to accelerate corridor traffic, the corridor's impact should be reassessed in the future.

As the above analyses show, benefit–cost comparisons reveal the impact of the GMS economic corridors. However, serious analytical constraints exist, including the lack of publicly available comprehensive data on the cost side; the difficulty of attributing each corridor component to the income growth of geographical regions along the corridor route (analytical rigor would call for multi-country and multi-region economic modeling, which is beyond the scope of this chapter), and the difficulty of assessing counterfactual scenarios against which to compare the actual outcome. Although these constraints also apply to the analysis of domestic infrastructure projects, they are much more pronounced for cross-border projects. Therefore, the above results should be interpreted as initial rough attempts that will be reassessed as more reliable data (especially on domestic public investments in each country) become available.

10.3 Panel Data Analysis at the Subnational Level

In contrast to the approach taken above, this section quantifies the impact of GMS economic corridors by using an econometric model involving major variables that influence living standards along the corridor routes. Extending from the neoclassical growth accounting framework, the dependent variable is the growth rate of per capita GDP for each administrative unit, while explanatory variables include population growth, physical capital growth, human capital growth, and various dummy variables representing transport-related variables and economic corridors.

A basic estimation model is as follows:

$$(pcgdpgrowth)_{it} = c + \alpha\,(popgrowth)_{it} + \beta\,(capitalgrowth)_{it} + \gamma\,(edugrowth)_{it} + \varepsilon_{it} \quad (1)$$

where c is a constant, $(pcgdpgrowth)_{it}$ represents the growth rate of per capita real GDP, $(popgrowth)_{it}$ represents the growth rate of population, $(capitalgrowth)_{it}$ represents the growth rate of physical capital, and $(edugrowth)_{it}$ represents the growth rate of human capital, for administrative unit i in year t. ε_{it} is an error term. In principle, human capital should include health-related variables; however, due to large disparities in the kinds of health-related data that are available across the GMS member countries, only education-related variables are adopted in the database.

The model is expanded by including transport-related variables in the road sector, represented by data on the ownership or haulage of passenger and commercial vehicles (buses and trucks), as follows:

$$(pcgdpgrowth)_{it} = c + \alpha\,(popgrowth)_{it} + \beta\,(capitalgrowth)_{it} + \gamma\,(edugrowth)_{it} + \delta 1(passvgrowth)_{it} + \delta 2(comvgrowth)_{it} + \varepsilon_{it} \quad (2)$$

where $(passvgrowth)_{it}$ represents the growth rate of passenger vehicle ownership (measured in kilometer carried per passenger), and $(comvgrowth)_{it}$ represents the growth rate of commercial vehicle haulage (measured in kilometer carried per ton of cargo) for administrative unit *i* in year *t*.

The model is expanded further by including dummies representing economic corridors; international ports (air, river, and sea); and the presence of land borders (international and local), as follows:

$$(pcgdpgrowth)_{it} = c + \alpha\,(popgrowth)_{it} + \beta\,(capitalgrowth)_{it} + \gamma\,(edugrowth)_{it} + \delta 1(passvgrowth)_{it} + \delta 2(comvgrowth)_{it} + \theta 1(crrdr\_all)_{it} + \theta 2(cross\_intl)i + \theta 3(cross\_local)_{i} + \theta 4(port\_air)_{i} + \theta 5(port\_river)_{i} + \theta 6(port\_sea)_{i} + \varepsilon_{it} \quad (3)$$

where $(crrdr\_all)_{it}$ represents the presence of any economic corridors in administrative unit *i* in year *t*, $(cross\_intl)_{i}$ represents the presence of an international land border (which third-country nationals can cross), $(cross\_local)_{i}$ represents the presence of a local land border (where only neighbor-country nationals can cross), $(port\_air)_i$ represents the presence of an international airport, $(port\_river)_i$ represents the presence of an international river port, and $(port\_sea)_i$ represents the presence of an international seaport in administrative unit *i*.

Panel datasets are created at the subnational level comprising 24 administrative units for Cambodia, 14 for the Guangxi Autonomous Region, 17 for the Lao PDR, 14 for Myanmar, 76 for Thailand, 63 for Viet Nam, and 16 for Yunnan Province (224 units in total). The dataset for 2001–2012 is compiled from data documented in yearbooks for each country, province, and/or region, with some supplementary information where economic data are lacking, particularly for Cambodia, the Lao PDR, and Myanmar.

Table 10.4 summarizes the data constraints faced and adjustments made in creating the dataset, Table 10.5 summarizes the location of economic corridors and criteria used for the dummy variables for each economic corridor, and Table 10.6 presents the assignments of various dummy variables to each administrative unit.

Table 10.4 Data Constraints and Adjustments Made in Creating the Dataset

Region	GDP	Population	Physical Capital	Human Capital	Road Transport Indicators
Cambodia	Data by province are not available.	Only occasional census data are available. Data in missing years are interpolated.	Data by province are not available.	The 3-year moving average for the number of teachers in general education is used.	Data by province are not available.
Lao PDR	Data for 2006–2010 collected by M. Ishida at IDE-JETRO are used.	Data by province are incomplete. Only those for 2007–2011 are used.	Data by province are not available.	Appropriate data by province are not available.	Data by province are not available.
Myanmar	Data by state and/or division are not available.	Data after 2010 are truncated and excluded from the dataset.	Data by state or division are not available.	The 3-year moving average for the number of high school students is used.	The 3-year moving average for road transport haulage is used.
Viet Nam	As GDP data by province are missing in many years, provincial income is substituted.	Complete data are available.	The 3-year moving average for fixed assets in the enterprise sector is used.	The 3-year moving average for the number of university students is used.	The 3-year moving average for road transport haulage is used.

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Table 10.4 *continued*

Region	GDP	Population	Physical Capital	Human Capital	Road Transport Indicators
Thailand	Data after 2009 are truncated and excluded from the dataset.	Data in 2004 are disrupted and excluded from the dataset.	The 3-year moving average for investments by firms registered at the Industry Ministry is used.	Appropriate data by province are not available.	The number of registered passenger and commercial vehicles is used. Data before 2004 are truncated and excluded from the dataset.
Yunnan Province	Complete data by city are available.	Data in 2004–2007 are truncated and interpolated from their previous and subsequent years.	Data for fixed capital formation are used, but data after 2008 are missing.	The 3-year moving average for the number of scientists is used.	The number of registered passenger and commercial vehicles is used. Data for 2001–2003 and 2006 are truncated and excluded from the dataset.
Guangxi Autonomous Region	Complete data by city are available.	Data for 2010 are truncated and excluded from the dataset.	Data for fixed capital formation are used.	The 3-year moving average for the number of high school graduates is used.	The number of registered commercial vehicles is used.

GDP = gross domestic product, IDE-JETRO = Institute of Developing Economies and Japan External Trade Organization, Lao PDR = Lao People's Democratic Republic.
Source: Data compiled by the author from statistical yearbooks of Cambodia, Lao PDR, Myanmar, Viet Nam, Thailand, Yunnan Province, and Guangxi Autonomous Region.

Table 10.5 Location of Economic Corridors and Criteria for Assigning Dummy Values

Corridor	Route Location and Criteria for Assigning Dummy Values
Central Corridor 1 (C1)	Connects Kunming in Yunnan Province and Sattahip Port in Thailand via Vientiane in the Lao PDR. No noticeable change was observed throughout 2001–2012. A value of 1 is assigned to all administrative units located along the corridor throughout the data period.
Central Corridor 2 (C2)	Connects Kunming and Sihanoukville in Cambodia via NR13 in the Lao PDR and NR7 and NR4 in Cambodia. NR13 in the Lao PDR became functional after 2001 and NR7 in Cambodia was paved by 2007. A value of 1 is assigned to administrative units located along the corridor after these years.

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Table 10.5 *continued*

Corridor	Route Location and Criteria for Assigning Dummy Values
Eastern Corridor 1 (E1)	Connects Kunming and Ha Noi in Viet Nam via the Hekou border. The highway was constructed in Yunnan Province in 2008. A value of 1 is assigned to administrative units in Yunnan Province along the corridor after 2008 (the new railway between Kunming and Hekou was completed in 2013, and a new road between Hekou and Ha Noi was opened in 2016; however, these events are outside the dataset period).
Eastern Corridor 2 (E2)	Connects Ha Noi and Nanning in Guangxi via the Yougiguan–Hhugi border. The Nanning–Yougiguan highway opened in 2005. A value of 1 is assigned to administrative units in Yunnan Province along the corridor after 2005.
Eastern Corridor 3 (E3)	Connects Ha Noi and Fangchenggang in Guangxi via the Donxing–Mong Cai border. The Bai Chai bridge at Halong Bay opened in 2006. A value of 1 is assigned to administrative units in Viet Nam along the corridor after 2006.
North–South Corridor (NS)	Connects Kunming and Bangkok via the northwest region of the Lao PDR. The Kunming–Pu'er highway opened in 2004, the road between Jinghong and the Mohan–Boten border was upgraded by 2008, and NR3 in the northwest region of the Lao PDR was upgraded by 2009. A value of 1 is assigned to administrative units located along the corridor after these years.
Northern Corridor (N)	Connects Mandalay in Myanmar and Fangchenggang in Guangxi via Shan State, Kunming, and Nanning. The Ruili–Muse border trade zone was established and the Mandalay–Muse and Ruili–Kunming roads are considered to have been functional by 2005. A value of 1 is assigned to administrative units located along the corridor after 2005.
East–West Corridor (EW)	Connects Da Nang in Viet Nam and Mawlamyaine in Myanmar via the southern region of the Lao PDR and central Thailand. The Hai Van Tunnel opened and the Da Nang Port improvement was completed in 2006, and the Second Mekong Friendship Bridge at the Savannakhet–Mukdahan border opened in 2008. A value of 1 is assigned to administrative units located along the corridor after these years.
Southern Corridor (S)	Connects Bangkok and Ho Chi Minh City via Phnom Penh. The Phnom Penh–Ho Chi Minh City road was paved and upgraded by 2005. A value of 1 is assigned to administrative units located along the corridor after 2005 (the "Tsubasa" bridge at Neak Loung in Cambodia opened in 2015, but this event is outside the dataset period).
Southern Coastal Corridor (SC)	Connects Bangkok and Ca Mau in Viet Nam via Thailand's eastern seaboard and coastal Cambodia and Viet Nam. The coastal road between Trat (Thailand), Koh Kong (Cambodia), and Sihanoukville was upgraded by 2008. A value of 1 is assigned to administrative units in Cambodia located along the corridor after 2008 (the coastal road between Trat [Thailand], Koh Kong [Cambodia], and Sihanoukville was upgraded by 2016, but this development is outside the dataset period).

Lao PDR = Lao People's Democratic Republic.

Source: Project documents available from ADB and JICA websites and the author's observations in the field between 2005 and 2012.

Table 10.6 Information Used for Dummy Assignments to Each Administrative Unit

Region		Int'l Port	Land Border	Economic Corridor
Cambodia (provinces)				
1.	Phnom Penh	Air, river		C2, S
2.	Kandal		Local	C2, S
3.	Kampong Cham			C2
4.	Svay Rieng		Int'l, local	S
5.	Prey Vent		Local	S
6.	Takeo		Local	
7.	Banteay Meanchey		Int'l	S
8.	Battambang			S
9.	Kampong Chhnang			S
10.	Kampong Thom			
11.	Siem Reap	Air		
12.	Oddar Meanchey		Local	
13.	Pailin		Int'l	
14.	Pursat			S
15.	Kampot		Int'l	SC
16.	Koh Kong		Int'l	SC
17.	Kep			SC
18.	Preah Sihanouk	Sea		C2, SC
19.	Kampong Speu			C2
20.	Kratie			C2
21.	Mondulkiri		Local	
22.	Preah Vihear		Local	
23.	Ratanakiri		Int'l	
24.	Steung Treng		Int'l	C2
Lao PDR (provinces)				
1.	Vientiane City	Air	Int'l	NS, C1, C2
2.	Phongsaly		Int'l, local	
3.	Luang Namtha		Int'l, local	NS, C1, C2
4.	Oudomxay			C1, C2
5.	Bokeo	River	Int'l, local	NS
6.	Luang Prabang	Air, river		C1, C2

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Table 10.6 *continued*

Region		Int'l Port	Land Border	Economic Corridor
7.	Houaphan		Int'l	
8.	Xayaburi	River	Local	
9.	Xieng Khouang			
10.	Vientiane (province)			C1, C2
11.	Bolikhamxay	River	Int'l	C2
12.	Khammouan	River	Int'l	C2
13.	Savannakhet	Air, river	Int'l	C2, EW
14.	Salavan			C2
15.	Sekong			
16.	Champasak		Int'l	C2
17.	Attapeu		Int'l	
Myanmar				
1.	Kachin State		Local	
2.	Kayah State		Local	
3.	Kayin State		Int'l	EW
4.	Chin State			
5.	Sagain Division		Int'l	N
6.	Tanintharyi Division	Sea	Int'l	S
7.	Bago Division			
8.	Magwe Division			
9.	Mandalay Division			N
10.	Mon State			EW
11.	Rhakaine State		Local	
12.	Yangon Division	Air, sea		
13.	Shan State		Int'l, local	N, NS
14.	Aeyarwady Division			
Viet Nam (provinces)				
1.	Ha Noi City	Air		E1, E2, E3
2.	Vinh Phuc			E1
3.	Bac Ninh			E2
4.	Quang Ninh		Int'l	E3
5.	Hai Duong			E3
6.	Hai Phong City	Air, sea		E3

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Table 10.6 *continued*

Region	Int'l Port	Land Border	Economic Corridor
7. Hung Yen			E3
8. Thai Binh			
9. Ha Nam			
10. Nam Dinh			
11. Ninh Binh			
12. Ha Giang		Local	
13. Cao Bang		Local	
14. Bac Kan			
15. Tuyen Quang			
16. Lao Cai		Int'l, local	E1
17. Yen Bai			E1
18. Thai Nguyen			
19. Lang Son		Int'l, local	E2
20. Bac Giang			E2
21. Phu Tho			E1
22. Dien Bien		Int'l	
23. Lao Chau		Local	
24. Son La		Local	
25. Hoa Binh			
26. Thanh Hoa		Local	
27. Nghe An		Local	
28. Ha Tinh		Int'l	
29. Quang Binh		Int'l, local	
30. Quang Tri		Int'l, local	EW
31. Thua Thien-Hue City			EW
32. Da Nang City	Air, sea		EW
33. Quang Nam			
34. Quang Ngai			
35. Binh Dinh			
36. Phu Yen			
37. Khanh Hoa			
38. Ninh Thuan			
39. Binh Thuan			

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Table 10.6 *continued*

Region	Int'l Port	Land Border	Economic Corridor
40. Kon Tum		Local	
41. Gia Lai		Int'l	
42. Dak Lak		Local	
43. Dak Nong		Local	
44. Lam Dong			
45. Binh Phuoc		Local	
46. Tay Ninh		Int'l, local	S
47. Binh Duong			
48. Dong Nai			
49. Ba Ria-Vung Tau	Sea		S
50. Ho Chi Minh City	Air, river		S
51. Long An		Local	
52. Tien Giang			
53. Ben Tre			
54. Tra Binh			
55. Vinh Long			
56. Dong Thap		Local	
57. An Giang		Int'l, local	
58. Kien Giang		Int'l	SC
59. Can Tho			
60. Hau Giang			
61. Soc Trang			
62. Bac Lieu			
63. Ca Mau			SC
Thailand (provinces)			
1. Bangkok City	Air, river		NS, S, SC
2. Samut Prakan			SC
3. Nonthaburi			S
4. Pathumthani			NS
5. Nakhon Pathom			S
6. Samut Sakhon			
7. Phrana Si Ayuthaya			NS
8. Ang Thong			NS

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Table 10.6 *continued*

Region	Int'l Port	Land Border	Economic Corridor
9. Lopburi			
10. Singburi			NS
11. Chainat			
12. Saraburi			
13. Chonburi	Sea		C1, SC
14. Rayong			SC
15. Chanthaburi			SC
16. Trat		Int'l	SC
17. Chachoengsao			C1, S, SC
18. Prachinburi			C1, S
19. Nakhon Nayok			S
20. Sa Kaew		Int'l, local	S
21. Ratchaburi			
22. Kanchanaburi		Int'l	S
23. Suphanburi			
24. Samut Songkhram			
25. Petchaburi			
26. Prachuap Khiri Khan		Local	
27. Chiang Mai	Air		
28. Lamphun			
29. Lampang			
30. Uttaradit			NS
31. Phrae			NS
32. Nan		Local	
33. Phayao			NS
34. Chiang Rai	Air, river	Int'l	NS
35. Mae Hong Son			
36. Nakhon Sawan			NS
37. Uthaithani			
38. Kamphaeng Phet			
39. Tak		Int'l	EW, NS
40. Sukhothai			EW
41. Phisanulok			EW, NS

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Table 10.6 *continued*

Region	Int'l Port	Land Border	Economic Corridor
42. Phichit			NS
43. Phetchabun			EW
44. Nakhon Ratchasima			C1
45. Buriram		Local	
46. Surin		Local	
47. Sisaket		Local	
48. Ubon Ratchathani		Int'l, local	C2
49. Yasothon			
50. Chaiyaphum			
51. Amnat Charoen			
52. Nong Bua Lamphu			
53. Khon Kaen			C1, EW
54. Udon Thani			C1
55. Loei		Local	
56. Nong Khai	River	Int'l, local	C1
57. Maha Sarakham			
58. Roi Et			
59. Kalasin			EW
60. Sakon Nakhon			
61. Nakhon Phanom	River	Int'l	C2
62. Mukdahan	River	Int'l	EW
63. Nakhon Si Thammarat			
64. Krabi			
65. Phang Nga			
66. Phuket	Air		
67. Surat Thani			
68. Ranong	Sea	Int'l	
69. Chumphon			
70. Songkhla	Air	Int'l, local	
71. Satun		Local	
72. Trang			
73. Patthalung			
74. Patthani			

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Table 10.6 *continued*

Region		Int'l Port	Land Border	Economic Corridor
75.	Yala		Local	
76.	Narathiwat		Int'l	
Yunnan Province				
1.	Kunming City	Air		E1, NS, N
2.	Qujing City			E1, NS
3.	Yuxi City			N
4.	Baoshan City			
5.	Zhaotong City			
6.	Lijiang City			
7.	Pu'er City	River		NS
8.	Lincang City		Local	
9.	Chuxiong Yi Aut. Pref.			N
10.	Honghe Hani and Yi Aut. Pref.		Int'l	E1, N
11.	Wenshan Zhuang and Miao Aut. Pref.		Local	N
12.	Xishuangbanna Dai Aut. Pref.	River	Int'l, local	NS
13.	Dali Bai Autonomous Prefecture			N
14.	Dehong Dai and Jimpo Aut. Pref.		Int'l	N
15.	Nujian Lisu Aut. Pref.		Local	
16.	Deqen Tibetan Aut. Pref.			
Guangxi Autonomous Region				
1.	Nanning City	Air		E2, N
2.	Liuzhou City			
3.	Guilin City			
4.	Wuzhou City			
5.	Beihai City	Sea		
6.	Fangchenggang City	Sea	Int'l, local	E3, N
7.	Qinzhou City			N
8.	Quigang City			
9.	Yulin City			
10.	Baise City		Local	N
11.	Hezhou City			

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Table 10.6 *continued*

Region	Int'l Port	Land Border	Economic Corridor
12. Hechi City			
13. Laibin City			
14. Chongzuo City		Int'l, local	E2

Aut. Pref. = Autonomous Prefecture, C1 = Central Corridor 1, C2 = Central Corridor 2, E1 = Eastern Corridor 1, E2 = Eastern Corridor 2, E3 = Eastern Corridor 3, EW = East–West Corridor, Int'l = international, Lao PDR = Lao People's Democratic Republic, N = Northern Corridor, NW = North–West Corridor, S = Southern Corridor, SC = Southern Coastal Corridor.
Note: In the second column, "air" indicates the presence of an international airport, "sea" indicates the presence of a seaport, and "river" indicates the presence of a river port in the administrative unit. In the third column, "int'l" indicates the presence of international border-crossing points and "local" indicates the presence of local border-crossing points in the administrative unit. The third column indicates which economic corridor(s) cross the administrative unit.
Source: Project documents available from ADB and JICA websites and the author's observations in the field between 2005 and 2012.

The estimation results are summarized in Table 10.7. Estimation models are chosen from the results of a Hausman test, as shown in the second row of Table 10.7.

The basic model (equation 1) yielded largely expected signs of the coefficients: negative for population growth, positive for physical capital growth, and positive and statistically significant for human capital growth. As the dataset is highly unbalanced due to missing data (particularly for Cambodia, the Lao PDR, and Myanmar), this result indicates that the basic model is a workable starting point for explaining changes in living standards in the GMS at the subnational level.

Model 2 (equation 2), which included road transport-related variables, yielded positive and statistically significant coefficients for the two variables representing growth in passenger and cargo traffic. This implies that traffic growth at the subnational level boosts living standards in the GMS. A correlation analysis between the explanatory variables in Model 2 yielded maximum coefficients of less than 0.3, and indicates a small likelihood of multicollinearity problems.

Model 3 (equation 3), which included various dummies for cross-border transport infrastructure, yielded similar results on road transport-related variables as well as two statistically significant coefficients. The first is a positive coefficient for the dummy for all economic corridors in the GMS combined. The dummy values (1 or 0) were chosen based on the author's long-term observations of the developments of individual corridors (Table 10.5). This result indicates that the development of economic corridors in the GMS as a whole has

Table 10.7 Estimation Results for Panel-Data Analysis at the Subnational Level (Dependent variable = per capita GDP growth)

Explanatory Variables	Model 1 Cross-section fixed effects	Model 2 Cross-section random effects	Model 3 Cross-section random effects	Model 4 Period random effects
Constant	0.0773***	0.0419***	0.0383***	0.0778***
Population growth	−0.2768	−0.2731	−0.1051	
Physical capital growth	0.0057	0.0068	0.0052	
Human capital growth	0.0418*	0.0309*	0.0322*	
Road transport growth for passengers		0.1478***	0.1482***	
Road transport growth for cargo		0.0709**	0.0794**	
Dummy for international land border			−0.0084	
Dummy for local land border			0.0046	
Dummy for international airport			−0.0363**	
Dummy for international river port			−0.0061	
Dummy for international seaport			0.0054	
Dummy for all economic corridors			0.0150*	
Dummy for C1 corridor				0.0055
Dummy for C2 corridor				−0.0108
Dummy for E1 corridor				−0.0263*
Dummy for E2 corridor				0.0124
Dummy for E3 corridor				0.0084
Dummy for EW corridor				−0.0026

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Table 10.7 *continued*

Explanatory Variables	Model 1 Cross-section fixed effects	Model 2 Cross-section random effects	Model 3 Cross-section random effects	Model 4 Period random effects
Dummy for N corridor				0.0636***
Dummy for NS corridor				0.0359***
Dummy for S corridor				–0.0092
Dummy for SC corridor				–0.0254**
Sample size	490	369	369	1743
R2	0.2931	0.0927	0.1131	0.0519

C1 = Central Corridor 1, C2 = Central Corridor 2, E1 = Eastern Corridor 1, E2 = Eastern Corridor 2, E3 = Eastern Corridor 3, EW = East–West Corridor, N = Northern Corridor, NS = North–South Corridor, R2 = r-squared, S = Southern Corridor, SC = Southern Coastal Corridor.
***Statistical significance at 1%.
**Statistical significance at 5%.
*Statistical significance at 10%.
Source: Author's estimates.

had an additionally positive impact on the region's living standards. The second is a negative coefficient for the dummy for international airports. Although various interpretations are possible for this result, one could argue that administrative units with international airports would have achieved high living standards by 2000 and, all other conditions being equal, have experienced relatively slower growth. If so, this result could be interpreted as evidence of some convergence occurring in the GMS—a long-term desirable sequence of economic corridors causing agglomeration followed by dispersion.

The effects of the development of individual economic corridors could not be estimated using various extensions from the basic model because the dataset is large and unbalanced. Therefore, with no theoretical rigor, a simple regression including dummies for all individual economic corridors was attempted, as in Model 4, to shed light on at least the relative impact of these corridors among themselves. The result included four statistically significant coefficients. The Northern Corridor (connecting central Myanmar through Shan State, and Yunnan Province with the coastal city of Fangchenggang in the Guangxi Autonomous Region) and the North–South Corridor (connecting Kunming in Yunnan Province with Bangkok through the northwestern Lao PDR) had positive coefficients. These two corridors appear to have already had positive economic impacts during the data period. Conversely, the Eastern Corridor 1 (connecting Kunming and Ha Noi) and the Southern Coastal Corridor (connecting Bangkok with Ca Mau, Viet Nam's southernmost city, via coastal Cambodia) had negative coefficients. These results may be due to the deplorable condition of the Lao Cai–Ha Noi road up through 2012 for the former and relatively small traffic along the coastal routes in Cambodia and Viet Nam, as witnessed by the author.

The above analysis, despite its constrained data, confirmed a positive additionality of GMS economic corridors as a whole, and yielded an interesting result suggesting that dispersion effects have begun to emerge after agglomeration effects. However, it was not possible to separate and identify the impacts of individual corridors due to serious data limitations. The advantages of the panel data analysis include an increased number of observations and improved reliability of causality among variables; however, it must be admitted that the limited dataset constrains the analysis' scope. In particular, estimation models including a dummy for economic corridors cannot pick up fixed effects for administrative units or periods, and therefore cannot provide detailed interpretations specific to geography and time. These remain subjects for similar future analyses.

10.4 Gravity Model Analysis of Intra-Greater Mekong Subregional Trade

The third approach to quantifying the impact of cross-border transport infrastructure in the GMS is to use a gravity model to measure its additional impact on intra-regional trade. An earlier analysis by Edmonds and Fujimura (2008) that applied 1981–2003 data to intra-GMS trade found that improving cross-border road infrastructure (measured in road density) had an additional incremental effect on intra-regional trade via land borders in the GMS. In contrast, Taguchi (2013) applied 1980–2010 panel data from Thailand and its trading partners and found that Thailand trades less intensively with its partners in the Mekong region than with those outside the region, implying that the service-link cost remains higher within the region than outside the region.

A recent analysis by Ono and Fujimura (2015) examined the effects of transport infrastructure development on intra-GMS trade. In considering this analysis, we focused on the intra-GMS trade in electric and transport machinery in particular, as trades in these manufacturing industries reflect vertical integration across borders by reducing the service-link cost. The trades are divided between final and intermediate goods to ascertain whether the latter would increase more than the former, thus more clearly demonstrating the reduction in the service-link cost.

Before looking at a gravity model analysis, it is necessary to consider a broad trend in intra-GMS trade. Table 10.8 shows intra-GMS trade in 2000, 2006, and 2012, in which years each GMS member's dependence on intra-regional trade broadly increased. Although missing data for Guangxi, Myanmar, and Yunnan in 2012 make it impossible to derive a clear picture of a recent trend, regional trade among these members has been presumably expanding rapidly given their geographical proximity and the opening up of Myanmar's economy since 2012. If adequate trade data were available, intra-GMS trade would be expanding more quickly than shown in Table 10.7 (If data were available for trade between Myanmar and Yunnan Province for 2012, which were available for 2000 and 2006, the figures for the GMS shares, i.e., 39% and 14%, would be much larger.)

Next, Figure 10.2 shows trends in intra-GMS trade in electric and transport machinery (divided between intermediate and final goods). We collected pairwise trade data from the United Nations International Trade Statistics Database and applied them to the categorization of intermediate and final goods devised by the Research Institute of Economy, Trade and Industry, Japan. Due to the data constraints that we faced for Guangxi and Yunnan individually (their statistical yearbooks do not include partner-wise trade by commodity grouping), we use the PRC's aggregate trade data together with those of the other five countries. Figure 10.2 indicates that intra-GMS trade in each of the four categories is increasing, with intermediate goods in electric machinery growing the fastest. This seems to imply that in the electric machinery industry, vertical integration across national borders in the GMS is well advanced, and final goods are exported to markets outside the GMS. In contrast, in the transport machinery industry, intermediate goods are mostly imported from countries outside the GMS such as Japan and Germany; assembled in major producing countries such as the PRC, Thailand, and Viet Nam (which predominantly produces motorbikes); and finally marketed mainly within the GMS.

Table 10.8 Trends in Intra-Greater Mekong Subregional Trade ($ million)

		Importer									
	2000	**Cambodia**	**Lao PDR**	**Myanmar**	**Viet Nam**	**Thailand**	**Yunnan**	**Guangxi**	**GMS total**	**Total exports**	**GMS share**
Exporter	Cambodia	X	3	0	19	23	0	NA	45	1,123	4%
	Lao PDR	0	X	NA	96	69	6	NA	171	330	52%
	Myanmar	0	NA	X	3	233	70	NA	306	1,646	19%
	Viet Nam	142	71	6	X	372	8	69	668	14,483	5%
	Thailand	347	381	504	838	X	8	22	2,100	68,963	3%
	Yunnan	1	13	293	93	24	X	NA	424	1,175	36%
	Guangxi	NA	NA	NA	222	23	NA	X	245	1,493	16%
	GMS total	490	468	803	1,271	744	92	91	3,959	89,213	4%

		Importer									
	2006	**Cambodia**	**Lao PDR**	**Myanmar**	**Viet Nam**	**Thailand**	**Yunnan**	**Guangxi**	**GMS total**	**Total exports**	**GMS share**
Exporter	Cambodia	X	0	0	75	15	0	NA	90	3,562	3%
	Lao PDR	1	X	NA	107	455	13	NA	576	882	65%
	Myanmar	0	NA	X	51	2,135	224	NA	2,410	4,5000	54%
	Viet Nam	245	83	15	NA	822	53	717	1,935	39,605	5%
	Thailand	1,235	1,025	761	3,098	X	16	30	6,165	130,790	5%
	Yunnan	1	65	541	208	96	X	NA	911	1,342	68%
	Guangxi	NA	NA	NA	750	51	NA	X	801	3,599	22%
	GMS total	1,482	1,173	1,317	4,289	3,574	306	747	12,888	184,280	7%

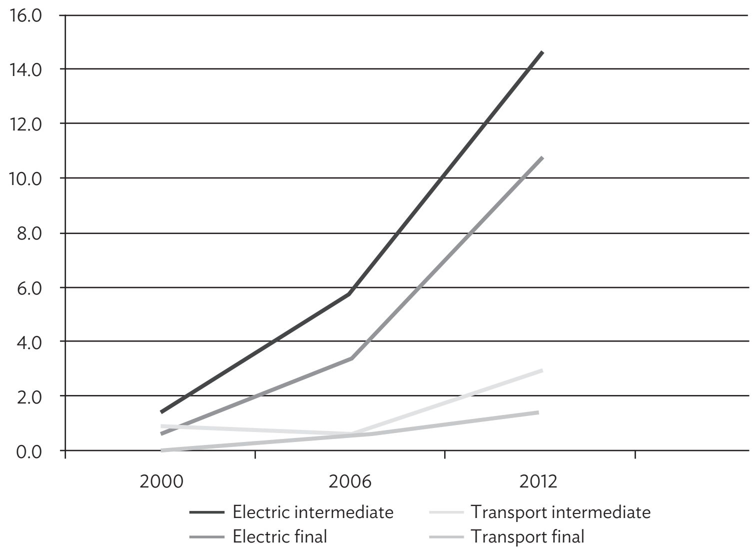
continued on next page

Table 10.8 *continued*

		Importer									
	2012	Cambodia	Lao PDR	Myanmar	Viet Nam	Thailand	Yunnan	Guangxi	GMS total	Total exports	GMS share
Exporter	Cambodia	X	1	NA	442	228	NA	NA	671	8,200	8%
	Lao PDR	2	X	NA	404	1,131	195	NA	1,732	2,400	72%
	Myanmar	0	NA	X	100	3,363	NA	NA	3,463	8,877	39%
	Viet Nam	2,831	421	118	X	2,832	217	146	6,565	115,458	6%
	Thailand	3,761	3,567	3,108	6,443	X	NA	8	17,149	228,178	8%
	Yunnan	7	152	NA	829	439	X	NA	1,427	10,018	14%
	Guangxi	NA	NA	NA	827	226	NA	X	1,053	9,722	11%
	GMS total	6,601	4,141	3,226	9,045	8,219	674	154	32,060	382,853	8%?

