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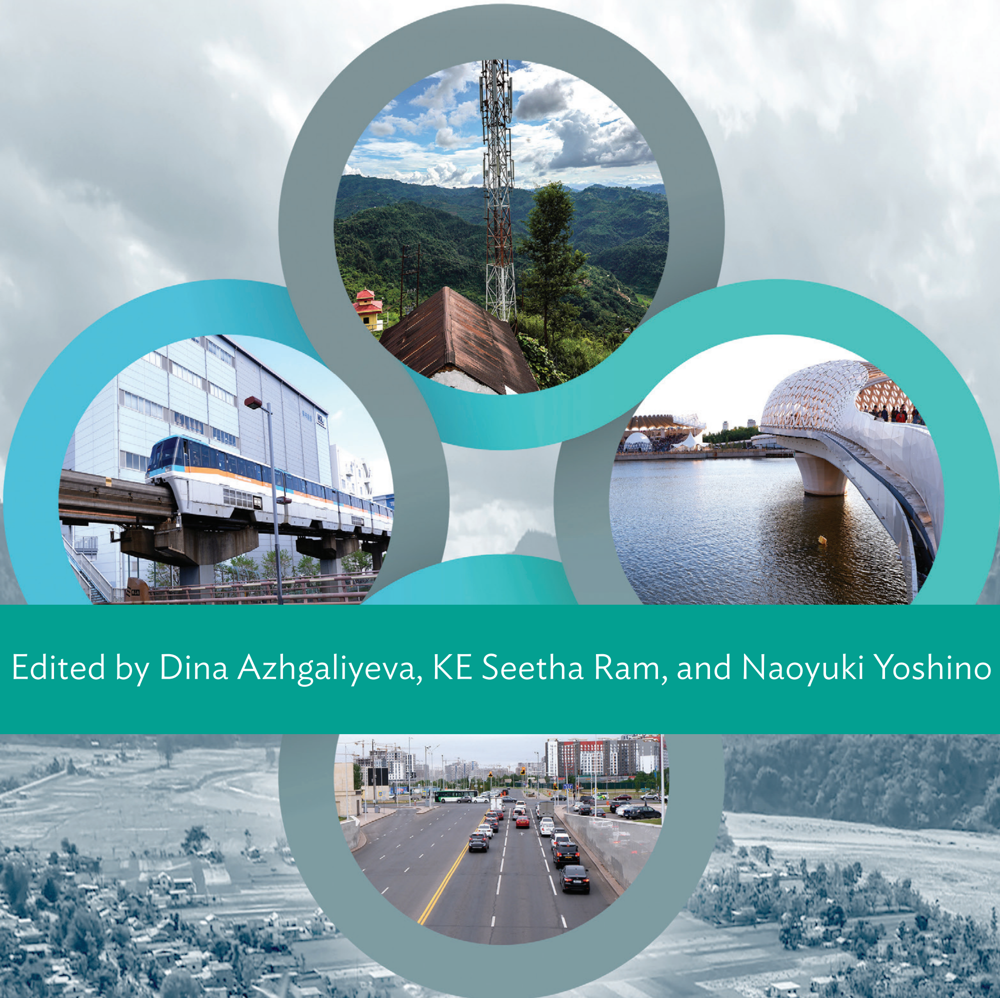
INFRASTRUCTURE SPILLOVER IMPACTS IN DEVELOPING ASIA



Edited by Dina Azhgaliyeva, KE Seetha Ram, and Naoyuki Yoshino

ASIAN DEVELOPMENT BANK INSTITUTE

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Tables, Figures, and Boxes

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Abbreviations

ADB	Asian Development Bank
ASI	Annual Survey of Industries
BIF	Broadband India Forum
CAREC	Central Asia Regional Economic Cooperation
CDR	call detail record
COVID-19	novel coronavirus disease
DCI	digital communications infrastructure
DDD	triple difference-in-difference
DID	difference-in-difference
e-VIN	Electronic Vaccine Intelligence Network
EAEU	Eurasian Economic Union
EU	European Union
FE	fixed effects
fkm	fiber kilometer
Gbps	gigabits per second
GDP	gross domestic product
GHz	gigahertz
GIS	geographic information system
GNI	gross national income
GSM	Global System for Mobile communications
GST	goods and services tax
GT	Google Trends
GTI	Google Trends Index
HSR	high-speed rail
ICRIER	Indian Council for Research on International Economic Relations
ICT	information and communication technology
IMF	International Monetary Fund
IoT	internet of things
IRR	internal rate of return
km	kilometer
MAI	market access index
MRPK	marginal revenue product of capital
NDCP	National Digital Communications Policy
NOAA/NCEI	National Oceanic and Atmospheric Administration's National Centers for Environmental Information
NPCI	National Payments Corporation of India

NPP-VIIRS	National Polar-Orbiting Partnership-Visible Infrared Imaging Radiometer Suite
NPV	net present value
NTL	night-time light
OECD	Organisation for Economic Co-operation and Development
OLS	ordinary least squares
PPML	Poisson pseudo-maximum-likelihood
PPP	public–private partnership
PRC	People's Republic of China
RDP	regional domestic product
REER	real effective exchange rate
ROA	return on assets
SMIS	Shared Mobile Infrastructure Scheme
SPV	special purpose vehicle
UID	unique identity number
UPI	Unified Payment Interface
US	United States
WBES	World Bank Enterprise Survey

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Foreword

Infrastructure has always been a critical driver of economic growth. However, traditional infrastructure development in developing countries is often weakened by delays, cost overruns, and inadequate operation and maintenance due to factors related to inefficient bureaucracy, inadequate planning, substandard construction, and deficient maintenance.

The good news is that digital technology is transforming the way we build and manage all hard and soft infrastructure. With digital technology, infrastructure can now be better prioritized, built, and managed and more cost-effective, inclusive, and sustainable.

The private sector is by far the largest user and beneficiary of infrastructure and a key player in the entire life cycle of infrastructure development and the delivery of public services. Without its participation, infrastructure development cannot be successful. However, the private sector would not be willing to invest in infrastructure if free riding and moral hazard were rampant due to poorly designed cost sharing between the private and public sectors and among private investors or a lack of transparency and accountability in implementation. Thus, for the private sector to confidently participate in infrastructure development, governments must provide an enabling policy environment.

Digital technology can help develop effective and efficient cost-sharing schemes and improve their transparency and accountability to build trust between the public and private sectors. This is because digital technology can provide everyone involved with real-time information on project progress, financing, and procurement processes and, hence, reduce the asymmetry of information and the risks associated with infrastructure investment.

This edited volume offers key messages on the need for an enabling policy environment that supports private sector participation in various countries. I encourage policy makers in governments, decision makers in the private sector, and other stakeholders to embrace digital technology in infrastructure development for inclusive and sustainable growth.

Tetsushi Sonobe
Dean
Asian Development Bank Institute

Introduction

KE Seetha Ram and Dina Azhgaliyeva

Infrastructure development could provide an important boost to recovery from the coronavirus disease (COVID-19) pandemic in developing Asian economies and global inflation due to the Russian invasion of Ukraine. However, public funds for health, education, and social welfare programs due to the crisis are constrained and require private investment. Policy makers are constantly looking for financing solutions and novel funding sources to tackle the region's infrastructure investment gap. New funding sources are particularly vital for tackling the region's sustainable infrastructure investment gap, which is equal to 2.4% of gross domestic product (GDP), and includes financing for climate mitigation and adaptation. Developing Asia will need to double its infrastructure investment to $1.7 trillion annually over the current decade to maintain growth momentum, eradicate poverty, and address climate change, according to the Asian Development Bank's book on *Meeting Asia's Infrastructure Needs* published in 2017. This includes $14.7 trillion for power, $8.4 trillion for transport, $2.3 trillion for telecommunications, and $800 billion for water and sanitation. Data-based evidence of infrastructure's spillover effects and policy recommendations for optimizing them will be critical to mobilize private investments in infrastructure.

To prepare this publication, the Asian Development Bank Institute organized four virtual workshops: (i) Analyzing Infrastructure Impacts in Asia Through Big Data: Spillover and Financing[1] on 3–4 June 2021; (ii) Workshop on Geospatial Futures for Social Impact on 4 August 2021; (iii) Analyzing Infrastructure Impacts in Asia Through Big Data: Infrastructure Development in the Context of COVID-19[2] on 10 September 2021; and (iv) Analyzing Infrastructure Impacts in Asia Through Big Data: Socioeconomic Spillover Assessment[3] on 16–18 May

1 https://www.adb.org/news/events/analyzing-infrastructure-impacts-asia-through-big-data

2 https://www.adb.org/news/events/infrastructure-development-context-covid-19

3 https://www.adb.org/news/events/adbi-virtual-workshop-on-analyzing-infrastructure-impacts-in-asia-through-big-data-socioeconomic-spillover-assessment

2022. The first three workshops (held virtually) included training on analyzing the impacts of infrastructure in Asia and use of big data, as well as presentations of research proposals on the socioeconomic spillover effects of infrastructure and measures for optimizing them to mobilize private investment growth. The papers were selected by the project's organizing committee from submissions to the open call for papers. The three workshops featured training sessions with Naoyuki Yoshino from Keio University (Japan), Satish Ukkusuri from Purdue University (United States), and Takahiro Yabe from Massachusetts Institute of Technology (United States). Cohosted with the Central Asia Regional Economic Cooperation (CAREC) Institute, the final virtual workshop on infrastructure impact analysis in Asia through big data examined new research on infrastructure's socioeconomic spillover effects and measures for optimizing them to mobilize private investment growth within the sector.

This introductory chapter gives an overview of the chapters in this book, focusing on the major findings and policy recommendations. The book is divided into three parts: Part I ICT Infrastructure, Part II Transport and Water Infrastructure, and Part III Infrastructure and Firm Performance.

Part I "ICT Infrastructure" overviews the spillover effects of ICT infrastructure using cases from India in South Asia and the Kyrgyz Republic in Central Asia. It comprises three chapters.

Chapter 1 "Spillover Effects of ICT Infrastructure: Empirical Evidence from India" provides empirical evidence of the spillover effects of ICT infrastructure using the case of India. The authors propose to attract private sector investors in ICT infrastructure by creating a steady stream of income flow for the investors. Chapter 1 quantifies the spillover effects of mobile network on tax revenues, using annual state-level data from 2005 to 2016 from across all states in India. Using simple fixed effect (FE) as well as FE two-stage least-squares (2SLS) estimations, the chapter shows that an increase in the number of mobile network subscribers is associated with an increase in the amount of regional tax revenue. An increase in the number of Global System for Mobile communications (GSM) subscribers per capita by 1 percentage point is associated with an increase of annual state tax revenues per capita by around 3% of average annual state tax revenue per capita (in 2016). The number of GSM subscribers affects tax revenues through increased economic activities, as shown by the 2SLS estimation results. Authors use the above results to justify their proposal to share the increased tax revenues to create a steady stream of income for investors. Authors also recommend supporting the development of digital and physical infrastructure in the national budget of India for 2022–2023.

Chapter 2 "ICT and Labor Mobility: Online Search and Prediction of Remittances in the Kyrgyz Republic" examines the Google Trends Index in the prediction of remittances in the case of one of the most remittance-receiving developing countries in the world, the Kyrgyz Republic. To this end, the authors employed a gravity model with the use of chosen search keywords in destination countries and in the Kyrgyz Republic. Six destination countries' remittance inflows to the Kyrgyz Republic are used for the empirical analysis. The dataset included searched keywords on Google Trends that could be related to migration and remittances. The authors find that searched keywords in destination countries have more statistically significant effects on remittances than those in the Kyrgyz Republic. As a result, the stock of migrants in destination countries plays an important role in explaining variations in remittance flows. Search words in the Kyrgyz Republic that indicate the pursuit of a job and flight tickets, however, are crucial for understanding remittances as well. These finding suggest that remittance flows can be explained by the Google Trends Index. These linkages on both sides of the migration process demonstrate how ICT infrastructure boosts job creation for migrants and income transfers to their sending households.

Chapter 3 "Socioeconomic Spillover Effects of Digital Communications Infrastructure in India" reviews the definition, features, and current situation of digital communications infrastructure (DCI) in India. Based on the body of existing papers, Chapter 3 demonstrates the DCI-related spillover effect. To be more specific, the authors employ several studies that associate the increase in DCI with the growth in GDP and illustrate the cross-country spill over impacts using previous studies. Furthermore, the authors highlight the notable case studies emphasizing the widespread spillover impacts of Aadhaar—a verifiable identity number given to Indian citizens by the Unique Identification Authority of India.

Part II "Transport and Water Infrastructure" overviews the spillover effects of transportation infrastructure, including rail and road infrastructure. It comprises three chapters.

Chapter 4 "Cost–Benefit Analysis of Spillover Tax Revenues of High-Speed Rail in Taipei,China" presents the notion of spillover tax revenues, which are also regarded as indirect or secondary revenues, or externality effects. Using the case studies of high-speed rail in Taipei,China, regional tax data are utilized in the difference-in-difference methods to estimate the spillover tax revenues. Combining the floating bond and land trust system, Chapter 4 offers various methods of financing infrastructure investments. The authors demonstrate that the suggested financing schemes exhibit considerable internal rates of return enhancement over the conventional investment system, encouraging private sectors to finance infrastructure investments. Furthermore, the authors find that the spillover tax revenues play a crucial role in fulfilling the demands of infrastructure investment in Asia.

Chapter 5 "Market Access and Firm Performance: Evidence Using Data from India" examines whether greater market accessibility provided by an improved road system contributes to increased profitability. Firms will find it easier to sell their products on the markets if they are located in states with better market connectivity, which will boost firms' profitability and reduce dispersion in return on assets (ROA). Therefore, the authors hypothesize that greater market accessibility arising from greater road networks could lower dispersion in the ROA. To this end, Chapter 5 employs a unique Indian state-level dataset over the period from 2001 to 2015 collected and merged from several sources using the latest data available. To be more precise, using shapefiles of the Indian road system, district boundaries, and nightlight raster pictures, the authors generate a district-level market access index and compute the shortest driving distances between districts. To investigate whether firms located in states with greater market accessibility emerging from better road connectivity could perform better in terms of profitability, the authors employ data from India's annual survey of industries for 2001 to 2015. Results demonstrate that better market accessibility improved firm profitability in India.

Chapter 6 "The Spillover Effects of Water Supply Infrastructure Development: A Theoretical Model" constructs a theoretical model of the spillover effects of water supply infrastructure development. The low willingness of consumers to pay for services in comparison with the high rate of return demanded by private investors and operators is one of the major difficulties in Asia and the Pacific, which often results in the failure of public–private cooperation for sanitation and water projects. Nevertheless, the impacts of water supply infrastructure on development, including the spillover effects or externalities, are significant. Governments' tax revenue collections are one of the spillover effects of the establishment of water supply infrastructure. The theoretical framework constructed in this study indicates how the incremental tax revenues, which were previously absorbed only by governments, might be partially distributed back to private investors and operators of the water supply infrastructure. Furthermore, in this chapter, a pooling system is suggested to obtain the incremental tax revenues emerging from the spillover effects in major cities, which could then be employed to fund the service fees for construction and operation of systems in rural areas. This pooling system can promote the development of a national system of water supply infrastructure, which swiftly diminish the negative externalities and boost the positive externalities in the country.

Part III "Infrastructure and Firm Performance" overviews the impact of infrastructure on firm performance. It comprises two chapters.

Chapter 7 "The Role of Customs Quality for Exports: Empirical Evidence from Firm-Level Data from Belarus, Kazakhstan, and the Kyrgyz Republic" examines the impact of joining the Eurasian Economic Union (EAEU) on export intensity (export sales as a percentage of overall sales). This chapter studies the value of customs policies aimed at increasing efficiency and reducing the time and cost to cross borders in increasing exports in three countries: Belarus, Kazakhstan, and the Kyrgyz Republic. These countries joined the EAEU in 2015 and implemented common customs clearance policies. Using firm-level data from the World Bank Enterprise Survey and employing the difference in difference approach, the results show that in three countries there is evidence that joining the EAEU has been beneficial in increasing exports. However, the extent of the benefit varies across the countries.

Chapter 8 "Evaluating COVID-19's Impact on Firm Performance in Four CAREC Countries Using Night-Time Light Data: Azerbaijan, Georgia, Kazakhstan, and Mongolia" explores economic activity evaluated in terms of firm performance indicators using the variations in intensity of night-time light in four CAREC countries: Azerbaijan, Georgia, Kazakhstan, and Mongolia. To this end, the authors use data from the 2019 World Bank Enterprise Survey and a follow-up survey during the COVID-19 pandemic. The enterprise survey dataset was supplemented with Google Earth data on night-time light intensity and a COVID-19 stringency index. Four variables are employed to evaluate firm performance: a decrease in sales, demand, export share, and working hours. Results demonstrate that the probability of degradation in firm performance decreases when the intensity of night-time light increases. Furthermore, compared to smaller companies, larger firms are more likely to better retain their performance. Sales in the manufacturing, clothing, and services sectors are more likely to shrink than those in the food sector. Additionally, findings indicate that during the pandemic, service sector enterprises performed significantly worse than those in the food sector.

Conclusion

In conclusion, the key policy recommendations for developing Asia from this book can be summarized as follows:

- Support the development of new infrastructure and improve the quality of existing infrastructure (including soft infrastructure).
- Support infrastructure projects due to their positive spillover effects not only on firm performance (profitability and exports) but also on tax revenue.
- Promote private sector investment in planned infrastructure projects by sharing the increased tax revenue from the spillover effects with investors to create a steady stream of income for investors.

PART I

ICT Infrastructure

1

Spillover Effects of ICT Infrastructure: Empirical Evidence from India

Naoyuki Yoshino, Tifani Husna Siregar, Deepanshu Agarwal, KE Seetha Ram, and Dina Azhgaliyeva

1.1 Introduction

Information and communications technology (ICT) is an important growth driver and an indispensable part of the modern economy. ICT infrastructure, such as fixed-line telephones, mobile phones, internet, and broadband, is the foundation of economic activities and technological applications. The growth of ICT infrastructure has increased the effectiveness of resource allocations, reduced production costs, and boosted demand and investment in many economic sectors (Jorgenson and Stiroh 1999; Vu 2011; Lee et al. 2012; Grimes, Ren, and Stevens 2012; Pradhan, Arvin, and Norman 2015; Aseinov et al. 2022). Other than the economic impacts, the development of ICT infrastructure also improves access to information, which may contribute significantly to long-term sustainable development.

The novel coronavirus disease (COVID-19) pandemic further emphasizes the importance of ICT infrastructure (Beirne, Morgan, and Sonobe 2021; Abdullaev et al. 2022). ICT has shown its strong contribution to overcoming difficulties during this devastating public health crisis by enabling people to connect, work, shop, and learn while maintaining restraints such as staying at home and physical distancing. Moreover, big data is used by many governments for pandemic control measures and impact measurement related to contact tracing, mobility, and health analysis. The use of the internet for healthcare and education during the COVID-19 pandemic has enabled patients to consult with healthcare professionals through online medical platforms and students to continue their learning activities despite school closures.

These models of online and/or virtual healthcare and education services are expected to continue even after the pandemic ends. Similarly, COVID-19 may have also affected people's willingness to commute to work post-pandemic.

Therefore, investment in access to and quality improvements of ICT infrastructure can be considered an important factor, not only for the well-being of humans, but also for economic development. It is no surprise that rapid growth of ICT services is occurring all over the world, including in developing countries.

However, the provision of ICT services is unable to keep up with its growing demand partly due to challenges in obtaining financing for investment in ICT infrastructure. The Global Infrastructure Outlook database shows that for telecommunication infrastructure, the projected investment for Asia in 2040 is expected to reach $193 billion, while the projected investment (using the current trend) for the year is only $162 billion (Global Infrastructure Hub 2022). This means that the investment gap for the telecommunications sector in Asia is expected to reach more than $30 billion in 2040. The reason for this widening gap in ICT infrastructure investment is the same as that of other types of infrastructure, that is the inability of many governments, especially those of developing countries, to fully finance their infrastructure needs. Consequently, governments have been turning to the private sector for infrastructure investment. This has led to the use of partnerships between the public and the private sectors, commonly known as public–private partnerships (PPPs). The Asian Development Bank (ADB 2018, p. ix) defines a PPP as a

> long-term contractual arrangement between public (national, state, provincial, or local) and private entities through which the skills, assets, and/or financial resources of each of the public and private sectors are allocated in a complementary manner, thereby sharing the risks and rewards, to seek to provide optimal service delivery, and good value to citizens.

While PPPs have been adopted by many countries as a method to finance infrastructure investment, they also have their own sets of challenges. First, the construction of physical infrastructure is risky. If construction takes more time than previously anticipated or if costs exceed estimates, usually the private sector bears the burden. Second, even after the project is complete, failure can still occur if demand for the infrastructure turns out to be less than projected. PPP projects are usually implemented for public goods (such as roads, bridges, electricity, water, and ICT infrastructure) where users expect low fees. In contrast, the private sector is profit-oriented and may be in a position (by the PPP agreement) to raise fees to cover construction and operational costs. However, increasing fees, i.e., user charges, may lower consumer demand. This mismatch in the needs of consumers and investors could lead to the failure of PPPs.

Therefore, to ensure the success of PPPs, it is important to guarantee the private sector that their involvement in infrastructure investment will not lead to losses. This chapter points out that one way to create a steady stream of income for private sector investors without adding increased burden on the users (through imposing higher user charges or fees) is by sharing the increased tax revenues obtained by the local governments that benefitted from the newly built infrastructure. It is important to realize that infrastructure development creates spillover impacts in the region, meaning that the effects of infrastructure do not only benefit its direct users and investors, but also other parties that may be indirectly affected by the infrastructure. For example, building good quality infrastructure may lead to increased economic activities in the region, such as higher business growth and more employment, which lead to higher incomes, including that of the government, i.e., tax revenues (Yoshino et al. 2021; Yoshino and Truong 2020; Yoshino and Abidhadjaev 2015; Yoshino and Pontines 2015; Yoshino and Abidhadjaev 2017).

In this chapter, we highlight the lessons learned from the COVID-19 pandemic on the importance of ICT infrastructure. We also discuss the continuity of the growing needs of ICT infrastructure post-COVID-19. Having illustrated the growing importance of ICT infrastructure, we quantify the "spillover effects" of ICT services on tax revenues using a large-scale ICT infrastructure development program in India as a case study. In order to quantify the spillover effects of mobile networks on tax revenues, we use annual state-level data for 2005 to 2016 from India across all states (some states are merged together—we will discuss this in further detail in Section 1.6.2). The results of the fixed effects two-stage least squares (FE 2SLS) show that the rise in the number of mobile network subscribers is associated with an increase in tax revenues. Based on these results, we argue that in order to fill in the financing gap for the investment of infrastructure, the government should further incentivize participation from the private sector. Such support could be a massive one-time program, such as the Shared Mobile Infrastructure Scheme (SMIS) program covered in this chapter or something continuous that could create a steady stream of income for the investors. We propose to mobilize private investments in ICT infrastructure through the sharing of the increased tax revenues with those private sectors that invested in the ICT infrastructure through an increased rate of return.

The remaining sections of this chapter are structured as follows. In Section 1.2, we discuss the role of ICT during the COVID-19 pandemic. We provide a brief overview of the mobile phone coverage in India, as well as the SMIS program in Section 1.3. Section 1.4 provides an overview of taxation in India. Section 1.5 reviews literature on the spillover effects of ICT infrastructure. Section 1.6 discusses the data and methodology used in this study. Section 1.7 presents the results and discussion. Section 1.8 provides a policy proposal. Section 1.9 concludes and provides policy recommendations.

1.2 Role of ICT During the COVID-19 Pandemic

As previously discussed, the COVID-19 pandemic has shown us how the internet has become a critical aspect of our daily lives. Access to health-related information can reduce the spread of the coronavirus and save lives. ICT also enables us to work, study, shop, communicate, and access other important services despite restricted mobility. People are now able to perform numerous activities online in place of physical in-person activities, leading to the term "virtual mobility" (Mouratidis and Pappagiannakis 2021). This section discusses the role of the internet during this pandemic and how the current trends may continue post-COVID-19.

1.2.1 Telework

With the increasing restrictions placed on in-person activities since the beginning of the COVID-19 outbreak, more and more people are shifting their work that can be done virtually online rather than in-person. A large-scale survey by Ono and Mori (2021) in eight countries including Japan, the People's Republic of China (PRC), and the Republic of Korea found that there was a significant growth in the number of workers teleworking and that the growth was highly correlated with the respective national lockdown orders. In July 2020, 75% of the respondents in the urban areas of the PRC mentioned that they were working from home, with 35% of them having started teleworking before the pandemic began. On the other hand, in the same period, only 31% of the respondents in Japan said that they were teleworking and 22% started teleworking after the pandemic.

It is important to note that teleworking is not free from challenges. Poor internet connection, which leads to difficulties in communicating with colleagues during online meetings, can hinder productivity, especially in East Asian countries, which tend toward collectivism and place importance on agreement with others (Ono and Mori 2021).

Similarly, although the use of ICT for teleworking has been on a growing trajectory, there are still disparities on who is able to access ICT services. In the study by Ono and Mori (2021), the results of the survey in the PRC and the Republic of Korea are only representative of the urban population because internet access is concentrated in the urban areas of these two countries. Other studies have also shown the prevalence of digital inequality between countries, such as the significant difference between international bandwidth per internet user and the percentage of population connected to the internet between developed and developing countries. Similarly, digital inequality also exists within countries, such as between urban and rural regions and between people with higher and lower incomes (UNCTAD 2021).

1.2.2 E-Commerce

Although online shopping had been growing since before the pandemic, COVID-19 has amplified the use of e-commerce and accelerated digital transformation. The share of e-commerce in global retail trade went up from 14% in 2019 to 17% in 2020 (UNCTAD 2021). The findings of the survey by UNCTAD (2021) show that the rise in e-commerce is occurring across regions, with consumers in emerging economies making the largest shift to online shopping. For example, the online share of retail sales in the PRC jumped from 19.4% to 24.6% between August 2019 and August 2020. Similarly, a study by Google, Temasek, and Bain & Company (2021) shows that 80% of internet users in Southeast Asia have made at least one online purchase. Around 16% of digital consumers in Southeast Asia first started purchasing digital services from the beginning of the pandemic, with e-commerce, food delivery, and digital financial services being the most popular digital services. Just like teleworking that is expected to continue post-COVID-19, the adoption of digital services by consumers is also expected to persist after the pandemic ends.

Sonobe et al. (2021) also show that medium, small, and micro enterprises in eight developing countries in South Asia, Southeast Asia, and Northeast Asia have begun resorting to online marketplaces and using mobile message services and social media to sell their products. Azhgaliyeva et al. (2021) show that broadband internet access significantly impacts small and medium-sized enterprises and large firms on total sales and exports, using an enterprise survey from nine Central Asia Regional Economic Cooperation (CAREC) member countries (Afghanistan, Azerbaijan, Georgia, Kazakhstan, the Kyrgyz Republic, Mongolia, Pakistan, Tajikistan, and Uzbekistan) in 2008, 2009, and 2013. Using an enterprise survey from four CAREC member countries—Azerbaijan, Georgia, Kazakhstan, and Mongolia—in 2020 and 2021, Aseinov et al. (2022) show that firms with their own websites are more likely to have production adaptability due to the COVID-19 crisis.

It is important to highlight that the rise in digital services, including e-commerce and food delivery services, not only benefits consumers and large manufacturers, but also small merchants and casual workers, such as those in agriculture. With the emergence of e-commerce and other types of online marketplace, such as online marketing through social media, small businesses can reach customers that would not have been accessible without the help of the internet. The study by Google, Temasek, and Bain & Company (2021) shows that one-third of digital merchants in Southeast Asia believe that they would not have survived COVID-19 if not for digital platforms.

The benefits of ICT for businesses are more than just for online marketing and sales. Jensen (2007) shows that in the span of his research period, 1997–2001, fishers in Kerala, India used mobile phones to obtain information on market prices. This resulted in lower price dispersion, increased profits for the fishers, and a lower consumer price of the sardines being sold.

1.2.3 Online Educational Services

With the outbreak of COVID-19, many schools closed down and students were faced with no choice but to study from home. Fortunately, ICT has been helpful in aiding remote learning, enabling teachers and students to continue their learning activities despite school closures. The Asian Development Bank (ADB) (2021) showed that by April 2021, schools had been closed for at least 200 days since the pandemic began in 19 out of 46 economies in developing Asia. Most economies in developing Asia implemented partial closures, such as closing schools only in certain regions or for some grade levels. In some instances, schools have adopted a hybrid learning method by combining reduced class time with remote learning. A World Bank study (2021) showed that 91% of countries delivered remote learning through online media and 70% of countries also delivered remote learning through mobile phones.

Even before COVID-19, there was an upward trend in the adoption of virtual education technology, such as language-learning applications, virtual tutoring, video conferencing tools, and online learning software. However, the use of education technology surged even more during COVID-19 (Li and Lalani 2020). The growth in the popularity of education technology is not only limited to students enrolled in schools, but also for adult or optional learning. For example, the Bank of Japan and Financial Services Agency began a financial education and financial literacy program in November 2021. This educational program is free of charge and can be accessed by anyone with an internet connection. There is also an examination after the course and certificates are provided for students who have completed the course and examination.

Such types of free learning programs are also offered by other institutions, such as ADBI e-learning, which provides training courses on development in Asia and the Pacific and edX, which offers online courses on various topics from world-class universities such as the Massachusetts Institute of Technology and Harvard University. Online courses increase access to education for people who otherwise could not attend such training and/or classes, such as those living far from where the in-person training and/or courses are held or those who could not afford tuition and training fees. Therefore, it is clear that the availability of remote learning offers more people the opportunity to increase their skills and enhances human capital.

However, besides increasing the access to remote learning, the COVID-19 pandemic also highlights the inequality of internet access and necessary equipment, such as computers or smartphones. ADB (2021) shows that while 86% of households in high-income economies have internet access, the number drops to 41% for lower-middle-income economies. Within countries, as discussed previously, the number of households connected to the internet also varies between urban and rural regions.

The three points discussed above are examples of how ICT has proven to be critical in our daily lives, especially during the ongoing pandemic. Demand for telework, e-commerce, and online educational services is expected to continue post-COVID-19. Especially for telework, a survey by Ernst and Young (EY 2021) shows that only 4% of employees in Asia and the Pacific prefer to go back to fully working from the office post-pandemic, while 19% and 42% prefer hybrid work and fully remote work, respectively.

Therefore, increasing access to and quality of ICT services is of crucial importance, even after the pandemic ends. As previously discussed, many countries are still faced with challenges in providing equal access to ICT for its citizens. In the next section, we illustrate the effect of digital infrastructure, specifically mobile towers, on the amount of tax revenue collected by state governments in India. It is important to note that what we are estimating here is the short-term spillover effect of digital infrastructure. The long-term spillover effects, such as on human capital as illustrated by the e-learning points discussed above, is a subject for future research when data become available.

1.3 Mobile Phone Coverage and Shared Mobile Infrastructure Scheme in India

Since the late 1990s, the development of telecommunication infrastructure in India has been impressive. The robust growth in the ICT sector is primarily due to a progressive regulatory regime, a strong demand for telecommunication services, and robust economic growth. Overall telecom density has increased from about 1% in 1994, when the telecommunications sector was first heard of in India, to about 90% as of June 2018 (IBEF 2018). With a subscriber base of 1.17 billion, India's telecom market is the world's second largest and contributes significantly toward gross domestic product (GDP) growth and job creation (IBEF 2018).

Nevertheless, the growth in rural areas has lagged behind that of urban areas. This is a common pattern, as ICT infrastructure is often regarded as an industry driven by private capital with limited need for public sector participation (A4AI and World Wide Web Foundation 2018). Therefore, most of the development has focused primarily on the needs of the growing urban middle class, resulting in a widening digital divide between urban and rural areas. Extending access to connectivity in rural areas is a highly complex, multifaceted challenge. In addition to massive capital requirements for infrastructure investment, projects have extra layers of complexity tied to economics, government participation, and physical conditions, which may increase the hurdles, especially for rural areas (A4AI and World Wide Web Foundation 2018).

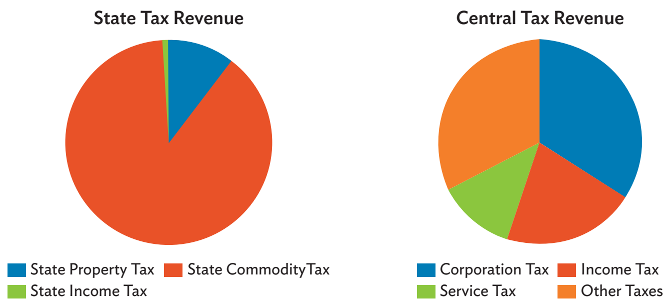
As a response to the lack of ICT infrastructure investment in rural areas, in 2007 the Indian government launched the SMIS program. Under the program, from 2007 to 2013, more than 7,353 mobile towers were constructed in 500 districts, spread throughout 27 states (see Appendix C). The scheme prioritizes villages or clusters of villages not covered by mobile or wireless services and with a population more than 2,000 (Gupta et. al. 2021). These towers covered a total of 170,821 villages that were previously not covered by mobile services. By the end of 2011, the total number of villages not covered by mobile services in India fell to 56,399. The mobile towers constructed were to be shared by multiple service providers for the provision of mobile services. Construction of the mobile towers began in 2007 and ended in 2010. Most of the towers were built between the second half of 2008 and the first half of 2009. Telecommunication operators that received government subsidies were responsible for the installation and maintenance of the towers between 2007 and 2013.

1.4 Taxation in India

In India, taxes are levied by state governments (state tax) and the central government (central tax). Taxes levied by state governments in India consist of sales and value added tax (VAT), property and capital gains tax, luxury tax, professional/employment tax, taxes on duties and electricity, etc. As shown in Figure 1.1, state tax revenues mainly consist of state tax on commodities and services, which consist of sales tax and VAT, vehicle tax, passenger tax, etc. The largest contributor of state tax on commodities and services are sales tax and VAT. On the other hand, taxes levied by the central government are comprised of more types of taxes compared to state taxes, for example corporation tax, which is the largest contributor, income tax, service tax, customs, duties, and wealth tax, among others.

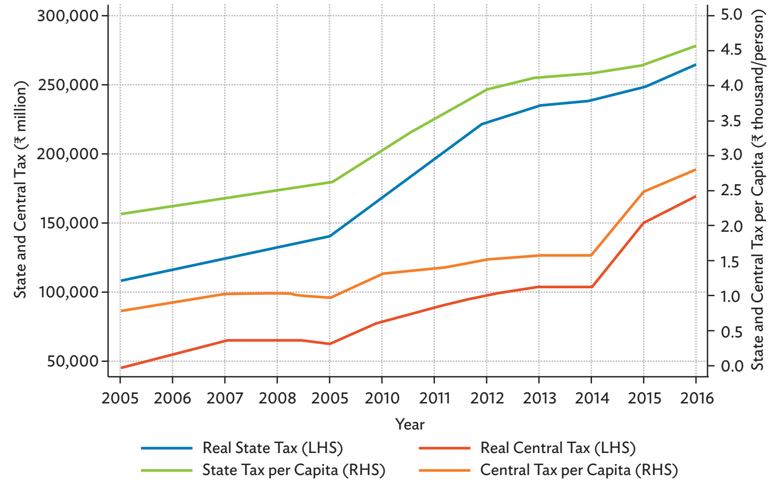
The amount of revenues received by the government from taxes are higher from state tax compared to that from central tax (Figure 1.2). In 2016, the average amount of state tax in 2004 prices collected by governments was ₹261.8 billion while for central tax the number was ₹170 billion. When taken by their per capita values, the average real state tax per capita in 2016 was ₹4.61 thousand while the average real central tax per capita was ₹2.8 thousand. Figure 1.2 also shows that both real state tax and real central tax revenues as well as their per capita values have upward trends, meaning that the Indian government has collected increasing tax revenues in 2005–2016.

Figure 1.1: State Tax Revenue and Central Tax Revenue Composition, 2005–2016



Source: Reserve Bank of India, State Finances: A Study of Budgets.

Figure 1.2: Real State Tax, Real Central Tax, Real State Tax per Capita, and Real Central Tax per Capita



LHS = left-hand scale, RHS = right-hand scale.

Note: Average tax revenues for all states in 2005–2016. All values are in constant 2004 prices.

Source: Reserve Bank of India, modified by authors.

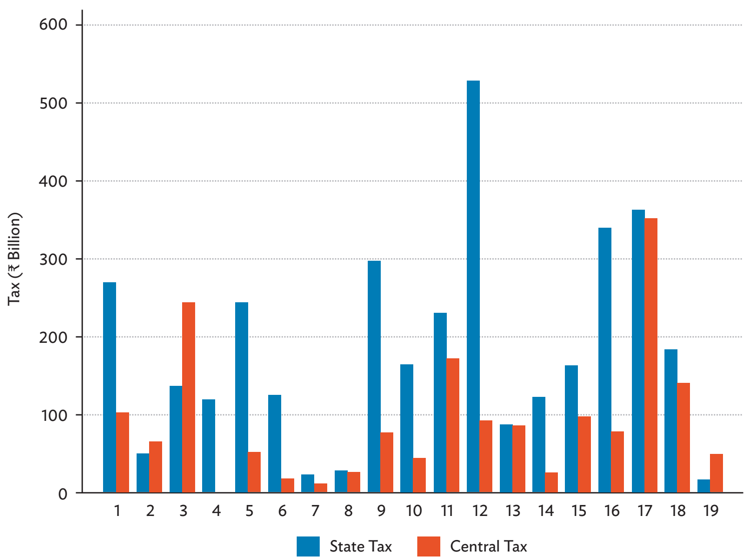
When divided by states (Figure 1.3), it is clear that the highest and lowest earning states differ based on the type of tax revenues (state and central tax revenues). For example, the largest amount of state tax revenues collected was in the states of Maharashtra, Goa, Dadra and Nagar Haveli, and Daman and Diu (State ID 12), while the smallest was in the northeastern region (State ID 19). On the other hand, the states with the largest share of central tax revenues were Uttar Pradesh and Uttaranchal combined (State ID 17).[1]

An important point to ensure that we obtain reliable estimates when using tax data is that the Indian tax structure did not undergo significant changes in the period of study. The consistency of the tax policy within our period of study is imperative for us to obtain reliable estimation results. Near our period of study, there were two major reforms that occurred in the Indian tax structure. The first was in 2005

[1] Due to data limitation, some states in this study are combined/merged together.

when the government made a sales tax reform in the form of VAT. The second occurred in 2017 when the government introduced the goods and services tax (GST) policy. No major reforms in the Indian taxation system occurred within our period of study of 2005–2016. However, many states adopted mandatory online tax filing in 2010–2014, which may have increased compliance and affected tax revenues. In order to control for this, we include year dummies as explained in Section 1.6 (Data and Methodology).