GMS = Greater Mekong Subregion, Guangxi = Guangxi Autonomous Region, Lao PDR = Lao People's Democratic Republic, NA = not applicable, Yunnan = Yunnan Province.
Source: International Monetary Fund Direction of Trade for Cambodia, the Lao PDR, Myanmar, Thailand, and Viet Nam; and statistical yearbooks for Yunnan and Guangxi.

Figure 10.2 Intra-Greater Mekong Subregional Trade in Electric and Transport Machinery ($ billion)



Source: Research Institute of Economy, Trade and Industry, Japan Trade Industry Database 2012.

A gravity model is used to investigate the extent to which cross-border transport infrastructure contributed to these expansions in intra-GMS trade. The logic of the gravity model, which has been a popular analytical tool among trade economists since the 1990s, is borrowed from Newton's law of universal gravitation, which states that any two masses attract each other with a force equal to a constant multiplied by the product of the two masses and divided by the square of the distance between them. When applied to trade, this law states that a trade volume between two economies increases proportionate to the product of their GDPs and inversely proportionate to the distance between them:

$$T_{ij} = A\frac{Y_iY_j}{D_{ij}} \tag{4}$$

where T_{ij} is a trade volume between economy i and economy j, A is a constant, Y_i is GDP for economy i and Y_j is GDP for economy j, and D_{ij}

is the distance between them. Taking the logarithm of equation (4) in a form of an estimation model yields:

$$\log T_{ij} = a + \beta_1 \log(Y_i) + \beta_2 \log(Y_j) + \beta_3 \log(D_{ij}) + \varepsilon_{ij} \tag{5}$$

This is the simplest form of the gravity model upon which many trade economists have expanded. Anderson and van Wincoop (2003) suggested that additional explanatory variables include language, free trade agreements, price levels, and/or real exchange rates. Our analysis includes variables representing cross-border infrastructure development in the GMS.

We modify the basic equation and add per capita GDP for trading partners to separate the effects of GMS members' diverse income levels. Per capita GDP also acts as a proxy for the degree of capital intensity and as an important determinant for trades in machinery manufacturing.

$$\ln M_{ijt} = \alpha + \beta_1(\ln GDP_{it}) + \beta_2(\ln GDP_{jt}) + \beta_3(\ln GDP\ percapita_{it}) + \beta_4(\ln GDP\ per\ capita_{jt}) + \beta_5(\ln Distance_{ij}) + \varepsilon_{ijt} \tag{6}$$

M_{ijt} is an import value of country i from country j in year t, GDP_{it} is GDP for country i and GDP_{jt} is GDP for country j in year t, $GDP\ per\ capita_{it}$ is per capita GDP for country i and $GDP\ per\ capita_{jt}$ is per capita GDP for country j in year t, and $Distance_{ij}$ is the distance between the two countries. is an error term.

We can further add a dummy variable (denoted as *INFRA*) representing a combination of events that reflect improvements in cross-border transport infrastructure in the GMS, as summarized in Table 10.5.

$$\ln M_{\text{ijt}} = \alpha + \beta_1(\ln GDP_{it}) + \beta_2(\ln GDP_{jt}) + \beta_3(\ln GDP\ percapita_{it}) + \beta_4(\ln GDP\ per\ capita_{jt}) + \beta_5(\ln Distance_{ij}) + \beta_6 INFRA + \varepsilon_{ijt} \tag{7}$$

Furthermore, we could construct an estimation model that includes dummy variables representing individual events that reflect cross-border transport infrastructure development, as follows.

$$\ln M_{\text{ijt}} = \alpha + \beta_1(\ln GDP_{it}) + \beta_2(\ln GDP_{jt}) + \beta_3(\ln GDP\ percapita_{it}) + \beta_4(\ln GDP\ per\ capita_{jt}) + \beta_5(\ln Distance_{ij}) + \beta_6 CA_{V2006} + \beta_7 CH_{L2009+\beta_8 CH_{V2006}} + \beta_9 L_{V2006} + \beta_{10} L_{T2008} + \beta_{11} river2012 + \beta_{12} tradezone2005 + \varepsilon_{ijt} \tag{8}$$

CA_V2006 is a dummy for road upgrading between Phnom Penh (Cambodia) and Ho Chi Minh City (Viet Nam) completed in 2006 along the Southern Economic Corridor. *CH_L2009* is a dummy for road upgrading between Kunming (PRC) and Houayxai (Lao PDR) completed by 2009 along the North–South Economic Corridor. *CH_V2006* is a dummy for the completion of an expressway by 2006 between the Huu Nghi-Yougiguan border and Nanning along the Eastern Economic Corridor 2. *L_V2006* is a dummy for the opening of the Hai Van Tunnel and the improvement of the Da Nang Port by 2006 along the East–West Economic Corridor. *L_T2008* is a dummy for the completion of the Second Mekong Friendship Bridge at the Savannakhet (Lao PDR)–Mukdahan (Thailand) border, along the East–West Economic Corridor. In addition, *river2012* is a dummy for the opening of the second Cheang Saen Port (Thailand) in 2012 that contributes to border trade between the PRC and Thailand along the North–South Economic Corridor, while *tradezone2005* is a dummy for the establishment of the border trade zone at the Ruili (Yunnan)–Muse (Myanmar) border in 2005 along the Northern Economic Corridor. Values for these dummy variables follow the criteria in Table 10.5.

We created panel data from the six GMS countries for the years 2000–2012 (the dataset is constrained by missing data for Cambodia, the Lao PDR, and Myanmar). We also faced the problem of inadequate partner-wise trade data for Guangxi Autonomous Region and Yunnan Province, at least as reflected in their statistical yearbooks. Therefore, we substituted their trade data with those of the PRC as a whole, making it somewhat difficult to interpret the results compared with those obtained by using data from the seven GMS economies. Descriptive statistics of the dataset are provided in Table 10.9 (dummy variables are excluded).

Table 10.9 Descriptive Statistics

Variable	Sample	Mean	Median	Max	Min	SD
X_GDP	390	10.81	10.46	15.94	7.42	2.31
M_GDP	390	10.81	10.46	15.94	7.42	2.31
X_PGD	390	6.83	6.78	8.71	5.01	0.96
M_PGDP	390	6.83	6.78	8.71	5.01	0.96
DISTANC	390	7.04	6.91	8.12	6.18	0.71
EL_INT	284	14.88	15.30	22.46	4.56	4.03
EL_FIN	284	14.66	15.29	22.38	3.66	4.15
TR_INT	253	13.79	14.92	20.30	3.00	3.87
TR_FIN	277	14.61	15.51	20.70	2.08	3.67

Max = maximum, Min = minimum, SD = standard deviation.
Source: Ono and Fujimura (2015).

Table 10.10 Estimation Results from Model (6)
(Dependent variable = pairwise import value)

Explanatory Variables	Electric Machinery		Transport Machinery	
	Intermediate	Final	Intermediate	Final
X_GDP	1.061***	1.424***	0.990***	1.050***
M_GDP	0.437***	0.373***	0.343***	−0.218*
X_PGDP	1.563***	1.074***	1.594***	1.187***
M_PDGP	0.638***	0.730***	0.316	0.652***
DISTANCE	−0.457	−0.922***	−0.748*	−1.370***
Sample size	284	284	253	277
R-squared	0.628	0.617	0.568	0.626

***Statistically significant at 1%.
**Statistically significant at 5%.
*Statistically significant at 10%.
Source: Ono and Fujimura (2015).

Despite these severe data constraints, some reasonable results were obtained (Table 10.10). The estimation model was chosen based on the result of the Hausman test. Consequently, the intermediate goods trade in electric machinery applied the period fixed effects model, and all the others applied the period random effects model.

Statistically significant coefficients with expected signs were obtained for almost all variables: positive for GDP and per capita GDP and negative for DISTANCE. The only anomaly is the negative and statistically significant coefficient for the GDP of the importing country in the final goods trade for transport machinery. This can be interpreted as a reflection of some"PRC (as a large economy) bias." Our panel data, including trade values for the PRC as a whole instead of two southern provinces, may have caused this anomaly because small countries like Cambodia, the Lao PDR, and Myanmar mostly import final machinery goods from the PRC, not vice versa. The result may have differed if pairwise trade data had been available for the two provinces instead of the PRC as a whole.

Adding a dummy variable representing the development of all economic corridors in the GMS combined or INFRA yields the results shown in Table 10.11. The same estimation model used in Table 10.9 was chosen. Here again, almost all coefficients proved to have the expected sign and to be statistically significant. The INFRA dummy obtained a positive and statistically significant coefficient for all trade categories,

Table 10.11 Estimation Results from Model (7) (Dependent variable = pairwise import value)

Explanatory ariables	Electric Machinery		Transport Machinery	
	Intermediate	Final	Intermediate	Final
X_GDP	1.297***	1.458***	0.976***	1.030***
M_GDP	0.607***	0.390***	0.306***	–0.262**
X_PGDP	1.461***	1.059***	1.604***	1.166***
M_PDGP	0.637***	0.709***	0.330	0.638***
DISTANCE	–0.923	–0.965***	–0.637*	–1.241***
INFRA	1.063***	0.818***	0.867***	1.035***
Sample size	284	284	253	277
R-squared	0.655	0.624	0.591	0.653

***Statistically significant at 1%.
**Statistically significant at 5%.
*Statistically significant at 10%.
Source: Ono and Fujimura (2015).

indicating that the development of economic corridors has enhanced intra-GMS trade overall. In addition, the coefficients of the INFRA variable are greater for intermediate goods than for final goods in electric machinery, but this effect is switched for transport machinery. This seems to reinforce the concept that, due to reduced service-link cost through economic corridor developments, vertical integration across national borders in the GMS is more advanced for electric machinery industry than for transport machinery industry.

Finally, we were unable to perform regressions on estimation Model 8 due to the lack of a sample size relative to the increased number of explanatory variables—this should be done in the future when the dataset has improved.

It is necessary to reiterate some reservations with regard to the above analysis. First, pairwise trade data for Cambodia, the Lao PDR, and Myanmar are very much lacking. The United Nations International Trade Statistics Database, routinely used by researchers on empirical studies, fills in missing data for data-scarce countries by using those of their trading partners, with some adjustments. For now, any analysis of intra-GMS trade like this one will face the same problem. The analysis also faced the problem of inadequate partner-wise trade data for Yunnan Province and Guangxi Autonomous Region. Substituting their trade data with those of the PRC as a whole makes it somewhat difficult to interpret the results. Future studies should collect detailed partner-wise trade data for these two regions to improve the analysis.

10.5 Concluding Remarks

This chapter used three approaches to evaluate cross-border transport infrastructure in the GMS. First, it presented partial attempts to produce benefit–cost ratios for the North–South, East–West, and Southern Economic Corridors. The estimates indicate that the degrees of economic viability seem to be in the order of the Southern, North–South, and East–West corridors. The result for the Southern Corridor fits well with the gravity model framework, as the corridor includes three large economies—Bangkok, Ho Chi Minh City, and Phnom Penh—along its relatively short length of about 900 kilometers. In contrast, the East–West Corridor includes no large economies (except Da Nang) along its route, which is about 1,450 kilometers in length. The East–West Corridor was presumably built with the intention of yielding benefits in the long term; and it may do so in 10–20 years. Numerous infrastructure developments, such as large bridges and port upgrades, are being carried out along these corridors. Future reevaluation efforts should incorporate new developments with longer term and more comprehensive data.

Second, the chapter presented a panel data analysis of how economic corridor developments have impacted living standards at the subnational level. The result indicates that economic corridors in the GMS as a whole yielded an additional net positive impact. It is also interesting to note that the impact of economic corridors may have shifted to the "dispersion" stage to some extent beyond the "agglomeration" stage.

Third, the chapter presented a gravity model analysis of how economic corridors have affected intra-GMS trade through a presumed reduction in service-link cost. The result indicates that the development of economic corridors has positively affected intra-GMS trade in intermediate goods, especially electric machinery. This implies that cross-border transport infrastructure in the GMS has contributed to lower service-link cost and facilitated vertical integration across borders in this industry.

While the second and third analyses are based on admittedly incomplete data and their rigor is therefore not subject to question, it is hoped that these attempts will interest researchers and practitioners working in similar areas.

All the analyses presented in this chapter are based on data related to physical aspects of transport infrastructure alone, and do not incorporate "soft" aspects of transport facilitation, such as the simplification of cross-border passage of goods and people and cross-border vehicle and driver licenses. These aspects are advanced under the Cross-Border Transport Agreement for the GMS. Although these aspects are admittedly hard to quantify systematically, if included in such analyses as presented in this chapter, it can be assumed that they would indicate an even greater positive impact of the development of cross-border transport infrastructure.

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PART IV

Financing Infrastructure

11

Back to the Future: Instructive Features from Past Innovations in Raising Private Finance for Infrastructure

Naoyuki Yoshino and Grant B. Stillman

> *Just by looking back at history, we can see how important the role of merchants seeking business opportunities around the world has been....Utilization of private funds for infrastructure, as in the case of gas lamps in Yokohama, is nothing new. In the 19th century, it was private sector companies that built most of the railways...*
>
> — Takehiko Nakao, President of the Asian Development Bank, "The Power of Merchants: Tales of a Swiss Company in Yokohama and Japanese Merchants," *BusinessWorld*, 20 November 2017 (translated from the original Japanese article appearing in Koken Magazine, September 2017).

11.1 Introduction

Financing infrastructure is not a recent policy challenge. In the past, many daunting engineering works were successfully completed by relying upon imaginative and innovative approaches to attract private finance to projects for the greater public good. Although the core idea advanced in this book is new and untried, we have been able to draw upon useful elements from forgotten experiences and overlooked prototypes to create its main practical features. Thus, we begin this historical survey by remembering that, in centuries past, privately-owned railway companies in the United States (US) and Japan serviced their massive debts primarily by selling or developing gifted real estate that was either adjacent to the tracks or part of their rights of way.

11.2 First Transcontinental Railroads across North America

By the middle of the 19th century, financiers knew that new railways could increase the value of land as much as four times its unserved value; for example, the price of land around the longest line in the world at that time, Illinois Central, appreciated from $1.25 per acre to $6.00 in 1853, and to $25.00 upon line completion in 1856 (Ambrose 2005: 32). The US Congress and the states readily provided inducements to investors by granting public lands along the planned route to the private company that would build the railway. As historian Stephen E. Ambrose noted perceptively, "*Far from costing the government anything*, the granting of land meant that the alternate sections retained by the government would increase enormously in value as the railroads progressed and finally joined" (Ambrose 2005: 80, emphasis added).

Ancillary sources of neighboring revenue were also relied upon, including mineral rights to coal and iron discovered on the land grants, which the construction companies could exploit for immediate profits (Ambrose 2005: 95). In this respect, they might find a parallel in modern-day billboard concession ad revenues running alongside a highway. Together with city, county, and state governments directly investing in the stocks and bonds of private railway companies, the outright sale or mortgaging of gifted land formed one of the main sources of immediate revenue to service company bonds and pay its bills before passengers and freight could be carried for fares. Yet it must be allowed that not every piece of land was valuable or easily sold, particularly in desert areas or before the completion of the railway (Ambrose 2005: 238). In the better lands of Nebraska, lots along the Platte River Valley were sold by the Union Pacific Company to settlers for $25–$250 on terms of one-third cash with the balance in 2 years; they were also obliged to plant trees for shade (Ambrose 2005: 188).[1]

The pinnacle in American ingenuity for encouraging two private companies to race across the middle of the US during the Civil War was

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1 Even railroad surveyors speculated on the side, buying lots for themselves in unfounded towns for as little as $2.50 and reselling them 5 days later for $25.00 each (Ambrose 2005: 264).

reached with the Union Pacific Act of 1862. The main components of that innovative financing scheme, as amended 2 years later, are set out in Table 11.1.

Table 11.1 Terms of the First Transcontinental Railroad Financing Scheme

Description of Feature	Original 1862 Version	Improved and Final 1864 Version
Right-of-way over public lands	200 feet on both sides of the route	Same; no change
Land grants (checkerboard pattern with other lots remaining in the hands of the Government of the United States)	Five alternate sections (in square miles) on each side per mile; or 6,400 acres per mile	Doubled to 10 alternate sections on each side per mile; or about 12,800 acres per mile
Materials for building track and/or sale to third parties	Earth, stone, and timber on rights-of-way and land	Plus coal, iron, and rights to other minerals found under the land
Government-issued "Sixes" Pacific Railroad bonds loaned to participating private railway companies	In amounts of $16,000 per mile on flat land; $32,000 per mile of foothills; $48,000 per mile in mountainous areas	In mountainous areas, two-thirds of subsidy bonds could be advanced upon the grading of the route, before tracks were laid and completed[a]
Schedule and conditions for the transfer of bonds	Handover after every 40 miles of track approved by government inspectors	Handover reduced to every 20 miles of completed track
Obligor for semiannual interest payments of 6%	Government during tenor; but repayable by private companies in 30 years or less	Same; no change
Securitization of bonds	Government given the first mortgage over built track, improvements, and all other assets of private companies	Government subordinated its priority in favor of the companies' right to issue the same amount of bonds so they could be reliably backed and easily sold
Services performed for the government over 30 years	Carry mail and transport troops and government stores; to be deducted from final principal repayments by companies	Same; no change

[a] An 1866 amendment to speed the closing years of the race allowed grading (ground preparation) up to 300 miles in advance of the continuous lain track, with partial collection of the bonds after each 20-mile segment (Ambrose 2005: 254–255, 305).
Source: Stillman 2017 after Ambrose (2005: 80, 81, 84, and 95); Cox (2015).

The bonds written by the Government of the United States on its own paper and loaned to the railway companies without payment[2] were known as "US Government Sixes" or "Currency 6," which were highly negotiable and could be assigned to suppliers and vendors ("6" being a reference to the 6% annual interest guaranteed and paid by the government to whomever held the bonds every 6 months). Moreover, the companies were relieved from having to pay the interest as they had few or no revenue streams at that point, only bills and expenses. In that sense they could be rightly described as subsidy bonds, a term used by the US Supreme Court in their later opinions (US Supreme Court 1896: 429, 433).

Upon receipt, the companies could sell the bonds on the open market (at par or at a discount if already borrowed against [Ambrose 2005: 245]) for cash on hand, or offer them in consideration to their construction suppliers (most laborers preferred to receive gold for a payday, whenever that rare event occurred).[3] Nevertheless, the subsidy only went so far, and the government expected the companies to repay the principal amount of the government railway bonds in full, as well as all the interest the government had paid thereon in the 30 years (or less) after track completion. Overall, the deal was advantageous for the government, as the following estimate of the final settlements of 1898–1899 shows (Table 11.2).

Importantly, as the companies themselves owed the debt obligations, the wealthy shareholders and promoters of private railroads were generally protected from having to guarantee repayment to the government from their personal fortunes, and were only liable to the extent of their equity shareholding.

Once the companies had a record of laying track, some net operating profits, and built or owned assets and equipment, they were able to sell their own 30-year first mortgage corporate bonds in similar amounts on basically the same terms as the government bonds (Ambrose 2005: 226). To aid uptake, Union Pacific sold a limited initial public offering to mostly East Coast investors at an original issue discount ($0.90 on the dollar), with the company reserving the right to increase the price

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2 As the certificates were transferred after track sections were laid, one could also view as consideration of the company for buying the bond its services of providing railway-building.

3 Being frequently cash-strapped, the Central Pacific Railroad Company had already borrowed heavily against any money it eventually expected to receive from the periodic transfer of government bonds; thus, these funds were often committed even before being paid to the company's account, and usually fell short of the expenditure requirements for forthcoming construction (Ambrose 2005: 149, 165).

Table 11.2 Estimate of the Final Settlements for Government Bonds

Description of Pacific Railroad Bonds	Aggregate Amount in Historical $
Initial loans from the Government of the United States of its bonds to railroad companies	64,623,512
Principal repaid to the government by railroad companies	63,023,512
Plus interest repayments by railroad companies	104,722,978
Railroad companies' total repayments to the government at final settlement	167,746,490

Source: Stillman 2017 after Ambrose (2005: 377).

at their discretion. As interest was paid in gold at the prevailing rate of premium on that precious metal, those bonds could effectively earn annual interest on their offered cost of 9%. Another selling point was the not unreasonable expectation that, upon successful completion of the transcontinental railroad, government bonds as well as those issued by the companies would trade well above par. In the West, the Central Pacific Railroad Company had a harder time selling its own corporate securities, and eventually had to rely upon a California state guarantee of the 7% interest promised on its first, $1.5 million bond issue to make them more marketable, even at the bargain offering price of half par (Ambrose 2005: 121, 124).

It should be noted that some promoters of these schemes will always believe that the best chance for profit in return is during the construction phase (and from government availability payments), while others believe the project can be profitably run upon completion as originally planned (Ambrose 2005: 212, 227). These interests are often not aligned, resulting in tendencies to build quickly (sometimes cheaply or fraudulently) for immediate profit versus prioritizing higher quality for sustained and efficient operations in the longer term.[4] In this respect, the use of specialized construction companies and operating companies geared to different expectations and income streams might be preferable to having a single entity as the build–own–operate bidder, which might be tempted to cut corners.

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4 For instance, adding more and unnecessary miles to a route would increase the amount of bonds and land grants (good for constructors) but slow the directness of the railway (bad for operators and freight customers) (Ambrose 2005: 271).

Once again, it was a private company, the Canadian Pacific Railway (CPR), that built Canada's first transcontinental railway in 1881–1885. This railway linked existing lines in what is now Ontario with the Pacific coast. The CPR signed a contract with the Government of Canada to build the railway. As with the US, Canada's reasons for building it were partly political and geo-strategic. The province of British Columbia joined Canada in 1871 on the promise that a transport route (wagon road) would be built linking it to the other provinces in the east. This route was later upgraded to a railway. The government sought to link the two ends of the country and open up the prairies for settlement and farming. It was basically a nation-building endeavor to resist the pull of the already connected US.

Although the CPR was a private railroad company, it received considerable public support, including C$25 million in credit (C$625 million in current terms) and 20,000 acres of gifted land. The government also transferred to the CPR existing publicly built and owned lines on which the government had already spent millions, resulting in a hefty underwriting of their construction costs. Interestingly, the company was generously exempted from paying property taxes for 20 years. Nevertheless, during the latter stages of construction the company faced bankruptcy and would have failed but for a last-minute government loan guarantee and a bond offering through Barings in London (Berton 1974).

11.3 Financing Interest during the Construction of the Suez Canal

Some interesting hybrid instruments were used during the 10-year excavation of the Suez Canal in the middle of the 19th century. The Egyptian authorities were willing and able to grant all lands required for the building of the canal free of charge as part of the original 99-year concession agreed in November 1854 (Baer 1956: 365). They also stipulated an equitable apportionment of future profits among stakeholders, including the surprising decision (for the time) to allow the back-end participation of common employees of the builder/operator (Table 11.3).[5]

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[5] In an interesting historical parallel dating from 17th-century Japan, part of the profits from barge traffic along the Hozu River and the canal waterway connecting the Tamba farmlands with Kyoto was regularly saved for maintenance, operations, and repairs, while the balance was split between the promoter and operator, and the Tokugawa shogunate. We are indebted to President Nakao for bringing this early example of a mutually advantageous public–private partnership to our attention (Nakao 2017).

Table 11.3 Apportionment of Future Profits among Stakeholders in the First Suez Canal Project

Profit-participating party	Percentage of profits allocated	Further subdivision of shareholders' allocated share
Egyptian government	15%	
Private shareholders	75%	Of which 5%, to be divided thus: 3% to administrators 2% to employees
Company founders	10%	

Source: Authors after Baer (1956: 365).

An Egyptian company headquartered in Paris was formed as a société anonyme, known initially as the Compagnie universelle du canal maritime de Suez (Suez Company). Owing to Anglo-French geopolitical rivalry, the Government of France was obliged to disavow all intentions to offer any state assistance for the ambitious engineering endeavor, which many thought impossible except at an exorbitant expense that would make it completely unprofitable or barely able to cover its running costs (Baer 1956: 367). The promoter, Ferdinand de Lesseps, balked at Baron de Rothschild's customary fee of 5% and gamely chose to raise the project costs—originally estimated at 160 million (historical) francs—on his own (Baer 1956: 367, 372).

Throughout November 1858, an international appeal to the general public to subscribe to shares in the canal company was opened across the major countries of Europe and in the US. The capital sought was 200 million francs, divided into 400,000 shares of 500 francs each. Although this would be thought of today as venture equity uncertain as to any dividends and liable to complete loss, as was the practice at the time in Europe to make speculative investments more attractive, 5% per year interest earned from the date of issue was nevertheless promised to all shareholders on any amounts to be paid back to them. In this way, 40 million francs would be raised above the immediate needs of the project to finance the payment of interest during construction (Baer 1956: 373). One contemporary commentator criticized this practice on the grounds that the shares were really certificates of co-ownership and not debt securities, and that the construction costs were being unnecessarily inflated to realize anticipated profits before the project had even been completed (Block 1870, cited in Baer 1956: 377).

Even with this guaranteed future return and original issue discount at less than face value, the offering failed to attract sufficient interest outside France. Once it became clear that the blocks of shares reserved for investors in the rest of Europe, Russia, and the US would not be taken up, the Egyptian government honored its guarantee as underwriter and bought nearly 45% of the issuance (Baer 1956: 374, 375). The majority owners were petty bourgeois smallholders of lots of less than 100 shares each,[6] whose capital would be callable in manageable installments throughout the course of the project (Table 11.4).

Table 11.4 Schedule of Call of Paid-in Capital for the Initial Public Offering of Shares in the Suez Company

Denomination	Dates Due	Amount in Historical Francs
500 franc face value per share	Time of initial subscription	50 francs
Second payment	1 January 1859	50 francs
Two more payments	1 July 1859 1 January 1860	50 francs 50 francs
Three final payments	July of 1862, 1864, and 1866	Balance of face value, less original issue discount

Source: Authors after Baer (1956: 376).

The minimization of construction costs was greatly aided by the regrettable pharaonic practice of using essentially forced manual laborers (i.e., unpaid, intermittent corvée or prestation workers for public purposes in lieu of their having to pay taxes or fines) so as not to stretch the capital during the early stages (Karabell 2003: 113, 169–180). Not all the raised capital was committed to fixed stock to keep a sufficient buffer of liquidity should unexpected circumstances necessitate alternative business decisions. In the event, epidemics of disease (as would later plague the digging of the Panama Canal), technological upgrades to machinery, subcontractor renegotiations, and political changes all conspired to double the initial estimates of project costs and delay the project's completion by 4 years.[7] Moreover, a change

6 According to de Lesseps' records, only two subscribers purchased more than 550 shares individually (Baer 1956: 374).

7 It is difficult to point to any major or pioneering engineering undertaking in the historical, modern, or postmodern eras that did not encounter some fundamental changes of circumstances resulting in cost overruns. Engineers and financiers always start with the best of intentions and laid plans, but conditions always change and unforeseen events invariably occur.

in Egypt's head of state led to the withdrawal or suspension of many of the initial favorable terms of the concession agreement, such as land grants and free labor. After the last installment of the shareholders' capital was paid in, the Suez Company tried unsuccessfully to sell its first bond issue (summarized in Table 11.5).

Table 11.5 Key Terms and Closing Results of the 100 Million (Historical) Franc Bonds of the Suez Company Issued in November 1867

Key Terms and Results at Closing	Units and Amounts
Number of bonds offered	333,333
Par value	300 francs
Bearing annual interest	25 francs per bond
Maturity date due	November 1882
Amount subscribed	30 million francs

Source: Authors after Baer (1956: 377–378).

These bonds failed to attract serious market interest as the company's reputation was being questioned while the canal's completion date continued to be postponed. To make up the shortfall of 70 million francs, de Lesseps convinced the Government of France, which had eschewed official assistance or other support, to pass a special law on 4 July 1868 allowing the company to conduct a national lottery. Over a 3-day period, the general public bought up these obligations with a face value of 500 francs at the issued price of 300 francs; again they bore a flat annual interest of 25 francs per certificate (Baer 1956: 378).

Although cross-country comparisons over disparate time periods can be of limited value in these analyses, it is noteworthy that in the final, desperate years to complete such mega projects, Union Pacific, the CPR, and the Suez Company all had to call upon government bailouts to complete the private financing packages.[8] This may be the unavoidable result of a combination of general market weariness for long drawn-out projects, less animal spirits, lower profit margins after the initial speculation subsides, and a loss of faith in the ability or commitment of private companies to finish the project without government support and back-stopping.

8 This list should include the Eurotunnel, which required a 65-year operating concession to repay its restructured loans and obligations, and to generate dividend returns.

11.4 Tokyo Metropolitan Rail Network and the Expansion of Transit-Oriented Development

During the 20th century, the megacity of Tokyo achieved an unparalleled level of transit-oriented development as private railway companies played an important role in both constructing lines and expanding cities along their metropolitan and commuter lines. These companies succeeded due to a business model whereby town development profits endogenously finance railway construction (Yajima et al. 2014: 44). For instance, the Tokyu Corporation would reallocate any capital gains from its real estate holdings and development to finance its railway operations (Suzuki et al. 2015).

Historically, private companies in Tokyo had two main strategies with regard to their railway business. First, they monopolistically ran lines using stations on the Yamanote circular line, one of the busiest and most convenient Japan Railway routes in Tokyo, as terminals. Private companies radiated main lines and stations to developing areas and set up shopping centers on top of their stations or in arcades under elevated tracks, thereby managing railway construction sustainably along with town development.[9] Second, they utilized their lands so that the railway business and town development business would affect each other positively. Most commuters from the suburbs travel to downtown office areas in the morning and return to the suburbs in the evening, making their business inefficient because railways transfer fewer people from downtown areas to the suburbs in the morning and downtown from the suburbs in the evening.

To compensate for these inefficiencies, railway companies invite factories, research institutions, and universities as well as home developers to suburban areas to expand demand for commuting from downtown areas to the suburbs. Consequently, private railway companies generate a surprisingly large share of their revenue from their real estate business. It is estimated that more than half of railway companies in Tokyo earn 30%–50% of their total revenue from businesses other than running railways (Yajima et al. 2014: 48).

Railway development in Japan in the 20th century can be summarized in four phases (Table 11.6).

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9 In the US and other developed countries, the establishment and selling of development rights (mainly for shopping space above and occasionally below stations and other transport facilities) is a form of value capture known as air rights. As with general land value capture (LVC) (see Section 11.6) and spillover principles, the combined commercial-transit facility is expected to leverage an increase in property values and mutually benefit the public, transit companies, developers, and shop-owners.

Table 11.6 Phases of Japan's Private Railways in the 20th Century

Pre-urbanization: 1920s • Some railway companies were merged. Railways were expanded. • Railway companies focused on railway business.
First urbanization (light industry): 1930–1944 • Continued mergers and further expansions. • Railway companies were not yet engaged in department store businesses on top of stations.
Second urbanization (heavy industry): 1945–1979 • Railway companies began developing towns along their lines, as well as department store and amusement park businesses in the countryside. • Some companies also entered the hotel business.
Third urbanization (high-technology industry and service industry): 1980s–present • Some amusement parks and hotels begin to be closed. • Department store businesses target the young or the elderly.

Source: Authors after Yajima et al. 2014: 44–55; Nakao 2017; Yoshino 2017.

The Government of Japan has played two key roles in transit-oriented development. First, it allows each private railway company to run profitable lines monopolistically. Second, it tries to achieve both town development and railway construction in suburbs to prevent population concentration in downtown areas. Apart from Tokyo, other densely-populated cities such as Osaka, Nagoya, and Fukuoka relied on private sector concessionaires to establish their embryonic networks and main lines (Nakao 2017).

After the Second World War, a large population rapidly moved to metropolitan areas, raising the price of land significantly and making it difficult for most households to buy houses. Therefore, the government pushed new town development in suburban areas while encouraging railway companies to construct lines through the newly-developed towns. Currently, the central government and local governments each pay 12% of the cost of constructing lines running through newly established towns. In addition, local governments hold 10% of the share capital of any special company building new lines (Yajima et al. 2014: 55).

In many countries, as baby boomer suburban-dwelling populations age and retire, they no longer tend to consume, shop, or commute on trains as much. Thus, older established suburbs begin to "hollow out," as observed in rural Japanese villages. Consequently, the strong and dependable revenue streams from Tokyo department stores and passenger fares are starting to weaken (Yoshino 2017).

One possible answer would be for the Tokyo railway and retail-property conglomerates to keep creating newer mixed-purpose growth areas along their lines to sustain this model (see Mori Building Company's business model of continuously erecting bigger, safer, and more integrated multipurpose skyscrapers in open areas of Tokyo that they want to keep developing).

11.5 Tax Increment Reversion inside Californian Redevelopment Districts

In 1952, California embarked upon a landmark local government financing experiment when it revitalized the Community Redevelopment Act of 1945 with a new feature—tax-increment financing (TIF)—after passing the constitutional amendment known as Proposition 18. Once a city or county had drawn the boundaries of a blighted (i.e., underdeveloped) urban area fit for rehabilitation as a redevelopment district, it could direct growth in mainly property (sometimes sales) tax revenues from that district back into qualified renovation projects for dilapidated infrastructure and slum buildings. These local redevelopment agencies (RDAs) even tapped tax revenues usually earmarked for schools throughout the postwar boom years (Blount et al. 2014: 1). TIF was also used extensively in other states and cities, most notably Chicago (Ko and Rosenblatt 2013).

Some important points of distinction can be made between these RDA tax increment schemes and our proposed difference-in-difference (DID) thesis. RDA schemes mainly relied on a baseline of annual steady step-ups in property taxes, which were later capped at no more than 1% increases. Conversely, a DID scheme would seek to access a fuller basket of possible designated taxes that would be allowed to grow (see, e.g., Appendix, Table 1), all of which can be scientifically shown to have increased by precise amounts due to the spillover impact when compared to a control zone. Further, each RDA entity would usually pool all their share of TIF income into general-purpose redevelopment accounts that could be used like common, open-ended viability gap funds to support multiple and subsequent projects—not just the initial project that attracted most of the tax revenue increases. These issues of priority of lien and dilution of the growing revenue stream could be mitigated by separate trust funds serving as secure and discrete lock-boxes for the identified wealth-generating infrastructure, as proposed in this chapter (see, further, Figure 11.2 and the Appendix). Finally, although RDA baseline forecasts were generally self-contained within that district, the DID method makes comparisons outside the project area with control zones, and can derive more precise calculations of cross-regional tax increases and gross domestic product.

While theoretically a laudable idea, in practice the RDA schemes can be criticized on the following grounds. District boundaries were sometimes gerrymandered to include property owners who were too far away from the improvements to enjoy and benefit from them. Furthermore, the gradual expansion of the RDAs across California meant that expected money usually meant for schools from property taxes was shifted to other projects and priorities. For example, the share of property taxes reverting to development projects increased from 4% in 1983 to 12% in 2011 (Legislative Analyst's Office 2011: 1).

Finally, many RDA agencies and the local governments controlling them simply accumulated the funds in large interest-bearing war chests instead of using them to complete needed low-income housing projects within the redevelopment districts (Blount et al. 2014: 3). Essentially, the scheme simply became a way to earmark or pre-attach predictable tax revenues to one of any number of other valid spending choices. In this sense, it is closer to a form of "revenue segregation" set apart from the general fund (Rybeck 2013), like the Highway Trust Fund (Section 11.7). Of course, each city and county could just as easily have been empowered to make these annual development spending decisions without mandating a legislative scheme to encourage the funding of the urban renewal projects that the state government wanted to prioritize. Moreover, the money basically stayed within the local and provincial government sectors until it was actually committed to pay private contractors or developers for their work. In contrast, the portion of DID taxes calculated for sharing is expected to be solemnly promised and transferred through trustees and transfer agents into the hands of external issuers of loans or bond securities, thus clearly passing outside the internal control of the collecting governments and their various taxing agencies.

Although the Legislative Analyst's Office did not disclose the assessment methodology consulted in its public report, it was not convinced that RDAs improve overall economic development statewide:

> There is no reliable evidence that redevelopment projects attract businesses to the state or increase overall economic development in California. The presence of a redevelopment area might shift development from one location to another, but does not significantly increase economic activity statewide (Legislative Analyst's Office 2011: 3).

Based on this evaluation, the Governor of California Jerry Brown determined that any new, private development that appeared in the project areas would have occurred even without the benefit of the RDA; and therefore, what was happening was merely the moving around of businesses and projects from one place to another within the same state (Blount et al. 2014: 4).

Due to California's general budget woes and political opposition to certain project excesses, by the end of 2011 the RDA scheme was effectively abolished, with some of its components rolled over, and replaced by a revised and more pointed program for funding Enhanced Infrastructure Financing in Districts (similarly-drawn community facilities) (EIFDs). In principle, property taxes were once again the main funding source; however, schools' shares and community college district monies were no longer to be attached or diverted, and other taxing entities had to agree to contribute a certain share of their tax increments to an authorized infrastructure project with a demonstrable funding stream and business plan (Day 2016). Crucially, tax-allocation bonds serviced by future increment revenues could not be issued by any EIFD entity without a vote of authorization by the local property holders who would be affected.

EIFDs would now have to be formed as separate, quasi-autonomous government entities in a more cooperative way among cities, counties, and special (water, sanitation, or flood-control) districts, with sufficient taxing entities or fee collectors agreeing to commit their shares voluntarily to ensure that enough combined tax increments and utility fees would eventually flow to bond against for the project (The Planning Report 2016).

The California Community Economic Development Association concluded that the EIFD program would primarily benefit projects that demand complex financial layering and want, in their words, "to lock up 'today' dollars" for investment in a long-term future (Amador 2016: 8) (Table 11.7). Lessons to be learned from successful examples of EIFD project financing and evolutions or variants of this scheme[10] will be very instructive for our DID thesis and back-end tax-participation models.

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[10] One novel alternative is where a municipality issues a TIF- or EIFD-backed bond, and the project developer simultaneously promises to take up all or most of them. In this way, the initial market for the placement is basically guaranteed, interest and underwriting fees are minimal, and the developer demonstrates her faith and reliability during the project's early stages. Once a TIF revenue stream is established, the municipal issuer can more easily remarket the bonds as tax-exempt to new investors replacing the initial developer (Greifer 2005: 34).

Table 11.7 Main Authorized Projects and Purposes for California's Enhanced Infrastructure Financing Districts Program

To finance the following types of infrastructure works, including traditional public works
• Roads, highways, and bridges • Sewage and water facilities • Flood control and drainage • Solid waste disposal • Parking facilities and transit stations • Parks and libraries • Child care facilities
Also to finance the purchase, construction, improvement, and retrofitting of properties, including
• Environmental mitigation • Affordable housing • Transit-oriented development projects • Private industrial buildings • Brownfield restoration

Source: Authors after Amador (2016: 2, 3).

11.6 Land Value Capture Experiences of the New Millennium

Land value capture (LVC) is a promising community infrastructure financing method that recovers part or all of the value (e.g., increases in land value prices) generated by developing and/or upgrading neighboring public infrastructure or, more generally, public good services. It is based on a common perception or general recognition that infrastructure, especially transport and public amenity infrastructure, creates economic benefits that exceed costs (i.e., positive economic externalities); and that the beneficiaries (usually existing landowners and specific householders or developers) would be willing to pay a premium for well-serviced commercial and residential properties, as well as some of the costs of implanting such infrastructure or offsetting any negative impacts.

For instance, the proximity of high-capacity transit stops—usually the addition of new subway stations or lines—can result in particularly high land value premiums.[11] The local authority can commonly achieve

11 Subdivision developers promised homebuyers that the value of their lots "will be easily doubled" when a proposed new railway stop within walking distance was added to the Frankston line between Moorabbin and Bentleigh stations. Auctioneer's Notice of Final Section Sale of the Grewar Estate, Victoria, Australia, February 1927, in the authors' possession.

so-called capture or more precisely cost recovery through either a one-time transit development impact fee paid by a developer, or an additional tax specially assessed on land parcels to contribute to the cost of the new improvement (Ko and Rosenblatt 2013). However, these are additional, higher taxes or further betterment charges imposed on existing taxpayers, rather than truly new sources of tax revenue growth as predicted by the DID thesis.

One major benefit of the LVC financing technique is that it makes more likely the launch of an infrastructure project that otherwise might not occur, by introducing private investors without incurring additional tax burdens on the government and general taxpayers. Although accepting LVC as loan collateral can be risky, some large-scale examples with reasonable results have been achieved in metropolises such as Cairo and Istanbul.

Since the early 2000s, a few other countries and economic zones in Asia have successfully used various LVC techniques. In these examples, the host government essentially already owns or fairly acquires the land, which it then sells, leases, or trades[12] in various ways to fund projects (ADB 2017a: 60, Box 5.4). Although these traditional forms of LVC remain primarily public sector inspired and initiated projects—despite aiming for public–private partnership involvement—the government must still find the money to pay for it, but instead of using taxes or deficit financing exploits local land values. [13]

Over the last 10 years, for example, land transfer fees paid by industrial developers to the People's Republic of China (PRC) have been channeled as fiscal revenue supplying about one-third of local and provincial authorities' needs (ADB 2017b). Hong Kong, China has also been able to use LVC to improve its mass transit systems by selling public lands to the transportation authority at less than market value, and allowing the authority to recapture the enhanced value in future resales after the new line is in place.[14] In 1997, the Republic of Korea passed a law requiring appropriate land values to be used to

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12 Completely free or overly generous land grants are no longer possible or popular in many countries. Thailand reportedly turned down a request from PRC contractors for development rights to land along a planned rail link under negotiation in the first half of 2017 (Ono and Kotani 2017).

13 Complex questions raised by equitable land use and rural–urban rezoning procedures, as well as the avoidance of unjust enrichment or fraudulent insider schemes must remain outside the remit of this section.

14 The Hong Kong, China Metro System is reputed to be one of the few underground mass transit railways in the world that generates sufficient profits to cover all of its construction and operating costs without relying on government subsidies.

finance transportation for new developments that either are large in scale or serve a high population density (ADB 2017a: 61, Box 5.4). India is reportedly considering a national framework to adopt a similar mechanism (Saxena 2017).

The main lesson from these successful historical examples centered on site land is that the planners of earlier public and private projects fully realized that pure revenue streams from fares and tolls would never be sufficient to induce and complete the complicated and expensive infrastructure projects of past centuries. Governments and financiers used to expect that the financing mix would include extra incentives in the form of free land (including mineral rights and timber sales), which private constructors and investors could turn into much-needed immediate cash or mortgage as security for loans. These sometimes became early forerunners of mortgage-backed securities, such as "land-grant bonds," which were issued with packaged collateral from unsold land (Cox 2015). This was more common if the company was young or solely focused on building a railroad, and lacked other corporate sources of revenue (e.g., income from finished projects) to cross-subsidize the interest servicing costs of its bonds and borrowings that fell due before project completion or customers began generating profits.

However, this lesson was forgotten when governments moved into the business of major project sponsorship and fulfillment; in the late 19th century, the Trans-Siberian railway could only be carried out as a completely czarist government undertaking, sometimes resorting to convict, unpaid laborers. Governments, which alone enjoyed the ability to print money or borrow cheaply, could readily cross-subsidize expensive public works until they returned future profits. Any losses could be offset by other successes in the portfolio of the government, which could even wait until the project simply became a historical legacy taken for granted, like the sewer system under the City of London.

These projects are some of the earliest examples of bonds being subsidized or enhanced, with regular interest installments either paid or guaranteed by the deeper, more dependable pockets of federal and state governments. Indeed, by using the public purse and expected future profits to pay off current project debts, governments were basically following the same concept proposed here of relying on future tax revenue streams. When the postwar pendulum swung back during the Thatcher and Reagan privatization revolution, governments were irrationally exuberant in their expectations of the private sector's ability to create infrastructure out of thin air. They forgot to pass back the hidden but necessary windfalls (or were simply greedy and chose to keep them to themselves), except for the occasional successful "crown jewels" of the public sector, dependable and profitable brownfield assets, or a foolproof sector like telecommunications.[15]

With the possible exception of undeveloped parts of Africa (i.e., parklands or nature reserves that are not environmentally protected) or certain deserted stretches of the Central Asian hinterland, very few countries have now any stock of available and undeveloped public lands that are not under the stewardship of traditional owners or nomadic people, and that can be given away to constructors and their investors as was done in the US and Japan. Thus, instead of giving away, sharing (alternate blocks), or selling at a discount actual land, it may be best to look to the economic fruits or profits a prendre emanating from that land in the form of increased property, business, and income taxes that grow alongside the communicating railroads and highways.[16]

11.7 United States Highway Trust Fund and Lock-Box for Dedicated Expenses

The landmark Federal Aid Highway Act of 1956, which established the Highway Trust Fund, was the basis for the development of the postwar interstate highway system. Earlier US highway programs were unreliably financed from the General Fund of the Treasury, and taxes

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15 Until the 1980s most airport income came from traditional landing and passenger-handling charges; however, airports worldwide now earn about two-fifths of their income in the form of so-called "non-aeronautical revenues" from shops, food and beverages, airport car parking and car rental fees, and advertising and property income (The Economist 2017a).

16 It is beyond the scope of this chapter to treat the complicated social and legal issues involved in acquiring land from private owners for rights-of-way. Certainly, we believe that equitable, prompt, adequate, and effective compensation for land subjected to eminent domain or compulsory acquisition, with proper avenues of appeal and voluntary relocation, is essential. For our part, we would like to encourage early sellers or first movers by offering them more attractive incentives to transfer their land, such as staying in possession, leasebacks, or a larger immediate payout or future participation share than offered to those who delay the project and consent later under a compulsory court order. This could be done using a sliding scale for a purchase plan that rewards early and voluntary sellers. It is also necessary to create proper channels for unwilling landowners and customary stewards to object, potentially inside a local infrastructure and development association or hometown trust before an independent ombudsperson. To ensure efficiency, enabling legislation should give a statutory authority or government-controlled commission some reasonable powers to acquire necessary land, either by agreement or compulsorily on behalf of the state pursuant to standard land compensation practices determined by an independent arbitrator in that country. However, no addition to the fairly-arrived-at purchase price of the land and improvements thereon should be made by reason of any actual, imminent, or prospective expenditure by the acquiring commission.

on motor fuels and automobile products were not linked to funding highways. The Highway Revenue Act of 1956 increased funding for state highway construction by increasing certain existing user taxes, as well as creating new ones. Taxes imposed under this act supported the trust fund through 1972. The duration of the trust fund has been extended several times by subsequent legislation, which prolonged the imposition of taxes as well as the transfer of the taxes to the trust fund and the payment of refunds.

The Highway Trust Fund is funded by taxes imposed on highway users, and the tax structure has changed several times. The Surface Transportation Assistance Act of 1982 and the Deficit Reduction Act of 1984 increased taxes on motor fuel. Subsequently, the Omnibus Budget Reconciliation Act 1990 increased per gallon tax by $0.05, although half of the tax revenues were directed to the General Fund of the Treasury until it expired in 1995. The Taxpayer Relief Act of 1997 redirected $0.04 of General Fund tax from the previous increase of the Reconciliation Act to the trust fund. The Transportation Equity Act for the 21st Century then extended the trust fund taxes, thus prolonging the fiscal "life" of the trust fund. The trust fund also has an additional source of revenue: since October 1984, the proceeds from fines and penalties imposed for the violation of motor carrier safety requirements have been deposited in the trust fund's highway account (US Department of Transportation).

Most of the taxes credited to the trust fund are paid to the Internal Revenue Service by producers or importers in the handful of states where major oil companies are headquartered. User taxes are deposited through the General Fund of the Treasury to the trust fund on a monthly basis. Funds in the trust fund that exceed current expenditure are invested in public debt securities. Due to uneven highway use, some states pay more in user taxes than they receive back; hence, the Transportation Equity Act included a provision called the minimum guarantee, to distribute additional funds to those states.

The Byrd Amendment established the Highway Trust Fund as a pay-as-you-go fund to ensure that unpaid commitments that exceed the amount available in the account are less than anticipated revenues following a 24-month period. If there is a shortage of funds, all highway programs for that fiscal year would be reduced proportionately. The trust fund, which comprises the highway account and the mass transit account, is currently the main source of funding for most highway development programs. The majority of the trust fund's income comes from motor fuel taxes. Some transfers to keep the trust solvent through the end of fiscal year 2020 also come from the Fixing America's Surface Transportation Act, which extended the heavy vehicle use tax until 2023.

In California, the revenue service collects $0.18 per gallon of gasoline and $0.24 per gallon of diesel fuel; of this income, 85% is deposited in the trust fund highway account and 15% in the transit account. In addition, as of July 2014, California collects an excise tax of $0.36 per gallon of gasoline and $0.11 per gallon of diesel, generating approximately $3 billion per year. The gasoline excise tax consists of two taxes: the base state excise tax, which is $0.18 per gallon; and the price-based excise tax of $0.18 per gallon. Of the state base excise tax revenue, 36% is divided among cities and counties, and the state receives 64%. The price-based tax revenue is first used to backfill weight fees that are diverted to the general fund. The remaining funds are allocated to local roadways (44%), new construction projects (the Statewide Transportation Improvement Program, 44%), and highway maintenance and operations (the State Highway Operation and Protection Program, 12%) (California Department of Transportation).

The Highway Trust Fund demonstrated an effective way to ensure that a few cents on every tax dollar raised by gas sales were locked away for future use for the rehabilitation and maintenance of the interstate freeway system without the risk of raiding by the Treasury for other purposes. Similarly, a lock-box trust fund for future tax revenues to be shared could be set up to reassure private investors that the government will honor its promises of back-end participation, especially when the issuer of the tax-participating bonds is not necessarily always a part of the government proper.

11.8 Historical Progression from a Government Department to Becoming a Private Issuer

At this point, it might be instructive to make a few observations as to how government departments have gradually spun off their specialized public works functions in favor of statutory authorities or state-owned enterprises with varying degrees of autonomy and independence for project finance borrowings. A government corporation has the benefit and privilege of operating free from political control and, depending on its constitutive charter, exercises certain levels of autonomy with regard to its finances and the accounting practices allowed it by the sponsoring level of government.[17] While strong and dominant private syndicates

[17] Foreword by T. T. Holloway, Premier of Victoria (S.E.C. 1949).

and companies have led the development of rail, canal, and road infrastructure, historically in a number of developed countries the electrical power and telecommunications sectors experienced the largest growth during the public-sector dominated period, roughly from the early 20th century to the mid-1980s.[18]

Two of the 20th century's major state-owned electricity suppliers were the Tennessee Valley Authority (TVA), which sought an integrated regional approach to power generation and interstate resource management; and the State Electricity Commission of Victoria (S.E.C.), which faced the problem of utilizing abundant, though moist, brown coal reserves as its base fuel source. Both were founded through statutory enactments, faced tight reins over their borrowing ability (which were gradually relaxed with the Treasurers' consent or increased by the legislatures as they gained experience and market respect), and eventually became stand-alone entities (Figure 11.1).

In both cases at various times in their histories, apart from being secured by lucrative and predictable revenues on power tariffs, their loans were regularly guaranteed by the government and their securities were legally recognized as suitable investments for trustees throughout the state or country (S.E.C. 1949: 128). Today, neither the TVA nor the disaggregated, privatized successors of the S.E.C. receive direct state or federal funding, and must finance their operations solely through the sales of energy produced and their loans and bond instruments. Moreover, it could be a useful discipline if outstanding debt were capped at any one time (for example, the US Congress has blocked the TVA from exceeding $30 million), and ensuring power tariff rates, if within the generator's ability to set, were calculated at levels sufficient to service debt repayments (TVA).

Developing countries and emerging powerhouses, particularly the PRC, should focus on the judicious use of government guarantees and how to wean successful state-owned entities or statutory corporations off reliance on them. If the claim that government guarantees are recommended investment-grade securities suitable for purchase by pensions is plausible, enacting or corporatizing statutes for state-owned entities could also explicitly state that these securities are at

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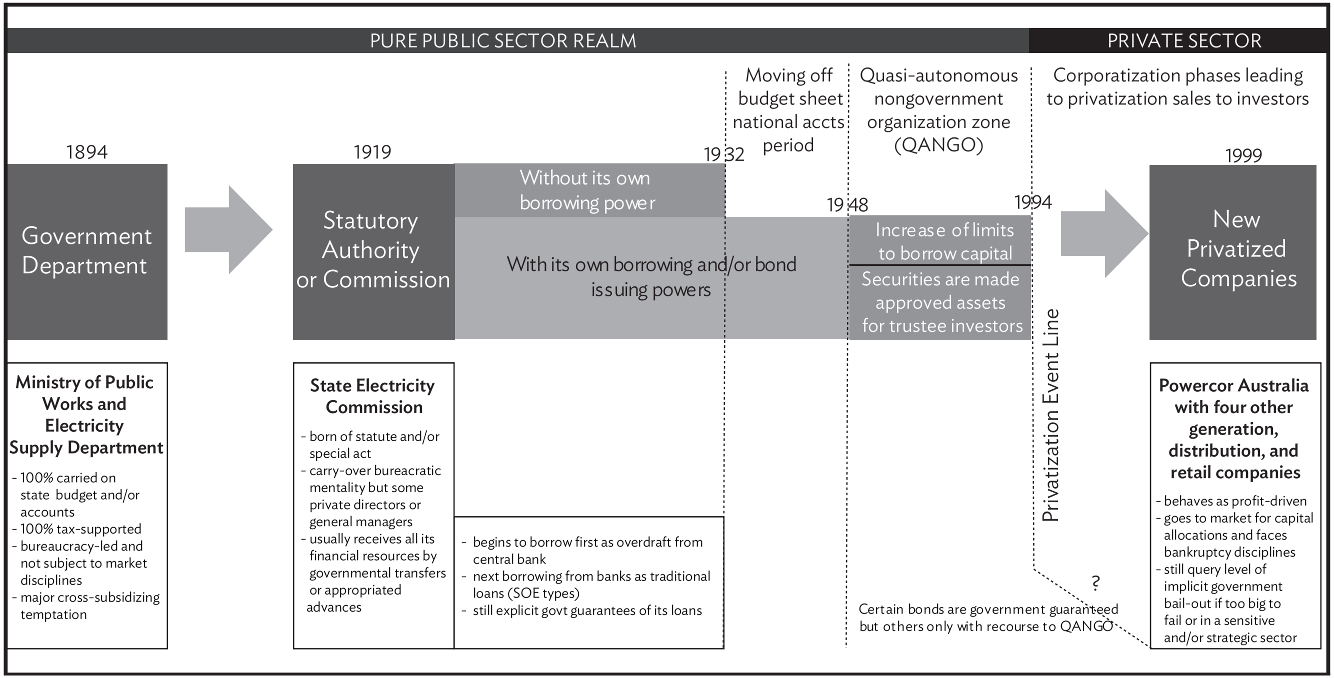
18 Of course, private companies often set up pioneering or demonstration projects for electrical lighting and traction during 1880–1900, and continued to do so during overlapping periods through the end of the First World War. Due to the novelty and risk involved, many of these companies were short-lived or were taken over by larger successors. Security of supply and universality of service often dictated the government's eventual entrance to these sectors.

Figure 11.1 Stereotypical Progression from a Government Line Department to a Private Issuer



SOE = state-owned enterprise.

Source: Authors after the State Electricity Commission of Victoria (1949: 18, 22, 36, 121, 128).

the recommended investment level and suitable for pension funds and others who can only invest in high-grade bonds.[19]

11.9 Build America Subsidy Bonds

As part of an emergency reinvestment package for local infrastructure after the global financial crisis, two innovative types of Build America Bonds (BABs) experimented with subsidies on the interest owed by issuers to investors, as well as refundable tax credits for the bondholders.

Pursuant to the American Recovery and Reinvestment Act of 2009, the Federal Government implemented a special financing program called Build America Subsidy Bonds for public infrastructure. Issuers of BABs received a subsidy that was 35% of their total interest payments. During the program (2009–2010), 2,275 BABS were issued, raising over $181 billion for the construction of much-needed schools, bridges, and hospitals. The scheme was also an important stimulus package similar to the New Deal public works program during the Depression.

Every state in the US sold BABs because they were less costly than normal tax-exempted bonds. State and municipal governments saved $20 billion with 30-year subsidized BABs, on a present value basis, compared with their normal tax-exempted bonds. Indeed, the US Treasury Department concluded that permanently implementing a BAB program could be more efficient for public infrastructure projects and might even lower government transaction costs compared to tax-exempted bonds (US Department of the Treasury 2011).

As outlined above, public subsidies on land, bonds, and interest as well as tax holidays, credits, and inducements have been effective historically, and they remain an obvious choice for governments wanting immediate and attributable results. In August 2017, for instance, the Iowa Economic Development Authority and a local city council agreed to a $188 million property tax abatement of 71% over 20 years as part of a package to entice Apple to buy land in Iowa to establish a $1.3 billion data center (Nellis 2017).

Nevertheless, these types of immediate subsidy and tax credit measures have two major weaknesses. They can be challenged as present transfer payments from one taxpayer category to another through government fiat and at the cost of other worthwhile spending

19 Apart from the progression path illustrated here, a government might also simply change a successfully operating authority into a company without selling it to the public, by incorporating it under a general government corporations act, as was done with Snowy Hydro Limited in 2001. In these situations, the government generally retains majority-share ownership until it divests in a public float or to private buyers.

priorities. Further, most of them must be recognized or carried in the government's national budgets as official commitments in the current fiscal year. An innovation from Europe elegantly solved the problem of delayed recording of future payments on national accounts, and represents one way toward new budget-neutral techniques, such as back-end participation in future tax revenue growth, as proposed here.

11.10 Vaccine Alliance and Future Conditional Payments

To reach the main health targets in the Millennium Development Goals, a fund was established for the operation of the International Finance Facility (IFF). Donor countries offered support when the IFF sold its bonds on international markets. In 2003, United Kingdom Chancellor of the Exchequer Gordon Brown approved the IFF for front-loading of support, making funds immediately available to borrowers. In the beginning, the most appropriate accounting treatment for this type of government pledge incorporated into law raised some novel questions; however, Eurostat's eventual ruling confirmed that such payments, to some extent, are better viewed as conditional. They can therefore be recorded at the time of each future payment installment, instead of registering the full amount immediately as firm expenditure commitments in the donor countries' national budgets in a single year when the pledges were first made (Standard & Poor 2017: 6).

The International Finance Facility for Immunization, the main charity project of the IFF system, has assets that are mandatory disbursement obligations from dependable donor countries, such as Brazil, France, Italy, Norway, South Africa, Spain, Sweden, and the United Kingdom. Critically, these countries' obligation guarantees were not immediately recorded as government debt, meaning that their obligations could be legitimately kept off-budget in the medium term.

In 2006, the International Finance Facility for Immunization issued its first bond in the amount of $1 billion with an annual yield of 5.019%, 31 basis points above the benchmark 5-year US Treasury bond. The novel idea of this program was to sell these bonds to raise a total of $4 billion in 10 years using government guarantees instead of collateral. The investments would be used to finance worldwide immunization through Gavi, the Vaccine Alliance (previously known as the Global Alliance for Vaccines and Immunization). Gavi estimated that this pledged bond value could prevent the deaths of 5 million children and the same number of adults over the course of 10 years (Brookings Institution 2016).

In Europe, Gavi proved that it was possible to estimate and monetize an expected future stream of government cash flows and bring them to the present day as capital to set up a huge and vital social program without having to carry them as immediately recognized government debt on their national balance sheets. Backing these 5-year immunization bonds with government contributions pledged over 2 decades ensured that the yield would be at least 30 basis points above similar-maturity US Treasury securities, consequently making it possible for new money raised from the markets to be spent immediately (Wood 2010).

Across various countries, the budget treatment and accounting characterization of a government's contingent promise to share future tax revenues that do not yet exist (and may never become payable if the project does not do well) will be important for the favorable reception and long-term acceptance of back-end participation in future tax revenue growth.

11.11 Conclusions

In light of these past experiences, we turn to the question of how to achieve more private financing for infrastructure in the future. As the historical record shows, private financing of public infrastructure is possible and desirable, not only in Asia but also worldwide. However, as described above, extra help is usually needed in the form of "deal sweeteners" required—not unreasonably—by financiers and builders, especially in the initial years before the project becomes operational with a reliable and healthy income stream. These may take the form of land grants, concessional rights of way, and ancillary revenue opportunities through commercial property development or minor side businesses (e.g., the sale of advertisement space).

Some public sector support for or subsidization of part of the costs of raising or enhancing the financing package seems unavoidable, except for the most fortunate projects with strong prospects. This usually takes the form of tax holidays and incentives, generous credit, favorable profit-sharing, government advancing the payment of interest due during construction, transfers in kind and a variety of guarantees (including implicit) of the loan and bond indebtedness. Governments and markets need to be both realistic and sympathetic to special accommodations and even bail-outs in the final years of a project when delays and cost overruns can strain the original financing plan.