Figure 1.3: State and Central Tax Revenues, Average 2005–2016 (Constant Price 2004)



Notes: 1: Andhra Pradesh and Telangana; 2: Assam; 3: Bihar and Jharkhand; 4: National Capital Territory of Delhi; 5: Gujarat; 6: Haryana; 7: Himachal Pradesh; 8: northern region; 9: Karnataka; 10: Kerala; 11: Madhya Pradesh and Chhattisgarh; 12: Maharashtra, Goa, Dadra and Nagar Haveli, and Daman and Diu; 13: Odisha*;14: Punjab; 15: Rajasthan; 16: Tamil Nadu and Puducherry; 17: Uttar Pradesh and Uttaranchal; 18: West Bengal and Sikkim; 19: northeastern region. Note that the capital territory of Delhi has no central tax revenue.

* In 2011, the Government of India approved the name change of the State of Orissa to Odisha. This document reflects this change. However, when reference is made to policies that predate the name change, the formal name Orissa is retained.

Source: Authors' calculations using data from Reserve Bank of India.

1.5 Literature Review: ICT Infrastructure Spillover Effects

Numerous studies have examined the effects of ICT infrastructure on the economies of various countries. Several studies examining cross-country comparisons between European countries (Madden and Savage 1998) and among OECD countries (Roller and Waverman 2001; Datta and Agarwal 2004) concluded that investment in telecommunication infrastructure is associated with higher economic growth. As for the case of India, Erumban and Das (2016) show the increasing role of investment in the ICT sector in driving aggregate economic growth in India, although the growth is largely limited to the service sector. For the mechanism, Sarangi and Pradhan (2020) show that ICT infrastructure can lead to a decrease in the costs of transactions, enrich market information, accelerate knowledge diffusion, enhance the quality of decision making, and augment productivity, all eventually increasing economic growth.

As for the spillover effects of infrastructure on tax revenues, many have focused on non-ICT infrastructure. Yoshino and Abidhadjaev (2017) estimated the effects of the construction and operation of the Kyushu (Japan) high-speed rail line on total tax revenues and personal income tax revenues. The findings show that prefectures affected by the Kyushu high-speed railway have higher tax revenues (both total and personal income tax) compared to prefectures that are not affected by the railway. Once the Kyushu high-speed railway was connected to another existing high-speed railway line, thereby increasing access to other prefectures, tax revenues in the region where the rail line was located and in adjacent prefectures, as well as prefectures along the connected high-speed railway line, increased significantly compared to unaffected regions. The spillover effects from railways, airports, and roads in Central Asia are provided in Yoshino, Huang, Azhgaliyeva, and Abbas (2021).

This chapter fills the gap in the literature by estimating the spillover effects of ICT infrastructure on tax revenue. It is important to provide evidence for ICT infrastructure because spillover effects vary by type of infrastructure (Azhgaliyeva and Kalyuzhnova 2021).

1.6 Data and Methodology

1.6.1 Theoretical Model of Spillover Effects Created by ICT Infrastructure

Based on the literature review presented in section 1.5, it is clear that infrastructure, including ICT infrastructure, not only has a direct effect on its users and providers but also an indirect effect on other aspects of the economy, such as GDP growth and tax revenues. Due to lack of data on central tax revenues, in this study we only focus on state tax per capita.

We argue that a plausible way for ICT infrastructure to affect state tax revenues is through increased economic activities in the state, which may result in increased consumption. This will eventually push up tax revenues collected by the state governments. As previously mentioned, the largest contributors of state tax revenues are sales tax and VAT. Thus, higher economic activities, such as increased sales of goods and services in a region may lead to increased state tax revenues.

The hypothesis on the effects of ICT infrastructure on increased economic activities is supported by other studies that found similar effects. Fabritz (2013) finds an overall positive relationship between local employment and local broadband infrastructure in Germany. The effects are larger in rural municipalities. Falck, Mazat, and Stockinger (2016) also find evidence of the positive effect of broadband infrastructure on the number of startup establishments, especially in rural areas, indicating that ICT infrastructure affects job growth. Another study shows that increased broadband infrastructure is associated with a significant increase in annual sales turnover and an increase in value-added (Canzian, Poy, and Schüller 2015).

1.6.2 Data

In order to estimate the effects of ICT infrastructure on tax revenues, we use annual state-level data from 2005 to 2016 from India. India has 28 states and eight union territories. However, due to data limitation especially on the number of Global System for Mobile communication (GSM) subscribers, we merged some smaller and/or newer states with originating states, resulting in a total number of 19 states (see Table A.1 for details of the states and union territories used in this chapter).

The data used in this chapter are collected from the following sources. Data on tax revenues were downloaded from the Reserve Bank of India. To take into account the effects of inflation, we use tax data at constant 2004 prices. We also consider population growth to be a factor that may cause the rise in tax revenue, regional domestic product

(RDP), and GSM subscribers, so this chapter consistently uses per capita terms. Data on RDP were collected from the Indian Central Statistics Office. Similar to tax data, we also use RDP per capita at constant 2004 prices, while data on the number of GSM subscribers were collected from the Cellular Operators Association of India.[2] We also control for capital per capita, and the number of persons engaged in industry work as these variables may affect RDP and tax revenues. We divided the number of GSM subscribers per state by the number of population in that state to obtain per capita values. For simplicity, we will refer to this as the GSM penetration rate and GSM per capita.

Table 1.1 provides the definitions of each variable used in this study. Table 1.2 presents the summary statistics of the data. Note that data on the breakdown of central taxes (corporation tax, income tax, and service tax), are only available from 2006. Therefore, the number of observations differ between state tax revenues and central tax revenues. It is also important to note that data on the actual tax revenues for 2016 are not published on the Reserve Bank of India's webpage. Therefore, instead of the actual tax revenues, we use the revised estimates for 2016.

Table 1.1: Data Sources and Definition of Variables

Variable	Data Source	Definition
State tax revenue (total) per capita	Reserve Bank of India	Revenues collected by the state governments from taxes divided by state population
State tax revenue on property and capital transactions per capita	Reserve Bank of India	Revenues collected by the state governments from tax on property and capital transaction divided by state population. This includes property tax, stamps, and registration fees, etc.
State tax revenue on commodities and services per capita	Reserve Bank of India	Revenues collected by the state governments from tax on commodities and services divided by state population. This includes sales tax/VAT, taxes on vehicles, taxes on electricity, etc.
GSM subscribers per capita	Cellular Operators Association of India	Number of GSM subscribers divided by state population

continued on next page

2 Because the SMIS program focused on rural areas, a more appropriate variable would have been the number of GSM subscribers in rural areas instead of the total number of GSM subscribers (in rural and urban areas). However, we were unable to find data on the number of GSM subscribers in rural areas broken down by states prior to 2008.

Table 1.1 *continued*

Variable	Data Source	Definition
RDP per capita	Indian Central of Statistics Office	Regional (state) domestic product at current prices divided by state population
Population	Office of the Registrar General and Census Commissioner, India	2001 and 2011 population census and population projection
Productive capital per capita	Reserve Bank of India	Total of fixed capital and working capital divided by state population
Persons engaged in industry	Reserve Bank of India	Employees and workers (who are paid and unpaid) who are actively engaged in work in industry divided by state population
Time fixed effects	–	Time fixed effects used to control for year-specific characteristics
State fixed effects	–	Fixed effects used to control for state-specific characteristics

GSM = Global System for Mobile communications, RDP = regional domestic product, VAT = value added tax.

Source: Various sources, please see data source noted in column 2 of the table.

Table 1.2: Summary Statistics

Variable (Annual, State-level)	Units	Obs.	Mean	Std. Dev.	Min	Max
GSM subscribers per capita		228	0.454	0.325	0.015	1.997
Real regional domestic product (RDP) per capita	₹ thousand	228	46.989	23.253	11.372	137.393
State tax revenue						
Real total state tax revenue per capita	₹ thousand	228	3.180	1.798	0.512	8.314
Real state tax on property and capital gains per capita	₹ thousand	228	0.349	0.251	0.025	1.101
Real state tax on commodities and services per capita	₹ thousand	228	2.800	1.599	0.456	7.358
Productive capital per capita	₹ thousand	228	20.903	20.465	0.584	101.241
Persons engaged in industry	₹ thousand	228	652.272	592.092	28.385	2,455.010

GSM = Global System for Mobile communications.

Source: Various sources. Refer to Table 1.1.

1.6.3 Estimation Strategy

We would prefer to conduct a difference-in-difference (DID) analysis with the construction of new mobile towers as the region treatment group to estimate the causal effects of a certain policy or program; however, it is not feasible with our data set. The DID method has been employed in numerous studies investigating the effects of infrastructure investment (Yoshino and Truong 2020, Yoshino and Abidhadjaev 2017, Yoshino et al. 2021, and Yoshino and Pontines 2015). However, because the smallest administrative (geographical) unit for tax revenues is "states," and all states in India already had mobile towers at the beginning of the period of this study, we are unable to identify "treatment and control groups" for this study (because all states have received treatment). Therefore, we employ another approach to estimate the effects of GSM subscribers on tax revenues. Our estimation method is as follows.

First, we calculate the actual growth in the number of GSM subscribers per capita and tax revenues per capita throughout our period of study. For the purpose of illustration in Figure 1.4, we use total state tax revenue per capita. However, for the actual calculation, we will estimate the effects of the number of GSM subscribers per capita on different types of taxes, as broken down in Table 1.2. In Figure 1.4, the number of GSM subscribers per capita is shown by the solid blue line while total state tax revenue per capita is shown by the solid red line. Second, we estimate what the number of GSM subscribers per capita (dashed blue line) and total state tax revenues per capita (dashed red line) would have been if the number of GSM subscribers per capita and tax revenues per capita did not increase substantially due to the introduction of the SMIS program. In other words, we estimate the number of GSM subscribers per capita and the amount of state tax revenues per capita collected for 2007–2015 using the slope obtained from the estimation for 2005–2007. Third, we calculate the difference in the number of GSM subscribers per capita from the predicted value (ΔGSM) and the difference in the actual state tax revenues per capita collected by the government from its predicted value (ΔTax). Finally, we estimate whether ΔGSM has a significant effect on ΔTax. As previously mentioned, we also included capital per capita and the number of persons engaged in industry.

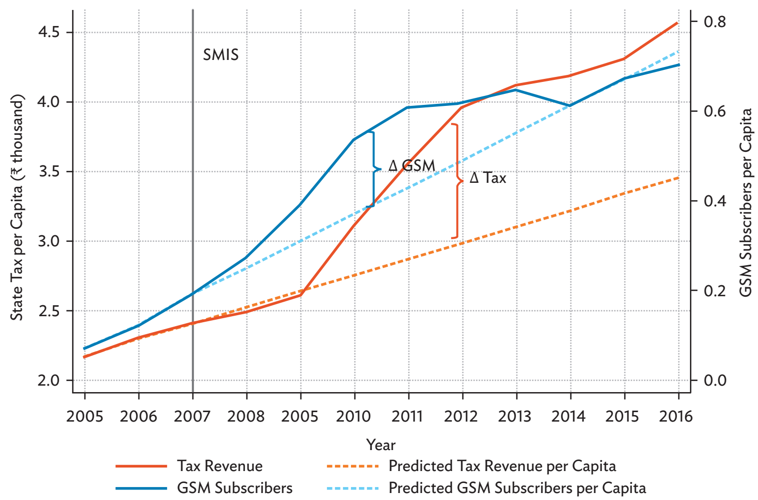
Specifically, the model that we estimate is as follows:

$$\begin{aligned}\Delta Tax\ per\ capita_{it} &= \propto_0 + \propto_1 \Delta Subscribers\ per\ capita_{it} \\ &+ \propto_2 \Delta Productive\ Capital\ per\ capita_{it} \\ &+ \propto_3 \Delta Persons\ engaged\ in\ industry_{it} + v_i + \delta_t + u_{it}, \qquad (1)\end{aligned}$$

Where:
Tax per capita$_{it}$ = the amount of tax revenue per capita in state *i* at time *t*,
Subscribers per capita$_{it}$ = the number of subscribers per capita at state *i* and time *t*,
Productive capital per capita = total of fixed capital and working capital per capita,
Persons engaged in industry$_{it}$ = employees and workers (who are paid and unpaid) who are actively engaged in industry work in state *i* and time *t*, and
v_i and δ_t = a set of state and time fixed effects.

Therefore, we are essentially estimating the effect of increase in the number of subscribers on the increase in tax revenues while controlling for capital, labor, time fixed effects and state fixed effects. We first analyze Equation 1 through a simple fixed effects estimator.

Figure 1.4: Actual and Predicted Values of GSM subscribers and Total State Tax Revenue



GSM = Global System for Mobile communications, SMIS = Shared Mobile Infrastructure Scheme.

Note: The figures above are averages of all states for each year. State tax revenue per capita is in thousand rupees and is shown by the left axis. GSM subscribers per capita are shown by the right axis. The data for this figure are given in Table A2.

Source: Authors' calculations based on data from Reserve Bank of India and Cellular Operators Association of India (refer to Table 1.1).

However, as discussed in Section 1.6.1, the process in which the number of mobile network subscribers affects tax revenue may be through increases in economic activity which are reflected in regional GDP (RDP). Therefore, we also analyze a 2SLS model (Equation 2 and Equation 3). Furthermore, because RDP is possibly endogenously determined with tax revenues, instrumenting it is necessary. We use subscribers per capita, productive capital per capita, and the number of persons engaged in industry as the instruments. We test for the exogeneity of RDP through an augmented regression test (Durbin–Wu–Hausman test) as outlined in Wooldridge (2010) and find that we could reject the null hypothesis of exogeneity (Appendix B.1). We also test whether RDP and subscribers per capita are endogenous and found evidence of exogeneity at the 10% significance level (Appendix B.2).

First stage:

$$\begin{aligned} \Delta GDP\ per\ capita_{it} = {} & \beta_0 + \beta_1 \Delta Subscribers\ per\ capita_{it} \\ & + \beta_2 \Delta Productive\ Capital\ per\ capita_{it} \\ & + \beta_3 \Delta Persons\ engaged\ in\ industry_{it} + v_i + \delta_t + u_{it} \end{aligned} \quad (2)$$

Second stage:

$$\Delta Tax\ per\ capita_{it} = \propto_0 + \propto_1\ \Delta GDP\ \widehat{per\ capita}_{it} + v_i + \delta_t + u_{it} \quad (3)$$

In selecting whether to use the random effects model or the fixed effects model, we use the Mundlak approach outlined in Wooldridge (2010) and found that the FE 2SLS is preferred for state tax revenue per capita equation. Results of this diagnostic test are presented in Appendix B.3 and Appendix B.4.

To be able to infer that the increase in tax revenues is a result of the implementation of the SMIS program, we have to verify that the rise in the number of GSM subscribers is due to the construction and operation of mobile towers during the years of the SMIS program rollout. Therefore, we regressed the number of GSM subscribers on a set of fixed effects while also controlling for RDP per capita and population, all of which could contribute to the number of GSM subscribers in a state. Based on the results (Appendix B.5), we find that the number of GSM subscribers increased in the years 2008–2012, with the largest increase in 2009, which is when the greatest number of towers were built (Apoorv, Ponticelli, and Tesei 2021). This suggests that the SMIS program was a significant factor in the rise of mobile (GSM) users in 2008–2012.

1.7 Results and Discussion

In this section, we discuss the estimation results of Equations 1 to 3. The discussion is divided into two parts based on the estimation method used: fixed effects and two stage least squares. We estimate the effects of the number of GSM subscribers on different types of taxes to see whether the effects are similar or different across sectors.

1.7.1 Fixed Effects Estimation Results

Table 1.3 shows the results of our simple fixed effects estimation. The results show that the number of GSM subscribers per capita has a positive and significant effect on tax revenues per capita: on total state tax revenues per capita, state property tax revenue per capita, and state commodity tax revenue per capita.

The estimates show that an increase in the number of GSM subscribers per capita by 10 percentage points is expected to raise total state tax revenue per capita by ₹134 (approximately $2 at the time of

Table 1.3: Fixed Effects Estimation Results, State Tax Revenue per Capita

	State Tax per Capita	State Property Tax per Capita	State Commodity Tax per Capita
GSM subscribers per capita	1.340***	0.391***	0.949***
	(0.280)	(0.0527)	(0.261)
Productive capital per capita	0.013**	0.001	0.0124*
	(0.006)	(0.001)	(0.006)
Number of persons engaged in industry	0.001	0.0003**	0.0006
	(0.001)	(0.0001)	(0.001)
Constant	−0.012	−0.003	−0.033
	(0.071)	(0.016)	(0.072)
Observations	190	190	190
R-squared (within)	0.358	0.68	0.365

GSM = Global System for Mobile communications.

Note: * $p<0.05$, ** $p<0.01$, *** $p<0.001$. Standard errors are in parentheses and are clustered at the state level. State fixed effects and time fixed effects are included in the estimation.

Source: Authors' calculations.

writing this article or 3% of the average state tax per capita in 2016). When divided by the type of taxes, that amount constitutes a raise of ₹39 in state commodity tax per capita, and ₹95 in state property tax per capita.

The mechanism on how the number of GSM subscribers may affect tax revenues is further explained by the 2SLS regression estimation results in section 1.7.2.

1.7.2 2SLS Estimation Results

The estimation results are given in Table 1.4 (first stage) and Table 1.5 (second stage). In the first stage, we find that a state's RDP per capita is significantly affected by the number of GSM subscribers per capita in that state. The estimate can be interpreted as follows. An increase in GSM subscribers' penetration rate by one percentage point is expected to increase RDP per capita by ₹306.18 or 0.5% of the average RDP per capita in 2016. The positive effect of the number of GSM subscribers on RDP is in line with the findings of other studies, such as the International Telecommunication Union (ITU) (2019), which found that in the Asia and Pacific region, an increase in the penetration rate of mobile broadband subscribers of 10% is expected to raise GDP per capita by 0.51%.

Table 1.4: Estimation Results, State Tax Revenue – First Stage

	RDP per Capita
GSM subscribers per capita	30.618***
	(4.993)
Productive capital per capita	0.127
	(0.089)
Number of persons engaged in industry	0.004
	(0.007)
Constant	–0.095
	(0.761)
Observations	190

GSM = Global System for Mobile communications, RDP = regional domestic product.

Note: ***: p-value<0.01, **: p-value<0.05, *: p-value<0.1. Standard errors are in parentheses and are clustered at the state level. State fixed effects and time fixed effects are included in the estimation.

Source: Authors' calculations.

Results from the second stage, which is our main estimation result of interest, show that the increase in RDP that is attributed to the effects of the rise in the number of GSM subscribers is positively associated with the change in state tax revenues. This result is significant at the 1% level of statistical significance (strongly significant) (Table 1.5). The coefficient of 0.0502 means that, on average, an increase in the number of RDP per capita by ₹10 thousand is expected to raise total state tax per capita by ₹502 or 12.5% of the average state tax per capita in 2016. When broken down by the type of taxes, this increase in total state tax revenue is comprised of a ₹132 increase in state commodity tax per capita, a ₹370 increase in state property tax per capita, and the remaining as an increase in state income tax per capita.

Table 1.5: Estimation Results, State Tax Revenue – Second Stage

	State Tax (Total) per Capita	State Property Tax per Capita	State Commodity Tax per Capita
RDP per capita	0.0502***	0.0132***	0.0370***
	(0.0138)	(0.00230)	(0.0132)
Constant	−0.0133	−0.00351	−0.0332
	(0.0743)	(0.0235)	(0.0672)
Observations	190	190	190

RDP = regional domestic product.

Note: ***: p-value<0.01, **: p-value<0.05, *: p-value<0.1. Standard errors are in parentheses and are clustered at the state level. State fixed effects and time fixed effects are included in the estimation.

Source: Authors' calculations.

The results of the first and second stages of the 2SLS estimation combined indicate the presence of spillover effects from the number of subscribers on the amount of state tax revenues collected through increases in the RDP. This indicates that the RDP, which is positively affected by increased access to mobile services brought by the SMIS program, has a positive effect on the determinants of state tax collection: consumption/sales of goods; land and buildings; and employment, among others.

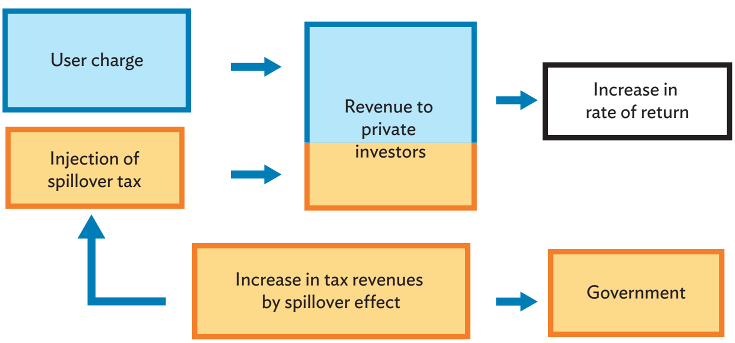
1.8 Proposal

Going back to our main argument, which is to propose a method of financing ICT infrastructure, our results suggest that state governments have an increased revenue due to the development of such infrastructure.

More specifically, an increase in the mobile (GSM) penetration rate by 10 percentage points is expected to raise state tax revenue per capita by ₹134. The mechanism in how the number of GSM subscribers affects tax revenues is through increases in economic activities, as reflected in its positive and significant effect on RDP (as shown by our 2SLS estimation results).

One way to ensure that the private sector remains attracted to infrastructure development is to provide a steady stream of income for them. We argue that that could be achieved by sharing the spillover effects of ICT infrastructure on taxes obtained by the government with the investors/operators of the infrastructure. Figure 1.5 illustrates this scheme. The orange "increase in tax revenues by spillover effect" box shows the increased tax revenues resulting from the spillover effects of infrastructure that was previously only absorbed by the government. However, if the government shares the increased tax revenues with the investors, the revenues of the investors will increase from only user charges (blue box) to user charges and injection of spillover tax (as shown by the "revenue to private investors" box in blue and orange), thus increasing the rate of return to investors.

Figure 1.5: Spillover Tax Revenues Increase the Rate of Return of Investors



Note: State tax per capita: ₹134 (3% average state tax per capita in 2016) (assuming 10 percentage points additional Global System for Mobile communications penetration rate).

Source: Yoshino et. al. (2019).

1.9 Conclusion and Policy Recommendations

In this chapter, we argue that the ongoing COVID-19 pandemic highlights the importance of ICT infrastructure, not only for the economy, but also for human welfare, such as through better health and education services. However, the development of ICT infrastructure faces hurdles, mostly due to the widening investment gap for construction. Moreover, rural and less-developed areas have also been disproportionately affected, as ICT infrastructure has mostly been developed by the private sector, leading to infrastructure being concentrated mostly in urban areas where it is more profitable for investors compared to rural areas.

An important way to fill in the investment gap is to ensure the private sector remains attracted to infrastructure projects by guaranteeing that these projects will be profitable. This chapter proposes sharing the tax revenues collected by the government as a result of infrastructure development in the area with the private sector.

We quantify the spillover effects of mobile network to tax revenues, using annual state-level data for 2005 to 2016 from India across all states. We show that for the case of India, a large-scale mobile tower construction program has increased the number of mobile network subscribers. Using a simple FE estimation and an FE 2SLS estimation, we show that the rise in the number of mobile network subscribers is associated with the increase in the amount of regional tax revenues collected by state governments. On average, an increase in the number of GSM subscribers by 10 percentage points is expected to raise regional state revenues by ₹134 or roughly 3% of the average state tax per capita in 2016. The results indicate that the development of mobile towers, as reflected in the rise in the number of GSM subscribers, increases tax revenues. The results support our proposal to create a steady stream of income for investors by sharing the spillover tax revenues with the investors, thus making infrastructure projects more attractive for investments. Moreover, the findings of this chapter also support the national budget of India for 2022–2023, which places emphasis on the investment of both digital and physical infrastructure.

Although the findings of this study are important, there are certain limitations to it. First, the amount of data collected is relatively small. Despite doing this to maintain consistency in the measurement and determinants of tax (we wish to avoid years where tax policies had undergone changes), the results would have been more robust if we could have collected more data, perhaps by not merging some states due to limited data, as we have done in this chapter.

Second, as previously mentioned, a more suitable variable to be used in our estimation would have been the number of GSM subscribers in rural areas. This is because the SMIS program specifically built mobile towers in rural areas where there was no prior mobile connection. However, we were unable to obtain data on the number of GSM subscribers in rural areas. Similarly, a more viable approach to test the spillover effects of the SMIS would have been to compare areas where the towers were built with those where there were no new towers built. This is especially important because the building of the towers occurred at different times depending on each location. Unfortunately, again, the lack of data available made it difficult for us to conduct such estimations.

Third, in this chapter, we argue that the mechanism of how the number of GSM subscribers affect tax revenue is through increased economic activity. Although we believe that this is true, "economic activities" as presented in this study by RDP, is somewhat vague. More interesting results could have been obtained if we use more concrete variables to represent "economic activities," such as number of business establishments, but the data were not available.

Finally, it is also important to note that what we are showing here is the short-term spillover effects of ICT infrastructure. We also expect there to be long-term spillover effects such as on human capital (brought about by increased access to education and information). However, this is a subject for future research.

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Appendix A: Data

Table A.1: State IDs and State Names

State ID	States and Territories
1	Andhra Pradesh and Telangana
2	Assam
3	Bihar and Jharkhand
4	Delhi
5	Gujarat
6	Haryana
7	Himachal Pradesh
8	northern India (union territory)
9	Karnataka
10	Kerala
11	Madhya Pradesh and Chhattisgarh
12	Maharashtra, Goa, Dadra and Nagar Haveli, and Daman and Diu
13	Odisha*
14	Punjab and Chandigarh
15	Rajasthan
16	Tamil Nadu and Puducherry
17	Uttar Pradesh and Uttaranchal
18	West Bengal, Sikkim, and Andaman and Nicobar Islands
19	northeastern regions

* In 2011, the Government of India approved the name change of the State of Orissa to Odisha. This document reflects this change. However, when reference is made to policies that predate the name change, the formal name Orissa is retained.

Source: Authors' classification of Indian states based on data availability.

Table A.2: Difference between Actual and Predicted Tax and GSM Subscribers

Year	State Tax per Capita (1)	GSM Subscribers per Capita (2)	Predicted State Tax per Capita (3)	Predicted GSM Subscribers per Capita (4)	Difference between Actual and Predicted State Tax per Capita (5) = (1) – (3)	Difference between Actual and Predicted GSM Subscribers per Capita (6) = (2) – (4)
2005	2.23818	0.071326	NA	NA	NA	NA
2006	2.449727	0.122942	NA	NA	NA	NA
2007	2.573503	0.192148	2.588131	0.189216	−0.01463	0.002932
2008	2.601531	0.272945	2.755793	0.249627	−0.15426	0.023317
2009	2.698529	0.389086	2.923454	0.310039	−0.22493	0.079048
2010	3.129462	0.536891	3.091116	0.37045	0.038346	0.166441
2011	3.451006	0.610411	3.258777	0.430861	0.192229	0.17955
2012	3.764293	0.616969	3.426439	0.491272	0.337854	0.125697
2013	3.763919	0.648749	3.5941	0.551683	0.169819	0.097066
2014	3.718641	0.615819	3.761761	0.612094	−0.04312	0.003725
2015	3.783324	0.67121	3.929423	0.672505	−0.1461	−0.0013
2016	3.993652	0.704047	4.097084	0.732916	−0.10343	−0.02887

GSM = Global System for Mobile communications, NA = not available.

Note: Predicted Tax per capita is the predicted amount of tax revenues per capita that would have been collected without the SMIS program. Predicted GSM Subscribers per capita is the predicted amount of people that would have been GSM subscribers per capita without the SMIS program.

Source: Authors' calculations.

Table A1.3: Correlation Matrix of Independent Variables

	GSM Subscribers per Capita	Productive Capital per Capita	No. of Persons Engaged in Industry
GSM subscribers per capita	1		
Productive capital per capita	0.561	1	
No. of persons engaged in industry	−0.0006	0.3237	1

GSM = Global System for Mobile Communications.

Source: Authors' calculations.

Appendix B: Diagnostic Test Results

Appendix B.1: Endogeneity Test of RDP per Capita

	State Tax per Capita
RDP on GSM subscribers	
GSM subscribers	76.11225
	(0.000)
Tax per capita on RDP and residuals from (1)	
RDP per capita	0.0513
	(0.000)
Residuals	0.0074
	(0.0949)
	Endogenous

GSM = Global System for Mobile communications, RDP = regional domestic product.

Note: p-values are in parentheses.

Source: Authors' calculations.

Appendix B.2: Endogeneity Test of GSM Subscribers per Capita

	State Tax per Capita
GSM subscribers per capita on population	
Population	−6.05e-06
	(0.015)
State tax per capita on GSM Subscribers and residuals from (1)	
GSM Subscribers	4.063995
	(0.064)
Residuals	−3.038515
	(0.206)
	Exogenous

GSM = Global System for Mobile Communications, RDP = regional domestic product.

Note: p-values are in parentheses.

Source: Authors' calculations.

Appendix B.3: Fixed Effect vs Random Effect (Equation 1)

	State Tax
Chi-squared	68.82
p-value	0.0000
Preferred model	Fixed Effect

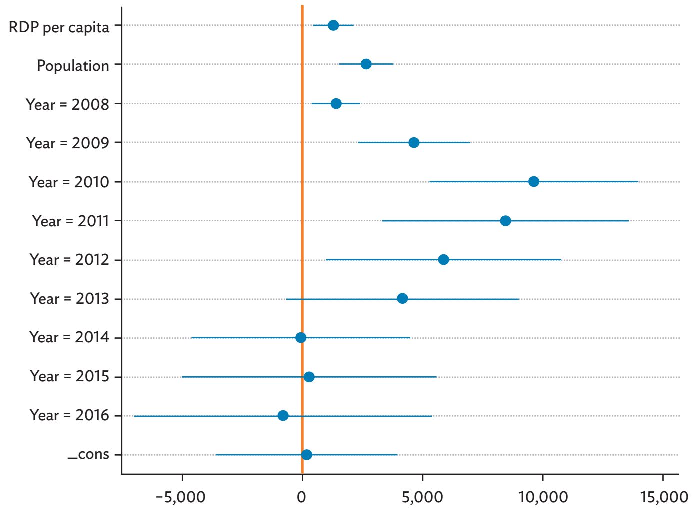
Source: Authors' calculations.

Appendix B.4: Fixed Effect vs Random Effect (2SLS)

	State Tax
Chi-squared	13.58
p-value	0.0088
Preferred model	Fixed Effects

Source: Authors' calculations.

Appendix B.5: Coefficient Plot on the Regression of the Number of GSM Subscribers on RDP per Capita and Population



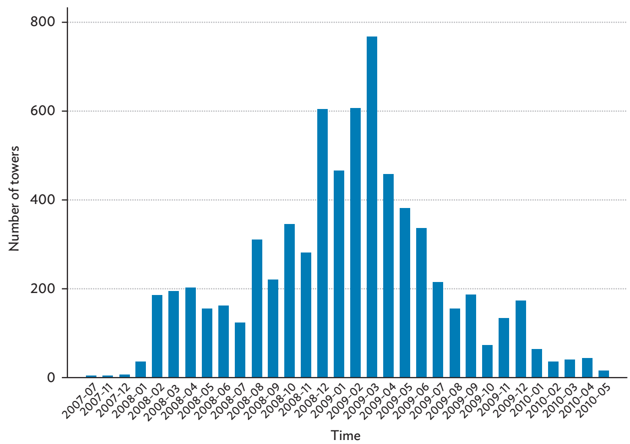
GSM = Global System for Mobile communications, RDP = regional domestic product.

Note: This figure plots the coefficients shown in Table 1.3 along with their time dummies. The lines represent a 90% confidence interval.

Source: Authors' calculations.

Appendix C: GSM Subscribers

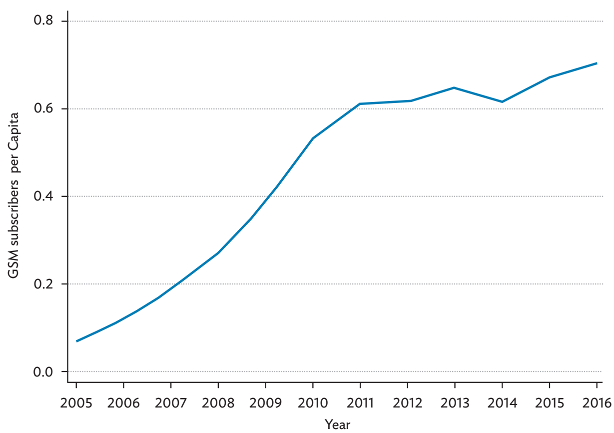
Figure C1: Shared Mobile Infrastructure Scheme (SMIS) in India



GSM = Global System for Mobile communications.

Source: Gupta et al. (2021).

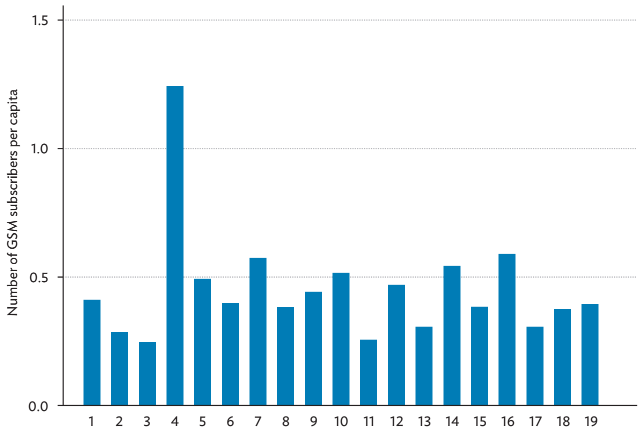
Figure C2: Number of GSM Subscribers by Year (average of all states)



GSM = Global System for Mobile communications.

Source: Authors, based on data from the Cellular Operators Association of India.

Figure C3: GSM Subscribers by State (average 2005–2016)



Note: 1: Andhra Pradesh and Telangana; 2: Assam; 3: Bihar and Jharkhand; 4: National Capital Territory of Delhi; 5: Gujarat; 6: Haryana; 7: Himachal Pradesh; 8: northern India; 9: Karnataka; 10: Kerala; 11: Madhya Pradesh and Chhattisgarh; 12: Maharashtra, Goa, Dadra and Nagar Haveli, and Daman and Diu; 13: Odisha;*; 14: Punjab; 15: Rajasthan; 16: Tamil Nadu and Puducherry; 17: Uttar Pradesh and Uttaranchal; 18: West Bengal and Sikkim; 19: north east. Note that the capital territory of Delhi has no central tax revenue.

* In 2011, the Government of India approved the name change of the State of Orissa to Odisha. This document reflects this change. However, when reference is made to policies that predate the name change, the formal name Orissa is retained.

Source: Authors' calculations using data from the Cellular Operators Association of India.

2

ICT and Labor Mobility: Online Search and Prediction of Remittances in the Kyrgyz Republic

David Roland-Holst, Kamalbek Karymshakov, Burulcha Sulaymanova, and Kadyrbek Sultakeev

2.1 Introduction

Infrastructure has always been a fundamental driver of long-term economic growth, but in recent decades information and communications technology (ICT) has supported and accelerated the growth of the global economy in ways beyond the imagining of our ancestors. In contrast to traditional transportation infrastructure, the deployment of ICT infrastructure has facilitated pervasive information exchange, which, along with other social and economic implications, has had important impacts on labor mobility (Hartje and Hübler 2017; McAuliffe 2018; Leng et al. 2020; Kotyrlo 2020). This study uses new data sources to better identify and measure the economic contributions of ICT, focusing on how it facilitates labor market access and efficiency.

The mobility of the labor force is often analyzed using administrative and survey data. In the context of remittances, this has recently been exemplified by Yoshino, Taghizadeh-Hesary, and Otsuka (2020), who use panel data from long-established migrant senders to reveal "life cycle" transition developing country access to external capital, from early reliance on migrant remittances to later hosting of foreign direct investment. In the majority of developing countries, however, the lack of administrative records and survey data can be a serious constraint to this kind of analysis. Today, accelerating ICT and access to the internet provides expanded opportunities to fill the information gap in migrant labor dynamics (Kozachenko 2013; Kotyrlo 2020). ICT is widely used by migrants to send remittances, to obtain information about migration, for travel details, and for everyday contact with families left behind. In all these ways, ICT infrastructure facilitates migration and remittance flows and provides the opportunity to disseminate information among both potential and current migrants.

Along with the widespread use of information technology and internet access, new sources for measuring migration and remittances have emerged. Online search data represent an important opportunity to analyze human behavior (Varian 2014). The availability of big data has also increased opportunities to measure migration at various stages. Empirical literature using big data for migration studies has expanded recently but is mostly focused on developed countries, such as the Organisation for Economic Co-operation and Development (OECD) countries. Zagheni et al. (2014) use the data of users of the social network "Twitter" for OECD countries to track migration flows. A recent study by Böhme, Gröger, and Stöhr (2020) uses Google search data for OECD countries to assess the predictive power for migration flows and demonstrate that online search data can be a useful proxy for migration intentions and support real-time predictions of migration flows. Golenvaux et al. (2020) find that a long short-term memory approach with Google Trends data provides better results than the linear and artificial neural network (ANN) models in predicting migration to 35 OECD countries. However, there is a sparse amount of literature for developing countries that use big data for migration and remittance studies. Among them, Nakamura and Suzuki (2021), who use data from the Google Trends Index (GTI) to explore the impact of the novel coronavirus disease (COVID-19) and various other economic restriction policies on job searches in the case of Southeast Asian countries, note that migration intention did not increase as it requires time and costs.[1]

Thus, recent literature focuses primarily on migration in the case of high-income countries. Intensive labor force mobility and data constraints in developing countries suggest benefits from the use of big data in these countries too. On the other hand, migration statistics in developing countries are less available than big data, while remittances as a consequence of migration flows are represented within monetary authority statistical information more often. Moreover, remittances are sensitive to social and economic conditions in countries of both destination and origin. Therefore, given the volatility of workers' money

[1] The GTI is explained in detail elsewhere; see, for example, Austin et al. (2021).

transfers, high-frequency data from the GTI represent an opportunity for a better explanation of remittance inflows.