Future tax revenues can also be tapped for sharing with the private financiers participating in infrastructure projects. Our DID thesis proposes a scientific way to prove the fair level of causation of the infrastructure to increase revenues from designated taxes. Economic corridors along transit routes can be conveniently widened into economic and tax zones that capture growing neighboring wealth, increased business activities, and future taxes. The economic boundaries of such a zone may not always correspond to geographical or political borders, or subnational municipal and state lines (Day 2016). Some ideas for the governance and development of such regional zones are advanced in the Conclusion of this book.

A responsible tax-collecting authority will put aside an agreed share specified in the loan or debenture of attributable new taxes in a project-specific trust fund to assure back-end participants that their money will be safe and locked away when interest payments come due. There are many models and approaches to tax-sharing arrangements among central and subnational governments,[20] or with specially created districts or development agencies. In the future, we may even see equitable tax-sharing arrangements across international borders. In certain cases, tax laws may have to be amended or modernized to permit such innovative arrangements.

Trust fund proceeds can then be used to close gaps in projects' viability and profitability and help finance them, or the new revenue might simply be segregated for financing any availability payments agreed by the government in a project's concession, which could also be indexed to keep pace with growth (or inflation).[21] Private investors will be attracted to projects that offer them this back-end participation in future tax revenues from affected zones (Figure 11.2). The back-end share can be simply transferred to the beneficiaries by something as basic as a check (e.g., Oregon's famous "kicker" check for rebates) or bank wire transfer, or realized in the form of compensating tax credits, deductions, or rebates on present and future tax return filings. Structured finance projects or traditional bank loan project syndicates can easily mandate such transfers among the known and fewer parties in their bespoke documentation, and have been quietly doing so in many diverse deals, business sectors, and legal jurisdictions. It is worth mentioning though that overseas financiers without domestic taxpaying obligations or local subsidiaries in a project-site jurisdiction might not be able to use any tax credit or rebate mechanism offered.

A more sophisticated global-standard instrument with securitization, registration, and negotiability can also be envisaged drawing on existing prototypes of tax-increment revenue bonds and social or development impact finance bonds with payouts contingent

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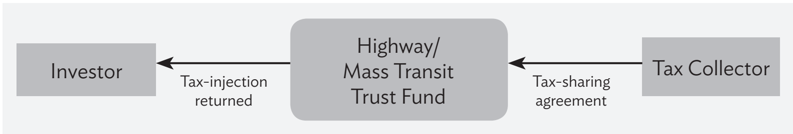
20 For a recent comprehensive analysis of the issues and opportunities involved in intergovernmental fiscal relations, see generally Yoshino and Morgan (2017).

21 Governments, public authorities, and even financiers of private projects have indexed securities to inflation or consumer price rises in a number of jurisdictions; for example, the Sydney Harbor Tunnel Company issued its own indexed bonds (Deacon et al. 2004: 99).

Figure 11.2 Potential Ways to Transfer Back-End Tax-Participation to Original Investors



1. Rebate check/electronic bank transfer (either to the issuer or directly to the bondholder)
2. Segregated revenue for backing any (gross domestic product-indexed) availability payments (unfettered or with collars in band)
3. Tax-injected into an open-ended viability gap fund for general purposes (but risks of dilution, raiding for other purposes, or underfunding)
4. Deduction or tax credit for infrastructure developers on future years' tax returns (may not be useful for overseas investors who are not taxpayers in the host country)
5. "Tax-kicker" (back-end future-tax-participating) bond

Source: Stillman 2017, revised.

on achievable targets—we could style them tax-kicker bonds for infrastructure (Yoshino and Stillman 2017b). If the implanted project is modestly successful in the long term and starts generating regional growth above the national gross domestic product, these tax-kicker bonds would be able to offer higher rates of return than traditional revenue (and toll only) bonds or (availability-payment) project bonds.

In theory, tax-kicker bonds should be issuable at all levels and by any entities—assuming that legal capacities to issue securities exist or are legislated for—including central and subnational governments, regional development areas, public authorities, state-owned enterprises, and even large and creditworthy private construction companies. The principle of subsidiarity would dictate that the issuer be as distant from the central sovereign as possible without having to rely always on automatic guarantees. Nevertheless, whoever the issuer may be, governments must stand by to steady markets if necessary by being prepared to underwrite issues or become the buyer of last resort for novel or high-profile infrastructure bond offerings.

In the Appendix to this book, we propose a very tentative explanation of how such an instrument might work in practice (updated and expanded from the preliminary version in Stillman 2017). An accompanying annex supplies a possible model term sheet for this new instrument to illustrate its key features, including dual tranching, a trust fund lock-box, independent certifier of participation due, and guarantees. Many of these were inspired by the historical innovations described herein (see Appendix and its Annex).

In closing, we hope that back-end tax participation will not be seen as a present transfer payment or credit, making it possible to treat it as budget-neutral and not immediately recordable in annual national balance sheets. This should interest governments around the world who want to minimize their present debt burden to encourage needed infrastructure investment.

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12

Infrastructure Financing Modalities in Asia and the Pacific Region: Strengths and Limitations

Michael Regan

12.1 Introduction

Asia and the Pacific region has been the world's fastest-growing regional economy since 2002 and the destination for over one-third of global foreign direct investment (ADB 2016; UNESCAP 2016: 3). Increased investment in economic and social infrastructure poses a major challenge to sustained regional growth and development, as well as to greater engagement between national economies. Adequate and efficient national infrastructure is a fundamental requirement of a well-functioning and high-growth economy. Infrastructure provides the assets and services that facilitate trade and exchange within an economy, increase output capacity, improve productivity, reduce congestion, and lower public and private transaction costs. However, governments around the world are struggling to maintain the rate of investment necessary to meet present and future needs, creating an infrastructure gap or future funding requirement estimated at around $800 billion annually for Asia and the Pacific region (Moore and Kerr 2014). In global industrialized economies, infrastructure investment averages around 3.9% of gross domestic product (GDP). The rate is higher among developed nations in Asia and the Pacific region—10.5% in Malaysia, 6.0% in Australia and Canada, 5.0% in Japan and New Zealand, and 4.0% in the Republic of Korea. In industrializing countries, demand drivers such as population growth and rapid urbanization are spurring higher levels of investment, particularly in the energy sector (electricity, oil, and gas), roads, ports, rail and urban transport, water, and sanitation services. As for Asia and the Pacific region, infrastructure investment is around

29.0% of GDP in Indonesia, 21.0% in Thailand, 19.0% in Viet Nam, 15.0% in the Philippines, 8.5% in the People's Republic of China (PRC), and 4.7% in India (Chong and Poole 2013; McKinsey Global Institute 2013; Seneviratne and Sun 2013). In industrialized economies, the average age of infrastructure capital stock is older than in industrializing economies, and depreciation accounts for around half of all new investment, nearly twice that in industrializing nations (Mackenzie 2013; Australian Bureau of Statistics 2014).

Governments provide the majority of infrastructure as a public good, although fiscal and public debt constraints since 2012 suggest that recent investment rates are unlikely to be sustainable in the medium term. Estimates indicate that infrastructure investment will converge at around 3% of GDP in 2010, which is insufficient to make significant progress toward closing the infrastructure gap (S&P 2014). The region was also affected by the global financial crisis of 2007–2008 and, although the impact on the region was not as severe as expected, project finance flows downturned in 2009, private bond financing in the region declined rapidly, and project finance supply changed due to the withdrawal of European and North American banks and greater participation from regional lenders. However, challenges remain and the changes introduced by the Basel III reforms have created future impediments for long-term, limited-recourse bank lending for infrastructure projects in the region (Asian Bankers Association 2010).

Infrastructure is a capital-intensive and highly networked asset class forming part of complex supply chains. Assets are generally site- and use-specific, involve high sunk costs, and require extensive advanced planning and long lead times. Since 2003, innovations in design and construction methods, new technology, and efficient management have become highly important to investment economics and are challenging traditional procurement practices. In addition to the supply problem, governments also face the challenge of encouraging significant private investment, and ensuring the sustainable delivery and management of infrastructure. As an asset class, infrastructure has several distinctive characteristics. Infrastructure returns reveal a low correlation with other asset classes and leading economic variables such as interest rates, investment, employment, economic growth, and exchange rate variables (Regan 2004). Infrastructure also relies on the quality of public institutions and effective policy frameworks in matters such as the enforceability of contracts, and effective regulatory and foreign investment rules.

Since 2003, most infrastructure investment has occurred in the telecommunications, energy, and transport sectors, which also account for around 65% of future investment requirements in Asia and the Pacific region (ADB and ADBI 2009). Public–private partnerships (PPPs) account for around 10% of investment and are mainly used for networked economic infrastructure. Infrastructure assets involve high sunk costs, are capital intensive, and form part of complex supply chains. In most cases, investments in telecommunications and energy rely on user-pay tariffs for their revenue and may be regulated internally and/or externally by a government regulatory agency. Investments in road and rail transport, social infrastructure, and water projects derive revenue from government availability payments and/or user-pay regimes. The investment characteristics of this asset class, the maturity of national institutions, and the quality of macroeconomic management significantly impact the manner in which infrastructure is financed in Asia and the Pacific region.

This chapter presents a status report examining the current modalities, strengths, and weaknesses of infrastructure financing in Asia and the Pacific region. The chapter examines 11 infrastructure finance methods in Asia and the Pacific region, including the finance support mechanisms that underpin investment viability and enhance the credit properties of public projects for private finance. The findings are designed to support the development of future infrastructure policy in Asia and the Pacific region.

12.2 Methods of Infrastructure Finance

Global infrastructure finance is experiencing a transition in post-2008 market conditions, with the return of project finance at record levels in 2014, stronger investment intention signals from pension and sovereign wealth funds (SWFs), renewed interest in alternative financing options, and the evolution of the PPP procurement models with improved risk-sharing and credit enhancement options. This chapter also examines the options for public procurement, which continues to account for around 70% of infrastructure expenditures, as well as the important role that multilateral development banks (MDBs) play in supporting capacity building in transitional countries and providing loans, grants, and noncommercial insurance to improve the bankability of both public and private projects in the region.

12.2.1 Government Provision

Governments have traditionally provided most infrastructure capital from consolidated revenue, and services are made available to the community as a public good. Since 2000, governments have adopted a variety of methods to help meet the cost of new infrastructure, such as user-pay and asset-betterment charges, thereby creating a new class of quasi-public goods that possess some elements of excludability.[1] Although these approaches can provide additional sources of capital, user charges may contribute very little toward the costs of operating urban transport, ports, waste management, and recycling services. In low-income industrializing countries, an additional problem is the affordability of user charges and the additional transaction costs imposed on low-margin sectors such as agriculture, fisheries, and forestry.

As a general rule, governments provide around 50% of infrastructure, government business enterprises 30%, and private investment around 20% (although significant differences exist among countries) (Chan et al. 2009). Government funding mainly targets health and education, transport, and utility services, reflecting the basic priorities of developing economies experiencing industrial transformation, high urbanization rates, and increasing congestion (PricewaterhouseCoopers and Oxford Economics 2014: 11). In contrast, private investors mostly invest in the energy, resources, and transport sectors, suggesting that private participation in infrastructure has as much to do with the underlying economics of the asset class as with the availability of capital.

In Asia and the Pacific region, governments face many challenges in attempting to meet the demand for new infrastructure and private participation in infrastructure provision, and management is a priority for most governments in Asia and the Pacific region as well as for multilateral development agencies (Moore and Kerr 2014). The main difficulty is the viability gap that exists between new greenfield infrastructure projects and the need for state-financed subsidies to support a high proportion of private investment. In most countries in Asia and the Pacific region, the demand for new and replacement infrastructure exceeds the financial capacity of most governments, especially in developing countries facing high transaction costs, inadequate port infrastructure, and the need for upgraded transport infrastructure in cities and towns. Governments meet the cost of new infrastructure in several ways, as described below.

Reordering Budget Appropriations

General budget appropriations are the most common method used by governments to finance public infrastructure. Governments may reorder appropriations and forward estimates to meet current investment needs (Chong and Poole 2013; Productivity Commission 2014). Public investment is volatile, and mid-cycle mini-budgets, budget reviews by parliamentary expenditure review committees, concern about fiscal

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1 Quasi-public goods impose some limitation on the use of government-provided facilities or services such as a user charge that may exclude use by members of society unable to meet the cost.

deficits, and changes in government cause frequent funding cutbacks and delays. Vertical fiscal imbalance may also contribute to volatility in jurisdictions in which many projects are initiated or managed by provincial and local government agencies.

Accounting and reporting procedures as well as governance vary among countries, although most governments order public spending according to a 3- or 5-year plan or set of forward estimates. Budget appropriations are mostly funded from general taxation or public borrowings, both of which may attract varying levels of deadweight costs. The strengths of appropriations include greater transparency and accountability for government fiscal management, although a disadvantage thereof is the absence of market discipline in project selection and evaluation (Chan et al. 2009: 228). However, sudden changes in priorities create investment shocks that have been shown to lower capital productivity and efficiency (International Monetary Fund 2015: 17).

Raising Taxes

Consolidated revenue, which provides the basis for most state appropriations for infrastructure spending, may take the form of (i) an economy-wide increase in direct and indirect taxes, (ii) the raising of a tax or levy confined to a province or local government area, (iii) the dedication of existing taxes to specific investment objectives (such as applying fuel taxes to road construction and maintenance, see, further, chapter by Yoshino and Stillman, Section 11.7), and (iv) the imposition of a user charge. New taxes to finance infrastructure have several disadvantages for an economy. First, taxes are costly to collect and administer, and create induced effects, such as tax avoidance behaviors. Taxes also carry significant deadweight costs in economic terms, which may exceed the net proceeds of new taxes (Regan 2009: 27). Second, increasing taxes has been shown to have a negative impact on regional savings and economic growth, may distort economic decision making, and creates perverse incentives (Chan et al. 2009: 53), although the extent of this depends on the purpose of the tax and whether or not the tax is applied to consumption or income (Helms 1985). Third, the discriminatory taxation of specific communities or users encounters Pareto-optimality problems and creates several equity and welfare problems (Regan 2009: 26–27).

Privatization, Initial Public Offerings, and Capital Recycling of Brownfield Assets

In the 1980s, the sale of stock in existing government business enterprises (GBEs), the disposal of assets by trade sale, and the placement of initial public offerings (IPOs) on a securities exchange were common practices in many nations in Asia and the Pacific region. The first cycle of privatizations occurred in industrialized economies and included fully integrated going concerns (brownfield projects) with trading histories that were relatively easy to sell to private investors. In many countries in Asia and the Pacific region, early privatizations included state banks, airports, insurance companies, telecommunications services companies, railways, ports, and energy supply chains including generation, transmission, and distribution assets (Megginson 2005: 14–21). A second cycle of privatizations based on trade sales and a small number of IPOs took place in the 1990s, particularly in industrializing countries in South and East Asia. By 2001, privatizations had raised $1.5 trillion for governments globally, although readily saleable assets were becoming much harder to find (Megginson 2005: 21–25).

A third cycle of privatization or asset recycling is now taking place whereby governments enter into long-term leases or sell mature, income-producing infrastructure to finance the construction of new assets. These assets must be financially viable and may require subsidies or other forms of ongoing support during the early years of operation. Recycled assets include toll roads, airports, electricity generators and transmission companies, defense establishments, ports, and commercial property portfolios. Unlike the enterprise privatizations that preceded it, asset recycling is a sustainable means of raising additional investment capital (Government of Australia 2014).

Public Borrowings and Budget Deficits

Fiscal deficits and public debt in 2008–2012 grew significantly as countries pursued expansionary and liquidity-generating policies in response to the global financial crisis of 2007–2008. The fiscal deficits of countries in Asia and the Pacific region also increased after 2008, with 2014 deficits greater than the average deficit for 2002–2007 (World Bank 2014: 7). The need for fiscal consolidation to rebuild resilience is also pressuring regional governments to lower deficits to longer-term benchmark levels. However, this is difficult for a number of countries in South and Southeast Asia attempting to balance national development priorities and fiscal sustainability considerations (UNESCAP 2015: 20). Part of the problem for these countries can be addressed by widening the tax base and fiscal deficit ceilings designed to restore fiscal deficits to long-term levels. Most countries in Asia and the Pacific region other than Australia, India, and Japan possess the fiscal headroom to adopt a development-oriented fiscal position.

Although public debt increased in industrialized economies during 2008–2014, public debt remained stable in East and Southeast Asia at 42% of GDP, slightly higher than average debt levels during 2002–2007 (UNESCAP 2015: 19). However, most economies in the region have experienced sustained growth in corporate and household debt since 2008, increasing their vulnerability to higher interest rates and presenting a challenge for future monetary policy management.

Public debt is also a major source of investment and may take the form of general-purpose public borrowings, overseas development assistance loans, and the sale of conventional, indexed, or tax-advantaged bonds. Many countries in the region offer tax exemptions to resident investors for public bond issues. Public debt attracts deadweight costs, induces credit rationing, and "crowds out" private debt, placing pressure on interest rates and diverting capital away from higher yielding private investment (Regan 2009: 31–32). In 2014, the average public debt of many regional countries exceeded their 2007–2014 external debt average in terms of GDP (International Monetary Fund 2014a, 2014b). Although the increase in budget deficits and public debt in Asia and the Pacific region is modest compared with that in other regions, it does impact sovereign credit ratings in the long term and represents a limited option for government infrastructure spending in the medium term.

Tax-Exempt Bonds

Tax-exempt bonds are interest-bearing, redeemable securities issued by governments for specific national interest projects or general infrastructure purposes; they form part of governments' capital budgets for infrastructure spending, and are considered a government liability (Marlowe 2009; Ang, Bhansali, and Xing 2010). In the United States, bonds issued by local governments may be accorded federal tax-exempt status. Tax-exempt bonds are examined in further detail in subsection 12.2.3.

Revenue Bonds

Governments in Asia and the Pacific region must seek alternative ways to finance national infrastructure in most sectors, especially new "big ticket" assets such as ports, national highways, energy generation, waste management, airports, and rail transport. In constrained fiscal environments, one option is for governments to issue project-specific revenue bonds. Revenue bonds can be used to finance publicly or privately managed infrastructure with tranches designed to meet investors' currency, maturity, and interest-rate risk appetite. Revenue bonds may be issued on a limited recourse basis, with full or partial government guarantee support, by a government business enterprise, a project special purpose vehicle, or private sponsor. Projects financed with bonds may be listed on local securities exchanges, or bonds may be listed on the home exchanges of the Asian Bond Market. Depending on the country's level of compliance with international public accounting standards, bonds that do not require full or partial government redemption may not be included in the country's public-sector borrowing limits. However, it may be necessary to record bonds supported by government guarantees or other forms of support on the government's balance sheet for accounting purposes.

Government Business Enterprises

Governments have traditionally used government business enterprises (GBEs) to finance infrastructure investment in specific sectors, such as energy, transport, and water resources. GBEs are independent legal entities with their own boards of directors, and their borrowings are not treated as public debt of the shareholding government. GBEs finance their activities with retained earnings, budget appropriations (usually as equity or payment for community service obligations), and borrowings. These entities may borrow or issue bonds in capital markets and access sovereign credit ratings for debt-raising activities. In many countries in Asia and the Pacific region, GBEs generally spend more on infrastructure than do national and subnational government agencies (Wihardja 2013). GBEs' obligations may be fully or partially guaranteed by the government, and Treasury Departments may borrow or issue bonds on behalf of their GBEs if this incurs a lower cost of funds (Chan et al. 2009: 93–94).

The advantage of the GBE option for governments is the opportunity to generate revenue from user charges, implement projects professionally, and quarantine GBE debt from public-sector borrowing ceilings. GBEs may address market failure and use cross-subsidy services to mitigate specific project risks without state support in the form of guarantees, subsidies, and viability gap funding (VGF). GBEs may also provide better governance, accountability, and transparency than can private firms, and borrowings may be off-balance sheet depending on the governing accounting standards.

GBEs' weaknesses include mixed social and economic objectives, weakened lender discipline, and enterprise vulnerability to government intervention from time to time, either in the appointment of managers, the withdrawal of accumulated earnings as dividends, or the substitution of equity for debt capital. Investments may be selected in response to short-term government priorities rather than on the basis of project viability. GBEs do not possess the private sector's aversion to investing in high-risk marginal projects that do not demonstrate a sound, risk-adjusted economic rate of return. Studies also suggest that GBEs are generally inefficient due to overstaffing, high levels of debt, low levels of innovation, and a bureaucratic management style. GBEs are not subject to the stimulus of a competitive market environment, and are slow to adopt new and alternative technologies (Megginson 2005). As captive government agencies exposed to expedient government interventions and operating at low levels of efficiency, GBEs may be unsustainable options for financing long-term infrastructure investment.

The 2007–2008 global financial crisis demonstrated the hazards of providing GBEs with indemnity against enterprise failure, poor investment, and operational decision making. There is no incentive for GBE managers to perform financially or operationally at a standard higher than that agreed with government. Long-term studies suggest that GBEs fail to earn a rate of return that exceeds government bond yields, suggesting both enterprise inefficiency and often competing social and economic objectives (Productivity Commission 2008).

12.2.2 Bank Loans and Project Finance

Historically, governments have provided 70%–80% of the capital required to finance global infrastructure investment; however, this position is changing with project finance, corporate, and project bonds presently accounting for a much greater share of investment (Project Finance International 2015). Recent data suggest that private capital now provides up to 40% of infrastructure investment in Asia and the Pacific region.[2] The global financial crisis and subsequent Basel III reforms had long-term impacts on global capital markets, such that long-term project finance became less attractive for banks. During 2007–2010, loan terms and leverage levels were reduced, and risk repricing led to higher spreads and more onerous lending terms (Reviglio 2012; Seijas 2013). These changes did little to soften the market appetite for project finance, and the level of lending held up well during 2010–2014 (Project Finance International 2015). Banks have provided the majority of global project finance since the 1960s, and syndicated project finance remains the most common method for financing private infrastructure investment in Asia and the Pacific region. In 2014, global project-finance lending stood at $260 billion, the highest level in 10 years. In the same year, Asia and the Pacific region accounted for $72 billion (27.7%) of the global market, the largest share among global regional markets, but less than the average share of 31.5% over the previous decade (Table 12.1).

During 2004–2014, the majority of global loans were issued for projects related to power (39.0%), transport (24.0%), oil and gas (21.2%), and property (5.4%). In Asia and the Pacific region, most lending was for power (34%), transport (23%), oil and gas (15%), and the telecommunications sector (6%) (Figure 12.1).

Bank lending for infrastructure generally takes the form of project finance, the features of which include limited recourse security, long

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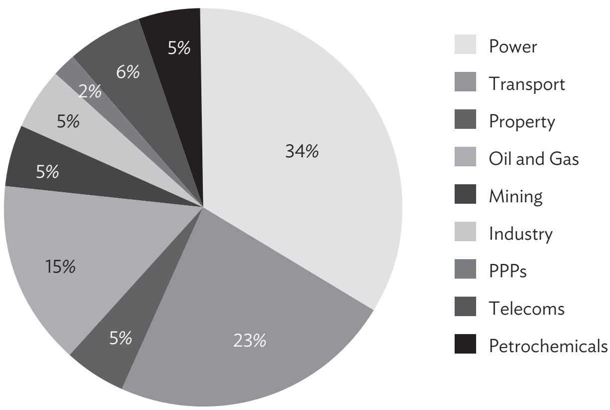
2 For example, in Australia, private debt and equity capital accounted for 58% of infrastructure investment in 2013, up from 33% in 1993 (Productivity Commission 2014).

Table 12.1 Project Finance Globally and in Asia and the Pacific Region, 2004–2014 ($ billion)

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Global	145	166	210	247	250	147	228	214	199	204	260
A-Pac	36	25	39	45	71	57	99	92	92	64	72
%	24.8	15.0	18.5	18.2	28.4	38.8	43.4	43.0	46.2	31.4	27.7

A-Pac = Asia and the Pacific region.
Source: Author. Data sourced from Project Finance International (2015).

Figure 12.1 Project Finance in Asia and the Pacific Region, 2004–2014 (% by sector)



PPP = public–private partnership, Telecoms = telecommunications.
Source: Author. Data sourced from Project Finance International (2004–2015).

tenors, a greater level of lender governance, and higher leverage than conventional corporate finance alternatives. Project finance relies on future cash flow to meet debt-servicing requirements, and lenders will generally exercise a higher level of due diligence and governance, make wider use of credit ratings, and apply financial compliance standards for the loan term.[3]

[3] Typically, these covenants include loan-asset value and debt-service coverage ratios, cash-flow distribution priorities and compliance with requirements for sinking funds, debt-service reserve, and cash-flow distribution covenants.

Bond finance accounts for around 20% of project finance transactions in Asia and the Pacific region, although volumes dropped to 10% during 2008–2012. This decline in the use of bonds is attributed to the rating downgrade of the major default guarantors in 2008–2009 and the repricing of bonds at underlying default risk, which, in many cases, was at S&P's BBB- or lower rating level (Debelle 2008: 78–79).

Notable characteristics of the project finance market in Asia and the Pacific region since the global financial crisis include the rise in importance of regional banks and the tendency for a greater share of bank lending to be allocated to home-country projects where debt is mainly priced in local currency (Project Finance International 2015). The supply gap created by the withdrawal of the Royal Bank of Scotland, Credit Agricole, the Bank of Ireland, BNP Paribas, and Banco Santander from the Asia and Pacific region market was met by growth in regional lending and the acquisition of assets and operations of several European banks, such as Mitsubishi-UFJ's acquisition of the asset portfolio and later the operations of the Royal Bank of Scotland group in 2012. During 2010–2014, local banks replaced European lenders as the leading arrangers and sources of finance in the region (Table 12.2).

Project finance loans are mostly used to finance infrastructure projects for which private firms provide equity capital, management, and operation and maintenance. These include economic infrastructure projects such as energy generation, ports and airports, destination freight rail services, and toll roads. In Australia, the Republic of Korea, and Japan, project finance has also been applied to social infrastructure in the form of schools and universities, hospitals, and public buildings.

Table 12.2 Sources of Project Finance in Asia and the Pacific Region, 2004–2014

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
1	US	UK	US	US	Spain	India	India	India	Aust.	US	US
2	UK	Spain	France	UK	US	Aust.	Spain	Aust.	India	Aust.	Aust.
3	Aust.	Qatar	S Arab	Aust.	UK	Spain	Aust.	US	US	UK	UK
4	ROK	US	UK	Spain	Aust.	US	US	RF	UK	India	India
5	Qatar	Italy	Spain	UAE	India	UK	UK	France	France	ROK	Brazil

Aust. = Australia, RF = Russian Federation, ROK = Republic of Korea, S Arab = Saudi Arabia, UAE = United Arab Emirates, UK = United Kingdom, US = United States.
Source: Author. Data sourced from Project Finance International (2004–2015).

The state bears market risk for social infrastructure, and project revenue is derived from state availability payments.

Strengths of Bank Lending for Infrastructure

A characteristic of project finance is that lenders are more active in asset management and performance by playing an important governance role to ensure borrower compliance with the loan terms, transaction contracts, and financial covenants applying over the life of the loan. Banks also play an important intermediation role providing over-the-counter risk management instruments to hedge borrower exposure to refinancing, currency, and interest rate risks. Multilateral agencies also provide support with grants for early-stage feasibility studies, environmental impact and management strategies, loans, and financial services, including political risk insurance.

Many project finance transactions in Asia and the Pacific region are delivered as PPPs, thus ensuring a high level of rigor in project selection, evaluation, and implementation. A recent survey of PPP policies in the region indicates that 19 countries in Asia and the Pacific region significantly improved the effectiveness of their PPP policies and supporting institutions from 2011 to 2014 (Economist Intelligence Unit 2011, 2014).

Lending institutions, regional governments and their agencies, and borrowers understand well the advantage of bank lending as a source of project finance. Debt servicing requirements over the project's economic life are matched to project cash flow and the financial economics of long-term infrastructure investments. Project finance is a major source of infrastructure provision in Asia and the Pacific region; supply increased in the region during 2008–2012 and it appears that finance will continue to be available for bankable infrastructure projects.

Weaknesses of Bank Lending for Infrastructure

The disadvantage of project finance is its inflexibility, and borrowers have limited scope for managing change. Loans cannot be retired early or refinanced without penalty, few conversion options exist, and interest rates may be linked to floating-rate indicators that, without hedging in place, expose borrowers to interest rate risk over the term of the loan.

A distinctive characteristic of project finance is long-term tenors, which permit a matching of the project's investment characteristics, the term of the service agreement, and the project's long-term debt-servicing requirements. Short-term finance or a reduction in project finance tenors creates refinancing risk for borrowers, particularly in times of rate volatility.

Challenges of Bank Lending for Infrastructure

Global capital markets are unpredictable and subject to systematic risk and the influence of global externalities. Many lenders in Asia and the Pacific region favor lending to the domestic market in local currency, indicating a financing gap for future regional cross-border transactions. Sustainable bank lending for infrastructure faces the challenge of transaction flow. Infrastructure investors and lenders argue that a regular flow of bankable transactions permits contractors to create and maintain skilled project teams, enhances collaboration with local consultants and contractors, and lowers bid costs (Preqin 2015a: 4).

12.2.3 Bond Finance

Bonds are financial instruments issued by a government or corporation obliging the issuer to make periodic interest payments and repay the principal on maturity. Bonds are an alternative source of capital to intermediated credit and equity financing (Hack and Close 2013). Bonds take many forms and are widely used by governments, corporations, and project sponsors to raise capital for infrastructure projects. Bonds provide many structuring alternatives, for example, interest payments may be at fixed or floating rates, tranches of a single issue may be issued in different currencies with different tenors, and interest payments may be indexed or guaranteed by the issuer or a third party such as a government or bank.

After the 1997–1998 Asian financial crisis, a corporate bond market was viewed as a possible solution to the capital flow problems that had led to the currency devaluations and economic downturn in Asia at the time. Asian bond markets experienced strong growth in the post-crisis years due to improvements in the regulatory framework, and clearing and settlement facilities. In 2015, corporate bond issues for "emerging Asia" (excluding Japan) stood at $8.78 trillion (around 61% of regional GDP), with the majority of issues in local currencies (ADB 2015).

Infrastructure bonds are frequently credit-rated and, leading up to the 2007–2008 global financial crisis, default guarantors (monoline insurers) insured a large number of issues and provided S&P's AAA-grade credit guarantees to projects with underlying ratings of BBB or lower (Debelle 2008: 78–79). This practice lowered the cost of debt for infrastructure bond issuers, and the rating downgrade that many insurers experienced after 2008 effectively closed the bond market as a financing option. Bonds accounted for around 20% of the project finance arranged in Asia and the Pacific region in 2014, having declined to less than 10% of the market in 2009–2010.

The average tenor of bonds in Asia and the Pacific region is around 6 years, although longer maturities are available in some regional markets, notably Indonesia, the Philippines, and Thailand (ADB 2015). The largest bond markets in the region are the PRC; Hong Kong, China; the Republic of Korea; Malaysia; and Singapore (Hack and Close 2013). The majority of bonds in the region are rated investment grade with low credit risk and low rates of default (Ehlers, Packer, and Remolona 2014).

Tax-Exempt Bonds

Tax-exempt bonds are government-issued securities that offer investors a full or partial exemption from taxation on interest receipts. Tax-exempt bonds are in high demand from investors paying higher marginal rates of income tax, which limits their attractiveness in low- and middle-income countries and suggests that a capital-guaranteed or indexed bond would be a more attractive option for many investors. Tax-preferred bonds may be issued by central government agencies or, as in the US, by municipal agencies with a national government income tax exemption. Depending on the terms of the issue, bonds may be traded in official markets or informally through intermediaries and secondary markets.

Tax-based incentives present a conundrum for governments.[4] A deduction from tax liability is an explicit transfer payment from the state to private investors to be offset by the welfare and private benefits of additional public goods.[5] The security will also be priced lower than other state securities in the market, which may reflect the lower risk of the revenue bonds or simply that buyers recognize the bonds' real post-tax return and adjust prices for the tax benefit. The subsidy effect may be significant. A US study showed that a reduction in borrowing costs for private corporations of 200 basis points (2%) created a loss to revenue estimated in 2006 at around $27 billion per year (Ang, Bhansali, and Xing 2010). More recent studies of capped deduction bonds indicate an implicit subsidy of bondholder returns of $31 billion for 10-year bonds and $112 billion for 30-year bonds (Scott 2012). Tax-exempt bonds may also create distortions and induce "crowding out" effects in capital markets.

A number of countries in Asia, including the PRC and Malaysia, grant an automatic income-tax exemption to resident holders of state-

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4 In the US, revenue bonds may be issued by subnational governments and guaranteed by the national government, which also carries the tax revenue reduction. Such arrangements suggest a need for controls on subnational government bond issues to minimize the impact of deadweight costs, as well as any impact on vertical fiscal imbalance.

5 Abelson 2003: 404–418; Hillman 2003: 131–138.

issued bonds. Other countries, subject to international tax treaties and free-trade agreements, grant full or partial exemption from transaction taxes, including capital gains and withholding taxes for non-residents.

Revenue Bonds

Revenue bonds are debt securities issued by governments to meet the cost of greenfield infrastructure, or issued by a project's private sponsors to raise investor capital on either a project-by-project or portfolio basis. The bonds are secured over the value of the assets and the contracts being financed. Issuers may provide enhancements by offering part or all of the issue at a discount or as indexed securities, in which case there is a discount to the yield spread (or interest) paid to retail investors. Issuers of indexed bonds have an advantage because the security is generally priced lower than conventional bond issues in the market (Chan et al. 2009: 84).

Corporate Bonds

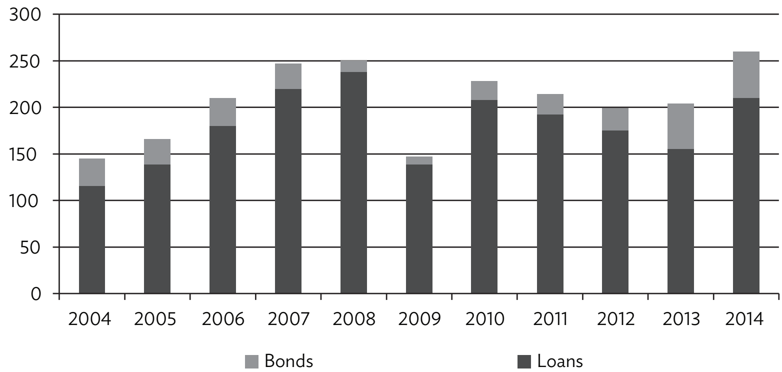
Corporate bonds for infrastructure finance account for less than 5% of infrastructure finance globally and significantly less in Asia and the Pacific region, with a 20% share of global infrastructure bond issues.[6] This is surprising given the strong growth of the Asian bond market, which accounted for around 61% of regional GDP in November 2015. This may be due to the issuing corporation's liability to redeem bonds in the event of project default. Of the regional infrastructure bonds on issue, around 94% are of investment grade credit standing, compared with 75% for global issues. The credit standing and liquidity of infrastructure bonds are generally more stable than those of corporate bonds (Ehlers, Packer, and Remolona 2014: 72).

Asian Bond Markets

Asian bond markets provide an opportunity to bridge the gap between Asia and the Pacific region's high domestic savings and the shortfall in infrastructure capital, although evidence suggests that this has not occurred on a significant scale. In 2013, the Bank for International Settlements and 11 regional central banks created the Asian Bond Fund to invest in local currency bonds across eight Asian markets (the PRC, Indonesia, the Republic of Korea, Malaysia, the Philippines, Singapore, Thailand, and Viet Nam), and to foster capital market liberalization, growth, and the harmonization of member capital markets. In 2005, a second fund with $2 billion in capital was established to facilitate

6 This can be compared with North America (41%) and Europe (21%) (Ehlers, Packer, and Remolona 2014: 72).

Figure 12.2 Global Bond and Loan Project Finance, 2004–2014



Source: Project Finance International (2015).

long-term local currency bond issues and develop supporting services, including derivatives and repurchase agreement trading.

In 2005, the Association of Southeast Asian Nations+3 and the Asian Development Bank created the Asian Bond Market Initiative to support and integrate regional bond markets for public and private bond issues. In December 2014, bonds on issue stood at $8.88 trillion across nine regional markets—the PRC (with a 63% market share); Hong Kong, China; Indonesia; the Republic of Korea; Malaysia; the Philippines; Singapore; Thailand; and Viet Nam. Government bonds accounted for 61% of the market, and nongovernment bonds accounted for 39%, an increase from 29% in 2007 (Zen and Regan 2014).

Government bonds accounted for most issues in the PRC, Indonesia, the Philippines, Thailand, and Viet Nam; and corporate bonds accounted for around 40% or more of issues in Hong Kong, China; Malaysia; the Republic of Korea; and Singapore (ADB 2015: 10). The majority of government bonds (33.7%) were issued with tenors of 3 years or less; 19.8% had tenors of 3–5 years, 24.6% had 5–10 years, and 21.8% had 10 years. Tenors were longest (10 years or more) in Indonesia and the Philippines, with most other funds favoring tenors of 5 years or less. Corporate bond issues were mostly issued with tenors of 3–10 years and 11% had 10-year tenors (ADB 2015).

The Asian Bond Fund and Asian Bond Market Initiative were important developments for the region providing liquidity, diversification, and risk-dispersion opportunities for investors. Although regional regulation has become more closely harmonized, most local currency bonds are held by a small number of domestic institutional investors, which may limit market liquidity.

Strengths of Infrastructure Bonds

As a financial security, bonds are an attractive investment for passive institutional investors, may be credit-rated, and offer investors liquidity and diversification. The security may be issued in a number of configurations, including different tenors, currencies, and security options. Bonds may be fully or partially guaranteed by the issuing institution, a bank, or government, and may be issued with an indexed payment stream, a convertibility option, or discount. Bonds may also be listed on securities exchanges and their performance measured by tracking market indexes. Recent studies confirm that infrastructure bonds in the region generally have significantly better credit ratings and lower default risk than corporate bonds (Ehlers, Packer, and Remolona 2014). Bond finance provides a flexible way to finance long-term projects and is well-matched to passive investor requirements for infrastructure finance.

Limitations of Infrastructure Bonds

Infrastructure bonds do not entail the active lender governance of project finance whereby lenders prescribe and then monitor performance criteria over the loan term. Bond investors are generally passive, have limited technical understanding of infrastructure, and possess little knowledge of the project's underlying economics. Although the risk of infrastructure bonds is no more complex than that of corporate bonds, the risks are different, consisting primarily of sovereign and political risk (Ehlers, Packer, and Remolona 2014).

Historically, bonds play an important, but not a dominant, role in project finance. Investor preference for brownfield risk and investment grade credit standing suggests that listed bonds may have a limited role as a future source of infrastructure finance. However, these characteristics do not rule out unlisted bonds playing a greater role in future infrastructure projects. The recent entry of investment funds managed by investment banks specializing in infrastructure is expected to grow the unlisted market through the 2020s.

12.2.4 Multilateral Development Banks

MDBs such as the Asian Development Bank (ADB) and the World Bank play a critical role in facilitating infrastructure development in Asia and the Pacific region. The World Bank provided $25.5 billion in 2012 for infrastructure- related projects and ADB lent $7.5 billion in 2012 for infrastructure, accounting for 64% of total lending (Moore and Kerr 2014). The services offered by MDBs include multi-currency loans, grants, equity, guarantees, technical assistance (TA) programs, and cofinancing activities in conjunction with other MDBs, multilateral development agencies, and public and private organizations.[7] MDBs may lend for longer tenors and at lower rates than do private banks, and have greater flexibility in designing debt-servicing requirements (Asian Development Fund [ADF] 2014). The average credit rating of ADB's loans and other financial exposures is investment grade (ADB 2014).

ADB also provides default indemnities through its Credit Guarantee and Investment Facility to leverage infrastructure projects to lower cost, investment grade credit standing. MDBs provide aid and concessional loans to low-income and developing countries (Chong and Poole 2013), and play an intermediary role by (i) bringing other financing institutions to a transaction, and (ii) arranging (a) debt syndications and sponsorship, (b) the provision of non-commercial risk insurance (sovereign, political, and currency non-convertibility risk), and (c) the management of donor programs such as the ADF (Moore and Kerr 2014). MDBs also play an important informative role by producing technical publications, national and project case studies, surveys, and reports. ADB sponsors the Economist Intelligence Unit's Asian Infrascope (Economist Intelligence Unit 2011, 2014), and publishes Key Indicators for Asia and the Pacific region annually (ADB 2016) and the Asian Bond Monitor quarterly (ADB 2015).

Strengths of Multilateral Development Bank Participation

MDBs are a major facilitator and provider of infrastructure finance in Asia and the Pacific region, and have a sound understanding of the region's economic, political, and social drivers, as well as the capacity to support projects with TA and financial and nonfinancial support services. MDBs play an important role in providing flexible intermediate lending that reduces the gap that often exists between underlying infrastructure project economics and a bankable transaction. MDBs also provide grants, equity, and debt on concessional terms, and may act as an intermediary for projects in low-income Asian countries by introducing co-lenders and third parties to help finance projects.

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7 ADB loaned $7.5 billion to infrastructure in 2012, around 64% of the institution's total lending (ADB 2014; Moore and Kerr 2014).

Limitations of Multilateral Development Bank Participation

MDBs have limited resources to meet the region's infrastructure financing needs, although the World Bank applies around 50% of its lending to infrastructure, and ADB applies around 65%. In March 2015, the Group of Twenty Nations (G20) committed to increase ADB's capitalization by $100 billion, suggesting that the institution will continue to play a leading role in Asia and the Pacific region through the 2020s.

12.2.5 International Development and Agencies

International development agencies (IDAs) are also an important source of loans, grants, financial services, and TA for infrastructure projects in Asia and the Pacific region. Loans and grants from MDBs and IDAs are often needed to address the viability gap that exists for private investment in many infrastructure projects in developing economies and in several industry sectors.[8]

IDA support for infrastructure may take the form of official development assistance, which was drawn from around 40 national agencies, 31 nongovernment agencies, and 26 international institutions in 2015. Official development assistance generally takes the form of loans, grants, and technical cooperation agreements for training, development planning, the financing of study teams and experts, and the provision of equipment. In 2013, the Japan International Cooperation Agency's global development assistance comprised loan aid (72%), technical cooperation (17%), and grant aid (11%) (Japan International Cooperation Agency 2014). Loan assistance is mostly provided as long-term loans for development at rates lower than those offered by commercial lenders. In Asia and the Pacific region, ADB manages the ADF, which also provides low-interest loans and grants to the region's low-income economies. In 2013, the ADF's assets were about $21 billion, of which about $14 billion was financed by ADB and about $7 billion by cofinancing partners (ADB 2014).

IDAs also provide TA to regional countries. Infrastructure is a capital-intensive group of assets requiring long-term planning and operating as part of networked supply chains in non-competitive market conditions. These characteristics assume greater importance when private firms in

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[8] Industry sectors such as water resources, public transport, roads, and road maintenance generally require that high levels of state subsidy or availability payment regimes for investment be viable for private investors. Viability is improved through low-interest IDA loans and grants, which may lower the level of subsidy support or guarantees provided by national governments (Estache 2010; Wihardja 2013).

the form of build–own–transfer and PPP contracts provide investment and finance. A challenge for governments is ensuring that the agencies commissioning these projects have the technical, financial, and commercial skills necessary to negotiate long-term and incomplete contracts with experienced international investors, operators, and financiers. IDAs provide TA to developing nations at a number of levels: project research, analysis, and studies; advisory services and payment for consultants to assist with project selection, appraisal, governance, and finance; and capacity building in the line agencies of national and subnational governments.

International development assistance may take the form of loans through import–export agencies and credit enhancement through international agencies such as the World Bank's International Finance Corporation, International Development Association, and Multilateral Investment Guarantee Agency.

12.2.6 Pension Funds

Global pension funds are significant global investors with an estimated $64.0 trillion in assets, of which $33.8 trillion was held by the top 300 funds in the Organisation for Economic Co-operation and Development (OECD) 2014 Global Pension Asset Study, with funds under management growing at an annualized rate of 7.3% during 2010–2014 (Towers Watson 2014). Sovereign and public funds accounted for 67% of assets under management, private corporate funds 19%, and private independent funds 14%. Around 64% of funds are located in countries in Asia and the Pacific region.[9]

Defined-benefit superannuation funds account for over 70% of survey assets in Asia and the Pacific region. This is important because defined-benefit funds permit fund managers to invest in long-term assets without the pressure of quarterly market-performance indicators and the need to maintain higher liquidity ratios. Accumulation funds place greater emphasis on the fund manager's ability to trade securities actively and maintain a competitive yield performance, particularly when regulations permit members to move their accounts freely between funds managers.

Significant differences exist in the asset allocation practices of global pension fund managers. For example, funds in Australia, Chile, and the United Kingdom (UK) typically hold 40% or more of their assets in

9 US (36%), Japan (13%), Canada (6%), Australia (3%), the Republic of Korea (3%), the PRC (1%), Malaysia (1%), and Singapore (1%) are among the funds controlling 90% of assets under management (Towers Watson 2014).

equities. In Asia and the Pacific region, significant weighting in equities also takes place in Hong Kong, China (65%); Australia (50%); and Japan (30%) but less in the PRC (20%) and the Republic of Korea (5%), suggesting that mature equity markets may be a factor in equities asset-allocation practices. Fixed interest accounts for 90% of investments in the Republic of Korea and 80% in the PRC. Fund managers in Asia and the Pacific region do not take a significant holding in property and other asset classes (Mercer 2014). The OECD study found that, on a weighted average basis, equities accounted for 41.2% of assets, bonds 44.9%, and cash and alternatives 13.9%. Pension fund investment in infrastructure takes several forms: direct equity investment, debt, and indirect investment through the agency of specialist infrastructure funds. The OECD 2014 Annual Survey of 104 Large Pension Funds estimated an average allocation to infrastructure of around 1% (Inderst 2014; OECD 2014: 51).[10] In contrast to the international norm, the infrastructure allocation of funds under management is around 6% in Australia and 5% in Canada (Inderst and Della Croce 2013). Debt instruments are believed to be a relatively insignificant medium for global pension-fund investment in infrastructure.

Strengths of Pension Fund Lending

As a debt security, infrastructure investments are well matched to the long-dated liability curve and yield preferences of pension funds. Infrastructure debt offers above-average risk-adjusted returns and portfolio diversification attributed to low-return correlations with equities, direct and indirect real estate, bonds, and leading economic indicators (short- and long-term bond rates, incomes, employment, inflation, interest rates, exchange rates, and investment levels) (Peng and Newell 2007). Infrastructure revenue streams are stable, generally indexed, underpinned by long-term service contracts, feature low price elasticity, and have the advantage of limited competition.

Limitations of Pension Fund Lending

Pension funds favor debt and equity participation in unlisted infrastructure, which accounts for 56% of their allocation to this asset class, and fund managers have difficulty identifying robust investment and lending opportunities. Infrastructure lending can also attract high transaction costs, although 33% of institutional investors point to liquidity as a concern and 26% to investment performance (Preqin 2015b).

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10 Preqin (2015a) estimates the average allocation to infrastructure of over 600 global funds to represent 3.3% of their funds under management. The allocation for all institutional investors is 4.4% (Preqin 2015b).

Pension funds prefer brownfield projects and will not lend for construction. As passive lenders, fund managers are not well equipped to exercise the governance generally required of lenders to this asset class. Pension funds in Australia, Canada, and the US prefer mature projects with stable and predictable revenues. Pension funds are not significant lenders to infrastructure either globally or in Asia and the Pacific region, although data are not readily available for portfolio allocations to infrastructure bonds and other debt securities with the fund's allocation to listed equities.

Pension-fund lending to infrastructure is essentially passive and does not import the technical understanding and governance roles provided by project financiers. Pension funds and institutional investors experience difficulty with the regulatory and political risk associated with these projects, and are expected to be a limited source of future infrastructure finance.

12.2.7 Sovereign Wealth Funds

Sovereign wealth funds (SWFs) are special purpose vehicles created by governments to provide financial security and stability during periods of international economic uncertainty. Clark, Dixon, and Ashby (2013: 4) view SWFs as a policy instrument and explain their rise as opportunities for states to identify investment platforms away from traditional capital markets. Although they have existed since the late 1950s, SWFs came to global prominence in the wake of the 1997–1998 Asian financial crisis when the number of funds increased from eight to 21, and helped stabilize many nations in Asia and the Pacific region during the 2007–2008 global financial crisis.

In April 2015, SWFs controlled $7.1 trillion of assets in diversified portfolios, generally allocated to interest-bearing domestic and foreign securities, equities, real estate, and alternative investments, which generally includes infrastructure assets. SWFs in Asia and the Pacific region account for five of the 10 largest funds, with $2.2 trillion under management. The largest regional funds are in the PRC ($1.5 trillion); Hong Kong, China ($400 billion); and Singapore ($300 billion) (Sovereign Wealth Fund Institute 2015). SWFs are a growing influence in the global investment community and are now contributing to the reshaping and decentralization of global capital markets and fiscal architecture.

Strengths and Limitations of Sovereign Wealth Fund Finance

SWFs possess the capital required for long-term equity and debt investment in infrastructure as an asset class. Infrastructure securities generally display the investment characteristics favored by portfolio investors and, with few liabilities, SWFs possess the necessary flexibility for direct participation in the infrastructure sector. As with pension funds, the attraction of infrastructure for portfolio investors is its strong diversification characteristics, with studies showing a low correlation with other asset classes and stable price-return performance against most leading economic variables (Peng and Newell 2007). It may also be argued that funds are designed to support the national interest and should maintain a high portfolio allocation to domestic infrastructure projects, although any discussion of a portfolio quota for a specific asset class raises the question of conflicting objectives. That is to say, SWFs possess a financial rather than a development purpose requiring high liquidity levels and a return commensurate with a given risk appetite. Minimum allocations to domestic infrastructure will involve political intervention in the SWFs' decision-making processes, and threatens the independence of fund managers, a matter widely discussed and rejected in 2008–2009 with regard to mandatory infrastructure investment levels for pension funds (Regan 2009: 47–50).

As portfolio managers, SWF managers, unlike banks, lack the retail apparatus to issue or trade in bonds, annuities, or derivatives, or to exercise the lender's traditional credit assessment and governance roles. Lender governance is particularly important in infrastructure finance, which requires lenders to design, monitor, and enforce covenants regulating borrowers' performance under loan agreements. Covenants may cover cash and operational management, observance of debt–security ratios, compliance with sinking-fund requirements, and debt-service coverage ratios.

These constraints limit the SWFs' capacity to serve as arm's-length providers of debt finance for domestic infrastructure projects, as suggested by the relatively low average allocation of 4.5%–4.8% to this asset class (S&P 2014: 4).

12.2.8 Initial Public Offering

In the 1980s, financial institutions raised equity capital for privatizations using trade sales and IPOs for listing on securities exchanges. Several recent privately financed infrastructure projects were securitized in a similar manner by issuing stapled securities in multiple entities, one of which will "loan" its share of the offer proceeds to another vehicle in the group. This device was used for four motorways in Australia (Hills Motorway, Eastlink, Clem 7, and Airport Link) from 1997 to 2011, although, in all cases, total return performance was poor and the vehicles were subsequently delisted and assets sold. Transactions using the IPO option have occurred in countries with mature capital markets, which limits the feasibility of this option in less well-endowed developing economies. Although a listed vehicle may issue stapled securities, bonds, and other debt instruments on a securities exchange, in most cases, the IPO option is used to raise equity capital for privately financed infrastructure projects.

Strengths of the Initial Public Offerings Option

IPOs provide an additional source of debt capital. Companies can raise debt in the form of stapled securities or issue bonds on the securities exchange. Stapled securities provide issuers with the opportunity to offer separate equity and debt securities within a corporate group structure. Listed bonds bring liquidity and the issuer has the option of issuing bonds in a variety of coupon and tenor configurations to reduce most project-financing risks.

Limitations of the Initial Public Offerings Option

The market for listed infrastructure projects is limited to single-asset infrastructure projects. Debt-finance options include listed bond markets in which infrastructure securities have demonstrated robust credit and performance characteristics. IPOs imply greenfield project risk, and market evidence in Canada and Australia indicates a high failure rate because recent transactions have resulted in significant loss to equity and write-downs for lenders (Regan, Smith, and Love 2015).

Low institutional support is another limitation of the IPO. Portfolio investors favor pre-commitment or sub-underwriting participation at a discount to the issue price for stapled debt and equity securities, an option not available to smaller portfolio investors and the retail market. Given the dominant position of institutional investors in capital markets throughout the region, the infrastructure IPO market has a limited pool of investors to draw from compared with offerings for other sectors.

12.2.9 Public–Private Partnerships

PPPs came into wide use in the global economy in the early 2000s, although the practice of government concessions for the private delivery and management of public goods has a long history dating back to the Romans. PPPs are long-term contracts for the provision and management of infrastructure services, whereby a private firm provides capital, constructs the required assets, and carries most of the development and operational risk over the contract term. The private firm derives sufficient revenue to provide a reasonable return on investment either through user charges or a government-availability payment, and debt is supported from cash flow with restrictions on payment to equity during the project's early stages. There is some ring-fencing of construction risk with a short-term construction loan, refinanced on completion. However, market-risk projects, in which a private party relies entirely on user tariffs, are difficult to finance, with recent transactional evidence suggesting that these projects have a high probability of failure (Regan, Smith, and Love 2015).

PPPs are generally highly leveraged with bond issues or project finance. PPP service delivery is regulated under the PPP contract and/or by an independent regulator, and assets pass to the state at the contract's conclusion. For availability-payment transactions, lenders to recent projects have required that debt servicing be met from a core-service payment, which is not subject to performance abatement. These negotiated terms and "take or pay" contracts effectively substitute sovereign risk for operator-performance risk, significantly reducing risk for lenders.

In Asia and the Pacific region, PPPs are an important source of infrastructure finance and are widely used to deliver economic infrastructure including motorways and roads, power stations, ports and airports, rail infrastructure, and urban transport (Zen and Regan 2014). Most PPPs are highly leveraged and may be financed with project finance or bonds. PPPs are delivered against a policy framework suggesting consistency in the procurement process. PPPs may be supported with credit enhancement, as demonstrated by the Phu My 3 BOT Power Company's gas-fired energy transaction finalized in 2003, the first PPP in Viet Nam. Phu My was a high-risk, limited-recourse, greenfield project that was supported by sovereign and political risk insurance, designed for the transaction by ADB and the Multilateral Investment Guarantee Agency (Cooper 2004).

PPPs are not suitable for all infrastructure applications and deliver their best returns when projects offer economies of scale, significant risk transfer (including lifecycle cost and operational risk), and the ability to be financed in capital markets. PPPs are not suitable for small, conventional projects, given their high transaction cost, and must be affordable for governments if they require an availability payment, capital contributions, subsidies, or guarantee support over the project's life.

Strengths of Public–Private Partnerships

PPPs are delivered under a procurement policy that brings some uniformity to the project selection, bid, and implementation process. Project finance is used in most applications, although bonds account for around 12% of recent transactions (Project Finance International 2015). For lenders, an important aspect of PPPs is alternative disputeresolution mechanisms for the speedy resolution of disputes between parties that may arise over the life of the contract. PPPs experience lower failure rates than do projects financed with conventional corporate loans. Since 2001, evidence has shown that PPPs deliver innovations in design and construction, achieve significant risk transfer away from governments, and deliver better services more sustainably than do traditional procurement methods (National Audit Office [United Kingdom] 2001, 2003; Infrastructure Partnerships Australia 2007; Regan 2009).

Limitations of Public–Private Partnerships

PPPs deliver the best value-for-money outcomes for the state when projects offer economies of scale and significant risk transfer to private investors, and require innovative design and construction solutions, as well as skilled and incentivized management. PPPs involve long lead times and high transaction costs for all parties, and must be capable of being financed in capital markets. Debt is usually syndicated, and sustainability requires a strong and effective governance framework. PPPs are not suitable for projects under $50 million and, if financed with tenors of less than 10 years, are vulnerable to refinancing risk. Another disadvantage of PPPs is the implied lack of flexibility with incomplete contracts 20, 30, and 40 years in duration, and governments' capacity to manage planning and change over such long operational periods, in particular.

12.2.10 Securitization

The unitization and/or securitization of revenue streams from mature infrastructure assets are a financing option for government agencies and private investors. The investment characteristics of mature infrastructure assets include limited competition, regulated tariffs, a stable and frequently indexed revenue stream, low variable costs, high leverage for enhanced return-to-equity, and low demand elasticity. In mixed asset portfolios, infrastructure assets are an option for portfolio diversification (Della Croce and Gatti 2014).

Securitization has been used to finance credit-enhanced bonds issued to finance social and economic infrastructure projects in sectors such as waste management, hospital and school projects, and regulated utilities delivering water, electricity, and gas services (Dexia 2007). In 2012, the Independent Debt Capital Markets Group issued consumer price-indexed notes for a solar power project based in the UK, and transactions in the resources sector have been completed in Europe, the Russian Federation, and Asia and the Pacific region (Project Finance International 2015).

Limitations of the Securitization Option

Securitization was widely used for homogenous revenue streams such as mortgage and credit receivables until 2007, and was an early victim of the financial crisis that followed. Securitization is an opportunity for lenders to recycle loans to a wider institutional investor market. However, securitization requires a mature capital market with larger institutions that can package and guarantee security offers, and provide the intermediation and distribution services required. Securitization is not viewed as a medium-term option by leading financial institutions in Asia and the Pacific region where bond markets offer a more liquid and flexible recycling and diversification alternative. Securitization is limited to assets with high credit standing in a stable interest rate environment.

12.2.11 Finance Support Mechanisms

Following the early privatization of brownfield projects in the mid-1990s, infrastructure projects in many sectors declined in credit quality. This is partly because privatizations and more bankable energy, port, transport, and airport projects have been replaced by a group of projects in such sectors as water supplies and sanitation, urban transport, roads and road maintenance, and railway services, many of which are located in regional areas. Project viability questions are far more common now than they were in the early 2000s. Governments and MDBs have responded by arranging the credit enhancements that improve the credit profile and bankability of infrastructure projects. Of these enhancements, many of which are discussed above, several warrant further examination: VGF, the European Investment Bank (EIB) mezzanine bond finance program, and the state as a lender-of-last-resort.

Viability Gap Funding

Infrastructure may not be viable for private investors if the revenue stream generated by the project is insufficient to service the level of debt required for the undertaking. This can occur when user-pays principles generate insufficient revenue to meet debt-servicing obligations, when output pricing is subject to discretionary state regulation or price caps, or when the level of risk allocated to the private party is unacceptable to lenders. In response, governments worldwide have introduced VGF policies in place of ad hoc project support negotiated on a case-by-case basis.

VGF is state financial assistance for privately financed infrastructure projects to support bankability, and is being adopted either formally or informally in outsourcing and in build–operate–transfer and PPP transactions throughout Asia and the Pacific region. VGF is used to ensure that a project designated for delivery as a privately financed project does not fail because of its marginal viability. VGF effectively internalizes externalities in infrastructure markets (Irwin 2006), and is used by governments when some form of assistance is warranted to reduce project costs, ensure timely delivery, or provide a basis for sustainable service delivery over long intervals (Regan 2009). VGF may take the form of up-front capital contributions, debt provision, payment of subsidies during the project's operation, and/or guarantees against specific transaction risks. VGF is embodied in policy, which, in many cases, creates contribution "caps," requires the full disbursement of private equity and debt before payment is made, and directs payment to project lenders when the project is commissioned. VGF assistance is normally accounted for as a budget appropriation in the case of capital contributions, or as a contingent liability in the case of subsidies or guarantees.

The European Investment Bank Mezzanine Bond-Finance Project

The EIB mezzanine bond-finance pilot project was introduced in 2010 to enhance credit for senior bondholders of privately financed and qualifying infrastructure projects. The EIB provides S&P's AAA-rated subordinated mezzanine bonds, or a guarantee to 20% of the senior debt, to meet cost overruns during construction or shortfalls in debt-servicing capacity during the early operational stage of an infrastructure project. The government or a multilateral development agency such as the EIB or the European Central Bank provides the finance or guarantee. The mezzanine bond program reorders project risk and benefits senior lenders by improving their credit risk, lowering the project's cost of capital, and permitting higher debt–equity ratios (subject to leverage limits) (EIB 2012).

Lender-of-Last-Resort

In the uncertainty that followed the global financial crisis, lenders reduced the level of debt that they were willing to contribute to syndicated project finance loans. This was most evident in large-budget PPP projects in Australia and Canada, and required quick policy responses on the part of the government. The A$3.5 billion Victorian Desalination Project was offered to the market at the peak of the 2009 crisis, and the Government of Victoria received bids from two consortia that both failed to raise the full debt requirement. In response, the government announced a successful bidder for the final negotiations, and pooled lender commitments for both consortia. The government stood as lender-of-last-resort, and relied on a pre-commitment to take a minimum quantity of water (the plant's base load) in an effort to reduce the project's financial risk. The successful bidder was able to raise the full debt requirement from the market without recourse to state loans (EIB 2012).

Lender-of-last-resort mechanisms, with the state providing senior debt, impart confidence and provide greater certainty to both bid and capital markets. However, as with the earlier credit guarantee, finance programs trialed in Australia and the UK in 2008–2010, state financial participation may impose rigidities such as debt ceilings and maturities that impose limitations on refinancing, leverage and capital structure and generally raise the cost of capital for the project (McKenzie 2008).