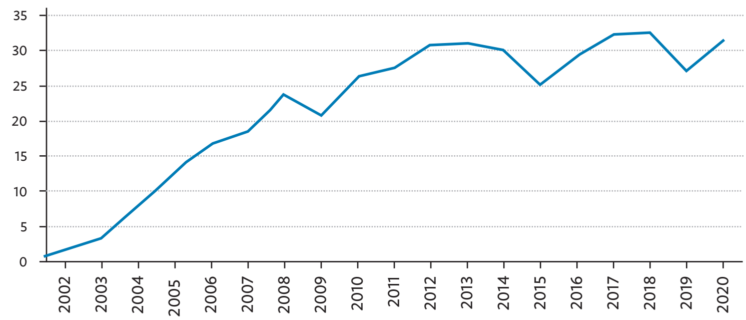
This study aims to examine the GTI in explaining the inflow of remittances in the case of one of the developing countries that receives the most remittances—the Kyrgyz Republic. The main contribution of this study to the literature is that it is the first attempt to explore remittance flows with GTI data in a developing country context. To do this, the gravity model is applied. Taking into consideration the fact that remittances of workers from abroad are consequences of the labor force outflow, we attempt to incorporate diaspora intensities in destination countries via the inclusion of search keywords on the Kyrgyz Republic and migration in destination countries. Also, search keywords used in the Kyrgyz Republic are applied to reflect local labor market conditions and search for migration opportunities as "pull" factors.

2.2 Background

The Kyrgyz Republic is a landlocked country in central Asia. The decrease in the industrial production capacity and overall fragility of economic production after the dissolution of the Soviet Union led to a low capacity to generate job places in the labor market. Nowadays, the economy of the country is heavily reliant on the mobility of the labor force and the inflow of remittances. Although there are no systematically available data on the exact number of temporary and permanent labor migrants abroad, reports indicate that there are between 700,000 and more than 1 million people who qualify as labor migrants (see for instance UNDP [2021]; RIA Novsoti [2021]). Given that the total population of the Kyrgyz Republic is 6.7 million, this is an important share of the labor force. The Russian Federation is the destination for almost 90% of the migrant workers from the Kyrgyz Republic. Fewer migrants currently work in Kazakhstan, and more recently in Türkiye and the Republic of Korea (WFP and IOM 2021). Because of the common history within the Soviet Union and the fact that the Russian language is spoken in the Kyrgyz Republic, the Russian Federation and Kazakhstan are the main destinations for labor migrants. Moreover, the accession of the Kyrgyz Republic to the Eurasian Economic Union in 2015 simplified the process for labor migrants from member states, such as the extension of the period without registration, removal of the history and language exams, and the requirement to obtain permits for a job (Shamyrbekova 2021). Therefore, most labor migrants from the Kyrgyz Republic have relatively high intensity in returning home and going back for work.

Remittances sent by labor migrants represent a significant population income source. Remittances in the Kyrgyz Republic accounted for 30% of gross domestic product (GDP) and ranked third in the world in terms of the volume of remittances as the share of GDP (Figure 2.1).

Figure 2.1: Remittances Received as % of GDP, Kyrgyz Republic (2002–2020)



GDP = gross domestic product.

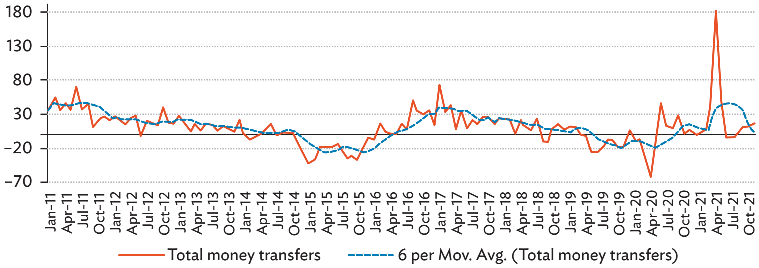
Source: World Bank. World Development Indicators (accessed 27 December 2021).

Migrant workers faced challenges during the COVID-19 pandemic, which forced some of them to return; this has increased their difficult social and economic situation, especially during 2020, the first year of the pandemic (UNDP 2021).

Generally, the volatility of the remittance inflows into the Kyrgyz Republic is significantly related to the economic situation in the Russian Federation. Year-on-year (YOY) growth rates of money transfers into the Kyrgyz Republic were negative from late 2014 up to the beginning of 2016, following the recession and economic slowdown in the Russian Federation. With the start of the COVID-19 pandemic, the growth of money transfers declined with the strict lockdown measures in the Russian Federation, especially in Moscow, and reached the lowest level at minus 62% YOY in April 2020. This reflected a low base in April 2021, with recovery at plus 183% YOY. According to the National Bank of the Kyrgyz Republic's data on money transfers up to November 2021, money transfers accounted for $2.5 billion.

The internet and mobile phones have empowered labor migrants by enabling them to keep updated with information about migration and labor force regulations in destination countries, as well as facilitating instant messaging with families, and sending remittances (Thompson

Figure 2.2: Growth Rate of Money Transfers
(monthly, %, year-on-year)



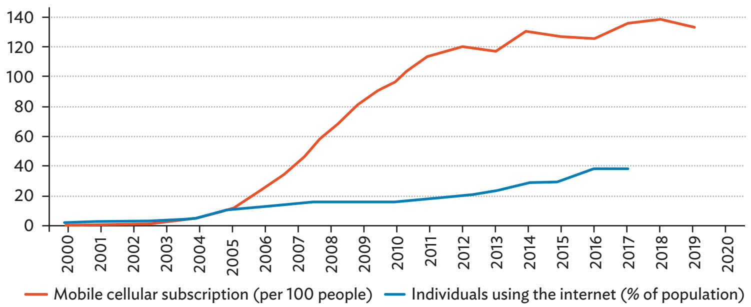
Note: Money transfers refer to transfers of individuals through transfer systems.

Source: National Bank of the Kyrgyz Republic. https://www.nbkr.kg/index1.jsp?item=1785&lang=RUS (accessed 10 January 2022).

2009; Bacigalupe and Cámara 2012; Molony 2012). The Kyrgyz Republic's labor migrants in the Russian Federation also make use of these services (Ruget and Usmanalieva 2019).

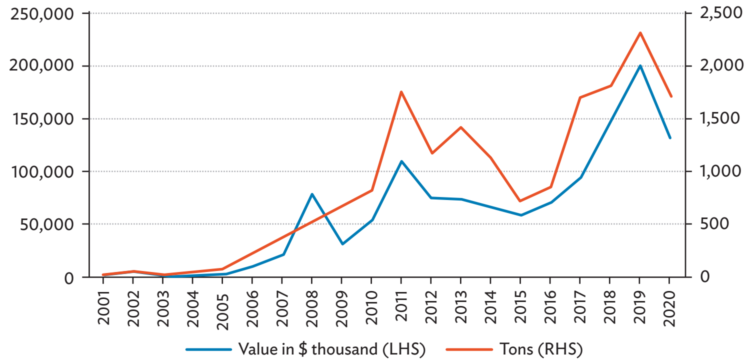
The widespread use of mobile phones and internet access in the Kyrgyz Republic has significantly increased over the last 15 years. According to World Bank data, mobile cellular subscriptions per 100 people increased from 10 in 2005 to 134 in 2019, whereas in the same period the share of individuals using the internet increased from 10% to 38% (Figure 2.3).

Figure 2.3: Mobile Cellular Subscriptions and Use of Internet in Kyrgyz Republic



Source: World Bank. World Development Indicators (accessed 27 January 2022).

Figure 2.4: Kyrgyz Republic Imports of Telephones (including for cellular networks, etc.)



LHS = left-hand scale, RHS = right-hand scale.

Note: Complete title of the goods category: "8517: Telephone sets, incl. telephones for cellular networks or for other wireless networks; other ..."

Source: Trade Map (accessed 25 January 2022).

The use of mobile phones, and particularly smartphones, increased significantly in the Kyrgyz Republic after 2010. This is supported by the evidence of imports of telephones, including those for cellular networks (Figure 2.4). In the pre-COVID-19 year of 2019, the value of imports of telephones reached 2,300 tons. Smartphones and soft applications enabled not only migrants in destination countries but also potential migrants to find helpful information for preparing for labor migration. It also facilitated remittance sending and receiving processes (see for instance, UN Kyrgyz Republic 2021). According to Harris and Prohorova (2021), among migrants from Central Asia in the Russian Federation, more than 90% of those with their own smartphones prefer sending remittances via the internet (digital remittances), while in recipient countries this rate is above 70%.

2.3 Literature Review

The literature on migration agrees that ICT contributes to solving the issue of incomplete information for potential migrants and impacts their decision to migrate (Wood and King 2001; Hamel 2009). Also, ICT increases opportunities for working and maintaining family life despite the long distances involved (Kotyrlo 2020). Not only potential migrants but also those in destination countries are active users of ICT (Bankole, Shirazi, and Brown 2011). Iqbal, Peng, and Hafeez (2020) found that there is a positive relationship between ICT and migration across the People's Republic of China's Belt and Road Initiative countries.

Empirical evidence on the importance of ICT for human mobility suggests that big data accumulated through the use of the internet and smartphones can be used to research migration flows (Ponzanesi 2019; Shen 2021; Sandberg et al. 2022). In these studies, the migration determinants have primarily been investigated and models have been constructed to track, map, and predict human mobility (Taylor and Meissner 2020; Sîrbu et al. 2021; Napierała et al. 2022; Cai 2022). One of the main advantages of measuring migration with big data is that migration flow can be continuously observed in real time, while migration data conveyed in censuses and household surveys rely on self-reporting by respondents about migration and mobility (Kirchberger 2021). Pajević and Shearmur (2017) investigated how big data can be used for analyzing the geographical trajectories of workers' mobility in urban areas. The authors argued that traditional approaches, like the use of census data, etc., for studying employment locations do not fully capture the locations where economic activity and economic value are created, and they suggested using real-time ICT-driven data, such as geolocation, intensity, and line use data recorded throughout the day, social network posts, and time data to explore worker mobility.

According to Kirchberger (2021), digital trace data from mobile phones can be classified as those that are compiled from the usage of smartphone applications and those that are inferred from call detail record (CDR) data from a mobile phone operator. The latter are widely used in migration studies and allows migration to be defined, in terms of whether it is permanent, temporary, or circular (Batran et al. 2018; Yang et al. 2020; Kirchberger 2021). However, these data are not widely available for low-income countries and depend greatly on the willingness of mobile phone operators to give access to call detail records, while the data compiled from smartphone applications are mostly available and provide the opportunity to carry out investigations across countries. For instance, Spyratos et al. (2018) estimated the number of expatriates in 17 European Union countries based on the data from Facebook network platforms that are smartphone applications—Facebook, Instagram, and Messenger. Google Trends data have been used to estimate a migration gravity model in addition to other economic and demographic migration determinants (Böhme, Gröger, and Stöhr 2020; Golenvaux et al. 2020). Xu et al. (2020) constructed a labor mobility network by collecting data on online résumés from social networks.

Migration Data Issues in Kyrgyz Republic

Even though big data improve the understanding of how and why people move, they have limitations such as the representativeness of data. Digital data drawn from smartphones and their applications, or internet-based devices, are constrained by those who use digital equipment. For instance, CDR data cannot measure the movements of migrants that do not hold mobile phones and may exclude from observation migrants in the lowest-income quintile (Kirchberger 2021). Also, countries where internet access is expensive or where full coverage is not available may yield a biased representation of the population. Another limitation of investigating migration with big data is the fact that, in low-income countries, temporary migration cannot be traced with official statistics.

However, remittances sent by labor migrants are recorded at a higher frequency. Moreover, literature suggests that worker remittances are a major determinant of labor migration (Fareedy 1984). Therefore, we suggest evaluating whether the online information-seeking behaviors of migrants and those looking for opportunities in the domestic labor market could explain the variations in remittances, alongside other known drivers of remittances. To analyze the explanatory power of Google Search indices on remittance inflows, we first begin by gathering Google Trends data that could be related to migration and remittances. Google is the dominant search engine in the Kyrgyz Republic with a share of almost 90%.[2] Google Trends (GT) is a publicly accessible internet-based service that provides a time series of word search volumes for the period starting from 2004 at weekly and monthly frequencies. The search volume is presented as indices, which reached a maximum of 100 at the peak point during the analyzed period.

We started by analyzing migration-related keywords presented in Böhme et al. (2020) by translating these words into the Kyrgyz and Russian languages, the latter being the second most common language spoken in the Kyrgyz Republic. Then we added new keywords that were assumed to be related to migration and remittances in the Kyrgyz Republic (including "blacklist"). Böhme Gröger, and Stöhr (2020) use the semantic links between words in the Wikipedia encyclopedia related to the overarching topic of migration and use semantic links that analyze the text of English language Wikipedia and identify pairs of keywords that are semantically related.

However, for the Kyrgyz language, we do not have such a semantic analysis platform. Therefore, for a better prediction of remittances we

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[2] For instance, see https://gs.statcounter.com/search-engine-market-share/all/kyrgyzstan (accessed 28 January 2022).

attempt to search keywords that may identify the intensity of labor migrants from the Kyrgyz Republic abroad and the Kyrgyz diaspora.[3] This may not reflect the current labor migration, but it may include those who have moved abroad from the Kyrgyz Republic and obtained citizenship there. To analyze remittances as a consequence of labor migration, it might be better to search words not only in the destination countries, but also in the Kyrgyz Republic and related to the destination country: for instance, "jobs in the Russian Federation," etc. However, it should be noted that Kyrgyz people generally tend to use informal (social) networks (relatives, etc.) to find jobs abroad, especially in the Russian Federation. Therefore, official use of Google Search to find jobs may not be widespread. However, other words related to the migration process might be employed. For instance, "look for air tickets" may indicate upcoming labor mobility trends. Also, looking for job search activities in the local labor market may indicate follow-up migration trends. Individuals in the local labor market, along with job search words, search main websites for vacancy announcements.[4]

Thus, GT search words in this research were chosen according to their relevance for migration and remittances. As both Kyrgyz and Russian are spoken in the Kyrgyz Republic, words in both languages are searched in GT. The geography of the search is based on the Kyrgyz Republic and on destination countries too.

It should be noted that in this study, for exploring the inflow of remittances, the search keywords used are from the general domain of migration and the labor market. Putting it differently, remittances are considered as a consequence of labor force mobility and the intensity of migrant stocks in destination countries. However, other potential macroeconomic factors affecting remittances are taken into account within the empirical gravity model.

The economic data for empirical modeling are remittances, and the real effective exchange rate for the Kyrgyz Republic has been compiled from the National Bank of the Kyrgyz Republic, while GDP data have been gathered from the Interstate Statistical Committee of the Commonwealth of Independent States. These are monthly data for the period from January 2011 to July 2021. This period is selected to represent periods of salient smartphone use in the Kyrgyz Republic and most Google Search words are available from 2011. Monthly data on remittances are taken from the National Bank of the Kyrgyz Republic's data on money transfers by individuals from abroad, which are also

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3 https://www.rs.undp.org/content/serbia/en/home/blog/2020/mo_e-li-google-pretraga-da-pomogne-u-lociranju-dijaspore-.html

4 https://kaktus.media/doc/439336_kak_nayti_raboty_v_kyrgyzstane._spisok_onlayn_servisov.html

given for sending countries. However, almost 97% of money transfers by individuals come from the Russian Federation. However, in our analysis we include four other countries with non-zero values: Kazakhstan, Germany, the United States, and the United Kingdom. Therefore, our monthly remittance data consist of money transfers from five countries to the Kyrgyz Republic.

Table 2.1: Search Keywords in Google Trends

Searched Words in Google Trends	Translation in English
Search words in countries of destination of migrants (Russian Federation, Kazakhstan, Germany, United States, and United Kingdom)	
Бишкек (Бишкек Москва, Бишкек Алматы)	"Bishkek" for Germany, United States, United Kingdom; for Russian Federation "Bishkek Moscow"; for Kazakhstan "Bishkek Almaty"
Ош	Osh (city in Kyrgyz Republic)
Иссык-Куль	Issyk-Kul (name of lake)
Той	Toi (festive event)
Чингиз Торекулович Айтматов	Chingiz Torekulovich Aitmatov (writer)
Комуз	Komuz (musical instruments of Kyrgyz Republic)
Кумтор	Kumtor (mining company in Kyrgyz Republic)
Кумыс	Kumis (horse milk)
Search words in countries of origin of migrants (Kyrgyz Republic)	
Employment	Employment
Job Kg	Job Kyrgyz Republic
Job	Job
Rabota	Work
Авиабилет	Air Ticket
Авиабилеты	Air Tickets
Бизнес	Business
Билет На Самолет	Plane Ticket
Билет	A Ticket
Бирге Ру	Birge.ru (website of Kyrgyz migrants)
Вакансии Бишкек	Vacancy Bishkek
Вакансии	Vacancies

continued on next page

Table 2.1 *continued*

Searched Words in Google Trends	Translation in English
Виза	Visa
Выезд	Departure
Гражданин	Citizen
Граница	Border
Жердеш ру	Jerdesh.ru (website of Kyrgyz migrants)
Жумуш	Work
Ищу Работу	Looking for Work
Лалафо Бишкек Работа	Lalafo (website name) Bishkek Work
Лалафо Работа	Lalafo (website name) Work
Опыт	Experience
Паспорт	Passport
Работа в Бишкеке	Work in Bishkek
Работа в Турции	Work in Türkiye
Работа дизель	Diesel (website name) Work
Работа	Work
Резюме	Resume
Родина	Homeland
Самолет	Plane
Черный список	Blacklist
Эмгек	Labor

Source: Authors' translation.

Table 2.2: Summary Statistics

Variable	Mean	Std. Dev.	Min	Max	Observations
Remittance ($ million)	36.50689	74.1957	0	274.1805	635
GDP ($ million)	607.3482	169.7376	293.3547	1,147.537	635
REER	111.826	4.50384	103.2	124.1	635
GT words for destination					
Bishkek	30.55433	23.14332	0	100	635
Osh	26.01417	25.60784	0	100	635
Toi	42.39213	25.22828	0	100	635
Chingiz Torekulovich Aitmatov	25.82677	22.18893	0	100	635
Komuz	19.27087	25.1099	0	100	635
Kumtor	10.44882	20.77812	0	100	635
Kumis	23.4063	20.55228	0	100	635
Issyk-Kul	23.7748	21.06677	0	100	635
GT words for origin, Kyrgyz Rep.					
Employment	22.51969	21.85154	0	100	635
Job Kg	26.20472	28.21821	0	100	635
Job	36.22047	21.80061	0	100	635
Work	30.74803	23.6146	0	100	635
Air Ticket	28.83465	22.73519	0	100	635
Air Tickets	45.8189	20.85719	0	100	635
Business	37.79528	16.11539	13	100	635
Plane Ticket	20.08661	20.87216	0	100	635
A Ticket	40.71654	21.75099	0	100	635
Birge.ru	18.15748	24.27122	0	100	635
Vacancy Bishkek	46.87402	23.4746	0	100	635
Vacancies	41.45669	12.07152	8	100	635
Visa	41.2126	18.17095	0	100	635
Departure	22.88976	17.49007	0	100	635
Citizen	26.32283	21.04257	0	100	635
Border	20.02362	21.38039	0	100	635
Jerdesh.ru	19.77953	27.75396	0	100	635
Work	34.84252	24.10591	0	100	635

continued on next page

Table 2.2 *continued*

Variable	Mean	Std. Dev.	Min	Max	Observations
Looking For Work	45.59843	24.98494	0	100	635
Lalafo Bishkek Work	20.59843	27.18649	0	100	635
Lalafo Work	20.93701	25.39677	0	100	635
Experience	25.67717	18.2408	0	100	635
Passport	46.65354	15.92242	14	100	635
Work in Bishkek	49.11024	23.88994	0	100	635
Work in Türkiye	21.83465	21.87351	0	100	635
Diesel Work	41.14961	27.03167	0	100	635
Work	56.37008	13.3225	21	100	635
Resume	23.68504	16.75708	5	100	635
Homeland	37.14961	21.28375	0	100	635
Plane	23.75591	12.70492	0	100	635
Blacklist	28.8189	24.22828	0	100	635
Labor	28.88189	21.0481	0	100	635

GT = Google Trends, GDP = gross domestic product, REER = real effective exchange rate.

Notes: The GT Index is normalized to a maximum of 100. Google does not disclose absolute values. See, for example, Austin et al. (2021) for details.

Source: Authors' calculations.

2.4 Model Specification

To analyze the impact of Google Search indices on remittance inflows to the Kyrgyz Republic from the Russian Federation, Kazakhstan, Germany, the United States, and the United Kingdom we have applied the gravity model, where the dependent variable is the remittance and it is regressed by GDP, real exchange rates, and GT words. The augmented gravity model is as follows:

$$X_{ijt} = \beta_0 + \beta_1 LnGDP_{it} + \beta_2 REER_{it} + \beta_3 Gt\_o_{it} + \beta_4 Gt\_d_{jt} + \delta_t + \varepsilon_{ijt} \quad (2)$$

where
i = represents the country of origin – the Kyrgyz Republic;

j = represents countries that send remittances – the Russian Federation, Kazakhstan, Germany, the United States, and the United Kingdom;

X_{ijt} = is the level of remittance inflow in period t, in million US dollars;

$LnGDP_{it}$ = is the level of gross domestic product in the Kyrgyz Republic in period t, in million US dollars;

$REER_{it}$ = is the real exchange rate;

GTo = GT words for origin – Kyrgyz Republic;

GTd = GT words for destination countries – the Russian Federation, Kazakhstan, Germany, the United States, and the United Kingdom; and

δ_t = time-specific fixed effects.

The level of GDP in the Kyrgyz Republic is expected to be negatively correlated with the remittance inflows. Hence, the relative growth of income in the Kyrgyz Republic decreases the migration outflow, thereby decreasing the remittance inflows from abroad. For this reason, β_1 is expected to be smaller than zero. The GT words are assumed to significantly impact the remittance inflows into the Kyrgyz Republic, meaning that definite search words may explain the pattern of remittance inflows into the Kyrgyz Republic.

Estimating the log-linearized gravity model in the presence of zero values—in our case, these are the zero values for remittance inflows in some months—leads to a loss of information from these observations and a reduction of the sample size. To deal with this issue, Silva and Tenreyro (2006) suggest using the Poisson pseudo-maximum-likelihood (PPML) estimation method. This technique makes it possible to estimate the gravity model in the presence of heteroskedasticity and deal with zeros in data. The interpretation of the results of this model is the same as with ordinary least squares (OLS), and the coefficients are interpreted as elasticity. The estimation in STATA is enabled by the *ppml* command with cluster-robust standard errors (Silva and Tenreyro 2006).

2.5 Empirical Results

In Table 2.3, the results of the impact of GT words on bilateral remittance inflow into the Kyrgyz Republic are presented. All results are presented with cluster-robust standard errors. Gravity models were used initially for GT words searched inside the Kyrgyz Republic, then inside countries of destination, and lastly, in the third column, the estimation model for all countries is presented.

Two salient relationships emerge from these results. First, it is clear that a decline of GDP in the country of origin is associated with amplified remittance inflow increases, showing that, in adverse economic cycles at home, migrants are more likely to remit, which is consistent with mutual assurance and spatial hedging theories of migration (see, for example, Lueth and Ruiz-Arranz 2007; Mustafa and Ali 2018).

Second, the evidence shows that exchange rate depreciation in the migrants' home country (Kyrgyz Republic) is significantly associated with lower remittance inflows. This suggests a prudential motive on the part of sending migrants, who recognize the increased home country purchasing power of their income. In other words, a smaller transfer of earned currency (e.g., dollars or rubles) is needed by their beneficiaries at home to buy the same basket of goods and/or services (Poghosyan and Blancher 2020).

Apart from these variables, for the available GT words examined in this study, the results do not indicate systematic impacts on Kyrgyz remittance inflows (1 column), and less likely to determine the inflows. Hence, the overall R^2 is quite low, indicating that most of these search words do not significantly explain the variation in remittances. However, the results on several individual search words are interesting. Thus, words that are closely related to job search in general and air tickets in particular ("air ticket," "a ticket," "looking for work," "border," "Jerdesh.ru," "work in Türkiye") have a positive correlation with the magnitude of remittance inflows. These words may signal individuals' limited opportunity for employment in the local labor market and their intentions to search for jobs abroad.

GT words that are searched in migrant destination countries significantly explain the remittance variation (R-square = 0.78). This shows that GT searches by migrants living within destination countries (remittance senders) help explain the flow of remittances back home. These fixed (origin) effects are weaker (below average or negative) for larger home cities related to the search for Bishkek or for Bishkek to Moscow (or Almaty), probably indicating that individuals from some origin provinces are more experienced migrants and less likely to consult the internet.

Therefore, it can be argued that the online information-seeking behaviors of migrants in countries of destination have a relatively strong statistical association with migration decisions, including remittance activity, alongside other known macroeconomic remittance drivers, such as GDP and the real effective exchange rate (REER). It should be emphasized that these search words are merely informational proxies, consulted by internet users to inform themselves about underlying economic fundamentals that motivate their labor market search and remittance decisions.

Table 2.3: Impact of Google Trends Words on Remittance

	(1)	(2)	(3)
GDP	0.0021*** (0.0007)	−0.0015*** (0.0006)	−0.0052*** (0.0015)
REER	−0.0352*** (0.0089)	−0.0809*** (0.0128)	−0.1181*** (0.0406)
GT words for origin			
Employment	0.0006 (0.0018)		
Job Kg	−0.0087*** (0.0028)		0.0535*** (0.0138)
Job	−0.0005 (0.0042)		
Work	−0.0007 (0.0016)		
Air Ticket	0.0023** (0.0011)		−0.0370*** (0.0109)
Air Tickets	0.0003 (0.0016)		
Business	−0.0076*** (0.0020)		
Plane Ticket	−0.0025 (0.0019)		0.0156*** (0.0056)
A Ticket	0.0090** (0.0041)		
Birge.ru	−0.0025 (0.0020)		
Vacancy Bishkek	−0.0027 (0.0062)		
Vacancies	−0.0073** (0.0029)		−0.0294*** (0.0109)
Visa	−0.0000 (0.0010)		
Departure	−0.0015 (0.0056)		
Citizen	0.0063 (0.0046)		
Border	0.0048** (0.0020)		

continued on next page

Table 2.3 *continued*

	(1)	(2)	(3)
Jerdesh.ru	0.0077*** (0.0021)		−0.0212*** (0.0055)
Work	−0.0016 (0.0062)		
Looking For Work	0.0065*** (0.0022)		
Lalafo Bishkek Work	0.0030 (0.0024)		
Lalafo Work	−0.0048** (0.0024)		
Experience	0.0038** (0.0017)		
Passport	0.0066 (0.0044)		
Work in Bishkek	0.0143 (0.0089)		
Work in Türkiye	0.0036*** (0.0005)		
Diesel Work	−0.0001 (0.0015)		
Work	−0.0077 (0.0090)		
Resume	−0.0012 (0.0066)		
Homeland	0.0017 (0.0041)		0.0185** (0.0077)
Plane	−0.0039 (0.0043)		
Blacklist	−0.0009 (0.0009)		
Labor	−0.0150 (0.0095)		

continued on next page

Table 2.3 *continued*

GT words for destination	GT Words in Origin	GT Words in Destination	Total
Bishkek Moscow		−0.0242** (0.0115)	−0.0256** (0.0118)
Osh		0.0599*** (0.0182)	0.0606*** (0.0185)
Toi		0.0403*** (0.0115)	0.0421*** (0.0122)
Chingiz Torekulovich Aitmatov		0.0204*** (0.0045)	0.0192*** (0.0046)
Komuz		0.0267*** (0.0069)	0.0285*** (0.0072)
Kumtor		−0.0074*** (0.0025)	−0.0090*** (0.0028)
Kumis		−0.0491*** (0.0157)	−0.0507*** (0.0154)
Issyk-Kul		0.0259** (0.0120)	0.0247** (0.0121)
Constant	6.2762*** (1.2684)	7.3250*** (2.6926)	13.8313*** (5.0329)
Month	+	+	+
Log likelihood	−34,478.01	−8,667.644	−8,399.845
R^2	0.0236	0.7785	0.7909
N	614	631	629

GT = Google Trends, GDP = gross domestic product, REER = real effective exchange rate.

Note: Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.010$.

Source: Authors' calculations.

2.6 Conclusions

This study examined the efficacy of using the Google Trends Index (GTI) to explain remittance patterns in the Kyrgyz Republic. A hybrid gravity model was combined with the frequency of use of selected internet search keywords in destination countries and the Kyrgyz Republic. Based on data availability, the remittance inflows from six destination countries were selected for the empirical modeling. Estimation results indicate that searched words in destination countries have more statistically significant impacts on remittances than those words searched in the Kyrgyz Republic, suggesting that remittance supply-side decisions are more search-dependent. However, outbound searches, using words in the Kyrgyz Republic that reflect job and air ticket seeking, are also important in explaining remittances. These results indicate that GTI can elucidate not only migration departure decisions by the labor force, but remittance flows as well. These correlations on both sides of the migration process reveal how ICT infrastructure facilitates migrant job creation and income transfers for sending households, both of which are potent catalysts of poverty reduction and growth in the Kyrgyz Republic and other developing countries.

Along with these findings and in line with earlier literature, we note from our new data that the use of smartphones, internet access, and digital skills generally vary across income, education, and age cohorts. These aspects are not controlled in our empirical approach but could assist future research on the potential of ICT to extend labor market benefits more inclusively.

Despite the limitations of sampling this new data resource, several policy implications can be derived from our empirical findings. First, labor outflow since the early 2000s has significantly increased the stock of Kyrgyz migrants abroad. This process makes it essential that government policy become more proactive in four new policy areas:

(1) Facilitating repatriation of remittances.
(2) Channeling remittances into productive domestic investment.
(3) Taking account of evidence in more experienced sending economies (Yoshino et al. 2020, among others), it is also important for Kyrgyz leaders to consider longer-term policies aimed at repatriating these workers, enhancing their skills, and generally improving the domestic investment climate to attract higher and more diverse steady-state levels of foreign direct investment.
(4) Recognizing the international potential of information technologies to facilitate these pro-growth dynamics should redouble domestic commitments to ICT and the information economy generally to support domestic education and skills development, improving productivity and market access for Kyrgyz workers and enterprises across the domestic economy and globally.

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3

Socioeconomic Spillover Effects of Digital Communications Infrastructure in India

TV Ramachandran, Garima Kapoor, and Neha Hathiari

3.1 Introduction

India is moving in leaps and bounds toward being a $1 trillion digital economy by 2025. Digitization and digital transformation around the basic utility sectors such as education, healthcare, banking, transport, and agriculture have brought socioeconomic transformation and is powering the economy on a massive scale. The bedrock for this transformation is undoubtedly digital communications infrastructure (DCI), which is enabling digital transformation in these sectors. This chapter attempts to bring the socioeconomic spillover effects of DCI on the Indian economy, businesses, and lives of citizens in a systematic manner.

This chapter is structured as follows. Section 3.2 defines the concept of DCI. The definition is in consonance with the International Telecommunication Union (ITU) definition and the National Digital Communications Policy (NDCP) 2018, a crucial policy pertaining to DCI in India. Section 3.3 deals with the key elements of DCI: optical fiber, public wi-fi, satellite communications (satcom), and others and their status in India to understand the scale of penetration.

In section 3.4, the spillover effects of DCI in India are discussed at length to provide the complete picture about the socioeconomic impact created by investments in DCI. There are varied elements of DCI and how each one contributes in creating spillover effects at the macro level in terms of growth in gross domestic product (GDP), employment creation, access to healthcare, education, and other socioeconomic factors is shown through a detailed literature review. The short-term and long-term spillover effects of DCI based on the evidence from the literature and data points are highlighted, along with the cross-country spillover effects due to robust DCI.

In section 3.5, the socioeconomic spillover effects of the digital initiatives launched by the Government of India are encapsulated through four detailed case studies of Aadhaar, UPI, CoWIN, and FASTag. Section 3.6 is a precursory on the role of big data in the gauging of spillover effects of DCI that provide further impetus in strengthening DCI in accordance with evolving technologies. Section 3.7 summarizes the findings of the report and also provides policy recommendations that will be pivotal in ensuring a prudent interplay of all elements of DCI in a proportionate and equitable manner.

3.2 Definition of Digital Infrastructure

The ITU defines digital infrastructure in their report on Digital Infrastructure Policy and Regulation in the Asia-Pacific Region (ITU 2019):

> Digital infrastructure is the key to enabling the benefits of the digital economy and society. Digital infrastructure is the physical hardware and associated software that enables end-to-end information and communications systems to operate. Digital infrastructure includes: internet backbone including national and trans-oceanic fiber cables; fixed broadband infrastructure such as analogue coaxial and optic fiber cable networks; mobile communications infrastructure and networks including [fixed wireless access] FWA, transmission towers, radio and optic fiber backhaul networks; broadband communications satellites; data and cloud computing facilities; end user equipment such as mobile handsets, PCs, modems and local Wi-Fi and bluetooth networks; software platforms including computer and mobile device operating systems as well as application programming interfaces; network edge devices such as sensors, robots, autonomous and semiautonomous vehicles, and other internet of things facilitating devices and software.

Like many other developing countries, India is a mobile-first nation where mobile is the only means of connectivity as well as access to the internet for more than 98% of the population (Department of Telecommunications). While mobile will continue to dominate the Indian market, we will also need fixed/cable infrastructure. Public Wi-Fi, E-band, V-band, and satellite communications (satcom) will also form important elements of digital infrastructure. The E-band represents the frequency range from 71–76 gigahertz (GHz) and 81–86 GHz. The V-band as defined by the Institute of Electrical and Electronics Engineers is a frequency range from 40–75 GHz.

The National Digital Communications Policy (NDCP) 2018 is broadly in consonance with the ITU definition. The NDCP 2018 is the apex policy document for the sector, whose overall goal is broadband for all. Broadband is at the heart of the NDCP and addresses broadband infrastructure as its very first objective. Chapter 1 of the Policy, under the "Connect India" section, elaborates on the need for the creation of robust digital communications infrastructure. Under the above chapter, specific targets have been set for the different elements of digital infrastructure, which among others, include the following:

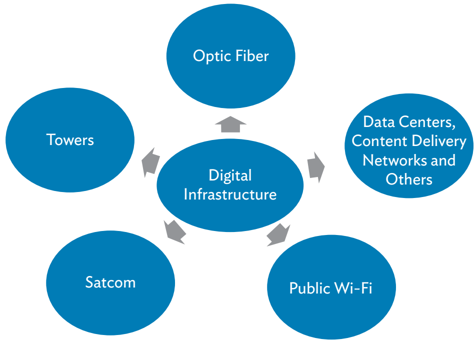
(1) Deploying public Wi-Fi hotspots – 10 million by 2022
(2) Promoting the effective utilization of high capacity backhaul E-band (71–76/81–86 GHz) and V-band (57–64 GHz) spectrum in line with international best practices
(3) Strengthening satellite communication technologies:
    (a) Review the regulatory regime for satellite communication technologies
    (b) Optimize satellite communications technologies in India
    (c) Develop an ecosystem for satellite communications in India

The common definition and understanding of digital communications infrastructure that was arrived at after extensive consultations and culminated in the formation of the NDCP, includes public Wi-Fi, satcom, and other elements.

3.3 Elements of Digital Infrastructure and Their Status in India

For geographically diverse nations such as India, ubiquity demands a holistic approach to infrastructure. The availability of more than one type of digital infrastructure helps ensure that there is no dependency on one type of infrastructure and switching traffic load is easier between available technologies in case of emergencies or disasters. This is vital for India. While towers and antennae will remain a key element, the role of optic fiber would be enhanced to all-pervasive, essential infrastructure, and the importance of public Wi-Fi hotspots, satcom, and other elements such as data centers, content delivery networks, and submarine cables assume higher proportions (Figure 3.1).

Figure 3.1: Elements of Digital Infrastructure



Source: BIF Research Team.

Thus, other than mobile, four key elements of digital infrastructure have to grow hand in hand for proliferation of broadband services, especially to rural and remote areas.

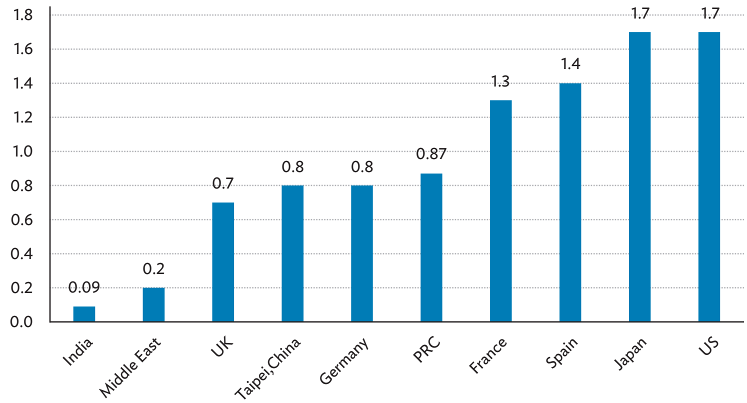
3.3.1 Fiber

A strong fiber network backbone is essential for high-speed broadband to help the country truly tap its digital potential. The future of Digital India lies in data-intensive 5G, machine-to-machine communications, and Internet of Things (IoT). Optical fiber networks are foundational and critical to the success of the digital era with the adoption of 5G, data intensive usage, and era of video, video calling, and IoT.