12.3 Conclusion

Governments provide the majority of infrastructure finance in Asia and the Pacific region, with the assistance of multilateral development agencies. Although continuing to plan and provide most infrastructure in the medium term, national government sources alone may not be sufficient to bridge the infrastructure gap created by high economic growth, urbanization, and rapid industrialization in factor-driven economies. Since the early 2000s, private infrastructure finance has assumed a more important role in the form of project finance, bonds, and build–operate–transfer and PPP procurement methods. As well as serving as an additional source of capital, private management of infrastructure also increases efficiency, improves productivity, and eliminates high-risk lifecycle costs for the state. However, private capital does have limitations, including a preference for projects in the energy, transport, and telecommunications sectors and an aversion to market risk with transport projects. Another limitation is the marginal bankability of many infrastructure transactions, which may be difficult and costly to finance without credit support from the state. In response, multilateral development agencies have increased credit-enhancement options, and VGF policies have been introduced, providing a systematic approach to improving the bankability of marginally viable transactions. In the region's mature PPP markets, this model has been modified to eliminate market risk for projects such as toll roads and rail projects, with availability-payment options for asset provision stapled to long-term, asset-and-service management contracts. Innovations in the way infrastructure projects are designed, changes to risk allocation, and improved project selection and risk-management methods are expected to improve future procurement methods and increase the attractiveness and bankability of infrastructure for private finance.

Pension funds and SWFs are not widely used to finance infrastructure projects, either globally or in Asia and the Pacific region; however, a majority of funds intend to increase equity participation in the medium term. IDAs, the Asian bond market, and specialized infrastructure-investment funds are potential sources of future debt, although passive investment is not always optimal for limited-recourse infrastructure projects. Although bond finance brings many attributes to infrastructure transactions, in listed form, they may be unsuitable for projects in which lenders need to bring experience and skills to the design and governance of transactions.

Bhattacharyay (2011, 2012) outlined the capital market policy objectives for the region, and these require little further explanation. Challenges faced by regional governments include fiscal repair, mechanisms for the recognition and funding of the contingent liabilities of national and subnational governments, the refinement of PPPs, and the outsourcing of policy frameworks with a view to adopt common policy principles to facilitate regional connectivity and simplify cross-border transactions. The Association of Southeast Asian Nations has made considerable progress in this respect, and the template can be applied more widely to Asia and the Pacific region.

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Infrastructure Investment, Private Finance, and Institutional Investors: Asia from a Global Perspective

Georg Inderst

13.1 Introduction

Good infrastructure is key to both economic growth and social and ecological development. Globally, infrastructure investment requirements are enormous, and particularly so in developing economies. Many countries are held back by chronic underinvestment in infrastructure and poor maintenance of existing infrastructure. However, there can also be overinvestment of taxpayers' money in infrastructure. With public sector budgets often stretched thin, the private sector is asked to play a bigger role in infrastructure financing.

This study evaluates infrastructure investment and finance in Asia from a global perspective. It provides an overview of infrastructure needs and the various sources of private finance, both globally and within Asia. Institutional investors are widely seen as a promising new financing source, but it is less clear what their potential contribution is. An increasing number of pension funds, insurance companies, sovereign wealth funds (SWFs), and other investors are seeking investment opportunities in this field but experience is mostly limited. Moreover, as they all have their own different objectives and constraints, they are not a homogenous group.

Given the importance of these subjects, there seems to be surprisingly little about them known. Information is typically scarce, and definitions of "infrastructure" vary widely. Nonetheless, it is important to look at the "bigger picture" of the supply of and demand for capital for infrastructure. This chapter gathers the available information into a simple framework, i.e., percentages of gross domestic product (GDP), in order to reach a better understanding of the "orders of magnitude" in this field. Further studies may provide more detail in particular areas.

13.2 Infrastructure Financing Needs

13.2.1 Historical Perspective

We take historical infrastructure spending as a starting point. About 3.8% of world GDP has been spent on economic infrastructure over the last 20 years, i.e., around $2.4 trillion per year (applied to the 2010 GDP). Infrastructure investment in both the United States (US) and the European Union (EU) amounted to 2.6% of GDP; this percentage was much higher in East Asia (5.0% in Japan and 8.5% in the People's Republic of China [PRC])[1] (Figure 13.1) (McKinsey 2013).[2] Infrastructure spending trended down in the developed world, from 3.6% of GDP in 1980 to 2.8% in 2008, but grew in emerging economies from 3.5% to 5.7%. This rise was primarily driven by East Asia, whereas Latin America in particular lagged behind.

World Bank research (Fay et al. 2011) estimated annual infrastructure spending in developing countries in 2008 at $800 billion–$900 billion, of which $600 billion–$650 billion was from the public sector, $50 billion–$100 billion from official development assistance, and $138 billion from private participation in infrastructure (PPI). Relative to GDP, this spending share was 4.2% globally; 6.8% in the East Asia and the Pacific region; 4.2% in South Asia; 7.1% in sub-Saharan Africa; 6.9% in the Middle East and North Africa; and 1.2% in Latin America, Europe, and Central Asia.[3]

Infrastructure investment patterns differ considerably, not only across regions but also within regions and countries. For example, spending on infrastructure investment is much lower in Association of Southeast Asian Nation (ASEAN) countries than in the PRC—roughly 1.5% of GDP in Indonesia, 2.0% in Thailand and the Philippines, and

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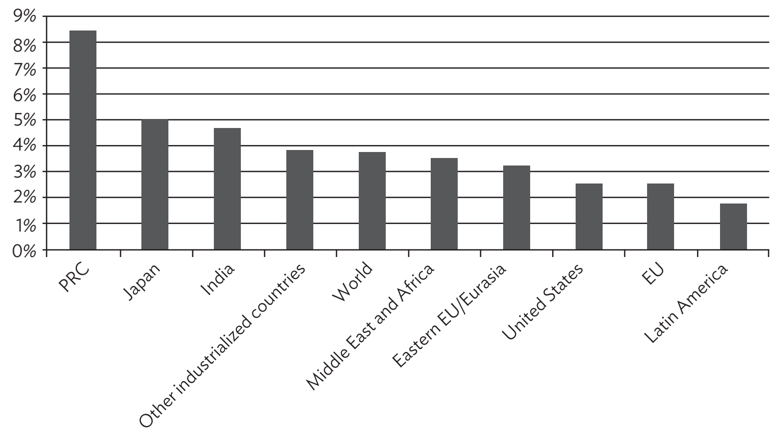
1 The country names in this chapter follow ADB conventions.

2 The chapter covers seven sectors of economic infrastructure (roads, rail, ports, airports, power, water, and telecommunications), merging data from different sources: International Transport Forum for transport, IHS Global Insight for energy (including generation) and telecommunications, and Global Water Intelligence for water.

3 Country groups of developing countries as defined by the World Bank (2015a). For simple reference: the world GDP in 2012 was about $72.0 trillion, of which Asia accounted for $21.0 trillion (30%), East Asia and the Pacific $18.5 trillion (26%), South Asia $2.5 trillion (4%), and emerging Asia $13.0 trillion (18%). Asia holds close to 60% of the world's population.

Figure 13.1 Infrastructure Spending, 1992–2011 (% of GDP)



PRC = People's Republic of China, EU = European Union, GDP = gross domestic product.
Source: McKinsey (2013).

3.5% in Malaysia (Goldman Sachs 2013). The Republic of Korea falls in the middle with a spending share of 4.3%. For the South Asia region, Andrés, Biller, and Herrera Dappe (2014) report that investment increased from 4.7% of GDP in 1973 to 6.9% in 2009, driven mainly by electricity generation.

Unfortunately, data are not available for global or Asian investment in social infrastructure. For Europe, Wagenvoort, De Nicola, and Kappeler (2010) calculated an additional 1% of GDP in the health (0.6%) and education (0.4%) sectors.

Overall, longer-term economic infrastructure spending as a share of GDP has been measured at about 2.6% for Western, developed countries, and 3.8% globally. A wide dispersion exists across emerging markets and developing economies (EMDEs). East Asia compares well among both developed and developing countries. However, infrastructure investment levels are much lower in many other Asian countries.

13.2.2 Estimates of Future Demand

Infrastructure bottlenecks are evident in many places. More investment is required, not only to build new projects, but also to maintain existing infrastructure. This chapter focuses on the financial aspects of the topic, as opposed to the physical. Future investment needs are not easily

Table 13.1 Global Infrastructure Investment Needs to 2030 (% of world GDP)

Water		**1.3**
Telecommunications		**0.5**
Transport		**0.8**
Road	0.3	
Rail	0.3	
Airports	0.2	
Ports	0.1	
Energy		**1.5**
Electricity transmission and distribution	0.2	
Electricity generation	0.7	
Other energy	0.4	
Oil and gas, transmission and distribution	0.2	
Total		**4.1**

GDP = gross domestic product.
Sources: OECD (2006, 2007, 2012); WEF (2012); Inderst (2013).

quantifiable, and financing gaps (i.e., the difference between the capital needed and the capital available) even less so. This study considers some of the main estimates in this respect.

Global Estimates

The Organisation for Economic Co-operation and Development (OECD 2006, 2007, 2012) produced some groundwork in a sectoral analysis starting in the mid-2000s. Infrastructure needs in key economic sectors add up to more than $80 trillion until 2030, i.e., about $3 trillion per year, or more than 4% of the world GDP (Table 13.1). Top-down estimates produce similar results.[4] Based on these figures, the World Economic Forum (WEF 2012) calculated a global infrastructure financing gap of about $1 trillion per year (1.25% of GDP).

[4] There are two basic estimate approaches: top-down and bottom-up. The first is based on the development of macro-statistics, such as GDP, capital stock, and investment. The second is based on microeconomic information, such as regional and sectoral case studies, planning documents from local entities, and experts' assessments.

Most estimates concentrate on the infrastructure needed to keep pace with "normal" economic and demographic growth, rather than any "social optimum."[5] Investment to mitigate and adapt to climate change or to meet low-carbon targets requires additional resources. The same is true when other targets for social and human development are introduced. For example, by adding "green infrastructure" needs, global estimates could rise to $3.5 trillion–$5 trillion per year (roughly 5%–7% of GDP) (WEF 2013).

Infrastructure Capital Stock and Productivity

It appears that capital investment could, to a certain extent, be replaced by good infrastructure policy and management. Better use of existing infrastructure and selection of new projects could reduce the financing gap (Andrés, Biller, and Herrera Dappe 2014). For example, McKinsey (2013) estimates a potential 60% improvement in infrastructure productivity that could save $1 trillion in spending worldwide each year. Furthermore, some countries might show high overall infrastructure capital stock from past investments, but it may be of poor quality, with overcapacity in some sectors, or including some infrastructure "white elephants" (i.e., infrastructure that is expensive to maintain or difficult to dispose of).

McKinsey (2013) estimated that infrastructure stock amounted to about 70% of GDP for most major countries; this figure was also considered a global average. Japan is a significant outlier on the upper side, with infrastructure stock at 179% of GDP; this is driven especially by road infrastructure. This figure is 76% in the PRC and 58% in India, compared to 30%–50% in Southeast Asian countries (International Monetary Fund 2014). In the Asian context, it is worth noting that past "overinvestment" in some places may permit lower future spending.

Emerging Markets and Asia

Infrastructure investment needs are expectedly higher in EMDEs than in developed markets. Using a top-down, multisectoral model, World Bank experts estimated the level of these needs at 6.6% of GDP on

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5 PricewaterhouseCoopers (2014) expects global capital project and infrastructure spending to grow from about $4 trillion to $9 trillion per year over the next decade. The Asia and the Pacific region is set to grow at an above average rate of 7%–8% per year, reaching an annual volume of about $5 trillion by 2025 and representing nearly 60% of the global total. The PricewaterhouseCoopers and Oxford Research Economics report uses a wide-ranging definition of infrastructure, including primary activities (e.g., the extraction of oil, gas, coal, metals, and other resources), key manufacturing activities (which enable the transportation and utilities sectors to develop and operate), and social infrastructure.

average in developing countries. New investments would amount to 2.6% of GDP, and operation and maintenance 4.0% of GDP. However, a very wide spread exists between low-income (12.5%), lower–middle income (8.2%), and upper–middle income countries (2.3%). Actual investment levels in 2008 were estimated at 5.0% in low-income countries, 3.3% in lower–middle income countries, and 1.0% in upper–middle income countries (Estache 2010; Fay et al. 2011).

According to Bhattacharya, Romania, and Stern (2012), to keep pace with the demands of rapid urbanization and economic growth, developing economies must increase spending from the current $800 billion–$900 billion to about $1.8 trillion–$2.3 trillion per year by 2020, or from about 3% to 6%–8% of GDP.[6] Thus, a spending gap of approximately $1 trillion per year is projected for developing economies. The East Asia and the Pacific region would require the highest share of this (35%–50%), followed by South Asia (20%–25%). In terms of sectors, electricity accounts for the largest share (45%–60%).[7]

Several regional studies have also estimated future infrastructure investment requirements and gaps. In his work for the Asian Development Bank (ADB), Bhattacharyay (2012) found that 32 developing economies in Asia would need $8.2 trillion (in 2008 prices) in infrastructure investments during 2011–2020.[8] In terms of sectors, about half of these investments should go to energy, about one-third to transport (mostly on roads), and the rest into telecommunications, water, and sanitation. Two-thirds is needed for new capacity and one-third for maintenance and the replacement of existing assets.

The PRC requires more than half, and India more than a quarter of the estimated amounts, followed by Indonesia (5.0%). Relative to GDP, however, infrastructure needs are very high in South Asia (especially for roads), amounting to 11.0% of GDP against the regional average of 6.5% (Table 13.2). Values of more than 8.0% are also seen in a number of other Asian countries (Afghanistan, Cambodia, the Kyrgyz Republic,

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6 This includes climate change mitigation and adaptation investments of $200 billion–$300 billion per year.

7 An alternative study by the Royal Bank of Scotland (2011) projected that infrastructure demand in emerging markets would rise to $19.2 trillion for 20 years through 2030, with Asia accounting for the largest share, at $15.8 trillion. Over the previous 20 years, infrastructure spending was estimated at $7.4 trillion, of which $5.1 trillion was in Asia ($2.9 trillion in the PRC, $1.3 trillion in India, and $0.3 trillion in the Republic of Korea).

8 This breaks down to $776 billion of national investments each year (estimated using a top-down approach), and $29 billion for regional infrastructure each year (estimated using a bottom-up approach).

Table 13.2 Infrastructure Investment Needs, 2010–2020 (% of GDP)

	Energy	Transport	Telecom	Water and Sanitation	All Sectors
East and Southeast Asia	3.2	1.6	0.5	0.2	5.5
South Asia	3.0	5.6	2.0	0.4	11.0
Central Asia	3.0	1.9	1.4	0.4	6.6
Pacific	0.0	2.6	0.7	0.3	3.6
All Developing Asia	3.2	2.3	0.8	0.2	6.5

GDP = gross domestic product, Telecom = telecommunications.
Source: Bhattacharyay (2012).

Lao People's Democratic Republic, Mongolia, Tajikistan, Uzbekistan, and Viet Nam).

Andrés, Biller, and Herrera Dappe (2014) found annual investment requirements in South Asia of $140 billion–$210 billion (in 2010 prices), or 6.6%–9.9% of GDP. In an analysis of four ASEAN countries, Goldman Sachs (2013) produced a figure of $550 billion through 2020, substantially higher than past spending and government estimates ($427 billion).[9]

In summary, future investment needs in global economic infrastructure are somewhat higher (more than 4% of GDP) than past spending. Projections are much higher for developing countries, at an average of 6%–8%. Within Asia, there is a very wide dispersion around the core estimate of 6.5%. Some countries would need to increase infrastructure investment substantially over a longer period, whereas others already have a high capital stock.

Investment in social infrastructure and to achieve green targets or development goals (e.g., the United Nations Millennium Development Goals) would require additional resources, but little is known about the necessary size of these investments. On the other hand, there is potential for substantial efficiency improvements in the use and construction of infrastructure. This is an area that deserves much more attention in future research and policy.

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9 This figure is the sum of $240 billion for Indonesia (Economic Master Plan 2011–2025), $45 billion for Malaysia (public spending on infrastructure in the 10th Plan, 2011–2015), $70 billion for the Philippines (2011–2016), and $72 billion for Thailand (2012–2020).

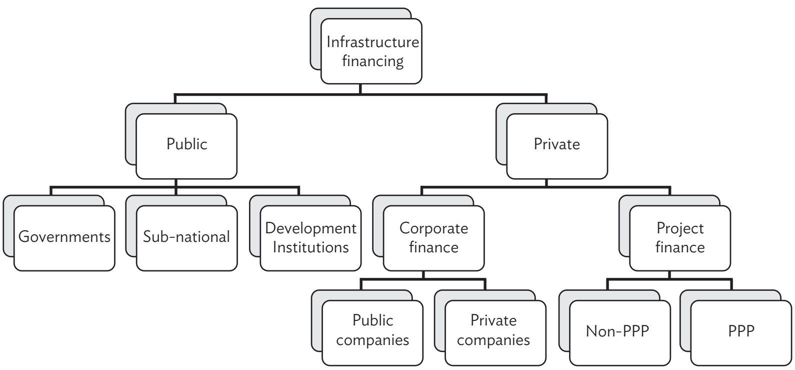
13.3 Supply of Capital

Next, it is necessary to consider the composition of infrastructure finance, supply of private capital, and investment vehicles. The main categories are outlined in Figure 13.2, and include the following:

(i) Public or private sources of finance. Public capital comes from central, regional, local, and other government institutions, plus national development banks and multilateral development banks (MDBs), such as the World Bank, ADB, or the Islamic Development Bank.

(ii) Private capital is provided in two main forms: corporate finance (on the balance sheet, from infrastructure companies' own resources) and project finance, a contractual financing arrangement much used for infrastructure.[10]

Figure 13.2 Sources of Infrastructure Finance



PPP = public–private partnership.

Source: Author.

10 Project finance is the financing of long-term infrastructure, industrial, extractive, environmental, and other projects (including social, sports, and entertainment PPPs) based on a limited recourse financial structure whereby project debt and equity used to finance the project are paid back from the cash flow generated by the project, typically a special purpose vehicle.

(iii) Within corporate finance, one can distinguish between listed (publicly traded) and unlisted (private) companies. Within project finance, one can distinguish between public–private partnership (PPP) and non-PPP arrangements.[11]

(iv) Infrastructure companies can operate in regulated or unregulated sectors.

(v) There is typically a mix of equity and debt finance. Infrastructure and PPP projects in particular are often highly leveraged.

13.3.1 Sources of Infrastructure Finance

Public and Private Finance

Since World War II, the public sector has traditionally played a central role in the ownership, financing, and delivery of infrastructure services. Private participation rose in several countries from the 1980s, due to privatization and, from the 1990s, through PPP schemes. Today, most developed countries, with the notable exception of Japan, have a higher share of private financing in infrastructure than do developing countries. For example, in the EU, the ratio of public to private financing is about 1:2 in old member states and 1:1 in new member states (Wagenvoort, De Nicola, and Kappeler 2010). About 70% of the United Kingdom's (UK) economic infrastructure is funded by private sources (Her Majesty's Treasury 2014).

In EMDEs, public funding of infrastructure accounts for about 70% of total infrastructure expenditure, according to World Bank estimates. Approximately 20% is financed by private sources, and the rest by development banks and agencies (Delmon and Delmon 2011). Bhattacharya, Romania, and Stern (2012) use similar figures (Figure 13.3).

Public finance generally dominates in emerging Asia, especially in the PRC. Among the ASEAN countries, Goldman Sachs (2013) estimates that the government share in infrastructure is 90% in the Philippines, 80% in Thailand, 65% in Indonesia, and 50% in Malaysia. Efforts are being made to shift this balance. For example, India is planning to move

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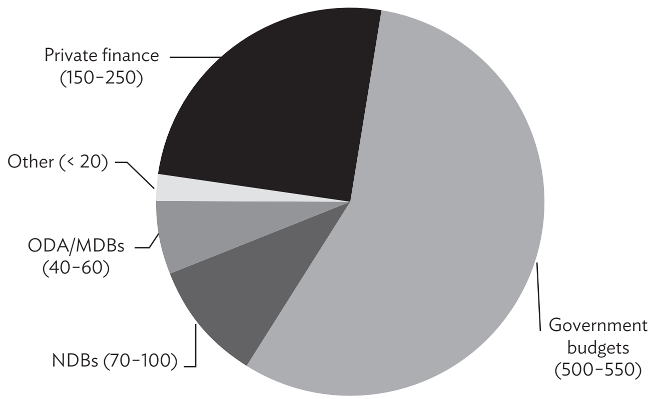
[11] A PPP is an arrangement between the public and private sectors for the purpose of delivering a project or service traditionally provided by the public sector. A private sector consortium typically forms a special purpose vehicle to develop, build, maintain, and operate the asset for the contracted period. The risk sharing depends on the specific contract.

Figure 13.3 Sources of Infrastructure Finance in Emerging Markets and Developing Economies ($ billion)



MDB = multilateral development bank, NDB = national development bank, ODA = official development assistance.
Source: Bhattacharya, Romania, and Stern (2012).

its ratio from about 2:1 to 1:1 between the 11th Five Year Plan (2007–2012) and the 12th Five Year Plan (2012–2017) (Sengupta, Mukherjee, and Gupta 2015).

Official development assistance flows to the Asian infrastructure sector grew to about $12 billion in 2013 (Llanto, Navarro, and Ortiz 2015). National development banks and MDBs have historically played an important role in Asia by providing loans, guarantees, and advice for infrastructure development, and catalyzing private sector finance. The new Asian Infrastructure Investment Bank and the New Development Bank of the BRICS countries (Brazil, the Russian Federation, India, the PRC, and South Africa) are designed to provide further finance.

Loan Financing and Capital Markets

Private capital investment, including infrastructure and project finance, is traditionally highly dependent on bank loans in most countries outside North America. Since the financial crisis, the impacts of bank recapitalization and stricter regulations (e.g., Basel III) have been widely felt, especially by European banks. However, very expansive monetary policies have boosted a recent recovery. In addition, some non-European (e.g., Japanese and other Asian) banks have been more willing to lend over longer tenors. In Asia, bank loans still dominate infrastructure project finance, and public sector banks play a major role, especially in the PRC.

Although Asia has historically high savings rates, it faces a massive maturity mismatch between short-term bank deposits and long-term project financing (Yoshino 2012). Bank lending may be substituted, to a certain extent, in two ways. First, non-bank financial institutions, such as pension funds, insurers, or investment funds, may provide long-term loans directly. However, low credit standards and the low cost of funds by liquid Asian banks tend to push out non-traditional and foreign lenders (Greer 2015).

Second, securitization and capital markets could be used more strongly in infrastructure finance. Several Asian countries made efforts to develop domestic capital markets in the 1980s and 1990s. Countries such as the Republic of Korea, Malaysia, and Thailand were early users of infrastructure bonds, corporate bonds, and listed equities (Kumar et al. 1997; Park 1998; Walsh, Park, and Yu 2011). However, considerable differences exist in the depth and structure of capital markets, such as in the use of state guarantees.

In comparison to other regions, there is scope for further development of Asian bond markets in particular (Ehlers 2014; ADB 2015; Burger, Warnock, and Cacdac Warnock 2015). In addition, some markets are more open than others to foreign investors.[12]

Conceptual and Data Issues

Infrastructure investment worldwide is finally receiving a high degree of public attention. Yet, it remains much under-researched, which is surprising given the importance of infrastructure investment for the economy and society.

A discussion of the demand for and supply of capital for infrastructure encounters several major conceptual issues. This chapter touches on some of these, such as in estimating infrastructure investment needs and financing gaps.

One crucial issue is the *definition* of infrastructure. Very different concepts are being used in the political, business, and financial worlds, including definitions along the following lines:

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12 For example, Ray (2015) produced a table with foreign direct investment restrictions in five Asian countries. The International Organization of Securities Commissions (2012) compares the value of foreign direct investment to stock market capitalization. This ratio is around 30% in economies like the Republic of Korea, Malaysia, and Taipei,China, but only 1% in the PRC.

(i) physical characteristics (e.g., roads, bridges, pipelines, and cables);
(ii) sectors (including economic infrastructure sectors such as transport, energy, water, and waste, and sometimes also social infrastructure, such as education and health);
(iii) public and private infrastructure (new projects versus maintenance);
(iv) economic characteristics (e.g., monopolies, networks, scale, and barriers to entry);
(v) regulatory regimes (e.g., for utilities and airports);
(vi) contractual approaches (e.g., project finance, PPP, and concessions); and
(vii) investment characteristics (e.g., long-term, stable cash flows, inflation protection, low correlation to other asset classes, and relatively low default rates).

In practice, the implicit and explicit definitions of infrastructure vary widely, and many gray and controversial areas exist (see, e.g., Beeferman and Wain [2012]; Inderst [2013]).

There are also major issues related to *data*, which are typically scattered in many places, incomplete, and not necessarily fully representative. Data problems include the following:

(i) Statistical sources have very different scopes and methodologies (e.g., national accounts, financial transactions, fund tables, asset allocation data, and investor surveys).
(ii) The underlying definitions of "infrastructure," "investment," "sectors," "projects," "institutional investor," and "public and private" can be unclear.
(iii) Figures used in the discussions are typically just partial representations. There are sampling issues, with many gaps and overlaps.
(iv) Data are often proprietary and of low transparency. Commercial data can be expensive or inaccessible to researchers.
(v) Data points are often incongruent, and figures out of date.
(vi) Geographic definitions vary, especially for Asia, the Asia and the Pacific region, and emerging Asia.
(vii) There appears to be a "development bias" in data. Smaller and poorer countries tend to be underrepresented in statistics and research.

It is clear that infrastructure statistics must be interpreted very carefully. National and international organizations could contribute significantly to the "public good" by helping to improve the statistical information. Next, it is necessary to consider the main building blocks of data available, keeping in mind the earlier categorizations and caveats.

13.3.2 Investment Vehicles

This report focuses mainly on private finance. From an investor's perspective, this results in a multidimensional investment universe, involving

(i) equity and debt (bonds and loans) investments;
(ii) listed and unlisted investment vehicles;
(iii) direct and indirect investment routes (via investment funds); and
(iv) commercial funds, or funds sponsored by governments or national or international development institutions.[13]

For example, investors can contribute to infrastructure debt finance by providing a loan to a particular project, buying a project bond, or investing in a pooled vehicle. Table 13.3 provides an overview of the main investment instruments. The range of vehicles tends to be larger

Table 13.3 Infrastructure Investment Vehicles

		Direct	Indirect
Equity	Listed	• Shares of transport, energy, water, utility and other infrastructure companies • MLPs, YieldCos	• Listed infrastructure fund • Investment trust • Indices, ETFs, derivatives
	Equity	• Direct investment in private companies or projects • Co-investment • Investor platforms, alliances	• Unlisted infrastructure fund (closed-end or open-end) • PPP fund • Fund-of-fund

continued on next page

13 There are many examples of commercial funds, especially in the Republic of Korea and India. Examples of public or publicly supported funds include the Asian Infrastructure Fund, the ASEAN Infrastructure Fund, InfraCo Asia, the Philippine Investment Alliance for Infrastructure Fund, the Infrastructure Development Finance Company Limited's Indian Infrastructure Fund, and the PRC's Silk Road Fund.

Table 13.3 *continued*

		Direct	Indirect
Debt	Bonds	• Corporate bond • Project bond, PPP bond Government infrastructure bond, *sukuk* • Sub-sovereign, municipal bond	• Infrastructure bond fund • Trust structure • Bond indices
	Loans	• Private infrastructure debt • Project loan, PPP loan • Syndicated loan	• Infrastructure debt fund • Hybrid or mezzanine fund

ETF = exchange-traded fund, MLP = master limited partnership, PPP = public–private partnership.
Source: Author.

in developed markets, although there are many practical examples of the use of different instruments in EMDEs (Inderst and Stewart 2014).

Listed Infrastructure Companies

Corporate finance is a key element of private infrastructure finance. Companies listed on public exchanges are sizeable owners of infrastructure assets, and their capital expenditure is a substantial contributor to infrastructure investment in many countries. This includes companies that act as developers and operators of projects and infrastructure service providers, as well as more diversified conglomerates.

Infrastructure has become an important element of stock markets due to the privatization of electricity, gas, water, telecommunications, and other utility companies. Some countries have also privatized transport assets, such as airports, ports, toll roads, bridges, and tunnels. Asian privatizations accounted for 22% of the global volume during 2013–2014 (Fondazione Eni Enrico Mattei 2014).[14] RREEF (2011) found an "infrastructure equity universe" of 535 companies with a market capitalization of $3.25 trillion worldwide. This was roughly 6% of the

14 Revenues from asset privatizations during 1988–2014 are estimated at roughly $3 trillion worldwide. Of the $357 billion raised by governments in 2013–2014, nearly $80 billion was in Asia: $41 billion in the PRC, $11 billion in India, $8 billion in Japan, $5 billion in Singapore, $4 billion in Malaysia, $3 billion in the Republic of Korea, $2 billion in Indonesia, and $1 billion in the Philippines (Fondazione Eni Enrico Mattei 2014).

estimated global stock market capitalization, a percentage similar to that estimated by Standard and Poor's (S&P) (2007).

With the emergence of the infrastructure investment theme in the mid-2000s, all of the major index providers began offering specialist infrastructure equity indices. Major differences exist between indices in terms of the countries and sectors covered, the number and size of stocks included, and the particular index methodology.[15] Regional and country weightings vary widely, with Asia, including Japan, normally ranging between 10% and 20%.[16] Some examples of indices indicate the relevance and structure of these markets.

Global emerging market infrastructure indices are usually dominated by Asian companies, ahead of Latin America. For example, Asia has a combined weighting of about 71% in the Dow Jones Brookfield Emerging Markets Index (of which the PRC accounts for 27%; Hong Kong, China 14%; and India 10%), and about 62% in the S&P Emerging Markets Infrastructure Index (of which the PRC accounts for 40%; Malaysia 8%; and the Republic of Korea 7%).

Dedicated regional Asian infrastructure indices also show a high degree of variation. The MSCI All Country Asia ex Japan Infrastructure Index has 64 constituents with a total market capitalization of $365 billion. The economy weightings are shown in Figure 13.4. In terms of sectors, telecommunications companies make up a sizeable percentage (61%); China Mobile alone has a weighting of 23%. Electrical utilities make up 17% of the index and gas utilities make up 10%. The S&P Asia Infrastructure Index comprises 30 of the largest listed infrastructure companies in the region, with a combined market capitalization of about $250 billion. While this includes Japan, it does not include

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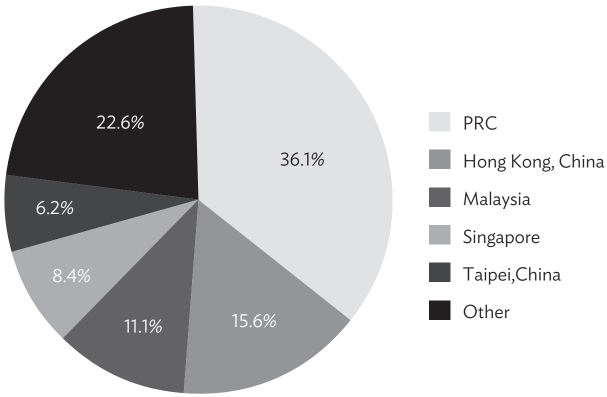
15 One of the main issues concerns the sectors and subsectors included or excluded in these indices, especially telecommunications, industrials, oil and gas, construction, services, or diversified companies. Some extreme examples of indices contain over 80% utility stocks.