With a promise of 10 gigabits per second (Gbps) speed, less than 1 millisecond (ms) latency, and 90% reduction in network energy utilization, 5G will change digital connectivity in India. It will spur the next round of telecom infrastructure investments across the globe fueled by the sharp increase in consumer data and the proliferation of IoT devices. However, a 5G reality will require fiber deployment in the country to increase two to three times from the current 16–18 million fibers per kilometer (fkm) per year.

In India, the fkm per capita is much less compared to other countries. For instance, fkm per capita in the People's Republic of China (PRC) with a population of 1.3 billion people is 0.87, whereas that of India with a population of 1.2 billion people is just 0.09, or one-tenth of the PRC. The score is 1.3 and higher in developed markets such as the United States (US) and Japan (Figure 3.2).

Figure 3.2: Per Capita Fiber Coverage (km)



PRC = People's Republic of China, UK = United Kingdom, US = United States.

Source: TAIPA (2019). https://tele.net.in/level-up-need-for-deeper-fibre-penetration/ (accessed 12 May 2022).

To rise to global benchmarks, Indian operators need to invest in optical fiber. Given the 5G requirement to reduce latency from 50 ms to 1 ms and increase speed from 100 Mbps to 10Gbps, the fiber deployment rate in India needs to increase from 16–18 million fkm per year to at least two to three times that amount per year. 5G will also require a multifold increase in small cell deployment, with each small cell connected to fiber backhaul. The percentage of tower backhaul on fiber for the operators will need to increase significantly from 35% to 70%–80% levels. The NDCP 2018 under the "Connect India" mission also highlights "facilitating fiber-to-the-tower program to enable fiberisation of at least 60% of telecom towers thereby accelerating migration to 4G/5G." However, only about 35% of the telecom towers in India are presently fiber-connected, and, coupled with lack of viable alternatives, place severe limits on backhaul capacity. India needs to enhance its fiber connectivity, and this is the right time to do this expeditiously. Increased fiber connectivity will not only strengthen capacity but will also enhance the quality of the services being delivered. As of September 2019, India has around 2.68 million km of optical fiber cables deployed across telecom networks. However, even at the global level, India continues to remain highly under-fiberized in comparison to countries like the US and the PRC that experience much lower levels of data demand in comparison to India.

It is highly recommended that the government ensures that the central “Right of Way” guidelines of 2016, along with the amended guidelines of 2021, are implemented uniformly across the country. It is suggested that a suitable mechanism for sharing of fiber and common duct infrastructure be created as was done successfully in the case of towers, so that the investment requirement is optimized, and the infrastructure thus created is optimally utilized in the most efficient manner.

3.3.2 Public Wi-Fi

Video downloads are expected to constitute almost 90% of the data traffic in the future, and Wi-Fi/public Wi-Fi would cater to such high capacity (video) downloads. Offloading data traffic to public Wi-Fi hotspots will help complement mobile broadband operators and ensure that precious mobile spectrum is conserved, thereby ensure higher efficiencies and better quality of service to their consumers. Data traffic generated by public Wi-Fi hotspots will be carried by the mobile service providers, which will lead to the opening of a new revenue stream for them. It will also enable small shop owners and micro entrepreneurs to provide Wi-Fi services. The increasing need of fixed broadband would accelerate the requirement of technologies, that is, Wi-Fi for indoor coverage within buildings and homes as mobile coverage at indoor locations is either non-existent or sparse.

At present, benchmarks against the deployment of public Wi-Fi in other nations reveals significant gaps in rollout and access of hotspots in India. Developed markets such as the US, the United Kingdom, and France have around 30% of their total public data offloaded to public Wi-Fi networks. Table 3.1 shows that India stands at less than 1% of the global average. Against every one hotspot in India per million population, the global average number of hotspots stands at 197 per million population.

The launch of the PM-WANI public Wi-Fi initiative by the Union Cabinet on 9 December 2020 is a positive and pragmatic step for the industry. PM-WANI’s vision for seamlessly delivering public Wi-Fi services to the citizens through public data offices, public data office aggregators, and application providers, may well mirror the success of the UPI interface in digital payments, as it would facilitate similar “liberalization of access” and enable great outreach and utility for the public. The Broadband India Forum (BIF) has constantly supported

Table 3.1: India's Position vis-à-vis Other Countries in Terms of Number of Hotspots

Country	Population (million)	Total Number of Hotspots	Number of Hotspots (per million persons)	Relative Index (with India at 1 as base)
United States	330	68.4 million	207,272	878
People's Republic of China	1,400	41.7 million	29,785	126
United Kingdom	67	5 million	74,626	316
Indonesia	273	1.045 million	3,287	20
India	1,300	0.35 million*	236	1
Global Average	**7,800**	**362 million****	**46,410**	**197**

Sources: iPass (November 2017), * DigiAnalysis (August 2019), ** Statista Research Department 2020.

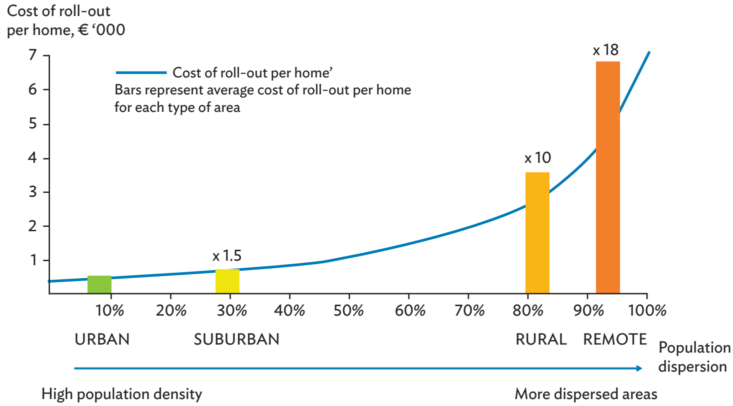
this important measure of enabling unlicensed entities to deliver public Wi-Fi services at the grassroots level in order to boost broadband proliferation across the nation.

3.3.3 Satcom

In rural and remote areas, especially areas situated in geographically and topographically challenged terrain, the cost of providing terrestrial connectivity ranges from 10–20 times the cost of rolling out fixed networks in urban areas. It is not economically feasible for terrestrial technologies like fiber to the home to reach the last 20% of the population (Figure 3.3). It is an irony that a high amount of data bandwidth is going to waste all over India from satellites, while rural India remains starved of connectivity. In such areas, satcom is a quick and economical means to deploy in rural areas as compared to terrestrial technologies.

An open skies approach to satellite communications would obfuscate the need for "right of way" permits or the huge costs associated with the rollout of terrestrial technologies in such areas. The NDCP 2018 has for the first time recommended adequate use of satcom in enhancing broadband services. It has three sections exclusively devoted to satcom—simplifying and streamlining the administrative and regulatory framework, leveraging the latest satcom technologies, and promoting increased private participation in the sector.

Figure 3.3: Cost of Rollout of Terrestrial Technologies in Dispersed Areas Increases with Remoteness



Source: Eutelsat Analysis.

Table 3.2 shows the number of satcom connections per million population in India vis-à-vis other developed countries. India lags behind the US and the European Union (EU) which, although highly fiberized countries, are far ahead of India in terms of numbers of satcom users. For every satellite connection in India per million population, there are 70 satellite connection in the US, 20 in the EU, and three in Asia on a per million population basis.

Table 3.2: Satcom Connections per Million Population–Comparison of India vis-à-vis Other Developed Countries

Region	Total No. of Satellite Consumers (million)			Population (million)	Total No. Of Satellite Connections (per million population)	Relative Index (with India as 1)
	Direct Consumers	Enterprise Consumers	Direct + Enterprise			
United States	2.1	2.6	4.7	330	0.014	70
European Union	1	1.1	2.1	450	0.004	20
Asia (including People's Republic of China, Japan, Republic of Korea, and India)	1.4	1.6	3	4,500	0.0006	3
India	NIL	0.3	0.3	1,300	0.0002	1

Sources: NSR 2019 www.nsr.com and TRAI Subscription Data for India December 2019.

In view of the above, there is a need to have a prudent interplay of essential elements of digital infrastructure such as public Wi-Fi hotspots, satellite communications, and use of E- and V- bands, besides fiber and towers, in a proportionate and equitable manner.

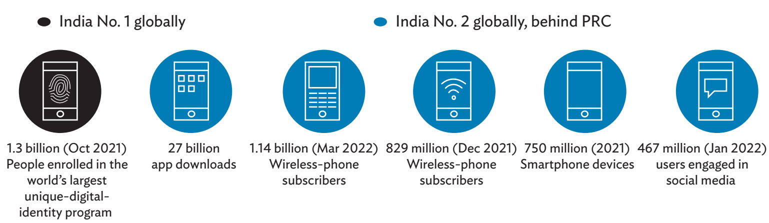
3.3.4 Others

Data centers, content delivery networks, and submarine cables will play a critical role as digital infrastructure. There is an immense economic potential associated with data centers, content delivery networks, and interconnect exchanges and the proliferation of these internet technologies has a key role to play in expanding the digital economy. The data centers in India are witnessing a robust growth in the era of digitization. India's cost advantage, availability of skilled labor, low climate risk, and focus on data protection laws make it well positioned to be a major data center hub. Content delivery networks and internet exchanges are budding services that allow for better quality services for internet users.

3.4 Literature Review: Spillover Effects of DCI in India

Telecommunications infrastructure has rightly acquired the tag of a general purpose technology, with the internet and mobile-based communications generating spillover effects to directly associated sectors as well as rippling through the entire economy. India is among

Figure 3.4: India is Among the Top Two Countries Globally on Many Key Dimensions of Digital Adoption



PRC = People's Republic of China.

Sources: Unique Identification Authority of India (UIDAI), App Annie's Annual State of Mobile Report 2021, TRAI, Deloitte's 2022 Global TMT (Technology, Media and Entertainment, Telecom) predictions, Data Reportal, McKinsey & Company.

the top two countries globally on many key dimensions of digital adoption (Figure 3.4).

It is also observed that growth dividends from the internet are significantly higher than mobile (voice). While the impact of mobile penetration may have begun to moderate, the impact of the internet continues to be on the rise. This is because of increasing use of the internet in improving existing business models and notably creating newer ones, thus enabling markets to become more efficient. In India, the digital communication infrastructure has created a domino effect in the growth of the region. The robust communication was previously considered to be essential only in service-centered industries like information and communications technology (ICT), which translated into the development of "soft" digital infrastructure, but now is considered as the backbone for the growth of other sectors, especially so in the post-COVID-19 scenario. The spillover effects due to a sturdy digital backbone, topped up with the innovative digitalization efforts has rich dividends in terms of the evolution of the Aadhaar, UPI, and others. The spillover effects due to DCI are extensive and lead to a decrease in the costs of transactions, enrich market information, accelerate knowledge diffusion, enhance the quality of decision making, and augment productivity, all eventually increasing economic growth as manifested in the study by Pradhan, Sarangi, and Pradhan (2020).

The spillover effect quantification for DCI is cursorily done by mobile internet penetration that drives the percentage of GDP. Studies pertaining to India and the states mainly focus on the impact of speed and penetration increase on the GDP. While direct benefits include increased revenues from GST, license fees, spectrum usage charges, spectrum auctions, corporate taxes, and property taxes, there are innumerable indirect benefits that accrue to GDP.

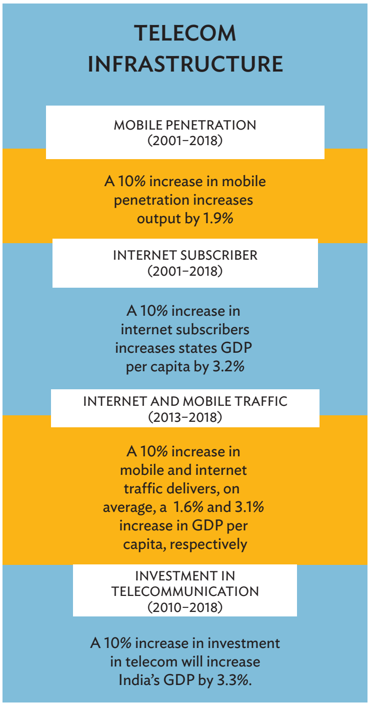
The short-term spillover effects are effectively quantified in terms of increased state tax revenues over a period of time. A study of ICT spillover effects on India by Yoshino et al. (2019) suggests that a large-scale mobile tower construction program has increased the number of mobile network subscribers. The rise in the number of mobile network subscribers is associated with the increase in the amount of regional tax revenues collected by state governments, using simple fixed effect (FE) as well as FE two-stage least-squares (2SLS) estimations. The study shows that, on average, an increase in the number of Global System for Mobile communications (GSM) subscribers by 10% is expected to raise per capita regional state revenues by ₹134, or roughly 3% of the average state tax per capita in 2016. The results indicate that the development of mobile towers, as reflected in the rise in the number of GSM subscribers, increases tax revenues (Yoshino et al. 2022).

India has diverse demographics and an increase internet penetration reflects in improving socioeconomic variables. The spillover effects in terms of employment and GDP increase are formidable growth drivers that, in turn, drive infrastructure for the nation.

3.4.1 Impact of Telecommunications Infrastructure on Economic Growth in India

In 2018, BIF and the Indian Council for Research on International Economic Relations (ICRIER) released a joint report that highlights the impact of DCI on economic growth in India (Figure 3.5). The report *Growth Dividends of Digital Communications: The Case for India*, highlights the impact of (i) mobile and internet penetration, (ii) mobile and internet traffic, and (iii) investments in telecommunications equipment on GDP.

Figure 3.5: Spillover Effects of Telecom Infrastructure



Source: Indian Council for Research on International Economic Relations and Broadband India Forum.

Impact of Mobile Telecom and Internet Penetration on Growth of States

The 2018 BIF-ICRIER study revisited an earlier ICRIER study carried out in 2009 that studied the impact of mobile penetration exploiting the geographical diversity between 19 Indian states. Using data for 19 states from 1999–2000 to 2007–2008, the earlier study concluded that a 10% increase in mobile penetration resulted in a 1.2% increase in the rate of state GDP growth. New estimates from the 2018 study show that a 10% increase in mobile penetration delivers on average a 1.9% increase in output. Moreover, for states with above average tele-density, a 10% increase in mobile penetration increases the growth dividend to 2.6%. Box 3.1 captures highlights from a research study for a smart city unlocking the potential of digital initiatives.

Box 3.1: A City Unlocking the Potential of Digital Initiatives

- A study modelling Pune as a "smart city" projected that an incremental value of 30% GDP valued at $10.67 billion can be unlocked over 6 years.
- This projection is for an area of 331 square kilometers and a population of 3.5 million.
- This study enabled the city to drive numerous digital service initiatives to capture the resulting growth potential of 15% a compounded annual growth rate.
- And this is just one city—imagine this evaluation across the whole country.

Source: Kaushik, P. (2017). Wireless Broadband Association Study.

Revised Impact of Internet Traffic on Growth (GDP)

ICRIER first estimated the impact of the internet in India using socioeconomic variables across 19 states from 2001 to 2010. The study found that a 10% increase in internet subscribers delivers on average a 1.08% increase in GDP output. As per the ICRIER-BIF 2018 study, new estimates based on internet usage instead of penetration show that a 10% increase in India's internet traffic leads to, on average, a 3.1% increase in GDP per capita, and a 10% increase in India's mobile traffic, leads to on average a 1.6% increase in India's GDP (Kathuria et al. 2018).

Impact of Investments in Telecom Infrastructure on National Growth (GDP)

The ICRIER–BIF 2018 study also captured the impact of investments in telecom infrastructure on the GDP. The NDCP 2018 underlines the potential for $100 billion telecom infrastructure investment with the convergence of ICT, telecommunications, and broadcasting. The study estimated the economic impact of the investment envisioned in the NDCP for 2010–2011 to 2017–2018. Telecommunications investments increased at a compounded annual growth rate of 16.3% during this time. The total investment during this period was around $103 billion or 2.5% of the total gross fixed capital formation for India through those years. The study estimated that a 10% increase in India's telecom investment can lead to, on average, a 3.3% increase in India's GDP (Kathuria et al. 2018). The $100 billion investment envisioned in the NDCP 2018 could cumulatively add $1.21 trillion to India's GDP.

3.4.2 Impact of Applications on National Growth (GDP)

According to a report by ICRIER, internet applications contributed a minimum $20.4 billion to India's GDP in 2015–2016. According to a 2017 report by Arnold et al., each user of applications in India receives on average $249 of consumer surplus annually. Applied to the total population, this number stands at $74 per capita annually (Kathuria et al. 2018). The impact of internet penetration is multiplied with the launch of various mobile applications, providing users (even with minimum digital literacy) with ample business, finance, and entertainment opportunities at their fingertips. The point of emphasis is that the monetizing aspect of such apps or information disbursement is possible only if users have access to telecommunication networks and devices.

3.4.3 Impact of Broadband on Job Creation

There are comprehensive estimated broadband employment creation multipliers in various countries that provide an estimate of the potential employment gains that could result from effective broadband development, which is between 2.5 and 4.0 additional jobs for each broadband job (Kelly and Rossotto 2011).

3.4.4 Cross-country Impact of DCI

The spillover effects from robust DCI of one nation rubs off on the neighboring countries positively. There are various studies that estimate the impact of the cross-border spillover effects specifically for broadband infrastructure to be larger than its within-country effect. A study by Kim et al. (2020) broadly implies that increased access to the internet can benefit not only one's own country's economic growth, but also other neighboring economies to a higher extent. The various digital initiatives that provide banking, health, and education are rapidly adapted by the neighboring countries and other nations even. The success of Aadhaar-WIN, UPI (mentioned in the next sections in detail) that flourished in India due to DCI are exemplary initiatives that have led to cross-country spillover effects.

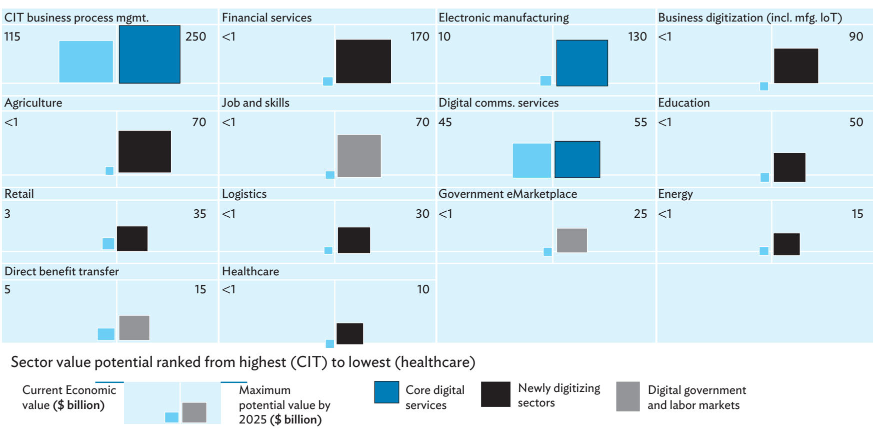
3.4.5 Impact of DCI on Education, Healthcare, Employment, and Other Socioeconomic Factors

A study on the spillover effects of ICT infrastructure in India by Yoshino et al. (2022) highlights the importance of digital infrastructure for healthcare and education, especially in the post-COVID-19 era. During the COVID-19 pandemic, education and health were the two worst-hit sectors, but these were able to rebound due to the online shift of service availability in India. ICT has shown its strong contribution to overcoming difficulties during this devastating public health crisis by enabling people to connect, work, shop, and learn while maintaining constraints such as "staying at home" and physical distancing. Moreover, many governments used big data for various pandemic control measures and impact measurement related to contact tracing, mobility, and health analysis. The use of the internet for healthcare and education during the COVID-19 pandemic has enabled patients to consult with healthcare professionals through online medical platforms and students to continue their learning activities despite school closures. These models of online and/or virtual healthcare and education services are expected to continue even after the pandemic ends.

With the outbreak of COVID-19, many schools closed down and students were left with no choice but to study from home. Fortunately, ICT was helpful in aiding remote learning, enabling teachers and students to continue their learning activities despite school closures. The remote education has been made possible due to the development of digital infrastructure in India that will increase the quality of human capital. Based on the production function of Y=F(K,L), the long-term increase of production will be achieved by human capital investments through remote education (Yoshino et al. 2022). Therefore, investment in access to and quality improvements of ICT infrastructure can be considered an important factor, not only for human well-being, but also for economic development.

Another study by McKinsey Global Institute (2019) estimates the impact of DCI on education, health, employment, and other socioeconomic factors. Discrete use cases were identified with their potential impact, in terms of greater output, time, or cost saved; these estimates were multiplied by their adoption rates to create a macro picture of potential economic gains for each application, scaled up for each sector. All the estimates are in nominal US dollars in 2025 and represent scope for economic value creation in that year. Figure 3.6 shows the current economic value of each sector in 2018 and the potential value by 2025 due to the impact of DCI.

Figure 3.6: Impact of DCI on Socioeconomic Factors



Source: Mc Kinsey Global Institute Analysis (2019). Report – Digital India: Technology to Transform a Connected Nation, March 2019.

3.5 Case Studies—Spillover Effects of DCI in India

This section focuses on the spillover effects of DCI on the overall economy, the socioeconomic sectors such as education, healthcare, the financial system, and agriculture, and most importantly, in improving the quality of life of the common Indian citizen. For a geographically vast and demographically diverse country like India, to have a singular impact on a massive scale is what makes the spillover effects evident.

With this as a base, in recent times, especially in the post-COVID-19 pandemic scenario, sectors such as education, health, banking, agriculture, and transport were significantly and positively impacted due to the government's initiatives that were backed by robust DCI. The triangulation of Aadhaar, CoWIN, and UPI made these sectors accessible and helped to reduce the urban rural divide that citizens faced in terms of these facilities.

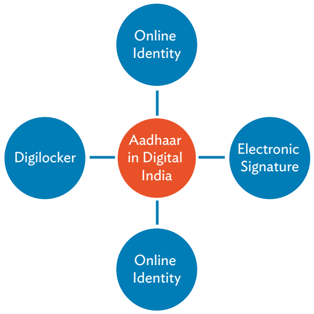
In this section, four case studies related Aadhaar, UPI, CoWIN, and Fastag are presented to depict the impact and spillover effects that have been possible due to the availability of robust DCI in India.

3.5.1 Case Study 1: Aadhaar

The Unique Identification Authority of India (UIDAI),[1] a statutory authority established in January 2009 by the Government of India, rolled out the largest biometric identity program in the world. Aadhaar—meaning "foundation" in several Indian languages—has the vision to provide and empower residents of India with a unique identity and a digital platform to authenticate anytime, anywhere.

Each Aadhaar recipient receives a 12-digit unique identity (UID) number. It is a random number linked to their demographic (name, address, date of birth, and gender) and biometric (one photograph, 10 fingerprints, and two iris scans) information. Aadhaar is the central pillar in Digital India as illustrated in Figure 3.7.

Figure 3.7: Aadhaar in Digital India



Source: UAIDI.

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1 UIADI - Aadhaar. https://uidai.gov.in/ (accessed 11 May 2022).

As of April 2022, Aadhaar enrolled nearly 1.3 billion Indian citizens and resident individuals above 18 years (about 15% of the global population), covering 99% of the eligible population. In the context of India's demographics and diversity, this is a singular achievement. A digital identity program of this scale allows the government to roll out several initiatives with ease and minimum intervention.

Aadhaar provides the foundation for good governance and efficient, transparent, and targeted delivery of subsidies, benefits, and services. In India, 312 schemes[2] have been notified having Aadhaar as one of the means of identification. By enabling end-to-end digitization of distribution and sales processes, Aadhaar helps eliminate issues related to fraud, disbursement of benefits, etc. For Fair Price shopping, distribution of the ration is done to the authorized beneficiary via a device that links to the Aadhaar database via a mobile, Wi-Fi, or cabled internet connection, and then verifies the beneficiary's identity and eligibility. Also, by linking Aadhaar to bank accounts, direct benefit schemes that are seeded on Aadhaar can be used to make payments directly in beneficiaries' account. Aadhaar has been an equalizing game changer and a significant feature in the lives of people in India.

3.5.2 Case Study 2: UPI

Unified Payment Interface (UPI) is a unified platform that allows users to merge and manage multiple bank accounts on one single platform and conduct various banking activities. UPI has been developed by the National Payments Corporation of India (NPCI). It is a revolutionary product in the payment system and was termed a "WhatsApp Moment" for the banking sector in 2016 due to the ease and accessibility of the payment system being as fluid as WhatsApp.

With UPI, a person can send money to anyone by entering their unique virtual payment address, Aadhaar number, or by scanning a QR code, to a merchant by scanning their QR code. The generic UPI working architecture is illustrated in Figure 3.8. Similarly, one can initiate payment collection from different platforms. One does not need to enter bank details or other sensitive information each time a new transaction is initiated.

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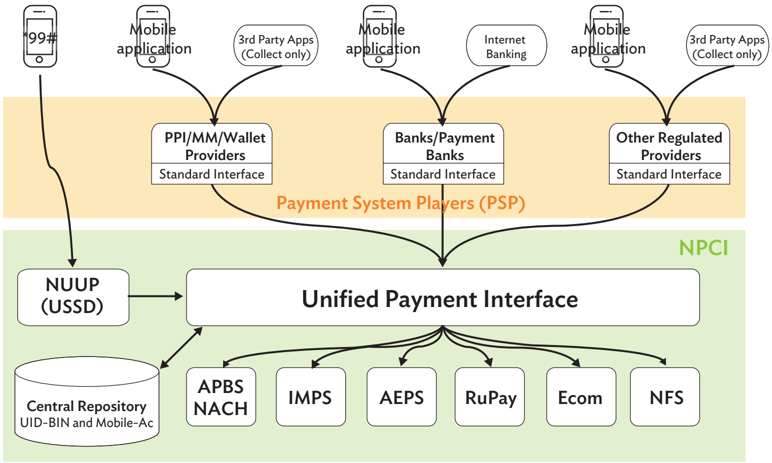
[2] The list is available at https://www.uidai.gov.in/images/Rajya_Sabha_Unstarred_Qn_No_1189_answered_on_29_7_2021.pdf (accessed 12 May 2022).

Figure 3.8: Unified Payment Interface Working Architecture



AEPS = Aadhaar Enabled Payment System, APBS NACH = Aadhaar Payment Bridge Service National Automated Clearing House, Ecom = e-commerce, IMPS = Immediate Payment Service, NFS = National Financial Switch, NPCI = National Payments Corporation of India, NUUP (USSD) = National Unified Platform (Unstructured Supplementary Services Data), Rupay = portmanteau of Rupee and Payment, Indian multinational financial services and payment service system, UID = unique identification.

Source: UPI.

As of March 2022, the total value of UPI transactions reached $130.44 billion. Digital transactions worth $2.60 billion are now taking place daily in India. UPI has driven financial inclusion across all segments. The outreach of UPI is powered by robust DCI, mobile penetration, and internet coverage in India. The digital payment coverage provides impetus to the widely unbanked rural sector with new norms and with minimal digital literacy required to operate. It has changed how small businesses operate owing to the digital payment facility available on their mobile. The ecosystem of the UPI indicates the investment in the "soft" digital infrastructure is paying large dividends (Box 3.2).

Box 3.2: PhonePe Pulse Data Show the Socioeconomic Spillover Effects of having Robust Digital Communications Infrastructure

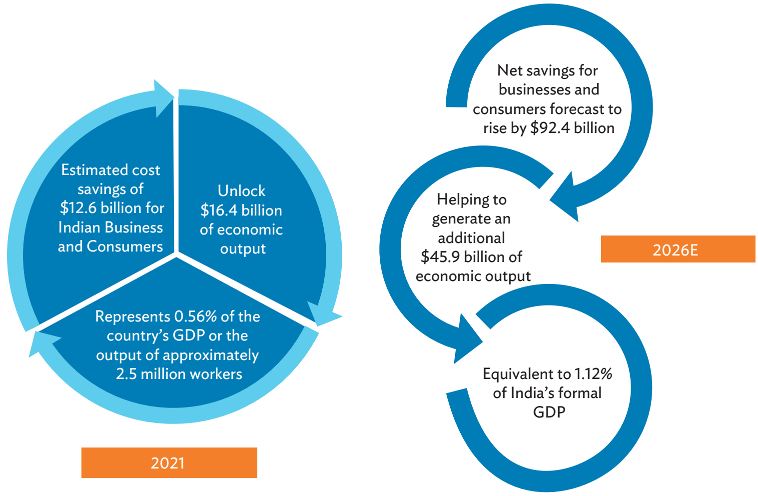
- In 2020, a PhonePe user, while driving his transport truck from north to south India, made transactions at 75 gas stations across 13 states.
- Small towns have started saving significantly, investing an average of $400 in mutual funds through digital means. This is 2.5 times more than Mumbai metro customers invest.
- Around 25 million businesses in 15,700 Indian cities and villages have digitized themselves, encompassing 99% of the nation's pin codes.
- The highest average transaction value in the nation was spent by residents of farthest state Mizoram via PhonePe in Q3 2021. They spent an average of nearly $40.
- On the PhonePe app, transactions from food and beverage retailers accounted for more than 37% of all transactions that take place after 6 pm. Visibly, the tourist season was booming, with merchant payments (online + offline) seeing a record 46% jump from the previous quarter.

Source: PhonePe digital payment system data points. https://www.phonepe.com/pulse/fun-facts/ (accessed 12 May 2022).

UPI Goes Global

The Reserve Bank of India and the NPCI are working together to expand the reach of UPI globally. It will boost open interoperable systems and enable UPI payment transactions in partnered country. These efforts will enable real-time, cross-border, person-to-person transactions between partnered countries and businesses to make instant, low-cost fund transfers between the two countries and also boost their respective financial sectors. Nepal has already adopted the system, while Bhutan, Singapore, and the United Arab Emirates will partner soon.

Figure 3.9: Economic Effects of DCI Enabled Real-time Payments



DCI = digital communications infrastructure, E = estimate, GDP = gross domestic product.

Source: Centre for Economics and Business Research (CEBR) Report (2021).

3.5.3 Case Study 3: Co-WIN

Co-WIN (Winning over COVID-19) is a digital platform of the Government of India. It is a cloud-based system that facilitates the whole process of the vaccination drive from registration and appointments, and issues digital vaccination certificates. The Co-WIN design drives India's vaccination program with its simple user interface to register and select the nearest accessible vaccination center, and also provides an option to choose the vaccine type. The citizen-centric operation of Co-WIN symbolizes the Digital India endeavor for the good of society.

India achieved the feat of covering 87% of the population in the COVID-19 vaccination drive, with 1.08 billion[3] registrations and 1.9 billion doses administered. In this vaccination drive, 73% of

[3] CoWIN website. https://www.cowin.gov.in (accessed 10 May 2022).

people were from rural and hard-to-reach areas. In the context of the global scenario, India has administered more than the combined total achieved by the US, Brazil, Indonesia, and Japan; only the PRC has higher numbers (according to data available as of March 2022) (UNDP 2022).

The success of Co-WIN as a digital health platform is an example of how the existing digital infrastructure, when adapted and integrated, improves assets and can be leveraged for different sectors. The array of digital public services that existed previously, i.e., Aadhaar, the Electronic Vaccine Intelligence Network (e-VIN a robust supply chain solution in India since 2015), Digital Infrastructure for Vaccination Open Credentialing to support digitally verifiable certificates, and DigiLocker (a cloud-based platform for storing, sharing, and verifying documents and certificates) are credited for the swift rollout of Co-WIN.

The Government of India has offered the Co-WIN system as a public good, which is constantly being diversified to accommodate relevant public health features. Co-WIN is going to be adapted in different locations worldwide and the transfer of knowledge to other countries is being supported by the United Nations Development Programme (News 18 2021).

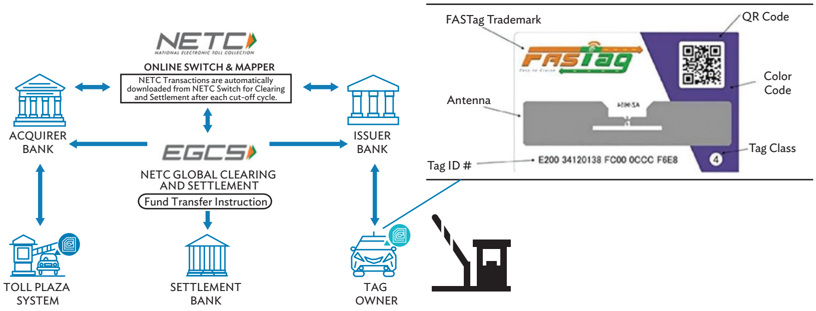
3.5.4 Case Study 4: FASTag

FASTag is a radio frequency identification technology that is operated by 23 different banks, governed by the NPCI and the National Highways Authority of India (NHAI). It was introduced in October 2017 to facilitate electronic toll collection across India. This measure helps to overcome several inconveniences for drivers.

There was a conservative estimate for waiting times carried out by the live monitoring of traffic at more than 488 national highway toll plazas. Based on that, a $1.6 billion loss was estimated, 35% on wasted fuel, while 54%–55% on wasted staff hours, and the rest due to the carbon emissions component (Times of India 2019). The factor of fuel waste and human exhaustion accounted in monetary loss, along with a considerably high level of air pollution in the perimeter of the toll plazas.

A FASTag is affixed on the windscreen of the vehicle and enables the customer to drive through toll plazas without stopping for any payments. The fare is directly deducted from the linked account of the customer. The schematics of FASTag operations (Figure 3.10) showcase the interplay of soft and hard digital infrastructure. By the end of 2019, about 1.10 crore FASTags had been issued through multiple

Figure 3.10: Schematics of FASTag Operations



Source: National Payments Corporation of India.

points of sale. The highway authority has been observing sales of nearly 200,000 FASTags daily, which is a reflection of this digital system being accepted (Hindu Business Line 2019).

FASTag was made mandatory from 1 April 2021 and has brought efficiencies in transport movements. The enablement and adoption of FASTag required minimal digital literacy. Further, the data of vehicle license numbers can be used to analyze transport movement patterns for policy making. The success of FASTag summates the DCI spillover effects in India.

3.6 Role of Big Data in Assessing Spillover Effects of DCI Growth

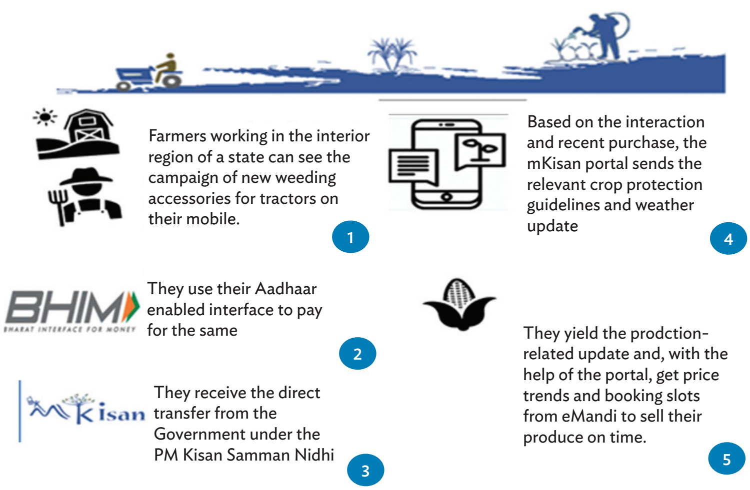
"Digital India"[4] is the flagship program of the government launched in 2015, which drives digitization, digitalization, and other initiatives to have a positive impact on India's economy. The Digital India program comprises three pillars, i.e., digital infrastructure as a core utility, governance and government services delivered digitally to citizens, and ensuring universal digital literacy. Robust DCI is the backbone for these initiatives and empowering the citizens of the nation.

4 Digital India website. https://www.digitalindia.gov.in/ (accessed 12 May 2022).

Big data (data sets with high variety and velocity) are generated owing to these digitization initiatives in India. The limitless scope of UID and the push to use it as the primary, if not the sole identifier for various government services leads to easy relational conjoining of databases. The presence of an identifier like Aadhaar in e-governance schemes can enable profiling, collation, and convergence of information. Aadhaar serves as a common identifier for disparate databases; through the seeding process, it is as a versatile authenticator in various government schemes (Kumar et al. 2022). The use of Aadhaar as a requisite for various e-governance schemes creates a comprehensive trail for various sectors and an integrated profile of an individual with various public services availed. These data footprints can be proposed as a DCI spillover effect in the education, health, finance, agriculture, and manufacturing sectors and can be gauged effectively.

In the previous section, the Co-WIN, UPI, and FASTag case studies are examples of originators of big data. India's COVID-19 drive to vaccinate 1.3 billion citizens through extensive use of the Co-WIN app is supported through big data. The data captured in terms of infected, recovered, and active cases helped to analyze the pattern, and

Figure 3.11: Big Data and Agriculture



Source: ResearchGate.

computational analysis helped to understand the spread and control of the virus. India also set an example for the entire world by setting up the world's biggest vaccine factory that supplies vaccines around the world.

The real-time observed benefits of DCI are rampant. For instance, a farmer having an Aadhaar card-linked mobile payment facility reaps the benefit of remotely buying agricultural products, inputs purchases, and subsidies from the government as cited in Figure 3.11. In turn, the farmer gets precise and relevant data regarding crop production trends and incentives. This atomic-level benefit can then be analyzed in an aggregated mode with the help of big data and translated into informed policy-making decisions.

3.7 Conclusion and Policy Recommendations

The near-ubiquitous diffusion and use of modern digital communications, especially during the COVID-19 pandemic, is an expression of their indispensability in contemporary economic and social existence. A new, holistic role of digital communications and services is needed to capture the realities of the new converged world. Digital infrastructure is an acknowledged precursor to digital growth. India should use technologies such as satcom, public Wi-Fi, and wireless broadband backhaul technologies especially in urban and rural areas where it is either difficult or not viable to deploy conventional technologies like towers and fiber optic cables, to overcome the significant infrastructure and service deficits that persist.

To meet the needs of a country as vast and diverse as India, with deep remote and rural interiors and geographically difficult terrain, all critical elements need to be included while defining digital infrastructure—fixed cables, E and V bands, public Wi-Fi, and satcom. A single network built on any single component would not be sufficient. The NDCP 2018 emphasizes the need for creation of a robust digital communications infrastructure and sets specific targets for the different elements of digital infrastructure to realize the goal of "Connect India". The definition of digital infrastructure according to the International Telecommunications Union (ITU) includes essential critical elements such as Wi-Fi and satcom, among others. There is a need to have a prudent interplay of essential elements of digital infrastructure viz. Public Wi-Fi hotspots, satellite communications, and the use of E and V bands, besides fiber and towers, in a proportionate and equitable manner.

To deploy reliable high-speed broadband services, optical fiber networks will be an important element. Fiber networks are pivotal to the success of the data-driven era propelled by the adoption of 5G, video calling, and IoT. Besides fiber, alternate and cost-effective multi-gigabit high-speed wireless technologies such as E and V bands will help backhaul the high speed and high capacity 5G access networks in both urban and rural locations where fiber laying is a techno-economic challenge. Public Wi-Fi services at the grassroots level will boost broadband proliferation across the nation significantly, converting the masses into digital citizens in the fastest and most cost-effective manner. The vision of the PM-WANI system for seamlessly delivering public Wi-Fi services to the citizens via public data offices, public data office aggregators, and app providers would facilitate liberalization of access and enable great outreach and utility for the public.

Much of rural India remains starved of connectivity. Satcom will be a principal resource for facilitating outreach and connectivity, especially to the remote, rural, and inaccessible terrains, in a faster and more cost-effective manner as compared to terrestrial technologies.

Digital infrastructure needs to increase several-fold in the next 5 years to help achieve the goal of trebling the GDP to $7.5 trillion and to complement the rollout of 5G rapidly across the country and across different verticals. This would require investments to the tune of $100 billion in digital infrastructure. Moreover, all the components of digital infrastructure require investments in an equitable and proportionate manner in order to help India become a truly digital economy and society and not just achieve but exceed Prime Minister Narendra Modi’s vision of attaining a $1 trillion digital economy by 2025.

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PART II

Transport and Water Infrastructure

4

Cost–Benefit Analysis of Spillover Tax Revenues of High-Speed Rail in Taipei,China

Naoyuki Yoshino, Kai Xu,
Deepanshu Agarwal, and KE Seetha Ram

4.1 Introduction

Sustainable economic development requires huge infrastructure investment in developing Asia. Traditional financing sources include public sector investment, long-term financing instruments such as insurance and pension funds, and multilateral international organizations such as the World Bank and the Asian Development Bank (ADB). However, in the context of developing Asia, most economies face a high government debt issue, and sources for long-term investment are lacking. Considering, in particular, the ongoing novel coronavirus disease (COVID-19) pandemic and the conflict between the Russian Federation and Ukraine, relying on traditional financing sources only cannot fill the infrastructure investment gap.

Against this background, the objective of this chapter is to attract private sector investment into infrastructure financing. The key is spillover tax revenues, which are also known as "indirect" or "secondary revenues" or "externality effects." Through a case study of high-speed rail in Taipei,China, the chapter describes how to identify spillover tax revenues quantitatively, and how to mobilize and combine them with floating infrastructure bonds and land trust schemes to improve the internal rate of return (IRR), which is an important indicator for private sector decisions in investment. Compared to the traditional approach to infrastructure investment, the proposed financing schemes would improve the IRR significantly.

This chapter contributes to the discussion on sustainable infrastructure financing in developing Asia by introducing spillover tax revenues. Floating infrastructure bonds can channel the available sources into long-term investment, while land trust schemes are helpful in mitigating bottlenecks in the land acquisition process, which is a problem for South Asia and Southeast Asia. The combination of these and the significant effect in terms of improved IRR are shown in the case study, and more context-specific integration of innovative financing schemes is expected in future practices.

The chapter is structured as follows: Sections 4.2, 4.3, and 4.4 address the situation of traditional financing sources in developing Asia, and the need for private sector investment is highlighted. Section 4.5 introduces the concept of spillover tax revenues and the difference-in-difference (DID) method. Section 4.6 introduces the concept of floating infrastructure bonds. Section 4.7 focuses on the case study on high-speed rail in Taipei,China that incorporates the proposed financing schemes. This is followed by Section 4.8 describing the cost-benefit analysis for both the public and private sectors. Section 4.9 presents the conclusion and policy recommendations.

4.2 Need for Private Sector Financing in Infrastructure Investment

Infrastructure such as water supply, electricity, roads, railways, among others, is an essential part of economic growth. Providing basic infrastructure such as water and sanitation, like the provision of security and safety, is an activity that should be treated as part and parcel of not only human development, but also enlightened governance at national and international levels (Seetharam and Rao 2006). Infrastructure can promote employment in the region and provide opportunities for small businesses to start their business after its completion (Sawada et al. 2014).

In 2016, ADB estimated that in developing Asia an annual investment of $1.7 trillion is required from 2016 to 2030 to fill the infrastructure investment gap for the ongoing growth momentum to be sustained (ADB 2017). Detailed estimation for regions in Asia is shown in Table 4.1.

However, COVID-19 and the associated emergent fiscal spending for healthcare and compensation for affected people has reduced the expected infrastructure investments in developing nations (Yoshino and Hendriyetty 2020). With the emergence of variants in the past 2 years, the pandemic and its impact will be long term. In addition, escalating global geopolitical tensions arising from the conflict between the Russian Federation and Ukraine and the associated increases in energy and other

Table 4.1: Estimated Infrastructure Needs in Asia

	Baseline Total ($ billion)	% of GDP	Climate-adjusted ($ billion)	% of GDP
Central Asia	33	6.8	38	7.8
East Asia	919	4.5	1,071	5.2
South Asia	365	7.6	423	8.8
Southeast Asia	184	5.0	210	5.7

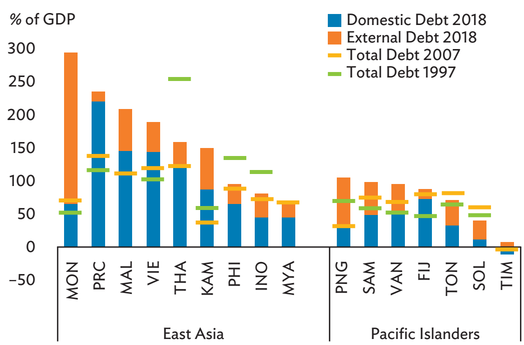
GDP = gross domestic product.

Source: ADB (2017).

commodity prices have pushed up the inflation rate in developing Asia, which is estimated to be 4.4% in 2022 and 3.1% in 2023 (ADB 2022). All risks are adding to the financial instability for infrastructure.

Public sector spending is an important source for infrastructure investment. As illustrated in Figure 4.1, Asia and the Pacific economies have faced a high debt ratio, which has put a constraint on the infrastructure investment from the government side.

Figure 4.1: High Debt Ratio in Asia and Pacific Economies



GDP = gross domestic product, MON = Mongolia, PRC = People's Republic of China, MAL = Malaysia, VIE = Viet Nam, THA = Thailand, CAM = Cambodia, PHI = Philippines, INO = Indonesia, MYA = Myanmar, PNG = Papua New Guinea, SAM = Samoa, VAN = Vanuatu, FIJ = Fiji, TON = Tonga, SOL = Solomon Islands, TIM = Timor Leste.

Source: Authors, based on IMF (2018).

Against this background, private sector financing becomes important to pursue planned infrastructure investments, and to keep sustainable and equitable economic growth in developing Asia.

However, it is especially difficult to induce private sector financing in infrastructure investments. There are several challenges for the private sector in making such a decision. First, corruption in infrastructure investments can be an issue. Second, land acquisition is difficult in Asia and politicians are often involved in negotiations between landowners and infrastructure investors. Third, and most importantly, the initial cost, such as that for land acquisition and construction, is high while user charges (for toll roads and water supply) are kept low, which will result in a low rate of return from the investment as the revenue is not expected to cover the construction and other costs (Bambang, Donghyun, and Shu 2019).

4.3 Need for Long-Term Investment

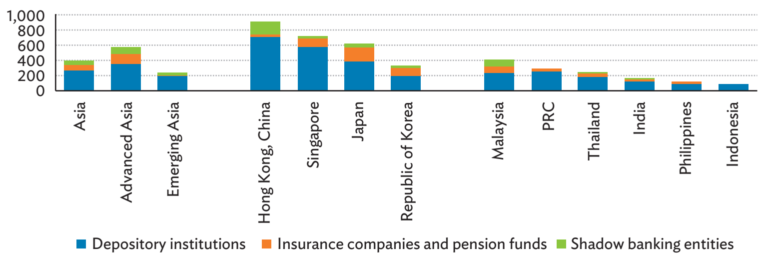
Infrastructure requires long-term finance. Insurance, pension funds, and long-term deposits can be utilized for long-term infrastructure investment. Life insurance has two merits. One is the support and protection of family against unexpected accidents, disease, or death. The other is the characteristic of its long-term nature. Life expectancy is increasing in many Asian economies, and pension funds and long-term deposits are essential as aging has become a social issue. Private pensions and public pension funds will also assist people's daily living after their retirement. Without a good pension system, people cannot be supported after their retirement. Household members can benefit from long-term deposits to support their living as they get old.

Insurance and pension funds are long-term investors and they do not change their portfolio based on short-term fluctuations in the rate of return. They are patient investors and very suitable for infrastructure investment. Insurance and pension funds can invest in infrastructure as long as the rate of return is high and risks are low.

However, the low share of insurance and pension funds in Asian economies makes investment in infrastructure difficult. As can be seen in Figure 4.2, Asian economies show a higher bank savings rate than in the 1990s when the Asian financial crisis of 1997–1998 hit the region. Many Asian economies relied heavily on foreign capital to support their investment because of the lack of domestic savings in the 1997–1998 period. Foreign investors normally request dollar-denominated infrastructure finance to avoid exchange rate risks. Foreign currency-denominated borrowing for infrastructure from abroad brought foreign exchange volatility to governments. Short-term capital made sudden inflows and outflows, which was one reason for the Asian financial crisis.

As a result, in Asia, savings are concentrated in bank deposits. In the Asian region, insurance and pension funds are often deposited in banks as deposits. Banks can provide 1- to 5-year loans. However, this is relatively short-term compared to the duration of infrastructure investment. Long-term savings such as insurance and pension funds are lacking.

Figure 4.2: Assets of Financial Institutions in Asia
($ billion)



PRC = People's Republic of China.

Source: IMF (2018).

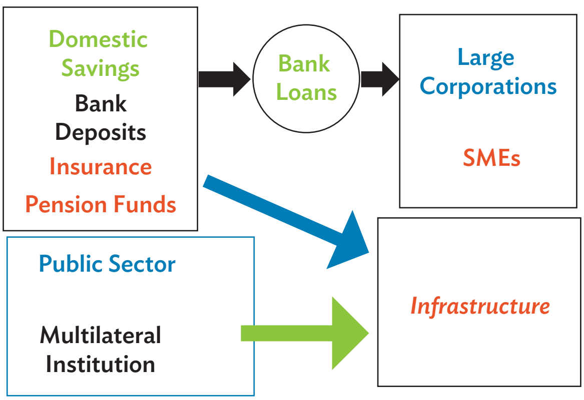
With the higher economic growth and higher remittance receipts in recent years, developing Asia has collected significant bank deposits. If domestic savings are well circulated for domestic investments including infrastructure investments, there is a reduced need for foreign investments. This is quite different from the 1997–1998 period, when huge overseas capital flew into the Asian region.

4.4 Role of Multilateral International Organizations in Infrastructure Investment

Infrastructure has been financed by multilateral institutions in the Asian region together with spending from local government. Multilateral institutions such as the World Bank, ADB, and the European Bank for Reconstruction and Development can play an important role in avoiding corruption in infrastructure investment. In our view, multilateral institutions can be involved by investing a small share of the total infrastructure project cost (say 3% or 5%) so that they can act as a watchdog to secure compliance with contracts and transparency in general. The involvement of multilateral institutions with a small share of investment could avoid corruption in infrastructure investment and thus attract more private investors.

At the same time, multilateral institutions can provide long-term fixed interest rate loans for infrastructure investments in various economies. Some recipients complain that the fixed rate of interest is high. However, as discussed in the following section, if the spillover tax revenues created by infrastructure investments were considered (which are subtracted from fixed interest loans from multilateral financial institutions), the net interest burden from multilateral institutions would be reduced.

Figure 4.3: Financing Sources for Infrastructure Investment



SME = small and medium-sized enterprise.

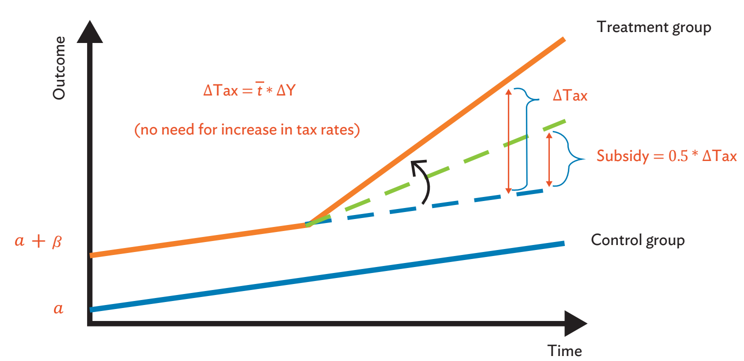
Source: Authors

In short, to attract private investors, as well as insurance, pension funds, and bank loans, to invest in infrastructure, the rate of return must be improved, and the risks must be minimized (Figure 4.3). A higher rate of return is the enabler for sustainable long-term infrastructure investment, and spillover effects and innovative financing schemes that incorporate spillover tax revenues are the key (Yoshino, Hossain, and Taghizadeh 2020).

4.5 Spillover Effects of Infrastructure Investment

The spillover effect is also called an "indirect" or "secondary," or "externality" effect of infrastructure investment (Yoshino, Helble, and Abidhadjaev 2018). To capture the spillover effect, the DID method is utilized. Two groups, the treatment and control group, are defined based on the impact of policy interventions or infrastructure projects. The methods assume that the changes in outcomes between groups are the same over time, and the policy or the project is the only intervention that creates a difference. It computes the double difference over time and region for groups, namely the differences between pre- and post-infrastructure investment (time-wise) and between treatment and control group (geography-wise). As illustrated in Figure 4.4, the differences in pre- and post-outcomes for both groups are obtained (the time axis). Then, for the treatment group, the difference is subtracted from the total difference to further exclude other time-varying factors (solid red line and dotted blue line). Finally, the net difference is interpreted as the spillover effect of the infrastructure project (Yoshino, Abidhadjaev, and Nakahigashi 2018).

Figure 4.4: DID for Spillover Effect



DID = difference-in-difference.

Source: Authors based on Yoshino and Abidhadjaev (2016).

One Japanese case (for details, see Yoshino and Abidhadjaev 2017b) is provided to illustrate the impact of infrastructure investment. Table 4.2 shows the productivity effect of infrastructure based on Japanese macroeconomic data and assuming translog production function. The direct effect of infrastructure investment is shown in the first row, and the second and third rows show the spillover effects on private capital and labor. In the 1950s and 1960s, both the direct effect and the indirect effects were very large. The direct effect of infrastructure investment pushes up regional gross domestic product (GDP). In later years, new businesses open alongside the new infrastructure project. New factories and new shopping malls hire people in the region, which will increase employment. The last row is the ratio of spillover effects to direct effects. It is estimated that about 66%–68% of all effects lie in spillover effects created by infrastructure investment.

These spillover effects increased regional GDP and various tax revenues in the region. Business tax, income tax, sales tax, and property tax revenues will rise as infrastructure projects generate a larger and larger impact in the region. Currently, all these spillover tax revenues are absorbed by central and local governments. They are not returned to infrastructure investors and infrastructure operators.

From the perspective of infrastructure investors and infrastructure operators, user charges are currently the main revenue source. In terms of water supply, the price must be as low as possible as water is a necessary good for the whole population (Seetharam and Fan 2014). As for electricity, the price must be as low as possible to serve the public. However, investors in infrastructure prefer a higher rate of return while users prefer a lower price. There are conflicts between users and investors in infrastructure. Rationalizing or raising tariffs may often require difficult institutional changes and the reasons for increasing tariffs may need to be fully explained to water consumers and producers as well as to politicians (ADB 2002). This is the reason why private participation in infrastructure investments is slow.

If part of spillover tax revenues were returned to investors in infrastructure, the rate of return would be user charges plus a fraction of spillover tax revenues, meaning a higher rate of return could be expected (Yoshino and Abidhadjaev 2017a). Detailed econometric estimation would be required to assess what percentage of spillover tax revenues should be returned to infrastructure investors. In the case of Japan, about 66%–68% of spillover tax revenues are identified, and a portion of this should be returned to infrastructure investors. In practice, sophisticated econometric methods cannot be easily applied to various infrastructure investments. In the case study, 50% of total spillover tax revenues are assumed to be returned to infrastructure

Table 4.2: Macroeconomic Estimates of Spillover Effects, Japan

	1956–1960	1961–1965	1966–1970	1971–1975	1976–1980	1981–1985	1986–1990	1997–1995	1996–2000	2001–2005	2006–2010
Direct effect of infrastructure investment	0.696	0.737	0.638	0.508	0.359	0.275	0.215	0.181	0.135	0.114	0.108
Spillover effect through private capital	0.452	0.557	0.493	0.389	0.270	0.203	0.174	0.146	0.110	0.091	0.085
Spillover effect through employment	1.071	0.973	0.814	0.639	0.448	0.350	0.247	0.208	0.154	0.132	0.125
Spillover effects of infrastructure investment (%)	66.644	67.481	67.210	66.907	66.691	66.777	66.222	66.200	66.094	66.122	66.139

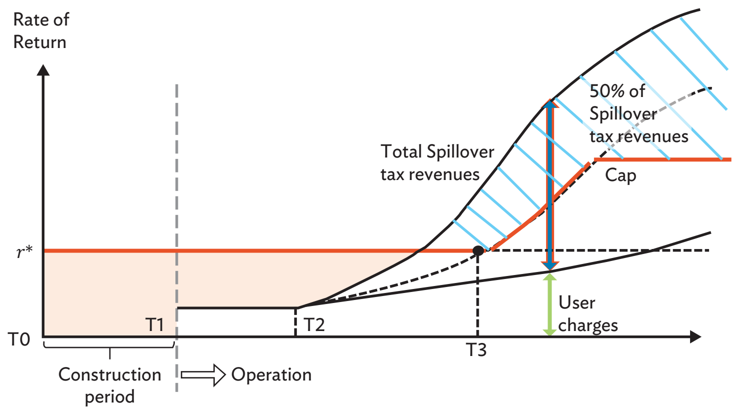
Sources: Nakahigashi and Yoshino (2016), Public Policy Review (Ministry of Finance, Japan).

operators and investors (Figure 4.5). In other words, the government and private sector should share spillover taxes half and half. If spillover effects are large, infrastructure investors and operating companies do not need to rely too much on user charges. Users should only pay a small fee for water, electricity, etc. (Seetharam and Rao 2010).

4.6 Floating Infrastructure Bonds

Figure 4.5 shows the proposed floating infrastructure bonds to implement spillover tax revenues in practice.

Figure 4.5: Proposed Floating Rate Infrastructure Bond Combined with Spillover Tax Revenues



Source: Based on Yoshino, Azhgaliyeva, and Mishra (2020).

T0 to T1 is the construction period where no return from infrastructure is observed. The interest rate of the government bond is set at r*. The operation starts at T1. User charges can be collected, and spillover effects from infrastructure will gradually become larger. Between T0 and T3 the interest rate of the infrastructure bond is the same rate as the government bond where enough revenues are not yet created by infrastructure. After T3, the rate of return is higher than the interest rate of the government bond.

If spillover effects are very large, the floating interest rate will rise to a very high level. The government will be able to set a "cap" for the interest rate to be paid to infrastructure investors. However, the cap has to be set up at the start of the infrastructure floating bond being issued. Otherwise, private investors will be skeptical about the cap level of floating bonds.

Extra revenues above the cap can be kept as reserves to prepare for future disaster damage. Maintenance and repairs may be needed if infrastructure is hit by disaster, which must be supported by government spending. The proposed floating infrastructure bonds set a rule, or rather a reference, for the practice of spillover tax revenues in terms of setting the interest rate. The implementation of a floating bond is demonstrated in the following case study.

4.7 Case Study on High-Speed Rail

In this section, the floating-rate infrastructure bond scheme combined with spillover tax revenues is applied to the case of high-speed rail (HSR) in Taipei,China.

Table 4.3: Timeline of High-Speed Rail Project in Taipei,China

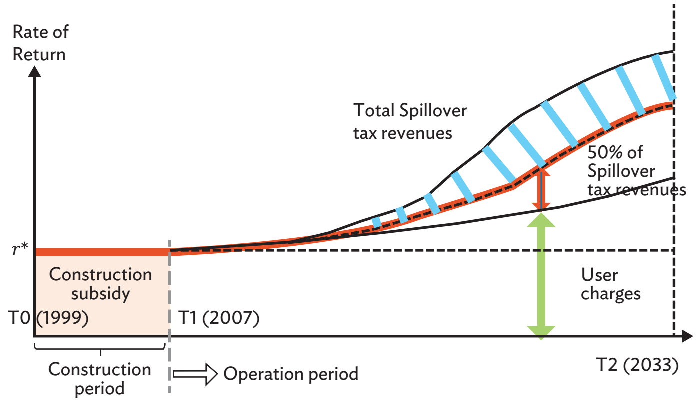
Project Phase	Year	Duration	Cost (NT$ billion)		Revenue (NT$ billion)	
Preparation	Before 1999	Not applicable	Land acquisition	106	0	
Construction	1999–2006	8 years	Construction	408	0	
Operation	2007–2033	27 years	Operation and maintenance	540*	User charge	1,890*
Total		35 years		1,054*		1,890*

Source: Authors.

Table 4.3 presents the project timeline. The project preparation period ended in 1999, during which the necessary land acquisition for construction was conducted. The land acquisition cost was NT$106 billion. Construction took 7 years (from 1999 to 2006) with total construction cost of NT$408 billion. The operation and maintenance period started in 2007. It was contracted to a private sector operator, and the 27-year operation contract is in effect until 2033. The operation and maintenance cost was estimated to be NT$540 billion. Summing the cost of different project periods, the total cost is about NT$1,054 billion. Revenues could be generated when operation began in 2007. Fare revenues are expected to be NT$1,890 billion by 2033. Therefore, as shown in the last row, the total expected revenue is NT$1,890 billion and the total cost NT$1,054 billion. Non-fare revenue is not considered for the case study.

Figure 4.6 and Table 4.4 show the evolution of the rate of return over the project implementation periods.

Figure 4.6: Rate of Return vs. Operation Period



Source: Authors.

During the construction period, the government bond interest rate is paid to infrastructure investors so that they can be sure about the rate of return even though revenues and spillover tax returns are not yet being received. The period between T0 and T1 is the construction period when the revenue is 0 but the government is providing interest payment to investors (indicated by the red shaded area in Figure 4.6). The operation started from T1 (2007) and user charges and spillover tax revenues gradually rose.

The blue shaded area is the 50% spillover tax revenue to the government and the lower half of Figure 4.6 shows user charges plus 50% spillover tax revenues for the investors. After T1, user charges plus 50% of tax revenues become higher than the government bond rate (the dotted line), meaning the investors' rate of return becomes higher than the government bond rate. As for the government, it subsidized the construction period between T0 and T1. However, after T2, the tax revenues will become bigger and bigger (as shown by the blue shaded area in Figure 4.6).

Table 4.4: Subsidy, IRR, and Spillover Tax Revenue in High-Speed Rail Case, Taipei,China

Subsidy Scheme	Construction Period							Operation Period			
Year	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Subsidy (NT$ billion)	118.4	58.3	58.3	58.3	58.3	58.3	0.0	0.0	0.0	0.0	0.0
IRR	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	16.6%	22.4%	25.9%	28.3%	30.0%
Total spillover tax revenue (NT$ billion)	0.0										
Year	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Subsidy (NT$ billion)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
IRR	31.2%	32.1%	32.8%	33.4%	33.8%	34.0%	34.3%	34.4%	34.6%	34.6%	34.7%
Total spillover tax revenue (NT$ billion)	8.8	14.7	21.4	24.8	24.4	22.3	30.4	33.7	37.0	40.3	43.6
Year	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**
Subsidy (NT$ billion)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
IRR	34.8%	34.8%	34.9%	34.9%	34.9%	34.9%	34.9%	34.9%	35.0%	35.0%	35.0%
Total spillover tax revenue (NT$ billion)	46.9	50.2	53.5	56.7	60.0	63.3	66.6	69.9	73.2	76.5	79.8

IRR = internal rate of return.

Note: Spillover tax revenue for 2007–2017 is based on actual tax data; for 2018–2033 it is based on authors' estimation.

Source: Authors.

As shown in Table 4.4, at the end of the operation period (2033), the total spillover tax revenue will become 502.7 (NT$ billion) and the total subsidy during the construction period is 409.9 (NT$ billion). Therefore, the net benefit is 92.9 (NT$ billion). This shows the benefit is bigger than subsidizing the government bond. It will be very attractive for private investors as traditionally private investors could not receive any return in the construction period. At the same time, as for the revenue of the operation infrastructure companies, 50% of spillover tax revenues is added in addition to these user charges. As a result, the rate of return will become higher and the internal rate of return will become about 35% when the spillover tax revenues are considered, which will attract many private investors.

From the government's perspective, the total cost during the construction period (is T0 to T1) is the interest rate on government bonds. This is the entire subsidy the government has to provide to infrastructure investors. After T2, the government starts to receive 50% of spillover tax revenues (Figure 4.6, blue shaded area). Meanwhile, the government does not lose money because 50% of the spillover tax revenue returns to the government, which will exceed the cost of subsidies (Table 4.5).

Table 4.5: Subsidy Scheme Summary
(NT$ billion)

1	Subsidy in construction period (1999–2006)	409.9	(Cost)
2	Subsidy in operation period (2007–2033)	0	(Cost)
3	50% of spillover tax revenue (2008–2033)	502.7	(Revenue)
4 (3–1)	Overall surplus for public sector	92.9	(Net revenue)

Source: Authors.

Further, the investment scheme for the private operator (the investor) under the land trust scheme and spillover tax revenues is simulated (see Box).

Simulation results are presented in Table 4.6. Three scenarios are considered: scenario 1—original (land acquisition), scenario 2—with land trust, and scenario 3—with land trust and spillover revenues. Total cost (1), net present value (NPV) cost (2), total revenue (3), NPV revenue (4), net NPV (5, which is 4–2), and IRR (6) for scenarios are listed. In the original scenario, where the investors purchased the land (thus a high initial cost), and spillover tax revenues are not considered, and total NPV cost (2) is –NT$620 billion. Compared to scenario 2 where the land trust scheme is applied and the initial cost is reduced and replaced by land rent cost, the NPV cost is reduced to –NT$606 billion.

In scenario 3, with both the land trust scheme and spillover tax revenues considered, the NPV cost remains the same (compared to scenario 2), while the total revenue increases from NT$1,890 billion to NT$2,393 billion. The NPV revenue (4) changes from NT$628 billion to NT$766 billion. In terms of net NPV revenue, it is NT$160 billion for scenario 3, compared to only NT$8 billion for the original scenario and NT$22 billion for scenario 2 when only the land trust scheme is applied.

Box 4.1: Land Trust to Smoothe Land Acquisition in Infrastructure Investment

In many developing Asian economies, land acquisition for infrastructure projects has been a major barrier. Due to the delay of land acquisition, the associated project delay may cause cost overrun, which prevents the investors from investing in infrastructure projects (Yoshino and Pontines 2015). Landowners are reluctant to give up their land for development projects. A land trust scheme can be a solution. Under the scheme, the ownership of the land is retained by landowners, while the right of use is leased to infrastructure developers for a stipulated period. A trust bank, which watches the proper use of land and guarantees the payment of dividends to landowners, can be involved. As a practice in Japan, land trust business can only be carried out by trust entities licensed under the Trust Business Act and financial institutions licensed under the Act for Financial Institutions' Trust Business, so that the land trust scheme can be implemented on a proper legal basis.

The land trust scheme can work as a way to avoid corruption related to land acquisition. Land prices are not always revealed in developing economies. Land acquisition is often handled face-to-face with individual negotiation. Land mafias can play a role in these transactions and create corruption. Disclosure of the land price based on transactions is an important step to avoid corruption. Land price evaluators can be set up to assess various land based on a hedonic approach.

Source: Authors.

Table 4.6: Net Present Value and Internal Rate of Return of High-Speed Rail Project in Taipei,China

(NT$ billion)

	Original (Land Acquisition)	With Land Trust	With Land Trust and Spillover Revenues
Total cost	–1,054	–1,134	–1,134
NPV cost	–620	–606	–606
Total revenue	1,890	1,890	2,393
NPV revenue	628	628	766
Net NPV	8	22	160
IRR	5.1%	5.4%	7.2%

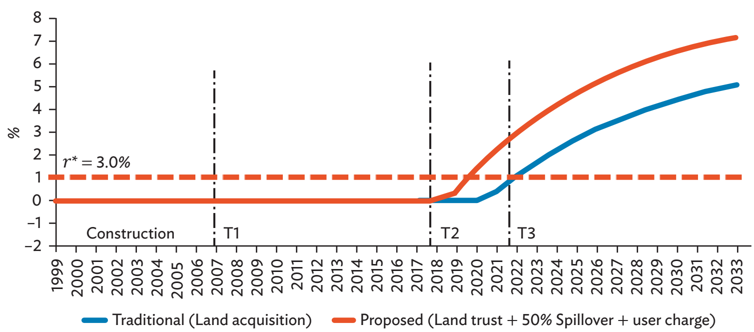
IRR = internal rate of return, NPV = net present value.

Source: Authors.

In terms of IRR, scenario 1 was only 5.1%. With the land trust scheme, the IRR increased to 5.4% in scenario 2. Combining the land trust scheme and spillover tax revenues, the IRR becomes 7.2% in scenario 3, with which the infrastructure project can attract much more private investment than with the original scenario.

The evolution of the IRR for the traditional and proposed investment is plotted in Figure 4.7. The proposed investment scheme considers not only the user charge revenue, but also 50% of spillover tax revenues, in addition to the shift of land acquisition to the land trust scheme. It is clear that spillover effects will increase the IRR by 2.1%.

Figure 4.7: IRR Evolution for Traditional and Proposed Investment



IRR = internal rate of return.

Source: Authors.

4.8 Cost-Benefit Analysis for Different Stakeholders

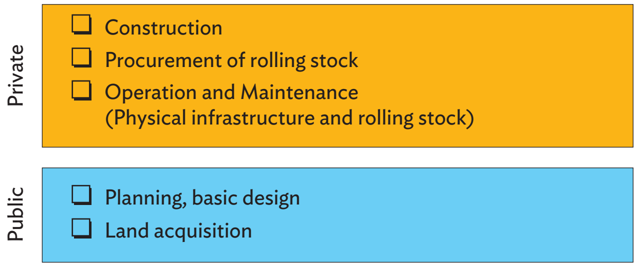
Considering different stakeholders' perspective, the introduction of spillover tax revenues would make the project much more attractive to private investors, yet without incurring additional financial burdens on the public sector.

The privatization of the project was decided by the government in 1998, before commencing land acquisition and construction. The project was awarded to a special purpose vehicle (SPV) called the

THSRC , which was given the right of construction and operation, while the planning and land acquisition responsibility was assumed by the public side, as indicated by Figure 4.8. It was planned that, at the end of the concession period, the THSRC would return the asset back to government.

From the private sector's perspective, based on the cost-benefit analysis, if 50% of the spillover tax revenue is returned to the private sector, the THSRC would receive much more revenue in the operation and maintenance stage. In addition, the revenue during the construction, procurement, and initial operation stage (T1 and T2 stage) could be guaranteed by the government's floating bond. Overall, the revenue situation of the private sector can be improved significantly for the whole project cycle.

Figure 4.8: Responsibility of Private and Public Sector



Source: Authors.

From the public sector's perspective, the provision of the floating bond would not incur additional cost to the government. After T3, the government will receive spillover tax revenues. In addition, the application of the land trust scheme would save the land acquisition cost assumed by the public sector. Therefore, it is a gain to the public sector as well.

The THSRC was taken over by the government after operating for a few years due to the high cost and low revenue, which put the private sector in an unsustainable financial situation. Under the traditional project finance scheme, a much longer time is needed before sufficient revenue is accumulated. It is believed that the proposed investment scheme would make the project much more attractive to private investors.

4.9 Conclusion and Policy Recommendations

In this chapter, we have shown the importance of the spillover effect for infrastructure investment. The key is to improve the rate of return. In the United States, property tax revenues are explored to increase the rate of return to infrastructure investors. This chapter suggests using not only property tax revenues, but also revenues from a variety of other taxes. Spillover tax revenues must be returned to investors so that the rate of return can be improved.

Governments can issue floating interest rate bonds to give incentives to private infrastructure investors. The interest rate of the bond is "floating," i.e., it is kept the same as ordinary government bonds at the initial stage where there are no or insufficient revenues generated from the infrastructure projects, and changes over time when spillover tax returns plus user charges are accumulated. These bonds will give incentives to infrastructure companies to reduce the investment burdens at the beginning of the development. The floating bond will also be a means of keeping user prices as low as possible, which could in turn expand the number of infrastructure users. Portfolios of insurance and pension funds, which are long-term financing sources and thus suitable for infrastructure investment but are not widely mobilized in developing Asia, can be transformed under the floating bond arrangement.

From the public sector perspective, even though governments share the spillover tax revenues with operators and investors, they will gain net revenues since the spillover tax revenues are additional revenues. The spillover tax returns above the cap (set between the government and infrastructure investors) would be kept as government reserves to compensate for the construction costs, maintenance costs, and other costs. Extra spillover tax revenues above the cap can be kept as reserves to repair damage to infrastructure caused by natural disasters such as typhoons or earthquakes.

In terms of private sector involvement in infrastructure investment, their revenue is increased as spillover tax revenues are shared with the local government. Furthermore, the infrastructure investor, or supply firm, should diversify its revenue streams by promoting secondary activities surrounding infrastructure development, such as transit-oriented development or real estate. In some cases, the revenue streams from these secondary activities may be more or less volatile than those from the main project. Subsequently, with a healthy financial situation, user charges like water tariffs and fares can be set at a more affordable level, making households better off. The improved social welfare will create a positive impact on the local economy and raise the marginal productivity of capital, which in turn will raise more tax revenues, assuming the tax rates are held constant. The dynamic circle of infrastructure investment justifies the viability of infrastructure projects and contributes to the sustainable development of the region.

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5

Market Access and Firm Performance: Evidence Using Data from India

Somnath Sharma, Shashi Kant, Ranjeeta Mishra, and Dina Azhgaliyeva

5.1 Introduction

Infrastructure development can improve transportation, making it easier and faster for people and goods to move around. This can reduce transportation costs, increase productivity, and stimulate economic activity. Infrastructure development, such as roads, railways, water supply, and electricity can make a region more attractive to investment by improving the business environment (Yoshino, Azhgaliyeva, and Mishra 2021; Yoshino et al. 2021). Transportation infrastructure can improve connectivity and the ease of doing business, thereby leading to greater sales and profitability. Numerous studies have quantitatively examined the spillover effects of infrastructure on the economies of various countries, and most confirm the positive spillover effects of infrastructure development (Yoshino and Abidhadjaev 2017; Yoshino, Azhgaliyeva, and Mishra 2021; Yoshino et al. 2021; Azhgaliyeva et al. 2021; Azhgaliyeva and Kalyuzhnova 2021; Yoshino et al. 2022). However, the impact of infrastructure varies by period (construction period, short term, medium term, and long term), infrastructure type (transportation, water, energy, etc.), connectivity (local or connected), population density, access to other infrastructure, economic growth, among others (Azhgaliyeva and Kalyuzhnova 2021). Most of the above literature measures the impact of infrastructure using a binary variable before and after construction and/or use of infrastructure, which has many limitations. Unlike other papers, this study uses a newly calculated market access index as a measure of road connectivity using geospatial data in addition to economic data.

We investigate whether better access to markets through an improved road network plays a role in improving profitability. We construct a district-level market access index using Indian road network shapefiles, district boundaries, and night-time light raster images and estimate the shortest driving distances for districts using the road network. Using the annual industries survey data for India during 2001–2015, we examine whether the manufacturing enterprises in the states that have better access to markets through improved connectivity of roads do better in terms of profitability. We measure profitability with an indicator, that is, return on assets (ROA). More specifically, if the firms are located in the states with better connectivity to markets, they will have easier access to markets to sell their products and buy inputs at more competitive prices, thereby increasing their profitability. It should also result in a lower dispersion in ROA. As an alternate specification, we also test our hypothesis using the dispersion of marginal revenue product of capital.

5.2 Literature Review

The seminal work of Krugman (1991) led to the development of the new economic geography literature. Krugman argues that the uneven spatial distribution of industrial activities is an outcome of market processes under conditions of agglomeration economies. In relation to endogenous growth theory, Krugman further highlights the mechanisms through which transportation and communication infrastructure augments productivity (Fujita, Krugman, and Venables 2001). In the pioneering work of Porter (1990), the author underscored the importance of industrial clusters in yielding a competitive advantage for firms and regions. In a similar vein, several studies have pointed out that geography has a central role to play in determining economic growth.

The related literature on agglomeration economies largely focuses on the role of infrastructure, communication, input access, and available markets in the development of industrial agglomerations (Markusen 1996). These factors play a significantly higher role for the development of industrial agglomerations in developing countries; especially the countries characterized with poor infrastructure and centralized institutions. However, as the costs of transportation and communication decline, access to markets becomes easier. Less costly access to distant markets leads to an improvement in sales outside the home state or province (Porter 1996). A similar effect is confirmed in the study by Yoshino et al. (2021), which finds that access to broadband internet has a strong positive impact on the total sales across firm sizes. It is argued that with improvements in transportation infrastructure, market expansion and increased integration will ensue. The structural change may take place through gains from trade, shifts in technology, and agglomeration (Lakshmanan and Chatterjee 2005). Gunasekera, Anderson, and Lakshmanan (2008), in their study on the analysis of the impact of expansion of highways in Sri Lanka using firm-level data, confirm the increase in firm productivity as a result of structural change in the production process. They confirm that the construction of highways induced a shift in the choice of firms to deploy capital and labor, with firms located close to the highway becoming more capital-intensive, and firms located far from the highway becoming more labor-intensive.