16 For example, the Financial Times Stock Exchange Global Infrastructure Index has 839 constituents with a market cap of $2.1 trillion. Of the companies, 291 are based in Asia—111 are in Japan, 59 in the PRC, and 34 in Taipei,China. Asia has a market cap weighting of about 17% (of which Japan accounts for 11%, the PRC 2%, and Hong Kong, China 2%). The more widely defined "Infrastructure Opportunities" Index has a market cap of $4.2 trillion. Asia has a weighting of about 20%. The S&P Global Infrastructure Index tracks 75 companies with a market cap of about $1.2 trillion. Asia has a weighting of about 12% (of which the PRC accounts for about 5%, Japan 4%, Singapore 3%, and Hong Kong, China 0.4%) (figures as of March 2015).

Figure 13.4 Example of an Asian Infrastructure Index (economy weightings, %)



Source: MSCI (2015).

telecommunications stocks.[17] The Dow Jones Brookfield Asia/Pacific Infrastructure Index has 23 constituents (of which about 35% are from Australasia), with a combined market capitalization of about $100 billion. Oil and gas stocks account for over half of this index.[18]

Finally, there are several individual country infrastructure indices. The MSCI Japan Infrastructure Index has 18 stocks with a market cap of about $220 billion. Examples for India are the S&P Bombay Stock Exchange India Infrastructure Index (with 30 stocks and a market cap of about $140 billion), and the Financial Times Stock Exchange-Infrastructure Development Finance Company Limited India Infrastructure Index (with 69 stocks and a market cap of $60 billion). The Indxx China Infrastructure Index with 30 constituents (listed in Hong Kong, China; the US; and the EU) has a market cap of $470 billion;

17 In terms of sectors, this consists of industrials (47%), utilities (43%), and energy stocks (11%). In terms of economies, this covers Japan (29%); the PRC (23%); Hong Kong, China (17%); Singapore (9%); Malaysia (8%); Thailand (5%); the Republic of Korea (4%); Indonesia (3%); and the Philippines (3%).

18 In terms of sectors, oil and gas storage and transportation account for 52%, toll roads 17%, airports 12%, ports 10%, electricity transmission and distribution 4%, water 3%, and diversified companies 3%. In terms of economies, Australia accounts for 32%; the PRC 23%; Japan 20%; Hong Kong, China 19%; Singapore 4%; and New Zealand 3%.

and the new Shanghai Stock Exchange Infrastructure Index with 26 constituents has a market cap about $200 billion, of which $75 billion is tradable.

Overall, listed infrastructure and utility companies represent about 5%–6% of the equity market universe, or around 4% of GDP, globally. Asia has a weighting of 10%–20% in global infrastructure indices. Regional Asian indices in the market vary widely, covering infrastructure companies with a market capitalization of up to $500 billion. This is about 2.0%–2.5% of GDP in Asia, more than half the global percentage.

It is worth noting that the listed company universe is not fully "private" because of stakes held by public sector entities. Going forward, it would be important to analyze the shareholder structure and investment behavior of listed companies, as well as the contribution of small and medium-sized enterprises.

Private or unlisted infrastructure investments have received much attention, especially from infrastructure equity funds but also increasingly from debt funds. Some investors have also started to take direct stakes in infrastructure projects, or provide private loans.

Infrastructure Funds

Dedicated infrastructure funds were first created in Australia in the 1990s, and were typically listed funds. Since the financial crisis, institutional investors have mostly moved to open-ended fund structures there. In Europe, the US, and elsewhere, the number of private equity-type, closed-end infrastructure funds have been growing since the mid-2000s.

Next, we consider some figures for the capital raised by such funds, the volume of deals that they generate, and the infrastructure managers and investors based in Asia. Consultant firm Towers Watson (2014) found assets of $305 billion in direct infrastructure funds, of which 22% ($67 billion) was invested in Asia.[19] According to the data provider Preqin, about 400 infrastructure funds were launched worldwide during 2004–2014, with an aggregate volume of around $300 billion. Annual figures have been rather volatile, with highs of $45 billion in 2007 and lows of $11 billion in 2009.

The majority of infrastructure funds are equity-oriented. Only 39 debt funds were closed in 1998–2013 with a total volume of about $30 billion, i.e., about 10% of total fundraising. However, interest in

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[19] This is a survey of 589 "alternative" fund managers (i.e., outside conventional equity and bond assets) with $5.7 trillion in assets under management. The weighting of infrastructure in this universe is about 5%, well behind real estate, private equity, and hedge funds.

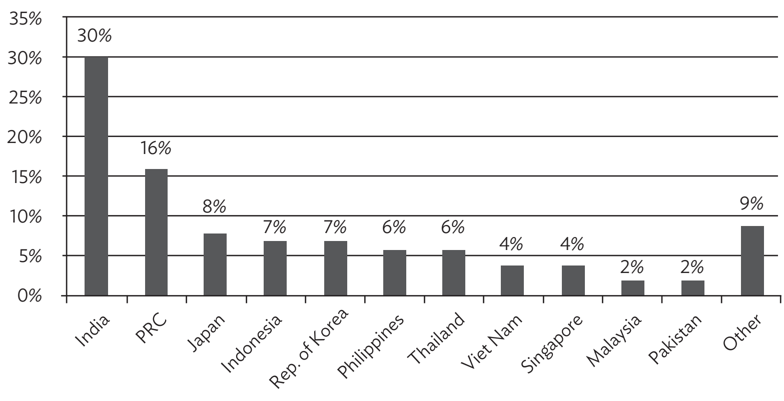
infrastructure debt is increasing: 31 debt and/or mezzanine funds are currently "on the road", seeking to raise a further $23 billion from investors. These are focused mainly on European debt markets (Preqin 2015a).

Preqin (2014) recorded 73 Asia-focused private infrastructure funds with aggregate capital raised of $27 billion. Another 16 funds are currently "on the road", seeking to raise another $10 billion. There are around 80 Asia-focused asset managers, mainly based in India (21%) or Singapore (18%), followed by Hong Kong, China; the US; and the PRC (9% each).

Worldwide, around 700 transactions per year are undertaken by infrastructure funds, with a deal volume of about $300 billion, i.e., 0.4% of world GDP. Preqin (2015b) registered around 100 deals per year in Asia since 2008, with an estimated annual deal value of around $20 billion–$30 billion, i.e., less than 10% of the global deal volume, or about 0.1%–0.2% of Asia's GDP. India and the PRC posted the highest numbers of deals in the Preqin database (Figure 13.5).

In terms of sectors, 44% of all Asian deals completed were in energy, 22% in utilities, 16% in transportation, and 3% in telecommunications. Social infrastructure accounted for 13% of deals (education 5%, healthcare 5%, and government buildings 3%). Of all Asia-based deals on record, 39% were greenfield developments, 10% were at the brownfield stage, and 51% in the secondary market.

Figure 13.5 Infrastructure Deals in Asia, by Country, 2010–2015



PRC = People's Republic of China, Rep. = Republic.
Source: Preqin (2015b).

Looking forward, infrastructure investors appear to remain primarily focused on the traditional markets in Europe and North America. Globally, around 150 new funds are seeking a further $95 billion of capital; only 22 of them, seeking $11 billion, focus specifically on Asia, although global funds will also express interest in the region.

Direct Investment

In recent years, some investors have decided to "in-source" asset management. In this process, direct equity stakes in infrastructure projects and companies have become popular with institutional investors, such as large pension funds, especially in Canada, Australia, and Northern Europe. In addition, several (Asian and other) SWFs have raised their interest in infrastructure assets, as have other financial and industrial companies.

Insurance companies, especially in Europe, are increasingly involved in infrastructure debt with direct loans, either by taking over loans from banks or by providing longer-term direct credit to, for example, renewable energy projects. However, this requires adequate resources for credit analysis and risk management, which many asset owners do not traditionally have. Several larger investors have begun to build such specialist internal expertise.

In conclusion, private infrastructure investments, either directly or via funds, have been growing globally since the early 2000s. Fewer infrastructure funds are based in Asia, or target Asia, relative to Europe and North America. Infrastructure funds are reportedly generating around 100 deals per year in Asia, with a volume of $20 billion–$30 billion. This equates to 0.1%–0.2% of GDP, lower than the global average of about 0.4%.

13.3.3 Project Finance

Project finance has traditionally been used for both private and public infrastructure. Project finance statistics are often used for representations of private finance developments in infrastructure. However, it should be noted that project finance reaches beyond infrastructure sectors (e.g., oil, mining, and industrial sectors), whereas infrastructure investment reaches much further than project finance (especially corporate finance).

According to the data provider Dealogic (2015), the overall global project finance volume (equity and debt) was $408 billion in 2014 from around 1,100 deals, down from the record level of $437 billion in 2013. Annual volumes have moved around $400 billion since 2011, i.e., about

Table 13.4 Project Finance Volume by Region ($ billion)

Region	2009	2010	2011	2012	2013	2014
North America	31	43	47	51	72	89
Latin America	34	19	30	42	48	57
Western Europe	54	75	74	55	77	68
Eastern Europe	11	20	28	8	9	12
Middle East/Africa	40	49	49	35	88	52
Australasia	17	19	37	83	38	43
Asia (excluding India)	50	48	52	63	46	43
Indian subcontinent	54	81	88	45	41	46
Total	291	355	406	382	418	408

Source: Dealogic (2015).

0.5% of GDP. Regional and country shares varied considerably over the years. Project finance is generally highly leveraged. In 2014, 12% was financed by equity, 9% by bonds, and 79% by loans.

The deal volume of Asia (excluding the Indian subcontinent) was $43 billion in 2014. It has ranged from $40 billion to $60 billion per year in recent years, i.e., about 0.2%– 0.3% of GDP, and a global market share of 10%–15% (Table 13.4). The Indian subcontinent's deal volume was $46 billion in 2014. It fluctuated widely between a few billion in 2007 and over $80 billion in 2010 and 2011 (0%–5% of GDP). The global market share of the two Asian regions dropped from around 35% in 2009 to 22% in 2011. In terms of countries, India has been the second-largest project finance market in the world (behind the US).[20]

Project Finance Loans

Project finance debt markets were impacted by the financial crisis but have since recovered. As an alternative data source, Thomson Reuters (2015) concentrates on project finance loans. The global loan volume in 2014 reached a record $258 billion, up 26% from 2013. In Asia, 150 transactions

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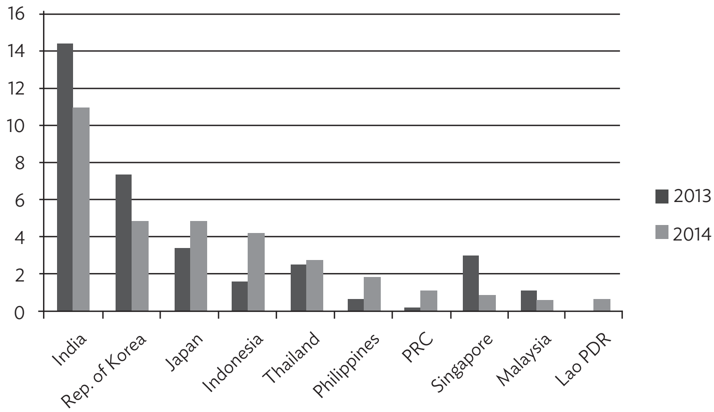
20 The ranking of the other Asian countries in the top-15 league tables changes every year. In 2014, Indonesia was ranked 11th with a volume of $8.2 billion and the Republic of Korea, was 14th ($7.7 billion). In 2013, Viet Nam ($11.0 billion) was ranked 11th. In 2012, Malaysia ranked 8th, the PRC 9th, the Republic of Korea, 11th, and Indonesia 14th. In 2011, the PRC was ranked 11th, and Singapore 14th.

Figure 13.6 Project Finance Loan Volume in the Asia and the Pacific Region ($ billion)



PRC = People's Republic of China, Lao PDR = Lao People's Democratic Republic, Rep. = Republic.
Source: Thomson Reuters (2015).

were recorded with a loan volume of $33 billion in 2014, down from $41 billion in 2013. This was a global market share of 13% (down from 20% in 2013), which was pretty evenly split between North, South, and Southeast Asia. According to this database, India has been one of the largest markets with a volume of $11 billion in 2014 (about 0.5% of GDP), and a peak volume of $55 billion in 2010 (3% of GDP) (Figure 13.6).

In terms of infrastructure sector, in the Asia and the Pacific region (including Australasia), 32.0% of the loan volume went to transportation and 26.0% to power, but only 1.0% to telecommunications and 0.4% to water, sewerage, waste, and recycling. As for the other sectors, 19.0% was recorded for oil and gas, and 12.0% for mining in 2014.

Infrastructure and Project Bonds

The term "infrastructure bond" is used to denote different things. First, it is worth noting that some sovereign bonds have been earmarked for infrastructure, such as in Kenya (Inderst and Stewart 2014). Sub-sovereign bonds may also be dedicated to infrastructure investments.[21]

[21] Platz (2009) finds a relatively low volume of sub-sovereign bonds in Asia of about $3 billion (from 43 issues) in 2000–2007, down from $8 billion (from 13 issues) in the 1990s. Yoshino (2012) proposes government-issued "infrastructure revenue bonds" (in local currency) for Asia.

Municipal bonds are major infrastructure financing sources, especially in the US.

Second, utility and infrastructure companies often also issue corporate bonds. Such bonds may be part of corporate bond indices, although no major dedicated infrastructure bond index is known (except in Canada).

Third, project bonds in the narrow sense constituted about 10% of long-term global project debt from 1994 to 2012.[22] Project bond financing experienced a setback with the financial crisis, exacerbated by the demise of monoline insurers. However, markets have since revived. The volume was $36 billion in 2013, representing 9% of project finance. Volumes and shares have fluctuated considerably over the years (between 4% and 13%), but overall volumes have been small (less than 0.1% of global GDP) (Dealogic 2015).

Project bonds are historically more common in North America than in Europe. Canada, for example, has well-established project bond markets and a long experience as insurance companies as long-term investors therein. The EU project bond market has revived somewhat over the last 3–4 years. Although emerging markets and Asia have a history of debt securities for infrastructure, levels have been low. For example, the issuance volumes of Asian project bonds recorded in the Thomson Reuters and Project Finance International databases ranged between $1 billion and $3 billion since 2010 (Kitano 2015).

Using a wider definition, Dailami and Hauswald (2003) analyzed 105 "infrastructure bonds" (mostly corporate bonds for financing infrastructure projects) in 20 emerging markets issued between 1993 and 2002 and denominated in US dollars. This set includes 43 Asian issues with a total volume of $14 billion (13 issues are from Malaysia; 11 from the PRC; 10 from the Philippines; 3 from Thailand; 2 from Hong Kong, China and India; and 1 from the Republic of Korea and Indonesia).

Ehlers, Packer, and Remolona (2014) found 1,625 infrastructure-related debt securities worldwide, with an annual average issuance of around $50 billion in recent years.[23] During 2009–2013, 551 infrastructure bonds were issued in emerging Asia with a value of $168 billion. The PRC's market dominated with 340 issues at a value of $142 billion,

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[22] Project bonds are debt instruments issued by project finance companies. They are often tradable on secondary markets but can also be private placements. The backing for the bond is the cash flow generated by the project, whereas with corporate bonds it is the company's ability to pay.

[23] Their definition is relatively wide in terms of sectors. It includes infrastructure-related corporate and project bonds, but also includes project bonds by national and multilateral development banks.

followed by Malaysia with 76 ($5 billion), and Taipei,China with 64 ($11 billion).[24] Without the PRC, the volume is still very low in emerging markets. In emerging Asia (excluding the PRC), the annual value is only $5 billion on average, or less than 0.1% of GDP, but including the PRC, it is about 0.4% of GDP.

The author notes the lack of depth and liquidity in Asian infrastructure bond markets, especially for longer maturities, compared to North America (and partly also to Latin America: 98% of Asian issuance is in local currency, issuance tends to be cyclical, and the average maturity (9 years) is relatively short. In comparison, the volume of syndicated loan finance in infrastructure in emerging Asia (excluding the PRC) over 2009–2013 was about $210 billion. This implies a ratio of bonds to syndicated loans of 1:8. Asian infrastructure financing is rather loan-centric, as it is in Europe.[25]

The market for Islamic bonds (*sukuk*) saw strong growth in recent years, reaching an annual volume of over $100 billion (Rasameel 2014).[26] The majority of sukuk (62%) are issued by sovereign issuers, with Malaysia being by far the largest issuer. Development banks such as the Islamic Development Bank also issue sukuk. A smaller percentage is issued by corporates, including in those infrastructure sectors (power and utilities constitute 9.4% of issuance, transport 7.2%, and telecommunications 3.1%), and there is an emerging market for "infrastructure sukuk."

In conclusion, the global project finance market has recovered from the financial crisis. In Asia (excluding India), annual project finance volumes represent about 0.2%–0.3% of GDP, roughly half the global average. India has been one of the largest (but fluctuating) markets in the world in recent years. Bank loans still dominate Asian infrastructure project finance whereas project bond markets are still very small (less than 0.1% of GDP outside the PRC).

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24 The PRC appeared to be a special case in that report, with a high issuance (since 2009) entirely due to state-owned enterprises with a perceived government guarantee. Traditionally, state-owned commercial banks have held around 80% of infrastructure loan portfolios (Walsh, Park, and Yu 2011).

25 A financing source of growing importance in emerging markets has been export credit agencies, not the least to insure against currency and political risks. Export credit agencies were involved in syndicated loans, especially for larger infrastructure projects, with a value of about $40 billion in the PRC and $10 billion in emerging Asia (excluding the PRC) during 2009–2013 (Ehlers 2014).

26 Sukuk are Islamic securities. They can be defined as certificates of ownership that grant the investor a share of an asset, along with the commensurate cash flows and risk.

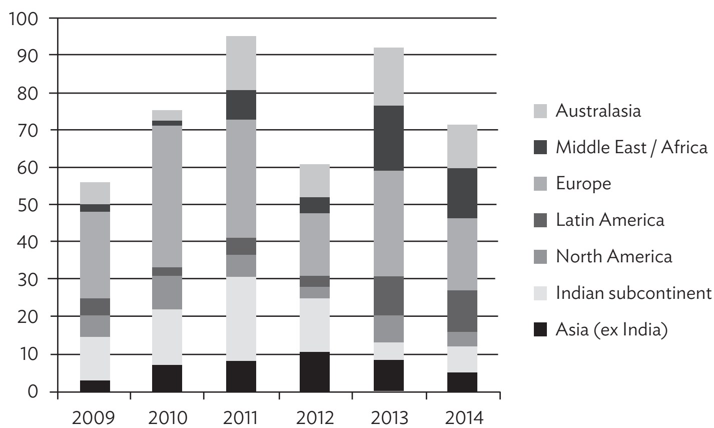
13.3.4 Public–Private Partnerships

PPPs have become increasingly relevant for public infrastructure investment as an alternative to spending by governments or (privatized) infrastructure companies. The UK and Australia are often seen as the most mature adopters, with PPPs accounting for around 10% (UK) and 5% (Australia) of public investment in infrastructure (OECD 2014a). Various models and forms of PPPs have since been implemented in many countries (see, e.g., Nataraj [2007], Zen and Regan [2014], Gatti [2014], Engel, Fischer, and Galetovic [2014], Kitano [2015]).

According to global database Dealogic (2015), global PPP volumes have totaled $60 billion–$100 billion (around 0.1% of GDP) since 2009. In 2014, the total volume was $72 billion, down from $95 billion in 2013 and about 0.1% of global GDP. The share of PPP within project finance was 18% in 2014; traditionally, this share has been 16%–25%. Transport and social infrastructure accounted for 69% of the volume.

Asia (excluding India) only posted PPP deals of less than $10 billion per year, i.e., well below the global average. Relatively high but strongly fluctuating figures are reported for the Indian subcontinent. PPP deals fell from a peak of over $15 billion in 2010–2011 to about $5 billion in 2013–2014 (roughly 0.2% of GDP) (Figure 13.7).

Figure 13.7 Public–Private Partnerships Volume by Region ($ billion)



ex = excluding.

Source: Dealogic (2015).

Private Participation in Emerging Markets

Governments in developing economies have been increasingly interested in attracting private capital for infrastructure investments. The Public–Private Infrastructure Advisory Facility (PPIAF) records "private participation in infrastructure" (PPI) in low- and middle-income countries.[27] This includes PPP projects, privatizations, and other forms of private participation.

Since 2007, 250–400 PPI projects per year were recorded, with combined budgets of $150 billion–$200 billion (PPIAF 2014), i.e., about 0.6%–0.8% of GDP.[28] In 2013, the volume was $150 billion from 291 projects, a decline from previous years, especially in Brazil and India. Figure 13.8 shows a breakdown of PPIs by region. Latin America traditionally has the largest share.

The East Asia and the Pacific region's volumes have been $15 billion–$22 billion since the mid-2000s, i.e., 0.1%–0.2% of GDP. Volume growth in the PRC slowed considerably in 2014, as difficulties with local government financing vehicles affected new project funding (PPIAF 2015; Reuters 2015). Private investment in South Asia grew strongly in the 2000s, peaking at $77 billion in 2010, but has since fallen back, with a 2013 volume of $15 billion (about 0.6% of GDP). The Indian model is showing signs of strain.[29]

Over a longer period, 1990–2014, deal volumes were by far highest in Brazil ($468 billion) and India ($330 billion). The PRC came fifth with $131 billion, Indonesia eighth with $65 billion, the Philippines ninth with $61 billion, and Malaysia tenth with $60 billion.

For the East Asia and the Pacific region, 1,819 projects are recorded in the PPIAF database, with a total volume of $389 billion—40% of the volume was in energy, 28% in telecommunications, 23% in transport,

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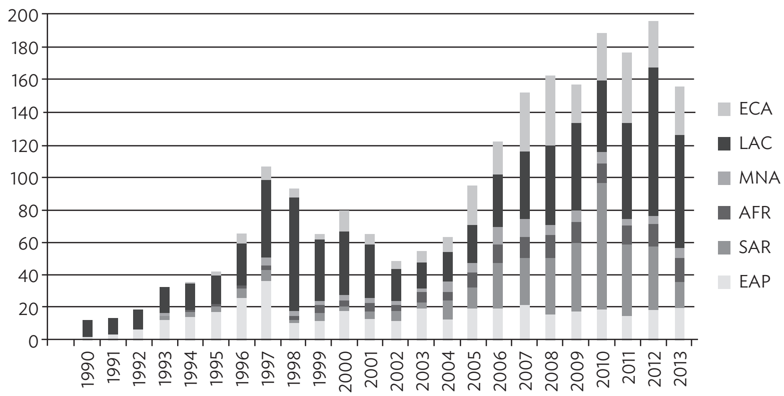
27 Projects are considered to involve private participation if a private company or investor is at least partially responsible for the operating costs and associated risks. Tracked projects have at least 25% private equity or, in the case of divestitures, at least 5% private equity. The database classifies private infrastructure projects into four categories: management and lease contracts, concessions, greenfield projects, and divestitures (privatizations).

28 The PPI database focuses on four sectors: energy (excluding oil and gas extraction, but including natural gas transmission and distribution), transportation, water and sewerage projects, and telecommunications services. The PPIAF (2015) shows smaller figures because a new definition of "infrastructure" excludes telecommunications.

29 Private developers "have largely been dependent for project financing loans on state-owned banks. Because of high leverage structures and a combination of market forces and policy uncertainties, the sector has become highly indebted and several projects have been under stress to meet their debt servicing obligations. With worsening credit quality and peaked exposure limits, most banks are showing reluctance to participate in further credit expansion in the sector" (Ray 2015: 7).

Figure 13.8 Private Investment in Infrastructure in Emerging Markets and Developing Economies ($ billion)



AFR = Africa, EAP = East Asia and the Pacific, ECA = Europe and Central Asia, LAC = Latin America and Caribbean, MNA = Middle East and Northern Africa, SAR = South Asia.
Sources: PPIAF (PPI project database, March 2015); author.

and 8% in water and sewerage. Two-thirds were greenfield projects, 13% concessions, and 20% divestitures. For South Asia, there were 1,090 projects with a total volume of $383 billion (of which there were around 85% in India, 9% in Pakistan, 3% in Bangladesh, and 2% in Sri Lanka). The sector breakdown is 42% energy, 33% telecommunications, 25% transport, and very little in water and sewerage; 76% were greenfield projects, 19% concessions, and 5% divestitures.[30]

In summary, private participation in infrastructure has been growing over the years in emerging markets. In the East Asia and the Pacific region, PPI only amounts to 0.1%–0.2% of GDP, well below the global average. South Asia showed strong cyclical movement, with a peak in 2010. Although PPPs have become an alternative financing mechanism in some places, many countries still make very little or no use of PPPs. With the exception of India, PPP volumes remain small in Asia in both absolute and comparative terms.

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30 Andrés, Biller, and Herrera Dappe (2014) note a clear division across sectors in South Asia: privatization is the favored route in telecommunications and energy, and PPPs in transport, water, waste, and sewerage, and partly also in electricity transmission.

13.4 Institutional Investors as Financiers

Institutional investment in infrastructure has become a much-discussed topic in recent years, also in terms of public policy. Governments frequently call for a higher engagement of asset owners in the financing of infrastructure projects.[31]

Many investors have become interested in infrastructure as an "asset class" for their own reasons (Inderst 2010). In an environment of low interest rates in major markets, they are looking for alternative sources of income and better diversification.

Infrastructure investments potentially offer some useful characteristics for pension funds and insurance companies that have to match (often inflation-linked) annuity-type liabilities. Such assets are often expected to have long-term, predictable income streams, low sensitivity to business cycles, and low correlations to other asset classes. Project finance debt has exhibited relatively favorable default and recovery rates compared to corporate debt (Moody's 2015). Finally, asset owners are also re-discovering "long-term investing," trying to capture an "illiquidity risk premium" from infrastructure assets.

Institutional assets grew strongly in recent years. The OECD valued institutional assets in 2013 at $92 trillion, of which $25 trillion was in pension funds; $26 trillion with insurance companies; $5 trillion in public pension reserve funds; and $2 trillion in foundations, endowments, and other institutions (Figure 13.9). Not shown in Figure 13.9 is the $7 trillion in SWFs (SWFI 2015).[32]

13.4.1 Asian Pension, Social Security, and Insurance Assets

In emerging markets, institutional assets are comparatively smaller, but growing fast. McKinsey (2011) estimated the assets under management of pension funds in developing countries at $2.3 trillion in 2010, which

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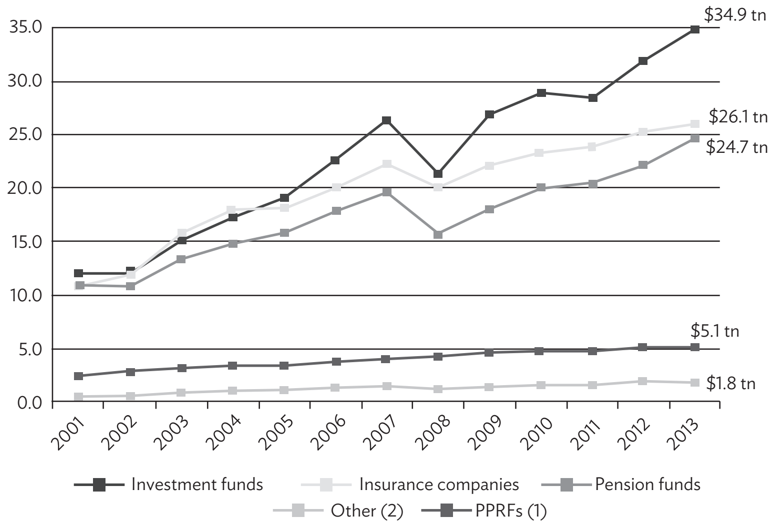
31 It is noteworthy that there was a "first wave" of institutional investor involvement in emerging markets infrastructure, including a number of Latin American and Asian social security and public pension funds in the 1990s (see, e.g., Ferreira and Khatami [1996]).

32 These figures do not include assets held by banks, nonfinancial corporations, central banks, or other government institutions. It is worth noting that there is also substantial wealth owned privately by households. Boston Consulting Group (2014) reports $152 trillion of private financial wealth globally, of which $15 trillion was in Japan and $37 trillion in Asia (excluding Japan) in 2013. Asian wealth in particular is expected to grow rapidly. Some of the non-institutional capital may also be available for infrastructure investment over time, although this requires the establishment of appropriate investment management capabilities and instruments.

Figure 13.9 Institutional Investor Assets ($ trillion)



PPRF = public pension reserve fund, tn = trillion.
Source: OECD (2014b).

is about 8% of global assets. The $2.3 trillion in the insurance sector is about 10% in the global context. In contrast, SWFs are mostly based outside the OECD.

Asian pension and insurance assets were estimated at roughly $10 trillion in 2010, i.e., a global share of about 18%. Asian pension funds held $4.4 trillion of assets, of which the vast majority of $3.3 trillion were in Japan, and $0.5 trillion in the PRC. Similarly, Asian insurance companies held $5.1 trillion, of which $3.5 trillion was in Japan and $0.6 trillion in the PRC. In terms of insurance assets, there is a big gap between advanced Asia (where insurance assets are 50%–70% of GDP) and developing Asia (less than 20% of GDP).

The OECD (2014b) recorded $1.8 trillion of (autonomous) pension plan assets in Asia, i.e., about 7% of the global volume.[33] The highest volumes were for Japan with $1,331 billion; Hong Kong, China with

33 Estimates of pension assets differ across data providers, depending on the definition of (private and public) pension funds, the inclusion of social security funds, investment funds, unfunded schemes (e.g., book reserves), and other factors.

$103 billion; the PRC with $99 billion; the Republic of Korea with $82 billion; and Thailand with $23 billion. As a percentage of GDP, this equates to 29% for Japan; 38% for Hong Kong, China; 1% for the PRC; 7% for the Republic of Korea; and 6% for Thailand. Even the largest Asian-funded pensions systems are well below the OECD average of 84% of GDP, with developing Asia at less than 5%.

There are several sizeable social security and public pension reserve plans in Asia, adding up to about $2.5 billion. Among the largest funds are Japan's Government Pension Investment Fund (about $1.2 trillion), the Republic of Korea's National Pension Service ($400 billion), the PRC's National Social Security Fund ($200 billion), Singapore's Central Provident Fund ($190 billion), Malaysia's Employees Provident Fund ($180 billion), and India's Employee Provident Fund ($116 billion) (OECD 2014c).

In terms of size relative to GDP, these funds account for about 60% of GDP in Singapore, 50% in Malaysia, 27% in Japan, 22% in the Republic of Korea, 16% in Sri Lanka, and less than 10% of GDP in a range of other countries (Musalem and Souto 2012). Most of these schemes traditionally run conservative investment policies with a high allocation to domestic government bonds and deposits (Blanc-Brude, Cocquemas, and Georgieva 2013).