Transportation infrastructure is a crucial factor contributing to economic growth. While developed countries possess dense transport networks, developing countries often suffer from underinvestment in infrastructure and thus have a sparse road network. At the firm level, studies have shown that a reduction in input tariffs is associated with a larger increase in firm productivity in towns that are better connected to other regional markets (Fiorini, Sanfilippo, and Sundaram 2019). Firms re-optimize their choice of supplier after the building of better highways. Decreased transportation costs have a direct impact on their profitability (Ghani, Goswami, and Kerr 2016).

A study based on the PRC's manufacturing sector from 1998 to 2007 highlights that an expansion of highway networks reduced interregional trade costs and affected resource allocation among firms. For the manufacturing sector overall, highway expansion contributed to 24% of the observed productivity growth, 40% of the decline in productivity dispersion, and 16% of the output growth. However, the magnitude of these effects may differ substantially across industries and locations, owing to the distributional impact of changes in trade costs (Huang and Xiong 2017).

In the case of India, Lall (2007) uses a pooled data set of Indian states and finds that transportation and communication infrastructure positively affect output growth. The study also points out that the effect of better transportation and communication networks on economic growth is larger in poorer states. Ghani, Goswami, and Kerr (2016) investigate the relationship between firm performance and infrastructure; however, they focus on the manufacturing sector only. A number of papers in recent years have looked at the impacts of the "golden quadrilateral" program—a large highway upgrade program from India connecting four major metropolitan cities—but the focus of these studies has been at an aggregate level either on the urban manufacturing sector or on economy-wide income and efficiency gains (Datta 2012; Ghani, Goswami, and Kerr 2016; Asturias, García-Santana, and Ramos 2019).

Banerjee, Duflo, and Qian (2020) show that proximity to transportation networks positively affects per capita gross domestic product (GDP) levels across sectors but does not affect per capita GDP growth. They argue for the role played by factor mobility in determining the economic benefits of infrastructure development.

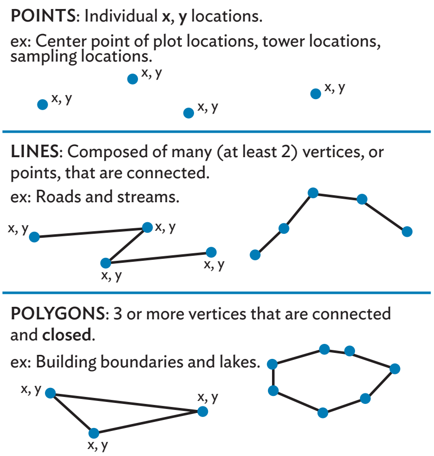
This chapter contributes to the literature by taking a microeconomic approach in a developing country context. We use firm-level data in addition to geographical road network data to estimate the effects of road network on firm profitability. This chapter particularly relates to the work by Gibbons et al. (2019) on the effects of new road infrastructure on firms. We build on these studies by applying the market access approach.

5.3 Data and Methodology

5.3.1 Market Access Index

We create a district-wise market access index (MAI) using three data sets: Indian road network shapefiles, district boundaries, and nightlight raster images. A road's geographic information system (GIS) shapefile is essentially a digital representation of a two-dimensional map consisting of points, lines, and polygons. Points represent geographical coordinates,

Figure 5.1: Components of GIS Shapefile

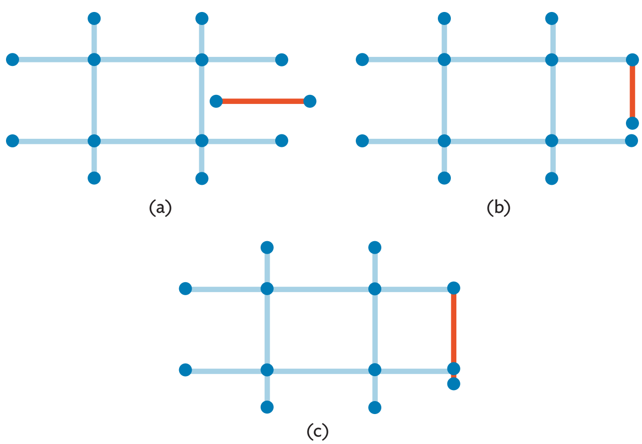


Source: Colin Williams (NEON). https://www.earthdatascience.org/courses/use-data-open-source-python/intro-vector-data-python/spatial-data-vector-shapefiles/

i.e., longitude and latitude, and lines are composed of at least 2 points—one start point and one end point. A series of such lines connected with each other forms a polyline. Road networks are represented by polylines in GIS data sets. Polygons, e.g., district boundaries, are bounded entities made up of polylines (Figure 5.1).

We calculate the shortest driving distances for districts using a road network from Open Street Maps. Open Street Maps data for India have been available and updated annually since 2014. This data set is a large GIS object in the form of a shapefile of road infrastructure that existed at a given point in the past (Figure 5.2). As it is crowdsourced, it contains topological errors such as undershoot, overshoot, dangling arcs, etc. Such errors lead to critical connectivity issues for the converted igraph object and, as a consequence, cause failures in calculating the shortest paths (Lu et al. 2018). We obtain the corrected shapefile using GRASS tools in the QGIS application.

Figure 5.2: Common Types of Topological Errors



Note: The topological errors in (a), (b), and (c) are called dangling arcs, undershoot, and overshoot. Refer to Lu et al. (2018) for more details.

Source: Shp2graph: Tools to Convert a Spatial Network into an Igraph Graph in R.

The shapefile is converted into a graph object using the Shp2Graph library in R to enable the calculations of graph algorithms for finding shortest driving distances. We derive the main connected network as it is a prerequisite for the graph algorithms to work. We also make use of the district boundaries published by the International Steering Committee for Global Mapping on the Texas GeoData Portal to find the centroids of the districts and overlay them on the road network using geospatial libraries in R (ISCGM 2016). The road's spatial lines are integrated with district centroid spatial points using the points2network function. It should be noted that the centroids of districts may not fall exactly on the road lines, resulting in the creation of a network that cannot be analyzed using standard graph theoretic algorithms. Therefore, we look for the nearest nodes on the road infrastructure network that can represent the centroids of districts most accurately. There are more accurate approaches; however, they come at the cost of a dramatic increase in computation time (Lu et al. 2018). Shortest distance calculations were performed using Dijkstra‘s algorithm through igraph implementation in R.

Longer driving distances from a district to the centers of major economic activity would imply a lower market access index for the district and vice versa. We use night-time light intensity as a proxy for economic activity in districts. Night-time light intensity is the monthly average radiance of night-time data from the Visible Infrared Imaging Radiometer Suite day/night band, which is made freely available by Google Earth. The data processing involves overlaying the vector file of district boundaries over the median nightlight raster composite for 2014 and taking a summation over pixels bounded by the district boundaries. The median composite of the nightlight images ensures that the images are free from cloud and other abnormal perturbations to a large extent. For each district *i*, the MAI was calculated by weighting the inverse of squared distances from all other districts *j* with their corresponding nightlight intensity (Figure 5.3). In essence, the MAI captures the weighted degree to which a district is connected to all other districts measured by the reciprocal of squared distances, with nightlight intensity being the weights. The squared distances are inspired by gravity models as is the case with the market access indicator constructed in Roberts (2016).

$$MAI_i = \sum_j \frac{NTL_J}{d_{ij}^2}.$$

We scale the index between 0 and 100 using the min-max scaler. We then take the state-level average of this index.

State-wise average market access is provided in Table 5.1.

Figure 5.3: Night-time Light Intensity, India

Source: VIIRS Stray Light Corrected Nighttime Day/Night Band Composites rendered by Google Earth Engine.

Table 5.1: State-wise Average Market Access Index

States	Mean	Std. Dev.	States	Mean	Std. Dev.
Andhra Pradesh	13.58	4.85	Kerala	9.63	2.45
			Madhya Pradesh	19.76	4.71
Assam	5.06	2.97	Maharashtra	17.77	12.44
Bihar	16.99	6.09	Manipur	1.69	0.58
Chandigarh	48.74	0.00	Meghalaya	3.76	1.25
Chhattisgarh	12.68	3.56	Mizoram	0.60	0.59
Dadra and Nagar Haveli	21.14	0.00	Nagaland	4.94	5.62
Daman and Diu	19.95	16.96	Odisha*	11.59	3.30
Delhi	76.81	0.00	Pondicherry	20.21	12.84
Goa	8.81	0.33	Punjab	36.40	11.18
Gujarat	18.44	6.41	Rajasthan	21.42	9.19
Haryana	60.49	21.13	Tamil Nadu	17.32	6.74
Himachal Pradesh	12.49	8.03	Tripura	2.48	1.85
			Uttar Pradesh	33.88	17.31
Jharkhand	16.42	3.44	Uttaranchal	15.62	9.84
Karnataka	17.77	12.43	West Bengal	16.86	10.33

* In 2011, the Government of India approved the name change of the State of Orissa to Odisha. This document reflects this change. However, when reference is made to policies that predate the name change, the formal name Orissa is retained.

Source: Authors' calculations.

5.3.2 Return on Assets

We use Annual Survey of Industries (ASI) data published by the Ministry of Statistics and Programme Implementation. These are establishment-level microdata pertaining to registered manufacturing firms. Factories with over 100 workers belong to the "census scheme", which are surveyed every year, while smaller establishments belong to the "sample scheme", which are surveyed every 3 to 5 years. As survey

Table 5.2: Number of Enterprises

States	Number of Enterprises	%
Andhra Pradesh	49,885	7.64
Assam	14,117	2.16
Bihar	9,962	1.53
Chhattisgarh	9,950	1.52
Dadra and Nagar Haveli	6,540	1
Delhi	15,863	2.43
Goa Daman and Diu	13,029	2
Gujarat	60,673	9.29
Haryana	28,111	4.31
Himachal Pradesh	9,706	1.49
Jharkhand	9,513	1.46
Karnataka	41,139	6.3
Kerala	24,406	3.74
Madhya Pradesh	18,902	2.9
Maharashtra	79,504	12.18
Odisha*	11,511	1.76
Punjab	36,192	5.54
Rajasthan	28,735	4.4
Tamil Nadu	91,435	14.01
Uttar Pradesh	51,115	7.83
Uttaranchal	11,716	1.79
West Bengal	30,860	4.73
Total	652,864	100

* In 2011, the Government of India approved the name change of the State of Orissa to Odisha. This document reflects this change. However, when reference is made to policies that predate the name change, the formal name Orissa is retained.

Source: Authors' calculations.

data may result in biased population estimates, we use the ASI multiplier to produce estimates valid for the population of registered factories in India. The ASI cross-sectional data are available in the public domain, but the firm identifiers are not consistent across years, thereby rendering a panel regression estimation impossible. However, the ASI also makes available panel data sets that have establishment identifiers allowing us to construct a plant-level panel for the entire 2001–2015 sample. The final number of enterprises after merging and cleaning the data from 2001 to 2015 is given in Table 5.2.

For cleaning and merging the ASI data from 2001 to 2015, we use Allcott, Collard-Wexler, and O'Connell (2016).

We define the ROA as the ratio of earnings before interest and tax payments (EBIT) to total assets (TA). We estimate that as follows:

$$ROA = \frac{Net\ Value\ Added}{Total\ Assets} \tag{1}$$

5.3.3 Data on Industrial Credit, Net State Domestic Product, Gross Fixed Capital Formation, Road Length, Railways Length, and Price

We obtain the industrial credit data from the Basic Statistical Returns of Scheduled Commercial Banks in India published by the Reserve Bank of India from 2000–2001 to 2015–2016.

The PDF versions of the Basic Statistical Returns are available until 2001–2002. Data after 2001–2002 are available in excel format. We take the data on net state domestic product and gross fixed capital formation from 2000–2001 to 2015–2016 from the *Handbook of Statistics on Indian States* published by the Reserve Bank of India. We use 3-digit commodity price deflators (with 2004–2005 as base) by groups and sub-groups (yearly averages) produced by the Office of the Economic Adviser–Ministry of Commerce and Industry as available in the commodity-based table of wholesale prices in India.

5.3.4 Data on Business Projects and Number of Pending Civil Cases

We use the CapEx database of the Centre for Monitoring Indian Economy. It provides information and insights on the new build-up of capacities in India in the short or medium-term future. Using this database, we find the state-wise number of outstanding and shelved business projects in India from 2001 to 2015. We take the number of pending civil cases (as a measure of contract enforcement) from Indiastat.

5.4 Regression Specification

Our interest here is in testing the initial hypothesis we made, i.e., to see whether better market access measured in terms of better road connectivity results in a lower dispersion of ROA (measured as the coefficient of variation and as Theil's Index). Please note that our method for testing this hypothesis is indirect since we look at the dispersion of ROA at the state level as we do not have firm-level market access. We control for other factors that may affect ROA dispersion—credit availability, electricity deficit, the ratio of stalled projects to total projects in the state, the per industry number of pending civil cases in the state, and infant mortality.

5.4.1 Variable Explanations

Profitability depends on many other factors, for example, business environment, human development, and state-specific conditions. For this, we control for a variety of variables that may affect the return on assets.

Credit Availability

We take the ratio of state-wise credit to net state domestic product as a measure of availability of credit in the states. A higher ratio means a better availability of credit to the markets where the manufacturing enterprises are located.

Electricity Deficit

Electricity is one of the important inputs in the manufacturing sector. The unavailability of or an uneven electricity supply affects the output of manufacturing plants. The availability of a proper electricity supply to a locality is measured by an indicator called "electricity deficit." This deficit is estimated by examining the total supply of electricity and the total demand for electricity in a state. If the demand is more than the supply of electricity, we refer to it as "electricity deficit." It is estimated in percentage terms. A high deficit means a bad supply of electricity in that state.

Ratio of Stalled Projects to Total Projects

This variable is one of the indicators of the business environment in the states. It is calculated as the ratio of stalled commercial projects to the total number of running commercial projects. If the number of stalled commercial projects is high compared to the number of total running projects, it means that there are some institutional bottlenecks in doing business in the state, which are hindering the progress of commercial projects.

Per-Industry Number of Pending Civil Cases

Civil cases are all cases excluding criminal cases. Civil cases include commercial dispute cases, contract breaking, cheating, among others. If the number of pending civil cases is high in a state, it means that the courts are overburdened, and the resolution of commercial disputes will take time. As a result, if manufacturing enterprises fall into any dispute, they will have to engage their resources and money to resolve such cases. The per-industry number of pending civil cases is calculated as the ratio of the total number of pending civil cases in the state at a particular time to the total number of manufacturing enterprises in the state at that time.

Infant Mortality

The infant mortality rate is calculated as the number of deaths of infants under 1 year of age in a given year per 1,000 live births in the same year in the same state. This is often used as an indicator of human development, especially health. There can be several other indicators of human development, such as the school enrollment ratio or other indicators related to education. The literature suggests that human capital is a significant determinant of productivity (Tamura 2006; Kalemli-Ozcan 2002). States with better human development indicators are considered to have a more productive labor force. Here we take one of the most basic measures of health indicators. A healthy and productive labor force is likely to have a positive effect on ROA.

Using the above variables as the control variables, we look at the impact of the MAI on the dispersion of ROA. The benchmark model specification is given below:

$$ROADispersion_{s,t} = \alpha_s + \gamma_t + \beta_1 MAI_s + \beta_2 CreditNSDP_{s,t} + \beta_3 ElectricityDeficit_{s,t} + \beta_5 ShareofStalledProjects_{s,t} + \beta_6 PerEnterprisePendingCivilCases_{s,t} + \beta_7 InfantMortality_{s,t} + \nu_{s,t} \quad (2)$$

where s denotes states and t year, and α_s represents the state-level fixed effect. We control for state-level fixed effects and time fixed effects and cluster the standard errors at the state level.

A summary of the variables discussed above is given in Table 5.3.

Table 5.3: Summary Statistics

Variable	Observations	Mean	Std. Dev.	Min	Max
ROA Theil's	272	2.366613	0.7750701	1.17947	3.57206
Market Access Index	288	23.10562	17.93174	5.061305	76.81
Credit to NSDP Ratio	333	55.56979	56.38402	6.836161	372.1976
Electricity Deficit %	338	–5.404438	5.616599	–22.5	7.8
Share of Stalled Projects out of Total	352	2.916715	9.095967	0	152.9115
Per-Enterprise Pending Civil Cases	316	7.257961	3.896778	1.389143	19.38576
Infant Mortality	352	45.64205	18.16425	9	95

NSDP = net state domestic product, ROA = return on assets.

Source: Authors' calculations.

5.5 Results

We present here regression estimations based on the above regression specifications using ROA dispersion utilizing Theil's Index. The results are presented in Table 5.4.

5.5.1 Market Access

Using the empirical model, we test whether the manufacturing enterprises in the states with better access to markets through improved connectivity of roads do better in terms of reduced dispersion of ROA. More specifically, if firms are located in states with better connectivity to markets, they will have easier access to these markets to sell their products. This should result in a lower dispersion in return on assets, and thus a negative impact of market access index (from 0 to 100) on dispersion of ROA.

From alternate specifications with different variables, we find that market access through improved road connectivity resulted in a lower dispersion of ROA during the period 2001–2015 as the coefficient of the MAI is found to be negative and statistically significant. Our results show, as expected, that market access has a negative and statistically significant impact (at the 5% level of significance) on the dispersion of ROA. Our results imply that improvements in market access will lead to an equitable access to resources and markets for manufacturing plants and to greater convergence. We also run this regression using an alternate specification using Theil's Index of Marginal Revenue Product of Capital (MRPK) (column (2) in Table 5.4). We find that improved access to markets leads to a reduction in the dispersion of MRPK.

Table 5.4: Regression Results Using ROA Theil's Index

	(1) Theil's ROA	(2) Theil's MRPK	(3) Theil's ROA	(4) Theil's MRPK	(5) Theil's ROA	(6) Theil's MRPK
Market Access Index	−0.082**	−0.056***			−0.026*	−0.023***
	(−2.790)	(−4.830)			(−2.010)	(−4.640)
Port Distance			0.002**	0.001***	0.001**	0.001***
			(2.790)	(4.830)	(3.200)	(4.710)
Credit to NSDP Ratio	0.001	0.0004	0.001	0.0004	0.001	0.0004
	(1.120)	(1.600)	(1.120)	(1.600)	(1.120)	(1.600)
Electricity Deficit %	−0.001	0.0003	−0.001	0.0003	−0.001	0.0003
	(−0.230)	(0.220)	(−0.230)	(0.220)	(−0.230)	(0.220)
Share of Stalled Projects out of Total	0.001	−0.0002	0.001	−0.0003	0.001	−0.0003
	(0.130)	(−0.160)	(0.130)	(−0.160)	(0.130)	(−0.160)
Per-Enterprise Pending Civil Cases	0.035**	0.008	0.035**	0.008	0.035**	0.008
	(2.640)	(1.570)	(2.640)	(1.570)	(2.640)	(1.570)
Infant Mortality	0.010*	0.004**	0.010*	0.004**	0.010*	0.004**
	(2.200)	(2.680)	(2.200)	(2.680)	(2.200)	(2.680)
Constant	3.232***	1.506***	1.437***	0.278***	2.007***	0.774***
	(5.200)	(6.330)	(6.160)	(3.850)	(7.500)	(8.290)
State Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Time Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Observations	225	238	225	238	225	238
Adjusted R-squared	0.942	0.472	0.942	0.472	0.942	0.472

MRPK = marginal revenue product of capital, NSDP = net state domestic product, ROA = return on assets.

Notes: Numbers in parenthesis are t-statistics. *** significant at the 1% level. ** significant at the 5% level. * significant at the 10% level.

Source: Authors' calculations.

As an alternate measure of market access, we take the distance of the district from the nearest port (columns (3) and (4) in Table 5.4). We find that the with increase in average distance from the nearest port, the dispersion of ROA and MRPK also increase. This finding also validates our claim that access to markets affects the profitability of firms in India. Our results hold for ROA and MRPK dispersion even when we take both the MAI and the distance from the nearest port (columns (5) and (6) in Table 5.4).

5.5.2 Control Variables

We use the per-industry number of pending civil cases (the ratio of total pending civil cases in the state) as a measure of contract enforcement in industries. The results, as expected, show that a greater number of pending civil cases increases the dispersion of ROA, implying a large variation in ROA profiles across firms.

We find that infant mortality, which is a rough measure of human development (greater infant mortality means a bad human development condition), results in a greater dispersion of ROA, which gives an indication that firms with a higher ROA may be attracting a better quality of human capital than firms with a lower ROA, thereby increasing the ROA dispersion. This finding is also as expected.

Table 5.4 reports the effects of increased credit availability to firms on the dispersion of ROA. Column [1] represents the result of the benchmark regression. From the regression results, we find that states with better average market access through road connectivity have a lower dispersion of ROA for firms from 2001 to 2015 as the coefficient of the MAI is found to be negative and statistically significant.

We also find that the share of stalled projects to the total number of commercial projects in the states, which is an indicator of better governance, is significant. This means that ROA dispersion is greater in states that are faced with governance issues. Bad judicial conditions, which are measured as the per-enterprise number of pending civil cases, increase the dispersion of ROA. In states with a poor governance setup, it may be typical for some firms with high-profile connections in political and judicial machinery to work their way through the system, while those that are not so privileged may have to struggle to get the necessary permits and licenses. This could result in a higher dispersion of ROA.

5.5.3 Robustness Checks

We set up alternate specifications with mean ROA as the regressor.

$$MeanROA_{s,t} = \alpha_s + \gamma_t + \beta_1 MAI_s + \beta_2 CreditNSDP_{s,t} + \beta_3 ElectricityDeficit_{s,t} + \beta_5 ShareofStaledProects_{s,t} + \beta_6 PerEnterprisePendingCivilCases_{s,t} + \beta_7 InfantMortality_{s,t} + v_{s,t} \quad (3)$$

The results are presented in Table 5.5.

Table 5.5: Regression Results Using Mean ROA

	(7)	(8)	(9)
	Mean ROA	Mean ROA	Mean ROA
Market Access Index	0.0989**		0.115**
	(2.790)		(3.180)
Port Distance		–0.002**	–0.0003*
		(–2.790)	(–2.420)
Credit to NSDP Ratio	0.0001	0.0001	0.0001
	(0.140)	(0.140)	(0.140)
Electricity Deficit %	0.012	0.012	0.012
	(1.210)	(1.210)	(1.210)
Share of Stalled Projects out of Total	–0.001	–0.001	–0.001
	(–0.260)	(–0.260)	(–0.260)
Per-Enterprise Pending Civil Cases	–0.066*	–0.066*	–0.066*
	(–2.560)	(–2.560)	(–2.560)
Infant Mortality	0.009	0.009	0.009
	(1.250)	(1.250)	(1.250)
Constant	–1.645*	0.532*	1.437***
	(–1.950)	(1.960)	(6.160)
State Fixed Effect	Yes	Yes	Yes
Time Fixed Effect	Yes	Yes	Yes
Observations	264	264	225
Adjusted R-squared	0.537	0.537	0.942

NSDP = net state domestic product, ROA = return on assets.

Notes: Numbers in parenthesis are t-statistics. *** Significant at the 1% level. ** Significant at the 5% level. * Significant at the 10% level.

Source: Authors' calculations.

We find that states with greater market access also tend to have a higher mean return on assets of firms. We also find that the mean ROA of firms located in states farther away from ports is marginally lower than the mean ROA of firms located in states near ports.

Additionally, we also check for the differential impact of the MAI on ROA and MRPK dispersion contingent upon the distance from a port. We find that the differential impact of the MAI is low. The corresponding results are presented in Table A5.1 in the appendix.

5.6 Conclusions and Policy Implications

Using the annual survey of industries data for India during the period 2001–2015, we examine whether manufacturing enterprises in states with better access to markets through road connectivity do better in terms of profitability as measured by return on assets.

This chapter provides empirical evidence for governments to focus on improving market access. We establish that better road access to markets reduces the dispersion of ROA across firms as better infrastructure is a public good that helps to improve the productivity of all firms at the same time. We also find that judicial conditions measured as per-industry pending civil cases are associated with a greater dispersion of ROA. An improved road infrastructure reduces transportation costs and assists in creating a better business environment by reducing the misallocation of capital. We also use an alternate specification of return from capital as the MRPK. We find that states with better road connectivity tend to have a lower dispersion of MRPK among their firms. Our results hold when we take the alternate measure of market access as the distance from the nearest port as we find that the dispersion of ROA and MRPK is associated positively with the distance from the nearest port.

This chapter has some limitations, mainly due to data availability. Because of the absence of district identifiers for enterprises in the ASI data, the district-level market access index had to be averaged at the state level. As market access can vary substantially within the same state, district identifiers for enterprise-level data would lend greater credence to the study. In addition to this, we make use of the crowdsourced data of the road network available until 2015, which may have their own limitations due to user reporting biases.

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Appendix

We also check the differential impact of the MAI on ROA dispersion with port distance as the moderating variable. We find that a better MAI leads to a reduction in dispersion when we make it contingent on port distance; however, the reduction in ROA dispersion is significantly small.

Table A5.1: Regression Results Using Interaction of MAI and Port Distance

	(10) Theil's ROA	(11) Theil's MRPK	(12) Theil's ROA	(13) Theil's MRPK
Market Access Index	–0.061**	–0.044***	–0.007	–0.049**
	(–2.660)	(–4.830)	(–0.180)	(–3.090)
Port Distance			0.002**	0.0002
			(2.750)	(0.610)
MAI*Port Distance	–0.00005**	–0.00003***	–0.00003	–0.00004*
	(–3.200)	(–4.710)	(–0.680)	(–2.280)
Credit to NSDP Ratio	0.001	0.0004	0.001	0.0004
	(1.120)	(1.600)	(1.120)	(1.600)
Electricity Deficit %	0.001	0.0003	0.001	0.0003
	(0.230)	(0.220)	(0.230)	(0.220)
Share of Stalled Projects out of Total	0.001	0.0003	0.001	0.0003
	(0.130)	(0.160)	(0.130)	(0.160)
Per-Enterprise Pending Civil Cases	0.035**	0.008	0.035**	0.0084
	(2.640)	(1.570)	(2.640)	(1.570)
Infant Mortality	0.010*	0.004**	0.010*	0.004**
	(2.200)	(2.680)	(2.200)	(2.680)
Constant	2.686***	1.179***	1.648*	1.276***
	(5.870)	(6.890)	(2.320)	(4.450)
State Fixed Effect	Yes	Yes	Yes	Yes
Time Fixed Effect	Yes	Yes	Yes	Yes
Observations	225	238	225	238
Adjusted R-squared	0.942	0.472	0.942	0.472

MAI = market access index, MRPK = marginal revenue product of capital, NSDP = net state domestic product, ROA = return on assets.

Notes: Numbers in parenthesis are t-statistics. *** Significant at the 1% level. ** Significant at the 5% level. * Significant at the 10% level.

Source: Authors' calculations.

6

The Spillover Effects of Water Supply Infrastructure Development: A Theoretical Model

Naoyuki Yoshino, Santi Setiawati, Tifani Husna Siregar, KE Seetha Ram, and Dina Azhgaliyeva

6.1 Introduction

Water services are one of society's basic needs. The United Nations recognizes access to water as a human right due to the fundamental role it plays in people's health, dignity, and prosperity. However, many are still living without adequate access to clean water. In Asia and the Pacific, around 500 million people do not have access to basic water supplies (WHO and UNICEF n.d.). This problem is exacerbated by rapid urbanization, as tens of millions of people each year move into slums and other infrastructure-poor areas. For example, it is estimated that approximately 80% of the 7 million residents of Dharavi, Mumbai, India have no running water. Similarly, because of the lack of water infrastructure, low-income households in Penjaringan, Jakarta are forced to purchase water from their neighbors at a 40–60 times higher price than subsidized pipe water.

Water supply infrastructure includes manufactured and natural components required to deliver safe drinking water. The development and operation of infrastructure, including that of water infrastructure, is costly. For public goods in particular, it is common for investors, often governments, to face budget constraints in financing infrastructure projects. As well as the high initial cost at the construction stage, investors also often face financial difficulties during the operation phase.

This is because most infrastructure operators rely on user charges to finance their operation. Yet, people's willingness to pay for public goods is usually low. Moreover, given that public goods must be provided at an affordable price to ensure access for all economic levels of society, keeping user charges low is a challenge given the high maintenance and repair costs.

This high-cost–low-revenue problem of infrastructure development and operation results in the private sector being reluctant to invest in infrastructure, especially for public goods. But, given the limited budgets of governments, especially during the novel coronavirus disease (COVID-19) pandemic, the private sector's involvement in infrastructure development is crucial. It is important, therefore, to increase the attractiveness of infrastructure projects for the private sector. One way of doing so is by ensuring enough revenues for the investors, while keeping user charges low.

This chapter develops a theoretical model to secure adequate revenues for the development and operation of water supply infrastructure, which will encourage the private sector to participate. Specifically, this chapter argues that the increased tax revenues that can be attributed to the development of water supply infrastructure should partly be shared with infrastructure developers and operators instead of being fully absorbed by the government.

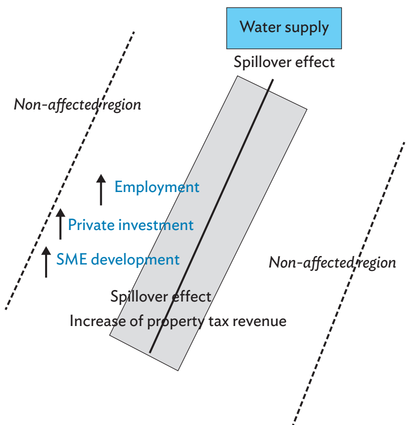
The main argument made in this chapter is that the development of water supply infrastructure will increase the amount of taxes, referred to as "spillover" taxes, collected by the government. We identify two ways in which this may occur. First, the improvement of water supply infrastructure is expected to stimulate economic activity such as the construction of new office buildings and new employment. Second, the development of water supply infrastructure will lead to better health outcomes and human capital development. These factors can be measured in economic terms, so the total spillover effects of water supply infrastructure development can be estimated.

This chapter is organized as follows. Section 6.2 reviews past studies and literature on spillover effects from infrastructure development. Section 6.3 discusses how water supply infrastructure creates spillover effects. This section provides a framework for estimating the impact of infrastructure investment and case studies. Section 6.4 focuses on the benefits of water supply infrastructure for human capital development and health. Section 6.5 explains the proposal for a pooling system of the benefits resulting from the creation of water supply infrastructure. It also estimates how much infrastructure investment will increase spillover effects. Section 6.6 concludes and describes policy implications.

6.2 Literature Review of Spillover Effects from Infrastructure Development

Traditionally, the sources of revenue for water suppliers came from the user charges for water supply infrastructure. However, users' willingness to pay for public goods such as water is low, while investors and water operators prefer a high rate of return. Hence, public–private partnership (PPP) projects for water supply and infrastructure projects sometimes fail.

Figure 6.1: Diagrammatic Spillover Effects of Water Supply Infrastructure Development



SME = small and medum-sized enterprise.

Note: The solid black line in the middle represents the water supply; the gray part is the area that enjoys a spillover effect; the dashed lines on the left and right are the borders of the area affected by spillover effects.

Source: Yoshino et al. (2019a).

On the other hand, the impacts are massive if we look at the overall picture of the effects, including the spillovers or externalities of the development of water supply infrastructure. Figure 6.1 illustrates the spillover effects of the development of water supply infrastructure. Suppose a new water supply infrastructure is constructed in the area shaded gray. After completion of the infrastructure, new industries and new companies start their activities in the region along these water supply corridors. Housing, restaurants, and services can be constructed along with the new water supply and start their businesses. The territory with the newly developed water supply infrastructure (dark gray shaded area) benefits from the spillover effects of the development of the new water supply infrastructure. This economic development due to spillover effects will raise tax revenues from this territory for the government, including government revenues from income tax, sales tax, and property tax (Yoshino et al. 2019b).

Yoshino and Nakahigashi (2004) estimated the direct effects of infrastructure investment and the indirect effects, or spillover effects, by using a translog production function in Japan. The direct effects refer to increments in production by a marginal increase in the production factor (private capital and private labor) due to an increase in infrastructure. The indirect or spillover effects refer to private enterprises' production increases and investment in production elements based on their initial increase in marginal productivity. The infrastructure that will increase the region's output creates the immediate impact of investment. The two channels of the spillover effects on construction and employment will increase regional output and contribute to the increased consumption and housing. The regional gross domestic product (GDP) will increase accordingly.

To investigate the effectiveness of the investment, the production function (Equation 1) is utilized to estimate the effect of infrastructure.

$$Y = f\ (K_p, L, K_G), \tag{1}$$

where Y is regional GDP, Kp stands for private capital such as factories and business, L stands for labor input, and K_G stands for government (or public) capital, which includes water supply infrastructure (water supply infrastructure is a part of government investment).

To identify the productivity effect of infrastructure in greater detail, Yoshino and Nakano (1994) classified the productivity effect according to its direct and spillover effects. The infrastructure effect is explained in marginal productivity in Equation 2:

$$\frac{dY}{dK_G} = \underbrace{\frac{\partial f}{\partial K_p}\frac{\partial K_p}{\partial K_G} + \frac{\partial f}{\partial L}\frac{\partial L}{\partial K_G}}_{\text{Spillover effect}} + \underbrace{\frac{\partial f}{\partial K_G}}_{\text{Direct effect}}. \tag{2}$$

The direct effect of infrastructure investment and its spillover effects is estimated in Table 6.1, using macroeconomic data for Japan. For example, in the period 1956–1960, the direct effect of infrastructure investments that increased output was 0.696. The spillover effect that emerged from an increase in private capital was 0.452, and the spillover effect induced by an increase in employment was 1.071. This shows the direct effect of infrastructure that increased the output, the spillover effect created by an increase in private capital, and the spillover effect produced by an increase in employment. Finally, the total spillover effect in the period 1956–1960 was 68.6% of the total effect of infrastructure investment.

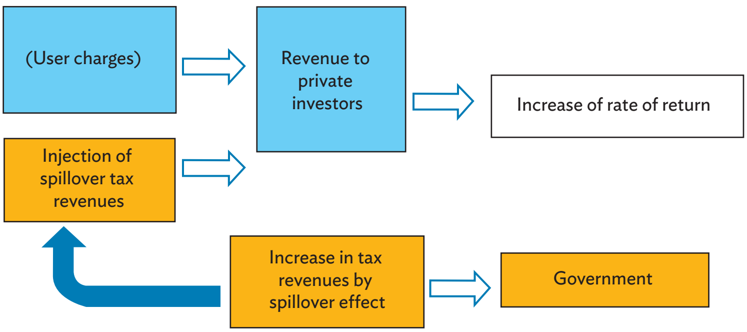
Table 6.1: Economic Effect of Infrastructure Investment in Japan (macroeconomic estimation)

Economic Effect	1956–60	1961–65	1966–70	1971–75	1976–80	1981–85	1986–90	1991–95	1996–2000	2001–05	2006–10
Direct effect	0.696	0.737	0.638	0.508	0.359	0.275	0.215	0.181	0.135	0.114	0.108
Spillover effect of private capital (Kp)	0.452	0.557	0.493	0.389	0.270	0.203	0.174	0.146	0.110	0.091	0.085
Spillover effect of employment (L)	1.071	0.973	0.814	0.639	0.448	0.350	0.247	0.208	0.154	0.132	0.125
Total effect of infrastructure investment	2.219	2.267	1.944	1.536	1.076	0.828	0.635	0.536	0.399	0.337	0.318
Share of spillover effect, %	68.6%	67.5%	67.2%	66.9%	66.7%	66.8%	66.2%	66.2%	66.1%	66.1%	66.1%

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

At the project level of estimation, the incremental benefits of transferring the spillover effects to the additional normal project revenues would change the internal rate of return for the project. Figure 6.2 demonstrates a model for returning a share of the spillover tax revenues to investors in water infrastructure projects. User charges are usually below the average cost of maintaining and constructing water supply infrastructure. Therefore, we propose using some of the spillover tax revenues created by the water supply infrastructure for the maintenance or operation of infrastructure. Thus, the government should share these increased spillover tax revenues with private investors in infrastructure investment.

Figure 6.2: Model for Returning Fractional Spillover Tax Revenues to Investors in Water Projects

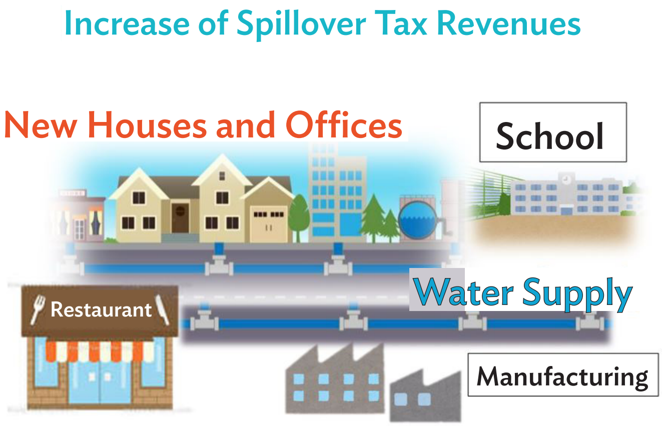


Source: Yoshino et al. (2019a).

6.3 Water Supply Infrastructure Investments and Spillover Effects

Water supply infrastructure comprises the physical and organizational structures and facilities used to deliver safe drinking water and sanitation. The development of water supply infrastructure creates spillover effects and impacts the economy, especially in the region where the infrastructure is developed, as illustrated by Figure 6.3. New restaurants, hotels, shopping malls, and residential areas will be developed if the water supply infrastructure is well equipped. These activities will contribute to increases in tax revenues, including corporate tax, property tax, income tax, etc. In the same way as water supply infrastructure, various infrastructure projects can be used to demonstrate the spillover effects. The construction of new roads and railways lifts the value of the assigned land. New apartments and new businesses can be established in the region, due to accessibility of water services.

Figure 6.3: Illustration of Spillover Effects of Water Supply



Source: Authors.

To provide a framework for estimating the impact of infrastructure investment, Yoshino and Abidhadjaev (2016) estimate the difference-in-difference (DID) coefficients to better understand the net difference brought about by introducing an infrastructure facility. The following two equations can be used to illustrate the DID method:

$$Y_1 = F(K_{p1,} L_1 , K_{g1}, X), \tag{3}$$

$$Y_2 = F(K_{p2,} L_2, X). \tag{4}$$

The notations are the same as in Equations 1 and 2, but note that Equations 3 and 4 include X, which represents other variables that affect the economy. Equation 3 shows regional GDP in Region 1 where new infrastructure is constructed, while Equation 4 represents the region where no infrastructure investments are made. The DID method measures the differences in Region 1 and Region 2 due to the impact of infrastructure investment (Kg), as shown in Equation 5.

Specifically, Equation 5 measures the difference in the GDP of Region 1 and Region 2, where Region 1 is enjoying the operation of infrastructure and Region 2 has no such infrastructure. $Y_1 - Y_2$ measures an increment of GDP created by infrastructure investments.

$$Y_1 - Y_2 = F(K_{p1,}L_1, K_{g1}X) - F(K_{p2,}L_2, X). \qquad (5)$$

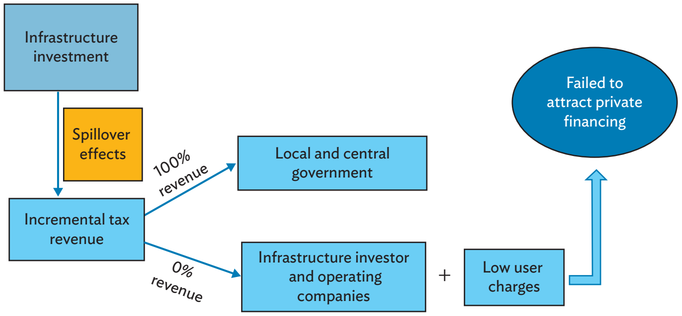
Changes in GDP will contribute much more to the tax revenues that result from the newly constructed infrastructure (Equation 6).

$$Tax\ revenue = tY, \qquad (6)$$

where t is tax rate and Y is GDP.

Tax revenues, including those brought about by the development of the new infrastructure, are usually absorbed entirely by the government. Therefore, the infrastructure investors or construction companies do not receive the direct benefit of increased tax revenues. Figure 6.4 shows that these incremental tax revenues went to the local and central governments and were not shared with infrastructure investors, who relied mostly on user charges for their sources of revenue. If governments want to attract more private investors, then they need to increase user charges because traditionally, all the revenues came from user charges. In particular, water is a necessary good and the government is reluctant to increase user charges. It is hard to attract private investors into the development of water supply infrastructure because of the low rate of return they can expect to cover operation and management. Low user charges, such as water tariffs, have caused water supply infrastructure and other infrastructure companies that depend on user charges to struggle with revenues.

Figure 6.4: Traditional Circle of Spillover Effect Benefits Created by Infrastructure Investment



Source: Authors.

This chapter proposes sharing spillover incremental tax revenues with infrastructure investors: for example, 50% of incremental tax revenues with infrastructure investors and infrastructure operating companies, to enable them to have enough revenue and to cover a significant part of their infrastructure maintenance and operations, which will lead to lower user fees.

In order to illustrate the increase in the rate of return (ROR) created by the spillover effect, we use past research on the spillover effect created by information and communications technology (ICT) infrastructure. We use data from the Global System of Mobile communication (GSM) subscribers from 2005 to 2016 from India in Table 6.2.

Table 6.2 shows the main estimation result for the GSM revenue and total state tax increase. The detailed data and estimation strategy are available in Yoshino et al. (2022). To calculate the increased ROR, the first step is to compute the total revenue obtained from subscriber fees as user charges; next, to define the tax revenue after the infrastructure has started. According to the estimation, a 10-percentage point increase in GSM subscribers per capita is expected to raise the total state tax revenue per capita by ₹134. Therefore, the estimated increase in total state tax revenues is ₹172,994 million (₹134 x 1,291 million people [India's population in 2016]). Using those figures, we obtain a 14.2% of tax increment (₹172,994 million/₹1,221,318 million).

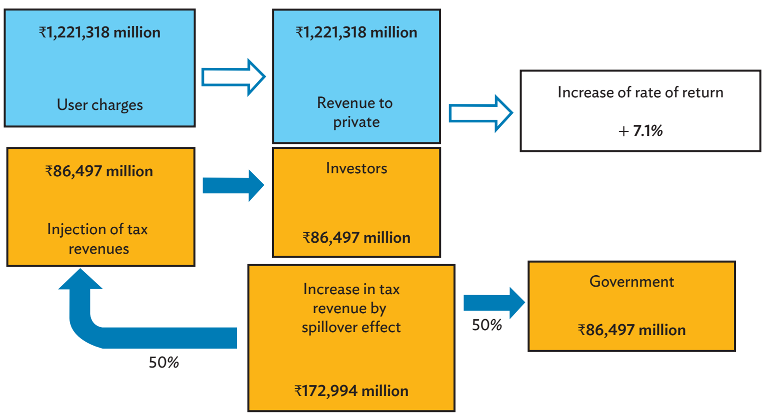
Table 6.2: Data Illustration to Define the Impact of Spillover Effects on Tax Revenue

Variable	Value
Average total revenue obtained from subscriber fees of mobile operators (2005–2016), ₹ million	1,221,318
Estimated average total state tax increase, ₹ million	172,994
Tax increment, %	14.2

Source: Authors' calculation using data from Yoshino et al. (2022).

Figure 6.5 illustrates a proposal to return spillover tax revenues to private investors based on the results shown in Table 6.2. The bottom part of the figure shows tax revenues created by the spillover effects of ICT infrastructure (₹172,994 million). Then, the government will inject a share of the increased tax revenues into private investors as subsidies. Out of the tax revenue increment received by the government, 50% can be shared with private investors and 50% will remain with the government. If 50% of incremental tax revenues coming from the spillover effect are shared with the infrastructure investor by the government, the investors will receive an additional revenue from the increment in tax revenue created by the spillover effect equal to ₹86,497 million (50% x ₹172,994 million). Finally, the return rate increases by 7.1% of the total revenue collected from user charges. The increase of return rate is calculated by dividing additional revenue to average total revenue.

Figure 6.5: An Example of Shared Fractional Spillover Tax Revenues with Investors Using the Case of ICT Infrastructure Development in India



ICT = information and communications technology.

Source: Authors' calculation based on Yoshino et al. (2022).

Table 6.3 shows the cost and revenue of the PPP water supply project in Jakarta. The planning and preparation stage took place before 2015. The construction took 4 years from 2015 to 2019, and the total construction cost was Rp74 billion. The maintenance and operation costs for 11 years, from 2019 to 2030, are estimated to be Rp83 billion. In total, Rp180 billion will be spent, as shown in the cost column. The revenue from user charges (over the same period) is expected to be Rp248 billion. Hence, this case study is expected to earn revenue of Rp248 billion and spend a total of Rp83 billion.

Table 6.3: Cost and Revenue of Water Supply Project in Jakarta

Project Phase	Period	Duration	Cost (Rp billion)	Revenue (Rp billion)
Planning and Preparation	Before 2015	NA	23	NA
Construction and Transaction	2015–2019	4 years	74	NA
Operation	2019–2030	11 years	83	248* (user charges)
Total		15 years	180	

NA = not available.

* Authors' estimate.

Source: Authors' calculation using data from Limbong (2019).

Next, we analyze the impact of spillover tax revenues on the cost-benefit structure. Table 6.4 shows an original scenario (Column 2) and a scenario with spillover tax revenues (Column 3). The original scenario describes the cost-benefit structure of the project without the return of spillover tax revenue. Another scenario includes the return of spillover tax revenue in the calculation. The introduction of the return of spillover tax revenues increases the total revenue from Rp248 billion to Rp270 billion, and therefore changes the net present value (NPV) of total revenue from Rp244 billion to Rp266 billion. By subtracting the NPV cost from the NPV revenue, the total revenue resulting in Rp131 billion, which is significantly higher than that of the original scenario of only Rp101 billion.

Table 6.4: Two Scenarios of Rate of Return of Water Supply Project in Jakarta

Variable	Without Spillover Tax Revenue	With Spillover Tax Revenue
(1)	(2)	(3)
Total Cost, Rp billion	–180	–170
Net Present Value (NPV) Cost, Rp billion	127	120
Total Revenue, Rp billion	248	270
NPV Revenue, Rp billion	244	266
NPV, Rp billion	101	131
Internal Rate of Return, %	47%	52%

Source: Authors.

As for the internal rate of return, introducing the return of spillover tax revenues increases the internal rate of return from 47% to 52%. The infrastructure project can attract much more private investment than the original scenario.

6.4 Theoretical Model of Spillover Effects of Water Supply Infrastructure on Human Capital Development and Health

In addition to increasing land and property values, which in turn will increase tax revenues collected by the government, the development of water supply infrastructure will also directly affect residents by improving their health and other environmental aspects. If all these benefits had been considered, the impact on water supply infrastructure would have been much more significant than what is reflected by the user charges. Therefore, in this section we develop a theoretical model on the effects of the development of water infrastructure on human capital development and health by analyzing the behavior of households, the behavior of producers, and water prices.

6.4.1 Behavior of Households

Equation 7 stands for the utility function of workers. C is positive consumption, L is labor supply as a negative utility, and β shows the relative magnitude of the labor supply in comparison to consumption.

Equation 8 is a budget constraint. Entire income is a wage revenue and PC stands for consumption. In this model, we assume income comes from work and all the money will be consumed for simplicity.

Equation 13 and Figure 6.6 show the labor supply curve. In Equation 13, β diminishes as clean water supply infrastructure increases. β represents the disutility of labor supply by households. If clean water supply infrastructure becomes available, it will enhance health and reduce the disutility of labor supply. As real wages rise, the supply of labor increases. Thus, the labor supply curve is upward sloping, as shown in Figure 6.6. An increase in clean water will shift the labor supply curve to the right due to the reduction in the disutility of labor supply by households.

Households maximize their utility function:

$$\text{MAX } U(C, L) = C - \beta L^2, \tag{7}$$

$$\text{subject to } PC = wL, \tag{8}$$

where L = labor, C = consumption, and w = wage revenue.

Equations 7 and 8 can be converted to a Lagrange function:

$$\mathcal{L} = U(C, L) - \lambda(PC - wL). \tag{9}$$

From Equation 9 the first-order conditions are as follows:

$$\frac{\delta\mathcal{L}}{\delta C} = 1 - \lambda P = 0, \tag{10}$$

$$\frac{\delta\mathcal{L}}{\delta L} = -2\beta L + \lambda w = 0, \tag{11}$$

From Equation 10 we derive the Lagrange multiplier: $\lambda = \frac{1}{P}$. (12)

From Equation (11): $L^S = \frac{\lambda w}{2\beta} = \frac{1}{2\beta}\frac{w}{P}$. (13)

From Equations 8 and 13: $C = (w/p)(1/2\beta)(w/p)$. (14)

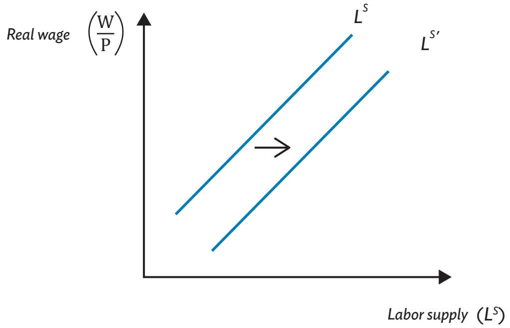
6.4.2 Behavior of Producers

The production function of producers is shown by Equation 15 as follows:

$$Y = F(K_P, AL, K_G) = K_P^{\alpha}(AL)^{\beta}K_G^{\gamma} + \theta_1[(AL)K_G] + \theta_2[KpK_G], \tag{15}$$

where K_P is private capital, A is quality of labor (if health conditions are improved by water supply, A increases), L is labor, and K_G is public capital.

Figure 6.6: Impact of Increased Water Supply on Labor Supply Curve



Source: Authors.

The producer's profit function is obtained by subtracting the costs of labor and capital from the revenues (Equation 16):

$$\pi = PY - r_P K_P - wL - r_G K_G. \tag{16}$$

Producers maximize their profits, which are as follows (Equations 17 and 18):

$$\frac{\delta\pi}{\delta L} = \beta\frac{PY}{L} + \theta A K_G - w = 0, \tag{17}$$

$$\frac{\delta\pi}{\delta Kp} = \alpha\frac{PY}{Kp} + \theta_2 K_G - r_p = 0. \tag{18}$$

Equation 19 is the demand for labor by companies, which depends on the real wage rate and also the magnitude of public infrastructure (shown by K_G, which includes water supply infrastructure). As the improvement of health created by water supply infrastructure increases, that will increase the demand for labor. As is shown in Equation 19, an increase in A (improvement of health conditions of workers caused by water supply) will increase the demand for labor.

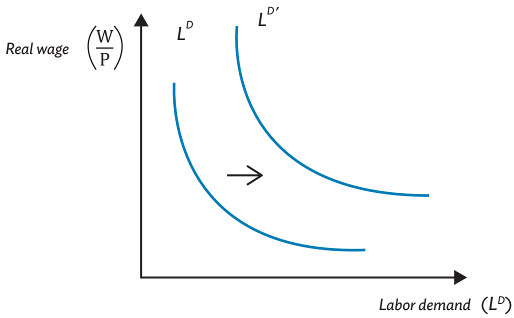
$$L^d = \frac{\beta Y}{\left(\frac{w}{P} - \frac{\theta A K_G}{P}\right)}. \tag{19}$$

And from Equation 20 we get capital demand. Equation 20 explains that a lower interest rate (r_P) will increase the demand for capital:

$$K_P = \frac{\alpha PY}{(r_p - \theta K_p)}. \quad (20)$$

Referring to Equation 19, Figure 6.7 illustrates that an increased supply of clean water will increase labor demand (shift the labor demand curve to the right) because of increases in government capital (K_G) and the quality of labor/productivity (A).

Figure 6.7: Labor Demand Curve and the Increase in Water Supply

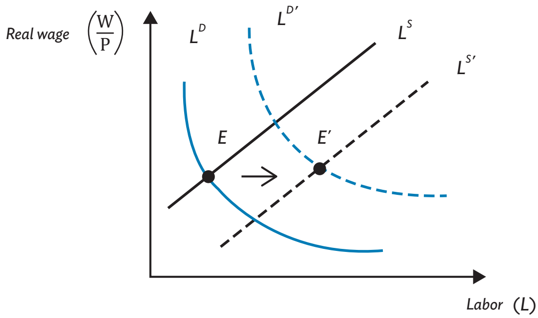


Source: Authors.

6.4.3 The Total Effects of an Increase in Water Supply Due to the Shift in Labor Supply and Labor Demand

Figure 6.8 shows the labor market equilibrium where labor supply is obtained from the utility maximization of workers, and labor demand is received from the company's profit maximization. The labor market equilibrium is at the intercept of the wage rate and supply and demand for labor as shown by point E. Improving water supply will increase labor supply because health quality will be enhanced, leading to an increased labor supply (a shift of the labor supply curve from L^S to $L^{S\prime}$). As for the demand, labor quality or productivity will rise and increase labor demand (a shift of the labor supply curve from L^D to $L^{D\prime}$). As a result, the new labor market equilibrium, shown by E', is determined at the new intercept of new labor supply and new labor demand. Most importantly, we can find a significant increase in labor demand and labor supply simultaneously owing to the rise in the supply of clean water.

Figure 6.8: Impact of Increased Water Supply on Labor Market Equilibrium



Source: Authors.

6.4.4 Spillover Effects of Water Infrastructure Investment on the Price Level of Water

This section discusses the impact of the spillover effects of water supply infrastructure investment on the price level of water.

Traditionally, the price of water was determined by the costs of maintaining water supply infrastructure based on user charges. However, according to this study, water supply infrastructure companies can receive a part of the spillover tax revenues, in addition to the user charges. That means the price of water by users can be diminished, and the extra payment created by spillover tax revenue can become additional income for the water supply infrastructure operating company.

Before, only a few people could afford the price of clean water. However, as income grows and the cost of water remains constant, the demand for clean water increases. More people can afford to pay for clean water, which will contribute to regional development including improved health conditions.

Equation 21 shows that aggregate demand (Y^d) consists of consumption (C), investment (I_p), and government spending (G). In this context, the increase in private capital (ΔK_p) is considered an investment. For example, if there is a new investment of government capital, it will be a part of the aggregate demand. If a new water supply infrastructure company comes along, it will belong to private investment (ΔK_p).

$$Y^d = C + \Delta K_p + \Delta K_G = C + Ip + G. \tag{21}$$

Equation 22 shows the production function, i.e., output is a function of private capital, quality labor, and government capital. Note that both consumption and labor supply are functions of the price level (P), as shown by Equations 23 and 24.

$$Y^s = F(K_p, AL, K_G), \tag{22}$$

where:

$$C = \frac{1}{2\beta}\left(\frac{W}{P}\right)^2, \quad L = \frac{\beta P\gamma}{W - \theta_1 A K_G}, \tag{23}$$

$$\Delta K_p = \Delta\left(\frac{\alpha P\gamma}{r_p - \theta K_G}\right), \quad K_p = \frac{\alpha P\gamma}{r_p - \theta K_G}. \tag{24}$$

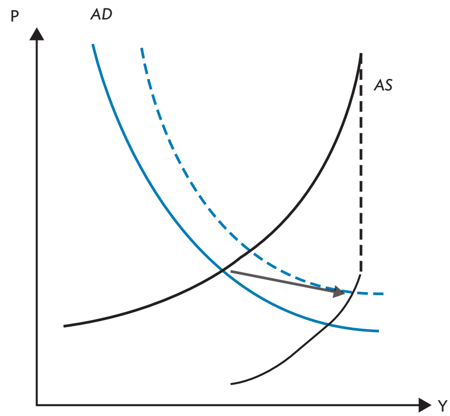
Thus, plugging Equation 23 and Equation 24 into Equation 22, we obtain:

$$Y^s = F[K_p(P), AL(P), K_G]. \tag{25}$$

Figure 6.9 displays the aggregate supply (*AS*) curve and aggregate demand (*AD*) curve. If there is an increase in aggregate demand (Y^d), the *AD* curve moves to the right. If the *AS* curve shifts more than the *AD* curve, meaning that aggregate supply increases more than aggregate demand, the price level goes down. Conversely, if the shift of the *AD* curve is greater than that of the *AS* curve, the price level will go up.

In Figure 6.9, the shift of the *AS* curve partly comes from the spillover effects of water infrastructure development. New water infrastructure investments will bring new employment in the region as new companies start their business. That will increase K_p as well as L, which will further increase aggregate supply. When spillover effects are very large, *AS* will shift more than *AD*, which will reduce the price level.

Figure 6.9: Shifts of Aggregate Demand and Aggregate Supply Curve



Source: Authors.

6.4.5 Interest Rate Impact on Spillover Effects

This part explains how the interest rate will affect the spillover effects of water supply infrastructure.

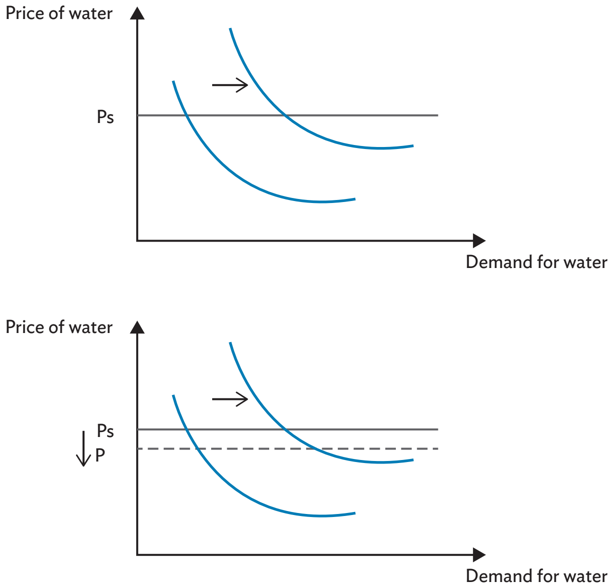
$$Y = F[K_p(r_p), AL, K_G]. \tag{26}$$

Equation 27 shows the magnitude of the relation between the spillover and the interest rate (r_p) If the interest rate goes down, it will be relatively less costly for companies to take out loans. Lower interest rates will likely lead to larger spillover effects from infrastructure investments as businesses are more likely to develop. The explanation behind this is dY and dr_p is negative, which means that if the interest rate r_p is lower, the increase of Y will be bigger.

$$\frac{dY}{dr_p} = \frac{\partial F}{\partial K_p}\frac{\partial K_p}{\partial r_p} < 0. \tag{27}$$

Finally, the relation between interest rate and spillover effects and real output shows that if the interest rates are lower than the spillover effects of water supply infrastructure development, the new private businesses will become much easier to operate due to the low costs of borrowing.

Figure 6.10: Shifts in Demand for Water and Price of Water



Source: Authors.

If a portion of the spillover tax revenues collected by the government is returned to water suppliers, the price for water can be pushed down. In Figure 6.10, this is shown by the shift of the horizontal line, depicting the price of water, from Ps to P. The lower price of water will further increase water demand, as it has become more affordable for more people. The rise in the demand for water is shown by the shift in the demand curve to the right.

It is important to note that there are variations in population density among regions, which may result in the attractiveness of infrastructure projects for the operators and investors of such projects, including water infrastructure projects, due to the difference in expected profitability. These are two ways to explain this phenomenon:

(a) Output and tax revenue

$$Y = F(K_p, L, K_G) \quad (28)$$

$$Tax\ revenue = tY \quad (29)$$

Equation 28 shows that output is a function that depends on private capital, government/public capital, and labor. If water supplies are started in the region, many people can use water. The total production will increase more in the densely populated area than in the less densely populated region. A larger increase in regional GDP in a more populated region will achieve higher tax revenues. Equation 29 explains that tax revenues are dependent on the GDP of the region. If part of increased tax revenues were returned to infrastructure operators, their rate of return would rise much more.

(b) Demand, consumption, and investment

$$Y = C + I + G \tag{30}$$

If the population density is higher, more people can increase their productivity when water supply infrastructure is built. Well-established water supply infrastructure is expected to increase consumption and investment, with the demand for consumption rising much more in the populated region. Likewise, companies' investment will rise more in the densely populated region.

Some regions in Japan have decreasing populations due to the aging population and urbanization of younger people. Similarly, there are areas, mainly rural ones, in developing countries that are less densely populated than urban areas. This has led to an extensive gap in water and sanitation infrastructure between urban and rural areas. According to ADB (2020), in 2020, rural areas in Asia and the Pacific had 50% or less access to water and sanitation compared to urban areas.

Focusing solely on single projects and the cost and benefits to those directly impacted might lead to an underestimation of their true effects. For example, in calculating the benefits of infrastructure development, the analysis often fails to include its spillover effects, such as better health outcomes of residents who now have access to clean water or increased employment due to the raised labor demand as a result of the growth in businesses.

Similarly, as discussed earlier, such spillover effects can vary among regions. Regions with larger populations might have higher spillover effects, for example on tax revenues, than regions with smaller populations. Therefore, it is crucial to take a comprehensive look at their impact on an entire region or nation. The positive spillover effects in large cities can be pooled together and used to subsidize water supply infrastructure in rural regions.

6.5 Proposal of Spillover Effects Pooling System

Large cities can provide enhanced water supply infrastructure because the spillover benefits are huge compared to the rural regions. However, the negative externality effects would be considerable if we looked at the negative aspects of non-existing water supply infrastructure. Hence, these industries should focus on nationwide, rather than segmented, policies. We came up with a proposal to shape a pooling system of their profits made by externality effects in large cities so that they can be transferred as a service fee to rural regions. These pooling systems will create a nationwide network of water supplies to reduce negative externalities and create positive externalities for the nation. To apply this idea, setting up a committee consisting of private investors and government (central and local government) is necessary from the beginning of the construction of the water supply infrastructure. The ratio of the initial setting is 50:50 incremental tax revenue to government and infrastructure operator investors. This arrangement shall be reviewed every year by the committee.

6.6 Conclusion and Policy Implications

With increasing operation and maintenance costs, maintaining the low price of water is not an easy task. In this chapter, we argue that the price of water can be kept very low by sharing the spillover tax revenues collected by the government with private investors and water infrastructure operators. Furthermore, this will bring private sector financing into water supply infrastructure development.

The spillover effects are actual and significant, as illustrated by some estimations in the literature review at the macro and project levels. Additionally, the theoretical model describes another potential spillover effect created by water supply infrastructure, human capital development, and health. By modeling the behavior of households, producers, and the price of water, it is easier to describe to policy makers the importance of water supply for the quality of health, which leads to an increase in labor supply. Through the same mechanism, workers' labor quality or productivity will increase labor demand.

A pooling system for the spillover benefits is crucial as there are variations in population density among regions, which can result in a difference in the attractiveness of water infrastructure projects for the operators and investors of such projects. The industries should focus on national policy rather than segmented policies. When relevant pooling systems exist, we hope they will create a nationwide network of water supplies to reduce negative externalities and create positive externalities for the nation.

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PART III

Infrastructure and Firm Performance

7

The Role of Customs Quality for Exports: Empirical Evidence from Firm-Level Data from Belarus, Kazakhstan, and the Kyrgyz Republic

Jonathan Andrew Lane

7.1 Introduction

The Asian Development Bank forecasts that developing Asia will need to invest in the region of $8.4 trillion in transport infrastructure over the next decade (ADB 2017). However, there is limited private sector appetite for this investment in low-income Central Asian nations due to the political, legal, and cultural barriers between these nations. In the aftermath of the novel coronavirus disease (COVID-19), most governments are highly fiscally constrained and thus policies to increase economic growth and development will need to be cost-effective. An area of opportunity for policy makers is to improve soft infrastructure, such as customs clearance procedures. These interventions can be done cost-effectively and would likely be well received by international investors looking at investing in capital projects at a later date. The Belarusian risk-based inspection policy required limited financial investment and allowed Belarus to maximize the efficiency of existing physical assets, without any significant new capital investment. The success of such a cost-effective (in financial terms) policy should be an example for other Central Asian governments looking to improve their fiscal position. This chapter builds on the existing trade literature by providing further analysis of specific policies and adding to the existing evidence that the challenge for Central Asian states is not just to design efficacious policies, but also to focus on successful implementation of the policies.

7.2 Central Asia Pre- and Post-COVID-19 Economic Issues

7.2.1 Overview

The COVID-19 crisis has not had the same human toll on the populations of Central Asian states (OECD 2020)[1] as in other regions. However, the crisis has brought to the fore the deep structural economic problems, such as the return of migrant labor from the Russian Federation, for the Central Asian states,[2] and the loss of the nearly $8 billion of remittances that they send home. In lower-income countries, such as Tajikistan, this loss of remittance income is even more acute, with remittances responsible for nearly 30% of gross domestic product (GDP) in 2018 (Lemon 2019). In addition to the loss of remittances, these states are facing a drop in tax revenues and other traditional sources of revenue (in the case of natural resource-exporting nations, a drop in the demand and thus prices of these exports). The challenges posed to the fiscal stability of these nations by the reduction in government income could be further compounded by a second spike in cases, leading to a much higher number of deaths due to the out-of-pocket expense medical systems that will likely become unaffordable and unable to cope with increasing numbers requiring their services, and thus present a serious potential contingent liability for the government. However, the bigger problems are corruption, bureaucracy, and the closed borders in the Central Asian region that hamper trade, tourism, and overall economic development (EBRD 2013; Lehne, Mo, and Plekhanov 2014).

7.2.2 Pre-COVID-19 Economic Issues: A Lack of Reform

The COVID-19 crisis' biggest effect was to lay bare the pre-existing structural economic problems in Central Asia, especially the informal barriers to trade (Vakulchuk and Irnazarov 2014). Figure 7.1 shows the evolution of the gross national income (GNI) per capita[3] in the former

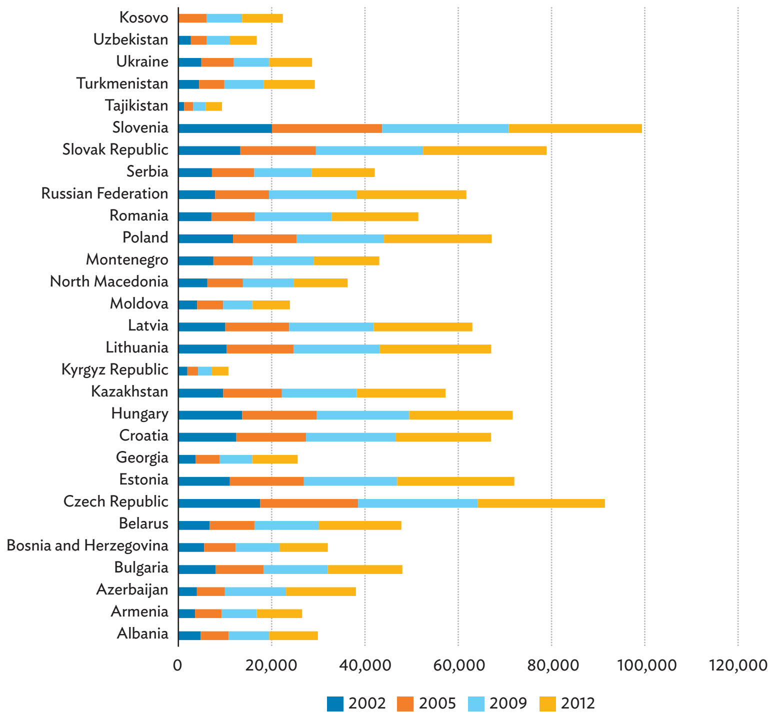
1 OECD (2020). Central Asia is defined as Kazakhstan, Kyrgyz Republic, Tajikistan, Turkmenistan, and Uzbekistan.

2 Due to the nature of migration from Central Asia to the Russian Federation and numerous undocumented workers, independently verifiable figures are challenging to find (Scollon 2020).

3 GNI per capita was chosen as a metric as it is the method used by the World Bank to class countries by income, which is a key component of lending decisions. The People's Republic of China (PRC) was removed due to its size and unique economic status vis-à-vis the other CAREC Central Asia Regional Economic Cooperation countries.

Soviet Union states and select former communist states in Eastern Europe over the last 2 decades. The most obvious observations are that countries with natural resources—Kazakhstan, Azerbaijan, and the Russian Federation—have seen large rises in GNI. Richer countries, which tend to be Eastern European states, were richer to begin with and appear to have prospered due to accession to the European Union (EU). The former Yugoslav states are landlocked and have had limited trading with their immediate neighbors due to informal trade barriers and lack of regional cooperation (Bechev, Ejdus, and Taleski 2019; European Commission 2018; Jusufi and Bellaqa 2019) and have therefore seen

Figure 7.1: GNI Per Capita of Former Communist States in Europe and Former Soviet Union States ($)



GNI = gross national income.

Note: These select years correspond to years that the World Bank Enterprise Survey was conducted.

Source: World Bank. https://data.worldbank.org. (accessed 21 March 2023).

limited improvements in GNI per capita, a situation not dissimilar to the Central Asian states. The most interesting observation is Belarus. It is not part of the EU, nor does it have significant natural resources (oil and gas transit fees aside) but appears to be growing faster than the other nations in similar circumstances mentioned previously. Belarus will be addressed subsequently in this chapter.

One of the major issues with Central Asia pre-COVID-19 was and is the lack of intraregional trade between the Central Asian states (Appendix, Figure A7.2). This can be attributed to a number of factors, but the most pertinent was the massive economic dislocation of all economies due to the loss of markets upon independence (Linn 2004; Pomfret 2006). Additionally, all the states inherited a transport network focused on Moscow and not the other Central Asian states (Werner and Linn 2011). This in itself would not be a long-term problem but the lack of regional consensus to overcome this has prolonged this issue (Linn 2007).

Despite the transport issues and legacies from the former Soviet Union, tariffs and formal barriers[4] are not a major issue in Central Asia (Pomfret 2010; Mogilevskii 2012). However, the range of informal barriers is extensive (Appendix, Figure A7.1). These states have some of the longest times taken to cross borders (i.e., the time it takes to follow all border compliance procedures) for both exports (Kazakhstan at 105 hours[5] [World Bank 2020a] and imports, Uzbekistan at 111 hours [World Bank 2020b], closely followed by Tajikistan at 106 hours [World Bank 2020d]. The Kyrgyz Republic is positively rapid at 96 hours [World Bank 2020c]). These physical barriers are further exacerbated by informal barriers such as a lack of understanding of the other markets, issues with customs documentation, and legal procedures (Appendix, Figure A7.1). These informal barriers to trade make just-in-time manufacturing, or the transport of perishable goods even more difficult if not impossible. In addition, there are closed borders between the Kyrgyz Republic and Tajikistan,[6] and politically motivated hold ups

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4 Formal barriers are defined as per Roberts, Josling, and Orden (1999, p.iii) as "regulations and standards governing the sale of products into national markets that have as their prima facie objective the correction of market inefficiencies stemming from externalities associated with the production, distribution, and consumption of these products."

5 The World Bank's Doing Business survey assumes a standard shipping container of 15 tons at a value of $50,000 imported from its major trading partner via the most widely used form of transport. In Central Asia, this refers to land border crossings via road.

6 The border appears to open and close frequently and for undisclosed periods (Putz 2020).

over and above the usual customs clearance times are not uncommon (Kuehnast and Dudwick 2008).

7.2.3 Economic Performance During COVID-19

The economic issues caused by weak regional integration and a lack of bureaucratic and structural reform in Central Asian states has been further compounded by COVID-19. Central Asian economies are expected to be hit by reduced tourism (Georgia, Kyrgyz Republic) and disrupted intraregional trade flows and supply chains, which are likely to lead to price rises (Tajikistan, Kyrgyz Republic) and a lack of imported consumer goods due to stringent containment measures in the People's Republic of China (PRC) (Uzbekistan) (IMF 2020). The economic downturn is forecast to be more severe than the global financial crisis of 2009–2010 and the 2014–2016 shock (IMF 2020). The Central Asian economies are forecast to shrink by 8 percentage points to –2.2% (IMF 2020) due to materially reduced exports, very limited tourism, but most importantly a near complete stop in remittance receipts (Poghosyan 2020) (Appendix, Figure A7.3). In addition, the drop in commodity prices affects oil-exporting nations less then oil-importing nations. Central Asian and Caucasian oil exporters are projected to contract by approximately 1% due to supply disruptions and a decline in export demand, mostly in oil; however, oil importers are forecast to be affected worse (Appendix, Figure A7.4).

7.2.4 Exchange Rates

International currency reserves and associated debt coverage ratios are being pressured by a decline in the value of a number of currencies, which is raising debt service costs and reducing fiscal space for other government interventions: public health, support for small and medium-sized enterprises, and commercial loan payment holidays (Appendix, Figure A7.4a). The most important currency of the region, the Kazakh tenge, has not depreciated as much as might have been expected due to the central bank management of the exchange rate but is still strongly linked to the ruble due to the significant trade links and large population of Russians in Kazakhstan (Appendix, Figure A7.4b). The Georgian lari has, however, depreciated by over 20%. The Kyrgyz som and the Tajik somoni have lost some value, while other managed currencies have generally remained stable due to demand for dollars being absorbed through either increased foreign exchange auctions or rationing by central banks (IMF 2020).

During the previous few years there have been improvements in fiscal transparency and public financial management resulting in more resilient economies (IMF 2019). In addition, increasing steps toward free floating of regional currencies has not resulted in a high speed of exchange rate pass-through,[7] one of the key reasons behind the "fear of floating" that many emerging and low-income countries face in policy debates. Despite these positive macroeconomic policies, all these countries are starting to face significant pressure on their ability to pay interest and capital on their debt. For countries with partial or free-floating exchange rates backed by credible monetary policy and limited currency valuation mismatches (e.g., Georgia and Kazakhstan) (Appendix, Table A7.1), exchange rates could act as buffers. However, countries with less credible monetary policies, volatile inflation, and large unhedged balance sheet exposure (e.g., Uzbekistan and Tajikistan) (Appendix, Table A7.1) are likely to require International Monetary Fund (IMF) support in addition to strong monetary policy tightening.

7.2.5 Sovereign Debt

The challenges described in the previous two sections of increased government spending, reduced revenue receipts, fiscal deficits, and depreciating exchange rates are likely to put pressure on debt servicing. Growth has returned in 2022 (Appendix, Table A7.1) so immediate debt service problems are currently not an immediate issue and support for this is available from the IMF (IMF 2020). However, in the long term, increased debt quantum will further put pressure on fiscal stability. This further increases the need to increase government receipts and reduce the dependence on government stimulation programs to ensure overall fiscal stability.

7.2.6 Belarus

Unlike any of the other former Soviet Union and communist states, Belarus did not rapidly privatize the economy (shock therapy), thereby avoiding the severe dislocation of markets experienced by many of these countries in the 1990s. It also avoided the corruption associated with the privatization process. However, by the time of the financial crisis in 2009, this model of gradual reform was failing to deliver continued economic growth and more market-based reforms were required

[7] Exchange rate pass-through: The degree to which exchange rate changes are transmitted to inflation. The fear of floating is essentially how inflation of goods may be driven by changes in the foreign exchange rate as per (Calvo and Reinhart 2011).

(EBRD 2016). As part of this move to more free-market policies, the inefficient Belarusian customs were streamlined to promote increased trade. The single most important event was Belarus joining the Eurasian Economic Union (EAEU) with the Russian Federation, Kazakhstan, and the Kyrgyz Republic in 2015. Apart from further harmonization efforts linked to the formation of the EAEU, the creation of a pre-arrival information exchange system with EU countries is one of the primary goals with the EU. The primary objective was to reduce the processing time of goods imported and exported and transiting via the Belarusian border crossing points (EU 2017). The border guard system is founded on a 10-year strategy covering 2008–2017, which, among others, saw the transformation of the border guard into a professional service; around 15% of all employees are conscripts.[8] Returning to Figure 7.1, these policies happened between the dates of the World Bank Enterprise Surveys (WBES), allowing a firm-level analysis to be run using the WBES data of the effects of theses polices on increasing exports and growth in the economy.