The Asian pension systems look relatively weak also in qualitative assessments. For example, the Melbourne Mercer Global Pension Index (Mercer 2014) ranks Singapore above average (band B), but the PRC, India, Indonesia, Japan, and the Republic of Korea are all in band D.[34]

Finally, the fund management industry in Asia (including mutual funds, unit trusts, exchange traded funds, and private equity funds) is also comparatively small and concentrated in more developed economies. ADB (2015) estimates assets under management of about $4 trillion for the ASEAN+3 countries (i.e., ASEAN plus the PRC, Japan, and the Republic of Korea).

Overall, there are some distinctive features of the institutional investor base in Asia. Private pensions and insurance assets are comparatively small and rather concentrated. However, there are several very large public pension reserve and social security funds in the region. Asia also has a good share of SWF assets, plus massive capital with other, mostly public, institutions, including central banks.

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[34] Ratings rank from A (best) to E (worst). The rating D indicates "a system that has some desirable features, but also has major weaknesses and/or omissions that need to be addressed" (Mercer 2014: 7).

13.4.2 Investors in Infrastructure

Most asset owners have traditionally been investors in infrastructure securities, for example, as shareholders of infrastructure companies listed on public stock exchanges, in initial public offerings of privatized utility companies, or as buyers of corporate bonds or municipal bonds. This is true not only for OECD countries, but also for a range of Asian and other emerging markets that have developed their capital markets in recent decades.

The situation is different for unlisted infrastructure investments. To start with pension funds in the leading countries, the average asset allocation for unlisted (or private) infrastructure is about 5%–6% of assets in Australia and Canada (Inderst and Della Croce 2013). Worldwide, an OECD (2014c) survey of large pension funds revealed $70 billion of unlisted infrastructure equity investments and $10 billion of infrastructure debt. However, infrastructure investments were only about 1% of the asset allocation of the whole investor group in the survey.[35]

Insurance companies have traditionally had hardly any investments in unlisted infrastructure assets. However, several insurers and their asset management subsidiaries worldwide have become active in recent times, especially in infrastructure debt.

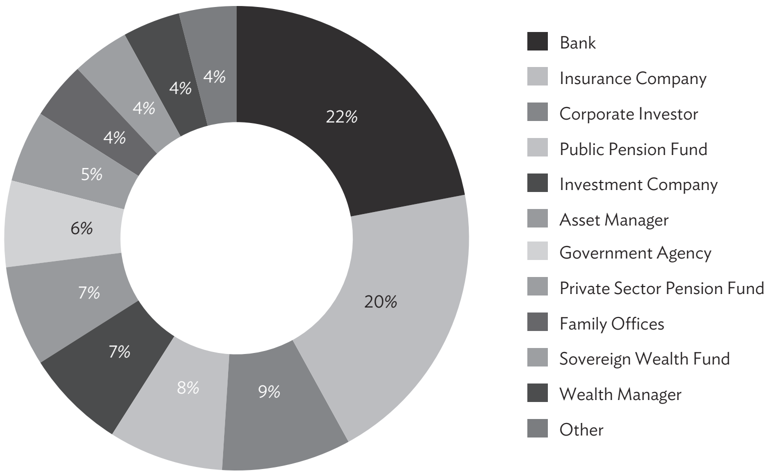
Turning to the Asia and the Pacific region, Preqin (2015b) tracked 295 infrastructure investors based in the region investing in infrastructure, i.e., 13% of their worldwide investor universe. The investor base is spread widely across investor types, with insurance companies and banks being the largest groups, with pension funds, foundations, and endowments less prominent compared to other regions (Figure 13.10).

The asset allocation to infrastructure of the largest 100 Asian investors is about $65 billion, i.e., only 0.3% of total assets of about $20 trillion. Of the top 100, 88 invest in private investment vehicles and 62 invest directly. Thirty of the top 100 investors are from Japan, 20 from the Republic of Korea, 13 from Australia, 11 from the PRC, and 10 from India. There is a notable rise of large Asian institutions on a global scale—there are now 15 of them among the top 100 global infrastructure investors, up from 5 in 2012.

Some Asian insurance companies are reported to have substantial (listed and unlisted) investments in infrastructure, especially in Japan; India; the Republic of Korea; and Taipei,China. Japanese pension

35 Unfortunately, none of the five Asian Pension Reserve Funds surveyed reported on infrastructure investments.

Figure 13.10 Asia-Based Infrastructure Investors, 2015



Source: Preqin (2015b).

funds also constitute an important element of the Asian investor base. The world's largest pension scheme, Japan's Government Pension Investment Fund, revamped its investment strategy in 2014 with the intention to invest in alternative assets, including infrastructure.

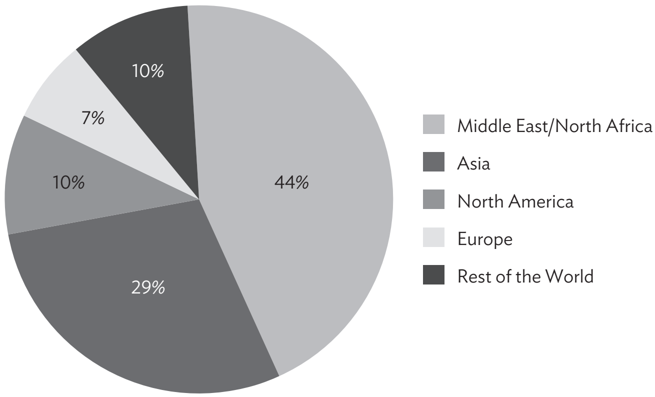
In summary, institutional investors, especially larger ones, have been increasing their unlisted infrastructure investments in recent years. Many smaller investors, but also some larger Asian reserve funds, have little or no exposure in this field. On average, the overall asset allocation to infrastructure is still small (globally about 1%–2% of assets, and it appears even lower in Asia).

13.4.3 Sovereign Wealth Funds

The assets of SWFs have grown to over $7 trillion, with 40% of them based in Asia and 37% in the Middle East (SWFI 2015). SWFs have very diverse sources of funds (e.g., commodities), investment objectives (e.g., stabilization and pensions), and investment policies (ranging from risk-return criteria to economic and political influence) (Gelb et al. 2014).

Some SWFs have substantial infrastructure allocations whereas others have none. In the Preqin database, 60% of global SWFs invested

Figure 13.11 Sovereign Wealth Funds Investing in Infrastructure, by Region



Source: Preqin (2013)

in infrastructure in 2014, of which 44% are based in the Middle East and/or North Africa and 29% in Asia (Figure 13.11).[36] Of the SWFs, 34% only invest directly in infrastructure, and 50% invest both directly and via funds.

Direct investments by SWFs are estimated to be roughly 10% of assets. About $500 billion was invested directly between 2005 and 2012, of which about $55 billion went into transport infrastructure, $60 billion into energy, and about $20 billion into the telecommunications sector (TheCityUK 2013). Put together, this would imply a (still moderate) asset allocation percentage in infrastructure of roughly 2%.

Direct investments increased in 2013 and 2014, with volumes of $186 billion and $117 billion. The US and the UK were the largest recipients, each accounting for around 16%. Other popular destinations

[36] Large Asian SWFs investing in infrastructure include the China Investment Corporation, the PRC's State Administration of Foreign Exchange, the Government of Singapore Investment Corporation (GIC) and Temasek, the Hong Kong Monetary Authority, the Korean Investment Corporation, the Samruk-Kazyna in Kazakhstan, Malaysia's Khazanah Nasional, the Brunei Investment Agency, the Azerbaijan State Oil Fund, and the Timor-Leste Petroleum Fund. In addition, there are smaller (but often growing) SWFs in places like Viet Nam, Indonesia, Mongolia, and Turkmenistan.

included other EU countries and the PRC. The majority of SWF direct investments seem to go into financial services and real estate. There is a preference for existing assets rather than greenfield projects, thereby contributing to rising valuations (TheCityUK 2015).

Nonetheless, some SWFs have been seeking opportunities in EMDEs, such as PRC funds with “infrastructure for resources” deals brokered in Africa. According to a survey by fund manager Invesco (2015), 17% of SWF infrastructure investments are in emerging markets. Assuming a 2% average asset allocation to infrastructure, this would imply a volume of about $240 billion. This raises the interesting question as to whether SWFs could crowd out opportunities for other local and regional investors in these markets.

In conclusion, Asia has a large share of SWFs that are growing their assets and becoming increasingly involved in infrastructure. With an estimated average asset allocation of 2%, a number of them already have direct holdings in infrastructure assets, although mostly in established markets. Unfortunately, transparency on SWF investments is generally still low.

13.5 Barriers and Risks

The question is whether institutional investors could contribute more to the financing of infrastructure. Two points of qualification: First, it is often overlooked in this debate that pension funds, insurance companies, and other investors have been keen buyers of publicly listed infrastructure stocks and bonds for a long time. Second, investment in unlisted infrastructure is an ongoing process, as investor intention surveys indicate continued interest in this sector.

Actual and perceived barriers to infrastructure investment by institutional investors have been flagged in the past (e.g., Inderst [2009] and Della Croce [2011]). There are constraints on the supply side (e.g., lack of suitable projects, poor procurement processes, project size) and demand side (e.g., investor resources and capability, portfolio concentration risk), as well as in the intermediation process and market structure (e.g., inappropriate, expensive investment vehicles; lack of secondary markets; weak capital markets) (Table 13.5).

Previous cases of investment in projects with poor returns and little economic value serve as timely reminders. Most investors have very little experience in infrastructure transactions and in managing infrastructure assets. Infrastructure is very heterogeneous, which does not make the task any easier.

Table 13.5 Barriers to Institutional Infrastructure Investment

Issues with government support for infrastructure projects	• Lack of political commitment over the long term • Lack of infrastructure project pipeline • Fragmentation of the market among different levels of government • Regulatory instability • High bidding costs
Lack of investor capability	• Lack of expertise in the infrastructure sector • Problem of scale of pension funds • Regulatory barriers • Short-termism of investors
Issues with investment conditions	• Negative perception of the value of infrastructure • investments • Lack of transparency in the infrastructure sector • Misalignment of interests between infrastructure funds • and pension funds • Shortage of data on infrastructure projects

Source: OECD (2014a).

From an investor's perspective, there are risks inherent not only to infrastructure projects and companies, but also to investment instruments and portfolios, including:

(i) construction and development risks of (greenfield) projects;
(ii) operational, demand, and market risks (e.g., changing traffic numbers);
(iii) financial and interest rate risks (e.g., leverage and refinancing);
(iv) governance standards (e.g., conflicts of interest, bureaucracy, and corruption);
(v) legal, social, and reputational risks (e.g., delays, failures, and environmental issues);
(vi) regulatory risks (e.g., changing regulation, cuts in subsidies, and investor regulation); and
(vii) political uncertainty (e.g., changes in government or infrastructure policies, and expropriation risk).

Some of these hurdles are difficult for foreign investors to jump, especially in emerging markets with capital markets of low liquidity and currency risks that can hardly be hedged. Risk mitigation mechanisms need to be carefully evaluated (Schwartz, Ruiz-Nuñez, and Chelsky 2014). This requires good credit analysis and currency management, knowledge of local practices, reliable local partners, and, first and foremost, trust in the political system.

13.5.1 Investor Regulation

Investor regulation is often a main hindrance. There are three sets of regulations on the investor side that can be very relevant for infrastructure investment: solvency, accounting, and investment rules.

Institutional investors in different constituencies are subject to more or less strict regulatory regimes. Risk-based solvency regulations and fair-value International Financial Reporting Standards accounting rules for insurers and pension funds are seen as a potential obstacle to infrastructure investments, as they could lead to de-risking and procyclical investment behavior (Severinson and Yermo 2012). For example, in the European Solvency II regime, capital charges are higher for less liquid assets, and bonds with longer maturities and lower credit ratings. However, the EU is in the process of somewhat reducing capital charges for a subset of lower-risk infrastructure assets.

In many countries, especially emerging markets, there are (quantitative and/or qualitative) investment restrictions by which investors have to abide, that may hamper infrastructure investment (see, e.g., Vives [1999]; City of London [2011]; OECD [2014d]). In a survey of 32 countries, the International Organisation of Pension Fund Supervisors (2011) listed numerous examples of regulatory restrictions on alternative investments that affect both direct and indirect infrastructure investments.

About half of the reporting jurisdictions have qualitative restrictions on unlisted or nontransparent investments. Examples of quantitative limits include:

(i) restrictions on equity or corporate bond investments;
(ii) investment in unlisted infrastructure companies (including Hong Kong, China, the Republic of Korea; and Japan);
(iii) direct investments in projects (including Thailand);
(iv) infrastructure funds or investments (including the PRC);
(v) alternative investments (including Pakistan);
(vi) minimum ratings for bonds;
(vii) constraints on leverage and the use of derivatives; and
(viii) prohibitions or limits on foreign exposure (including India).

Such legal constraints on infrastructure and other investments may often have good justifications, such as the lack of transparency, the containment of excessive risks, and liquidity requirements. A number of countries have introduced special "positive" rules for infrastructure investments, such as India with minimum thresholds for insurers in infrastructure bonds. However, regulators should review investment regulations in light of their effect on long-term performance (such as the lack of investment opportunities and diversification), and the economy.

13.5.2 Institutional Investor Potential

Estimates of the institutional investor potential are particularly speculative, given the poor data situation. Also, institutional investors have very different objectives (including pensions, profitability, social, and political) and different policies, also in respect of infrastructure. Investment behavior is influenced not only by law and regulation but also by considerations of diversification, liquidity, liability profile, scale and "investment culture."

Expectations for future involvement need to be realistic for developed markets and even more so for EMDEs. Here is a simple calculation: a major asset allocation shift of 3%–5% by Asian institutional investors across the board (assuming assets of $20 trillion) into infrastructure over 10 years would imply an average annual flow of about $60 billion–$100 billion, or about 0.3%–0.5% of Asian GDP. Such an (optimistic) scenario would generate a substantial addition to the private finance flows into infrastructure. Nonetheless, it would still only amount to a contribution of less than 10% of the projected investment needs.

There are several factors to consider in the discussion of the future potential:

(i) There needs to be a sufficient supply of suitable, investable infrastructure assets.
(ii) The impact would also depend on the type of finance (equity or debt) and the availability of bank loans, given the leverage typical for infrastructure financing.
(iii) Calculations also depend on the growth of private assets and especially changes in investor regulation. Appropriate investment management capabilities and instruments are needed for institutional assets (and even more so for individual savings).
(iv) Given the relatively strong concentration of assets in a number of large public reserve funds and SWFs in Asia, much depends on their specific behavior.
(v) What assumptions can be made about the "infrastructure capital balance"? Currently, a lot of Asian capital seems to be

going to Western markets, whereas the attractiveness of Asia's infrastructure still appears to be subpar for international investors.

13.6 Conclusions

This study evaluates infrastructure investment and finance in Asia from a global perspective. A "bigger picture" of demand and supply of capital for infrastructure is created by using a simple framework, i.e., percentages of GDP. There are major conceptual and data issues in this field, and infrastructure statistics need to be interpreted carefully. Asia is, of course, a highly heterogeneous continent, but some interesting features emerge from global comparisons, using the data currently available.

Historically, there has been a wide dispersion of infrastructure spending across regions and countries. Future investment requirements for economic infrastructure are estimated at around 4.0% of GDP globally, 6.0%–8.0% in emerging markets, and 6.5% in Asia. The capital stock is already high in some (East) Asian places, but most countries would need to increase infrastructure investment considerably.

Developed countries worldwide tend to have a higher share of private financing in infrastructure than developing countries (the shares of public and private finance are, very roughly, 1:2 versus 2:1). This ratio varies considerably across Asia. Bank loans dominate Asian infrastructure project finance, implying a large maturity mismatch between short-term bank deposits and long-term project financing. There are considerable differences in the structure and openness of Asian capital markets, and there is scope for further development of securitization.

Corporate finance is a main element of private infrastructure finance. Listed infrastructure companies represent about 6% of the equity market universe, or 4% of GDP globally. Asia has a weighting in the range between 10% and 20% in global infrastructure indices. Asian infrastructure indices have a market capitalization of up to $500 billion, about 2.5% of GDP.

Much of the focus in recent years has been on unlisted infrastructure investments, either directly or via funds, as they have been growing since the early 2000s. Asian infrastructure funds are reportedly generating a deal volume of $20 billion–$30 billion per year, i.e., 0.1%–0.2% of GDP, which is less than half the global average.

The global project finance markets have recovered from the financial crisis. Project finance in Asia (excluding India) runs at an annual value of about 0.2%–0.3% of GDP, i.e., roughly half the global average. India has been one of the strongest (but fluctuating) markets in the world in recent years. Project bond markets are still very small (less than 0.1% of GDP outside the PRC).

Private participation in infrastructure is only about 0.1%–0.2% of GDP in the East Asia and the Pacific region, well below the EMDE average. South Asia showed a strong cyclical movement with a peak in 2010. With the exception of India, PPP volumes are still small in Asia, and many countries still make little or no use of PPPs.

Institutional investment in infrastructure is currently a much-discussed topic. There are some distinctive features of the institutional investor base in Asia. Private pensions and insurance assets are comparatively small. However, there are several very large public pension reserves and social security funds in the region. Asia also has a good share of SWFs assets, plus important currency reserve funds and other public funds.

Asset owners worldwide have been traditional buyers of listed utility and infrastructure stocks and bonds. Since the mid-2000s, interest in unlisted vehicles, especially infrastructure funds, has risen. However, the overall allocation is still small (globally about 1%–2% of assets, and even lower in Asia). Some large investors have started to build substantial direct holdings in infrastructure projects, although much of the capital flows into established markets.

Infrastructure has specific risks for investors that need to be properly managed, and there are barriers and risks to higher involvement that need to be worked on. Investor regulation is often the main hindrance. Expectations as to the future potential of (domestic and foreign) institutional investors need to be realistic. In Asia in particular, much depends on the specific behavior of the large public funds, and the (still low) attraction of international investors.

Lessons and Recommendations

Overall, the private sector still plays a relatively subdued role in Asia. The volumes of listed and unlisted investment instruments of project finance and PPP are well below the global average (with some exceptions), and still small compared to future investment requirements.

The involvement of institutional investors in the provision of infrastructure finance has been changing over time. Investing in listed infrastructure is typically undertaken along the usual lines of securities investing. Unlisted infrastructure as "alternative investments" is more closely related to private equity and/or real estate. The experience of most investors, if any, is still very limited. Nonetheless, some useful lessons can already be learned:

(i) Infrastructure assets are very heterogeneous. There are many dimensions, such as geography; sector; greenfield, brownfield, and secondary markets; regulated and unregulated; PPP and non-PPP; concessions; degree of inflation protection; and ultimate funding (user charges or availability payments).

(ii) Infrastructure investing, especially direct investment, requires adequate size, resources, and good governance. For public (pension, social security, and sovereign wealth) funds in particular, there is the risk of political motivation and interference—therefore clear financial objectives and good governance are paramount.

(iii) There are major cycles in the valuation of assets, including periods with "too much capital chasing too few assets."

(iv) The financial crisis revealed risks at all levels: projects (e.g., excessive leverage and optimistic demand projections); funds (governance, conflicts of interest, and fees); and asset management (concentration risk and lack of understanding).

(v) Infrastructure investment is inherently political. A lot depends on the trust put in the state authorities.

The infrastructure market has seen some ups and downs, and it has been evolving in several respects. New developments include:

(i) deeper scrutiny of projects and investment vehicles;
(ii) a broader universe, including new regional markets, sectors, and specialist funds;
(iii) open-ended, cheaper, more transparent funds;
(iv) more direct investing;
(v) more infrastructure debt investment;
(vi) co-investment by investors, syndicates, and capital pooling platforms for (smaller) pension funds (with or without public capital); and
(vii) increasing awareness of climate change and "green" infrastructure (Inderst, Kaminker, and Stewart 2012; OECD 2015).

There are also some important lessons for policy makers:

(i) Governments want private capital for new projects but most institutional investors prefer low-risk assets which implies a risk-preference mismatch. This is a key intermediation problem, and not easy to resolve. There is a debate in Australia, for example, about more "asset recycling," i.e., the sale of operational public assets to build new infrastructure.

(ii) Many countries are seeking to develop capital markets (e.g., for project bonds), but new markets take time and trust to evolve.

(iii) Rule of law, political accountability, and continuity are paramount for investors. Investors express the need for consistent infrastructure policies (e.g., improving procurement processes, steady project pipelines, and good dialogue with the industry and investors).
(iv) Retrospective changes to regulation and contracts are particularly harmful.
(v) Ultimately, it is not the financiers who pay for infrastructure services but the users or tax payers.
(vi) There are advantages to having a mix of a domestic (e.g., for local knowledge) and foreign investor base (e.g., for external discipline and international standards).

Extensive recommendations have been made for policy makers on how to strengthen the role of private finance and institutional investors in infrastructure by many experts and organizations, such as the Group of 20, the OECD, and the MDBs. There are also more specific recommendations for Asia.[37]

A number of countries have set up dedicated infrastructure or PPP agencies, national infrastructure banks or green banks. Such institutions can be instrumental in directing institutional investor involvement. New initiatives have also been started by international institutions such as the World Bank's Global Infrastructure Facility or the Group of 20 Global Infrastructure Hub.

Governments can facilitate and incentivize private infrastructure investments in various ways (World Bank 2015b):

(i) Financial leveraging tools such as guarantees, insurance policies, and credit enhancements (e.g., the European Project Bond Initiative).
(ii) The public sector can set up or co-invest in fund vehicles, such as a national or regional infrastructure fund.
(iii) Grants, tax exemptions, and other fiscal incentives, among others.

The long-term costs and risks of such tools need to be carefully assessed. MDBs can play an important role as catalysts for private investments in various ways (project design, policy advice, co-investor, insurance, etc.). Private investors often appreciate the expertise and "political clout" of MDBs in new ventures.

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37 See, e.g., Bhattacharyay, Kawai and Nag (2012), Basu Das and James (2013), Sheng (2014), Zen and Regan (2014), Ray (2015), and ADB (2015).

Work needs to be done on all fronts, by governments, infrastructure businesses, investors, the financial industry, and academia. Asian governments in particular need to increase the attractiveness of private investment in infrastructure. Policy recommendations emphasized in this chapter include:

(i) Implement clear infrastructure policies, stable sector and PPP regulation, and effective government institutions. Reduce policy inconsistencies between different departments.
(ii) Expand the role of private, long-term savings institutions with strong governance (such as autonomous pension funds and asset management).
(iii) Review investor regulation (and regulators), especially with regard to its effect on infrastructure investment.
(iv) Review sectoral regulation (in energy, transport, etc.), especially with regard to potential barriers for private investment.
(v) Increase the depth and breadth of local and regional capital markets (e.g., for project bonds, sub-national revenue bonds, and infrastructure funds).
(vi) Review the competitive situation in loan markets, especially the position of public banks.
(vii) Open markets for regional and international infrastructure investors.
(viii) Improve statistical information on infrastructure investment, transparency of
(ix) investment vehicles, and disclosure on infrastructure projects.

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Conclusion

Naoyuki Yoshino, Matthias Helble, and Umid Abidhadjaev

This book presents the latest scientific evidence on infrastructure investment and finance in Asia and the Pacific region. We invited prominent researchers to submit their work evaluating the impact of infrastructure and its financing options. Difference in methodologies, data, and narrative provided much-needed diversity and synergy.

The first part of this book was dedicated to spillover effects, which capture the impact of infrastructure on regional or neighboring economies through marginal increases in productivity of capital and labor, better proximity to markets, and lower costs. For example, with regard to economic growth, infrastructure in Uzbekistan positively impacted regional gross domestic product (GDP) and its decomposition in the form of agriculture value added, industry value added, and services valued added. In terms of fiscal revenues, transportation infrastructure had a statistically significant impact on tax revenues in Japan and the Philippines once the effects of the Kyushu rapid train and Southern Tagalog Arterial Road were quantified. Such changes in tax revenues can serve as a solid basis for various financing options, including infrastructure financing.

The second part of the book explained that the impact of infrastructure on economic development is differential. For example, in Thailand, growth accounting by industry revealed that total factor productivity growth has increased in the manufacturing and service sectors, while declining in the agricultural sector. Similarly, in Japan infrastructure appears to have a higher impact in urban areas than in rural, and marginal productivity decreases more rapidly in secondary industry than in tertiary industry. A similar pattern of differential impact was observed for firm-level data in the case of the People's Republic of China, revealing that infrastructure investments benefit firms in the western and central provinces more than those in the eastern provinces. In addition, in the People's Republic of China we noticed a strong spillover effect on firm productivity from infrastructure in neighboring provinces, supporting the pattern of spillover effects observed in Part I. Similar patterns of a non-uniform effect of infrastructure were observed when estimating the impact of port improvements in the Philippines, and that of road development in rural Papua New Guinea.

The third part of the book dealt with cross-border infrastructure and connectivity. In particular, we investigated whether infrastructure had a positive impact on cross-border economic activities, especially trade. An analysis of 14 Pacific islands revealed that a direct shipping connection more than doubles trade in goods, and that the frequency of transport connections also matters. A similar cross-country analysis for transportation and information and communication technology infrastructure revealed that infrastructure positively impacts trade flows in Southeast Asian countries. Finally the economic viability of cross-border infrastructure was estimated in the Greater Mekong Subregion.

The fourth part of the book looked at infrastructure financing options. Stillman described the history of infrastructure financing, with a focus on the experiences of the United States and Japan, Regan examined contemporary supply and demand conditions for infrastructure investment, and Inderst outlined features emerging from their global comparisons.

There are many difficulties related to infrastructure provision, including demand risk, which is related to future demand for infrastructure; and price risk, which is related to the fact that customers may be unprepared to pay the user fee for new infrastructure services. Such factors affect the survivability of projects. To avoid this, we must find a solution to help us design a financing mechanism that will encourage and support infrastructure productivity.

New or upgraded infrastructure will spur private sector investments along highways and railways, which will create jobs and boost GDP. Eventually, property values will also rise. In parallel, revenues from corporate, income, sales, and property taxes will rise along the highway. Thus, instead of increasing user fees or transferring the demand and price risk to the private sector, part of these new tax revenues could be returned to private investors to increase the rate of return of the infrastructure project. Of course, this can be conditioned on positive changes in the tax revenues of the affected regions and the absence of profit by the infrastructure company under fixed price and given demand.

However, in some countries it may be difficult legally to return the incremental tax revenues to private investors, since once the revenue enters the budget tax revenues must stay in the government. This can be solved through an institutional solution whereby a government would set up a regional development agency consisting of representatives of the taxation authorities, the ministry of finance, and the regional authority; and having charge of infrastructure investment and special regional development. The agency would not only help to coordinate and finance infrastructure investment, but would also be responsible for regional development along highways and railways. The closest example of this type of agency in the history of Japan is the Development Bank of Japan, which was established in 1951 to facilitate loans for infrastructure development and modernization. Similarly, the Hokkaido-Tohoku Development Finance Public Corporation promoted industry in the Hokkaido and Tohoku regions of Japan through investment and financing after its restructuring in 1957.

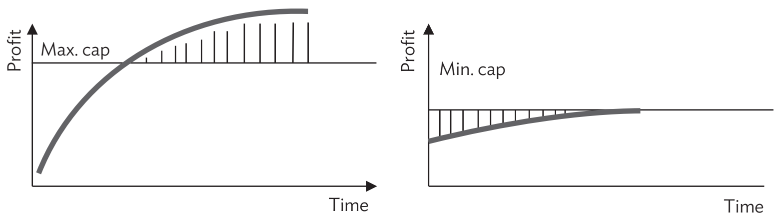
In contrast to these examples of regional agencies, the development agency's main task would be to issue infrastructure bonds, part of which would be purchased by private investors, and the rest by the government. Both the private and government sectors would receive the returns from the agency. The infrastructure bond is a revenue bond whose interest rate varies based on the additional tax revenues along highways and railways. It is important to mention that we are not proposing that payments on the bond interest rate should be made by introducing new taxes or an additional increase in tax rates. Instead, we suggest that the incremental increase in tax revenue due to the new infrastructure should be used to service the bonds. As a corollary, the return on infrastructure bonds only grows when tax revenues in affected regions increase.

In developing countries with a high level of economic growth, additional infrastructure often leads to a substantive increase in taxes. However, some infrastructure projects might not provide the expected positive stimulus. To ensure adequate balance and avoid moral hazards a maximum cap for interest rate revenue should be adopted when the rate of return from infrastructure investment is relatively high. On the other hand, a minimum interest rate (minimum cap) should be guaranteed to private investors in case the infrastructure project remains below the break-even point. Figure 1 illustrates the two cases. The left side shows the case of a successful infrastructure project that leads to higher-than-expected tax revenues. The graph on the right side illustrates a case where tax revenues are too low to repay the bondholders, and additional support is needed.

In the best case, the public and private sectors agree on specific minimum and maximum caps to assess the project's performance. When profits exceed the maximum cap, the difference in actual revenues will be transferred to a special reserve within the development agency. Consequently, this reserve fund can be used to support projects that fail to reach the minimum cap.

Another important aspect to consider is the country's tax-collection system, especially with regard to local and central systems. The main point is that the development agency, targeting a specific region, should

Profit Stream of Infrastructure Projects



Max. = maximum, Min. = minimum.
Source: Authors.

directly receive a share of the taxes levied in the region. This allows the development agency to repay the due payments to the bondholders.

Other possible difficulties concern the ability to collect taxes due to the existence of so-called black markets. Our model cannot be successfully implemented in contexts characterized by low levels of tax collectability and tax avoidance of due payments, which would reflect real underlying economic processes. In this respect, it is necessary to boost the tax payment discipline of businesses and citizens. At the same time, the government should pursue more technocratic tax-collection solutions using information technology and transparent collection mechanisms, making it easier for taxpayers to fulfill their payment obligations.

Of course, this book is not free from limitations. For example, in revealing spillover effects, the authors construct a so-called counterfactual scenario that depends heavily on the choice of the control group, which, in its turn, is limited due to a lack of observations. Thus, discussions are needed to estimate infrastructure's impact more accurately. This would require considering other factors affecting economic growth in the region. Where data are lacking for the optimal control group, the mean of the existing sample of observations, excluding that of the treatment group, can serve as a counterfactual benchmark. The availability of continuous time series data on the labor force, fixed capital formation, exports, and imports of the affected regions can provide more accurate estimates.

Similarly, the method assumes an additive impact, while a multiplicative effect could be examined by formulating the research framework better in the future. Although the variety of approaches and methodologies used throughout the book provide wider angles and geographic scale, more accurate and uniformly observed data are required to reveal clearer patterns and decompose country- and region-specific effects.

Finally, the next step in this direction can be taken by connecting the empirical findings of current studies with a new framework for the ex ante analysis of infrastructure finance in the future. Only when knowledge from past data is used for future purposes can we hope that our work may contribute to a positive change in the form of more effective decision making in Asia and the Pacific region.

In the future, the same method can be applied not only to transport infrastructure but also to electricity and water supply, airports, and sea ports. Of course, each infrastructure type requires a specific approach, depending on various individual factors. For example, electricity will enhance regional development, but user charges are regulated to keep them low since electricity is a necessary good for everybody. This, in its turn, might discourage private investors. Once spillover tax revenues are returned to investors through the model mentioned above, the private sector will be willing to invest in infrastructure projects, including electricity.