7.2.7 Summary

Central Asian governments are facing the twin challenges of COVID-19 expenses such as business and social support as well as decreased taxes and other traditional sources of revenues. These are challenging fiscal stability, and also potentially national solvency depending on the denomination of the debt, a material portion of which is in foreign currencies and thus at the risk of fluctuating exchange rates as well. They will struggle to follow a more Keynesian approach to inducing economic growth such spending more on "hard" infrastructure. If the Central Asian nations were to consider infrastructure as a service, it is important to tackle the serious "soft" infrastructure issues of the unnecessary and convoluted customs clearance procedures between nations due to lack of cooperation. These issues require limited financial capital and is an obvious starting point given the challenging fiscal space these governments are in at the moment. Taking the example of Belarus, reducing bureaucracy and increasing the efficiency of customs would be a logical and cost-effective policy for these governments to increase trade in manufactured goods and agricultural products, and thus hopefully improve employment and economic growth as shown by the Organisation for Economic Co-operation and Development (OECD) OECD (2012) (Appendix, Figure A7.5).

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8 For further information see the UNECE 2010 report.

7.3 Literature Review

7.3.1 Overview

There is a limited explicit body of literature that deals with infrastructure as a service, or soft infrastructure, as this is a relatively new term. An infrastructure investment consists of two parts: hard and soft.[9] Hard infrastructure is the physical investment in new roads, railways, school buildings, and electricity grids. Soft infrastructure refers to effective policy well implemented to ensure that the physical asset performs well and has a material impact. While the importance is alluded to, there exists very little quantitative work in this area. Azhgaliyeva et al. (2021) look at "customs performance" as one of the statistically significant factors in determining international trade in the Central Asia Regional Economic Cooperation (CAREC) countries. However, this paper does not explicitly analyze the different policy regimes that could explain the differing levels of customs performance.

On the other hand, there exists a wide body of empirical literature that explores openness to trade and trade policy reform as a source of economic growth, especially in emerging economies and in the 20th century, the "Asian Miracle". The Asian Miracle has led credence to export-led growth theories like Frankel and Romer (1999), Alcala and Ciccone (2004), and Wacziarg and Welch (2008), who among many others find a positive causal link between openness to international trade and economic growth. This body of work is comprehensively summarized by Hallaert (2006) and more recently by Winters and Masters (2013).

As a result, the focus of academic literature has been on trade policies such as tariff rates, quotas, and the role of borders and other formal barriers to improving export performance. Studies like Hoekman and Nicita (2008) and Anderson and van Wincoop (2004) show that bilateral tariff rates materially reduce exports. Yet despite these two strands of literature, there is a strong body of evidence that well-designed relevant policy alone is insufficient to increase trade. Beginning in the 1960s and guided by the World Bank and the IMF, many countries have reduced formal trade barriers such as tariffs and quotas. However, the results are unevenly spread. Clarke (2005) and Morrissey (2005) comment that the liberalization of trade policies in African countries has resulted in a reduction of import tariff rates from 33% in the early 1980s to 15% by 2002. However, Gupta and Yang (2006) show that manufactured

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9 As summed up by the Asian Development Bank (2012).

goods as a share of total exports remains constant at about 30% during the same period. Analyzing the limited exports of manufactured goods from African countries and overall limited export growth, Iwanow and Kirkpatrick (2009) show that liberal trade policies alone are insufficient to drive export growth. Easterly (2019) updates his work (Easterly 2001 and Easterly 2005), which concluded that poorly thought-out policy could reduce trade but that liberal trade policy alone did not ensure trade increase. Easterly (2019) concludes a positive role for trade policy in enabling growth. Irwin (2019) returns to this question by addressing methodological issues with previous work and finds a link between trade reform and growth, however this issue of heterogeneity between countries remains. Based on this work showing the unequal performance of trade policies alone, researchers have focused their studies on more informal trade barriers such as business environment, institutional quality, customs procedures, and institutional quality effecting export performance. Anderson and Marcoullier (2002) use a gravity model approach to show that bilateral trade is positively influenced by higher institutional quality. Francois and Manchin (2007) further assess this problem with a richer dataset and also account for infrastructure, the business environment, and formal trade policies. They empirically find that informal barriers of trade (or lack of) are more important than infrastructure and formal tariffs in accounting for bilateral trade. Djankov, Freund, and Pham (2010) calculate a direct relationship between the effects of delays on trade. Hummels and Schaur (2013) calculate the premium paid for air shipping versus ocean shipping in the United States; the estimates can be used to assess the impact of policies that raise or lower transport times. De Soyres et al. (2018) use the estimate of the monetary value of the time-savings benefits of the PRC's Belt and Road Initiative, in addition to the direct benefits of increased trade. Hornok and Koren (2015a, 2015b) empirically show that countries with higher administrative trade costs per shipment (according to the World Bank's Doing Business indicators) import fewer and larger shipments. In spite of this significant body of work on trade costs, there is limited empirical evidence on what actual policies should be introduced to reduce these informal barriers. Fernandes, Hillberry, and Mendoza (2015) use actual shipment level data to specifically assess the effect of the reduction of inspections by Albanian customs using a risk-based management system to better identify inspections targets. They find that this policy has increased trade by about 7% and was worth about $12 million in 2012.

7.3.2 Summary

The literature shows a positive benefit of liberal trade policies in increasing exports and, by extension, economic growth, and its associated benefits. However, there is strong evidence that policy alone is not enough. Informal trade barriers pay a huge role as do cumbersome administrative procedures and long times to cross borders. While it is true that better hard infrastructure reduces trade times and associated costs, soft infrastructure, poor policy, and, in most cases, poor implementation of policies are all areas that governments can address without needing to raise significant amounts of capital. If the case of Belarus is applicable, it could lead to rapid positive increases in trade. If there is increased demand for more infrastructure via increased trade, that will attract private investment.

7.4 Methodology and Data

7.4.1 Overview

The goal of this chapter is to build on the literature by addressing three key current issues:

(1) First, despite huge interest in international trade and barriers to trade, there is a lack of actual policy analysis of the effectiveness of different policies.

(2) A criticism of the applied trade literature as identified by Fernandes, Hillberry, and Mendoza (2015) is that they rely on cross-country gravity equations using aggregate measures from the World Bank Doing Business database (Hornok and Koren 2015a, 2015b). While good at identifying the cross-country variations in administrative and bureaucratic hurdles to trade, they do not provide specific information about the effectiveness of specific policy reforms.

(3) There is still a gap between policy reforms and policy implementation; this chapter intends to shed some more light on this area. All countries joining the EAEU had the same objective of implementing a common set of policies; however, the actual result on trade has been very different. It is highly likely that Belarus's EU border and interaction with the border encouraged Belarus to implement the reforms in a different way. This different implementation is more in line with the risk assessment as proposed by the World Trade

Organization and studied in depth by Fernandes, Hillberry, and Mendoza (2015).[10]

7.4.2 Data

The data are sourced from the WBES and are at the firm or company level. For each of the three countries, all observations (firms/companies) were separated into "patient" and "control" groups depending on if they exported or not. There were 874 observations for Belarus, 440 for Kazakhstan, and 320 for the Kyrgyz Republic. Data were from the 2008, 2013, and 2018 WBES. Due to the difference-in-difference methodology, all independent variables are indicators (Table 7.1).

Table 7.1: Description of Variables

Dependent Variable		
Y	Export Intensity	Export sales/total sales
Independent Variables		
1	Customs issues	0 if no reported issues with customs delays, 1 if any form of delay ranging from a few hours to a few weeks
2	Post Joining EAEU	0 for data pre-2015 accession, 1 for data post-2105 accession
3	Issues with customs post joining EAEU	1 for firm reporting an issue with customs post-2015, 0 otherwise
4	Large firm	Data set of firms was divided into three based on sales. Top third was deemed to be large 1, and 0 for bottom third. Middle third was removed to ensure distinct difference between the groups.
5	Large firm and problems with customs	1 if large as per previous definition reporting issues with customs as per variable 1, 0 otherwise
6	Large firm following joining EAEU	1 if large as per variable 4 and data post-2015 accession, 0 otherwise
7	Problems with customs and large firm following joining the EAEU	1 if reported problems as per variable 1 and large as per variable 4 and post-2015, 0 otherwise

EAEU = Eurasian Economic Union.

Source: Author.

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10 https://www.customs.gov.by/en/strategy-en/. While not strictly the World Trade Organization program, the methodology and process are similar.

7.4.3 Methodology

The accession of Belarus, Kazakhstan, and the Kyrgyz Republic to the EAEU in 2015 has created a natural experiment, whereby Belarus implemented a common customs policy differently, using a risk-based shipment monitoring system. The natural experiment allows two distinct groups to be formed: a patient and a control group, much like a medical trial. The two groups need to be the same except for the "treatment", in this case the implementation of the common policy. The main aim of accession to the EAEU was to increase trade among members, which would be registered as an increase in exports as a proportion of total sales for firms. The effect of this policy implementation can be assessed with a difference in differences (DID) methodology.

The methodology is a two-step process, the first being a DID model, where the statistical significance of the 2015 accession (coefficient 2) on firms who reported difficulties with customs (coefficient 3) will be tested. If this proves to be statistically significant, there is an attributable increase or decrease in exports as a proportion of a firm's total sales. As identified in the literature review, we would expect to see an increase in trade after joining the EAEU, and especially with firms reporting customs issues as this would indicate that these have reduced due to the new policy.

If there is a positive effect on export intensity after 2015, the data can be further analyzed based on firm size with a triple difference-in-difference (DDD) equation. This equation allows us to further divide the control and patient groups into more detail based on firm size. This would enable us to determine the difference between and a large and a small firm (coefficient 7). The coefficient of this estimator could be interpreted as the percentage point difference increase (decrease) in exports attributable to larger firms as opposed to smaller firms. Firm size has been shown to be important in explaining exports as a proportion of a firm's sales (Hayakawa 2015; Azhgaliyeva et al. 2021). This is likely due to more resources and dedicated teams to handle exports. This additional detail provides further insights for policy makers about the effect of policies, to enable more insightful and targeted policy interventions.

7.4.4 The Difference-in-Difference Model

In the DID model, the dependent variable *Yit* is the value of export sales over total sales: export intensity. This means that the coefficients can be interpreted as a percentage point increase or decrease in the proportion of exports of total sales of a firm. Indicator variables are created for firms that self-reported an issue with customs either importing or exporting

($\beta 1$), the accession to the EAEU post-2015 ($\beta 2$) and an interaction term for firms that had an issue with customs and post-accession to the EAEU ($\beta 3$). β1 is created by identifying firms that responded with a 4 or 5, which are either "severe problems" or "very severe problems" when dealing with customs as identified by the WBES.

The DID takes the following functional form:

$$Y_{it} = \alpha + \beta_1 Customs\ Issues_i + \beta_2 Post\ 2015_t + \beta_3 Post\ 2015\ x\ Custom\ Issues_{it} + \varepsilon_{it} \quad (1)$$

Where the subscript "i" refers to individual firms in the treatment group: those firms experiencing customs issues, and "t" refers to firms post-2015 after accession to the EAEU.

The DID will be post-checked for normality, multicollinearity, and heteroscedasticity If accession to the EAEU is significant then the dummy, $\beta 2$, should be statistically significant with a positive coefficient indicating a positive effect of the customs reforms on increasing exports to the EAEU.

7.4.5 Triple Difference in Difference (DDD)

Equation (1) is expanded by adding this additional new term to account for large firms, with subscript "s" indicating a large firm as per the table of variables.

$$\begin{aligned} Y_{ist} = \alpha + \beta_1 Customs\ Issues_i + \beta_2 Post\ 2015_t \\ + \beta_3 Post\ 2015\ x\ Custom\ Issues_{it} + \beta_4 Size_s \\ + \beta_5 Size\ x\ Custom\ Issues_{is} + \beta_6 Size\ x\ Post\ 2015_{st} \\ + \beta_7 Size\ x\ Customs\ Issues\ x\ Post\ 2015_{ist} + \varepsilon_{ist} \quad (2) \end{aligned}$$

Due to the strong time-invariant effects between each of the industries and firms in each country, a fixed effects model will be run, since we are interested in the time variance (Wooldridge 2010). In the interests of academic rigor, both a fixed effects and a random effects model will be run, and the results tested with a Haussmann test (Wooldridge 2010).

To ensure the efficiency of the estimators, a number of tests will be run on the data and model:

- Testing for cross-sectional dependence and/or contemporaneous correlation: using Breusch-Pagan LM test of independence and confirmed with the Pasaran CD test (Wooldridge 2010).
- Testing for heteroscedasticity with a modified Wald test (Arellano 2003).

- Testing for serial correlation using the Wooldridge test (Wooldridge 2010). Serial correlation tests apply to macro panels with long time series (over 20–30 years), so it is not expected to be a problem in this panel.
- Testing for unit roots/stationarity with tests devised by Levin, Lin, and Chu (2002) and Harris and Tzavalis (1999).
- Normality and linearity using QQplots, scatter plots, and other descriptive statistics and generalized additive models (Arellano 2003).

Depending on the results of the above tests, the regressions will be run with “robust standard errors” with the specifications of the errors the same as Stock and Watson (2008) and Hoechle (2013).

7.5 Results

7.5.1 Overview

Six regressions were run, a DID for the Kyrgyz Republic, Kazakhstan, and Belarus with the post-estimation tests as per the methodology. Based on the statistically significant result for the post-2015 accession to the EAEU, the DDD was run for each country. The accession variable ($\beta 2$) was positive and statistically significant for all three countries, indicating the positive effect on exports of the more efficient risk-based customs-clearance procedures introduced to comply with the new common customs policies. This was also the case for firms reporting issues with customs clearance ($\beta 3$) in Belarus and Kazakhstan. However, this was not the case for Kyrgyz Republic where the results were less clear, likely due to the large grey economy and the lack of official data.

To ensure the key confounding element of a DDD equation is met, the significance of previous years will also be tested to support the argument in favor of the accession to the EAEU and that the parallel trend assumption holds. No additional statistically significant years were found except post-2015.

7.5.2 Full Results

As discussed in the introduction, Belarus, Kazakhstan, and the Kyrgyz Republic all joined the EAEU in the same year. While all three nations had to enact common policies for the customs union, how each country implemented these policies was different. In the case of Belarus, the priority was to also enable faster access to the EU as part of the rail link from the PRC to Europe and so introduced the risk-based customs

Table 7.2: Results for Pooled OLS and Difference-in-Difference Regressions

		Triple Difference in Difference (DDD)			Difference In Difference (DD)		
	Regression	1	2	3	4	5	6
Variable		Belarus	Kazakhstan	Kyrgyz Rep.	Belarus	Kazakhstan	Kyrgyz Rep.
1	Customs issues	0.0157 (0.0348)	−0.114** (0.0063)	−0.0082 (0.0256)	0.0142 (0.0221)	−0.0026 (0.0103)	0.0117 (0.0209)
2	Post-joining EAEU	0.0468 *** (0.0215)	0.0056 (0.0074)	0.0405** (0.0243)	0.0857** (0.0325)	0.0084** (0.0039)	0.0303** (0.0188)
3	Issues with customs post-joining EAEU	0.2101** (0.1204)	0.0787*** (0.0335)	0.0181 (0.0581)	0.0398*** (0.0074)	0.0598*** (0.0223)	−0.0067 (0.0283)
4	Large firm	0.0561** (0.0295)	0.0274 (0.0205)	0.1183** (0.0681)	–	–	–
5	Large firm and problems with customs	0.1477** (0.0891)	0.0183 (0.0445)	0.0025 (0.1087)	–	–	–
6	Large firm and post-joining EAEU	0.0695** (0.0401)	0.0025 (0.0239)	0.0007 (0.0834)	–	–	–
7	Problems with customs and large firm and post-joining the EAEU	−0.1720 (0.1987)	−0.0553 (0.0640)	0.0832 (0.1744)	–	–	–
Constant		0.0248** (0.0134)	0.0114** (0.0062)	0.0282** (0.0169)	0.0291*** (0.0065)	0.0163*** (0.0047)	0.0741*** (0.0174)
R^2		0.56	0.39	0.28	0.44	0.09	0.12
Sample Size		874	440	320	874	440	320
Robust Standard Errors		Y	Y	Y	Y	Y	Y

EAEU = Eurasian Economic Union, OLS = ordinary least squares, R2 = fit of regression.

Notes: Standard errors in parenthesis, *** statistically significant at 1% confidence level, ** statistically significant at 5% confidence level. Since the dependent variable is firm exports over firm sales, the coefficients can be interpreted as a percentage point change.

Source: Author.

clearance system that uses data to identify the shipments most at risk of being used to hide contraband to target inspections and decrease the number of physical inspections.

In regression 1, Belarus, the coefficient is statistically significant and positive from the customs reforms; large firms also benefitted, unsurprisingly. What is also interesting is that firms that reported an issue with customs did not seem to be suffering from reduced exports as a result of these issues unlike Kazakhstan. This could also be due to the composition of the Belarusian economy and the large number of manufacturing firms (for example MAZ, Volat, Belshina), which have always had to export due to their size and the limited internal market in Belarus.

In regressions 2 and 5, Kazakhstan, the 2015 accession coefficient is positive in the DID but not in the DDD. This is likely due to the limited number of non-natural resource (not mining, oil, or gas) exporting firms in Kazakhstan and the sample size could be too small. It is also flagging the very limited exports from Kazakhstan and the dependence on volatile natural resource prices. In regression 2, the statistically significant and negative coefficient for firms reporting issues with customs is concerning as this could indicate that the customs bureaucracy is having a material and negative effect on the ability of the few exporters to export.

In regressions 3 and 6, the Kyrgyz Republic, there again is a statistically significant and positive coefficient for the post-EAEU accession indicator variable and for large firms. It is surprising that there are not more statistically significant coefficients for the Kyrgyz Republic data given the large number of garment manufacturing and retail import and export firms at the Dordoy bazar.[11] This is likely due to the large gray economy and small scale of these garment or retail firms and so would not be picked up by the WBES data. While there is some evidence of loss of other markets on the Kyrgyz garment industry on accession to the EAEU, the advice from the EU and OECD was to focus on the countries of the former Soviet Union where it enjoyed a competitive advantage. It looks like that has been paying off to some extent.

7.5.4 Summary

For all three countries, there is evidence that joining the EAEU has been beneficial in increasing exports; however, the results vary dramatically between the countries. This further supports the literature, which indicates that a policy intervention such as removing formal barriers to trade is not enough. In the case of this chapter, the implementation of more efficient customs procedures was key to benefitting from the policy.

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11 See the OECD (2014) report on developing the garment sector. The export-orient nature of this industry has been helped by the regional customs arrangements, but it still remains highly fragmented, and high-quality firm level data are hard to acquire.

7.6 Conclusions and Policy Recommendations

7.6.1 Conclusions

This chapter used data to empirically assess the differing effects on export intensity of joining the EAEU but implementing the common customs policies differently. A DID methodology to take advantage of the quasi-natural experiment of Belarus, Kazakhstan, and the Kyrgyz Republic joining the EAEU in 2015 was used to assess an effective policy intervention and its implementation. The results show, in line with an emerging body of literature, that well-designed policy is irrelevant without an effective implementation strategy. It has added to the literature by using firm-level data to assess the impact of a policy intervention, and to attempt to value the wider spillover benefits to the economy. While there are pressing issues around infrastructure in Central Asia, there is an undoubted need for more capital investment. However, the full benefits of a major capital investment program are highly unlikely to be realized without careful policy design and thought on how to successfully implement the policy to achieve the desired outcomes. In fiscally constrained times, the best way forward for Central Asian governments is to focus on the policy surrounding infrastructure generally, not just customs clearance, and on how to best implement the policy. Due to the data challenges and thin datasets, the author is reluctant to draw any more quantitative conclusions from the results.

The biggest single hurdle has been access to accurate data. The only dataset that the author is aware of that would allow for the comparison of the three countries in this chapter is the WBES. However, the dataset is pooled and does not allow a comparison of the same firm over time. If governments were to collect customs clearance time by container with associated company and sector information, that would provide a much richer, more granular dataset from which to conduct similar analysis. The "real time" nature of this data would allow much more frequent analysis to assess the effects of more localized policy interventions.

7.6.2 Policy Recommendations

COVID-19 provides what John Kingdon (1984) called a window of opportunity. Due to COVID-19, the governments of Central Asia are facing the combined challenges of increased spending on social security and business support, while grappling with reduced income from lower taxes. In the case of Kazakhstan, the drop in prices for commodities is also putting pressure on the national budget. Any policy recommendations will have to be cost-effective to avoid putting any additional strain on stressed national budgets. Customs service reform is cost-effective in monetary terms but expensive in terms of spending political capital. The will to continue integrating regional economies dropped off significantly during the last decade as the largest economy, i.e., Kazakhstan, slowed reforms due to increasing revenue from oil and gas. However, with commodity prices at historic lows, there is renewed interest in looking for alternative sources of income. The risk-based customs reforms studied by Fernandes, Hillberry, and Mendoza (2015) in Albania were introduced over a period of 6 months with immediate tangible results to trade and likely associated political windfall.

Large-scale infrastructure projects are unlikely to be financially viable in Central Asia (Reed and Trubetskoy 2019) and will struggle to attract international capital in the current investment environment. The first step in developing and financing infrastructure is to develop relevant policy with thoughtful implementation strategies to increase trade. Then, on the basis of increased trade and clear demand, forecasts should be developed to make the case for major capital investment. Implementing a risk-based customs system can be funded by grants from one of the supranational financial organizations to fund any additional infrastructure upgrades: computer systems, digitization, and training. The remaining challenges are cultural and potentially educational. According to the OECD (2012) (Appendix, Figure A7.5), the top four most successful reforms are better training, processes, procedures, and policy. New physical infrastructure (roads, railways, ports) comes in fifth.

Additionally, an investment in time and political capital on economic integration might also bring some of these countries closer together in negotiating other areas of mutual benefit: water and energy security.[12] These two areas are a major source of contention between the Central Asian countries, but, with better regional cooperation, hopefully fostered by improvements in customs procedures, they could be addressed to mutual benefit. As Winston Churchill once said, "Never waste a good crisis".

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12 https://www.worldbank.org/en/region/eca/brief/cawep. Water and energy security are two other material issues that need to be addressed, especially with population growth and increasing demand on limited resources.

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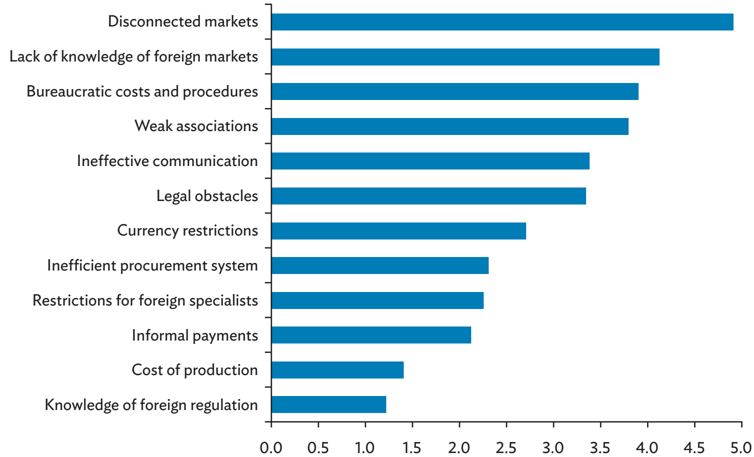
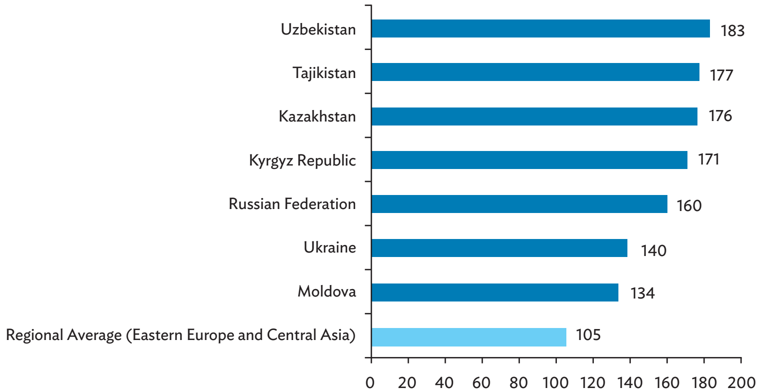
Appendix

Figure A7.1: Informal Obstacles to Trade in Central Asia (aggregate distribution of answers, average mean)



Source: Vakulchuk and Irnazarov (2014), p.10.

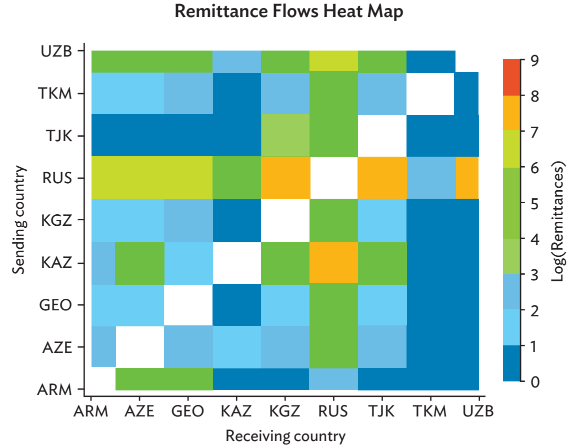
Figure A7.2: Ease of Trading Across Central Asian Borders



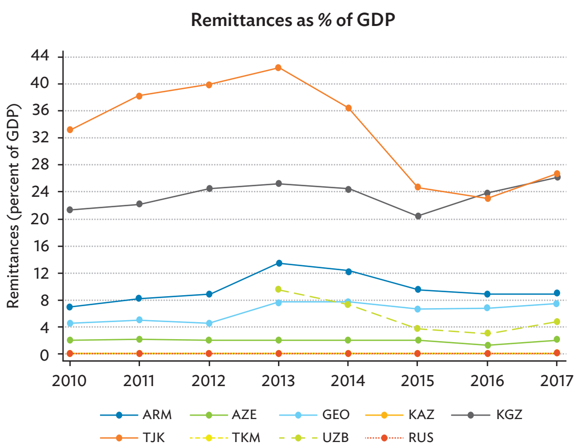
Note: Ease of trading ranking is in reverse order, i.e., the highest ranked nation is the most difficult to trade with. Here, Uzbekistan is the most difficult nation to trade with, and Moldova the least difficult.

Source: World Bank (2012).

Figure A7.3: Remittance Flows: Russian Federation, and Caucasus and Central Asian States



Sources: IMF and World Bank.

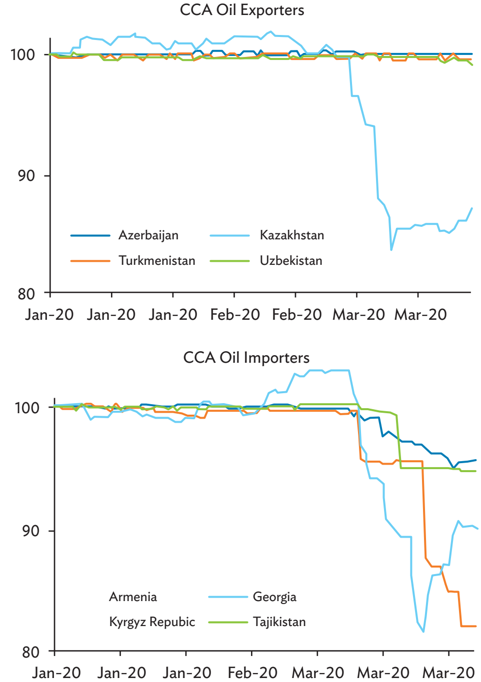


AZE = Azerbaijan, GDP = gross domestic product, GEO = Georgia, IMF = International Monetary Fund, KAX = Kazakhstan, KGZ = Kyrgyz Republic, RM = Armenia, TJK = Tajikistan, TKM = Turkmenistan, UZB = Uzbekistan, RUS = Russian Federation.

Source: Poghosyan (2020).

Figure A7.4: Currency Exchange Rates: Caucasus and Central Asian States

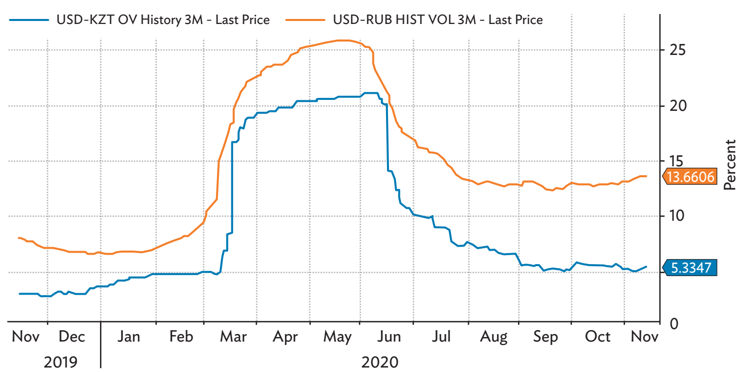
(a) All currencies, index January 2020 = 100



CCA = Caucasus and Central Asia.

Sources: Bloomberg, IMF (2020).

(b) Kazakh tenge



Source: Bloomberg.

The Kazakh tenge has been volatile and has seen some depreciation, but it has been managed by the government using $8 billion of oil revenue reserves from the $56 billion reserve fund to pay for fiscal stimulation and support for the economy, unlike the Russian Federation, which has raised debt.

Table A7.1: Selected Economic Indicators

	Average 2000–2016	2017	2018	2019	2020(f)	2021(f)
Real GDP Growth						
Annual change %						
Armenia	6.6	7.5	5.2	7.6	−1.5	4.8
Azerbaijan	9.5	0.2	1.5	2.3	−2.2	0.7
Georgia	5.5	4.8	4.8	5.1	−4	3
Kazakhstan	6.9	4.1	4.1	4.5	−2.5	4.1
Kyrgyz Republic	4.4	4.7	3.5	4.5	−4	8
Tajikistan	7.7	7.1	7.3	7.5	1	5.5
Turkmenistan	9.7	6.5	6.2	6.3	1.8	6.4
Uzbekistan	6.8	4.5	5.4	5.6	1.8	7
Consumer Price Inflation						
Year Average %						
Armenia	3.8	1	2.4	1.4	0.8	2
Azerbaijan	6.3	12.8	2.3	2.6	3.3	3.2
Georgia	5.1	6	2.6	4.9	4.6	3.7
Kazakhstan	8.6	7.4	6	5.2	6.9	6.8
Kyrgyz Republic	8	3.2	1.5	1.1	10.6	7.2
Tajikistan	12.5	7.3	3.8	7.8	8.1	6.9
Turkmenistan	5.6	8	13.3	5.1	8	6
Uzbekistan	13.8	13.9	17.5	14.5	12.6	10.6

continued on next page

Table A7.1 *continued*

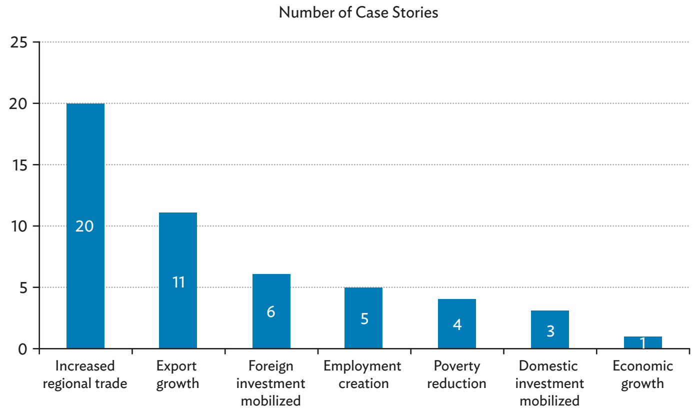
	Average 2000–2016	2017	2018	2019	2020(f)	2021(f)
Overall Fiscal Balance						
% GDP						
Armenia	−3.4	−4.8	−1.8	−1	−5	−2.5
Azerbaijan	5.9	−1.4	5.5	8.4	−12.8	−9.7
Georgia	−2	−2.7	−2.3	−2	−7.8	−3.8
Kazakhstan	2.1	−4.3	2.5	−0.6	−5.3	−2.7
Kyrgyz Republic	−4	−3.7	−0.6	−0.1	−9.6	−6.4
Tajikistan	−2.9	−6	−2.8	−2.1	−6.4	−3
Turkmenistan	2.4	−2.8	−0.2	−0.3	−2.3	−0.5
Uzbekistan	0.5	1.6	2.1	0	−3.3	−1.3
Current Account Balance						
% GDP						
Armenia	−8.1	−3	−9.4	−8.2	−8.6	−7.2
Azerbaijan	7.7	4.1	12.8	9.2	−8.2	−3.7
Georgia	−10.8	−8.1	−6.8	−5.1	−10.5	−6.9
Kazakhstan	−1.1	−3.1	−0.1	−3.6	−6.8	−5.5
Kyrgyz Republic	−5.7	−6.2	12.1	−9.1	−16.6	−11
Tajikistan	−9	2.2	−5	−3.3	−7.7	−4.5
Turkmenistan	−10	−10.4	5.5	5.1	−1.4	−0.4
Uzbekistan	4	2.5	−7.1	−5.6	−9.4	−6.4

GDP = gross domestic product.

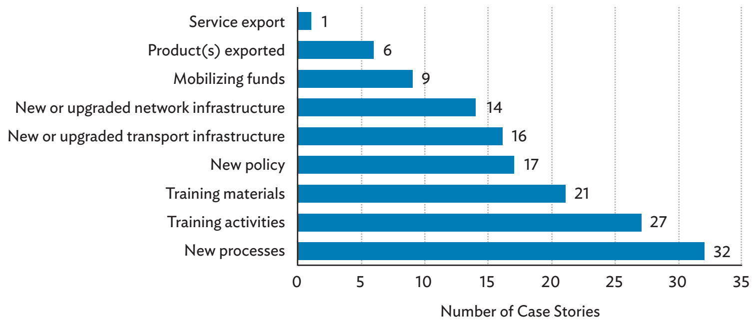
Source: IMF (2020).

Figure A7.5: OECD Case Stories: Summaries of Successful Customs Reform

(a) Impacts Reported in Trade Facilitation Case Studies



(b) Specific Results Reported in Trade Facilitation Case Stories



Source: OECD (2012).

8

Evaluating COVID-19's Impact on Firm Performance in Four CAREC Countries Using Night-Time Light Data: Azerbaijan, Georgia, Kazakhstan, and Mongolia[1]

Kamalbek Karymshakov, Dina Azhgaliyeva, Ranjeeta Mishra, and Dastan Aseinov

8.1 Introduction

One of the main advantages of remote sensing data for economic analysis is the opportunity to analyze the intensity of economic activity when information is difficult to obtain (Henderson, Storeygard, and Weil 2012; Donaldson and Storeygard 2016). Lan et al. (2021) argued that, in the case of the People's Republic of China (PRC), change in the intensity of night-time light is correlated with people's activities and government prevention measures, meaning that night-time light data can be used to monitor changes in human behavior during restrictions. Analogously, Beyer, Jain, and Sinha (2021) indicated that the divergence of night-time light intensity from that during the relative pre-novel coronavirus disease (COVID-19) months in India is positively associated with restrictions in districts. Roberts (2021) showed that changes in night-

[1] The views expressed in this chapter also do not reflect the views or policies of Kyrgyz–Turkish Manas University or the Reserve Bank of India.

time light in Morocco explain the drop in economic activity measured as changes in the real gross domestic product (GDP) during the COVID-19 pandemic.

Although there is a large consensus on the use of night-time light intensity to track changes in economic activity, night-time light might itself be subject to energy demand and consumption behavior changes caused by COVID-19. Overall, the restrictions on mobility because of COVID-19 caused a decrease in energy consumption (IEA 2020). However, along with the decreased consumption, there were substantial spatial and temporal differences (Jiang, Van Fan, and Klemeš 2021). The increased time spent at home during the pandemic and the transition to remote work may have affected building energy consumption (Rouleau and Gosselin 2021; Tleuken et al. 2021). This may not necessarily imply low intensity of night-time light. Therefore, along with the general expectation that night-time light may help to understand private sector performance during the pandemic, the energy consumption behavior during the restrictions may create some vague perspectives on the ability to explore economic activity with night-time light data.

The Central Asian region has recorded impressive economic growth rates since 2000, driven mainly by the exporting of commodities. Small and medium-sized enterprises play an important role in these economies, on which COVID-19 has had a severe negative impact. However, under the conditions of unavailability of regional income estimates in high-frequency periods, night-time light could serve as a useful proxy indicator for measuring economic activity at the national and/or subnational level, especially in countries with low statistical capacity.

The Central Asia Regional Economic Cooperation (CAREC) program, which extends from Azerbaijan to the PRC, is an increasingly important channel for international trade and energy resources. The COVID-19 pandemic and subsequent economic crisis have brought unprecedented challenges to the CAREC region. The COVID-19 crisis led to a reduction in demand and supply due to both uncertainty and policy interventions, such as lockdowns, social distancing, and travel restrictions, which had a severe impact on CAREC countries (Azhgaliyeva et al. 2022). Aseinov et al. (2022) provided empirical evidence from Azerbaijan, Georgia, Kazakhstan, and Mongolia, showing how different factors, including firm characteristics and government policy, affect the probability that a firm will adjust its activities to COVID-19. The results indicate that the firms that adapted to the COVID-19 crisis are younger foreign firms that have been innovative in the recent past, with female managers, a formal firm strategy with key performance indicators, and their own websites. Li et al. (2017) showed that night-time light satellite images are an effective tool for monitoring spatial and temporal social economic parameters in Central Asia.

Empirical studies on the impact of COVID-19 on firm performance in the CAREC region are limited. This chapter contributes to the literature by studying this topic, controlling for regional economic activity, using night-time light data.

This study aims to examine the change in firm performance as a factor of the change in intensity of night-time light, COVID-19-related restrictions, and other microeconomic attributes in four CAREC economies: Azerbaijan, Georgia, Kazakhstan, and Mongolia. The empirical analysis is based on the World Bank Enterprise Survey data for 2019 and the follow-up survey performed during the COVID-19 pandemic. The enterprise survey dataset is enhanced with data on night-time light intensity from Google Earth, COVID-19, and the strictness of "lockdown-style" policies, i.e., the stringency index (Hale et al. 2021). The main contribution of this chapter to the existing literature is that it uses night-time light data to study firm performance in Central Asia.

The chapter is structured as follows. Section 8.2 describes COVID-19's dynamics in the four economies. Sections 8.3 and 8.4 discuss the data sources and methodology, respectively. Section 8.5 presents the estimation results. Section 8.6 concludes and provides policy recommendations.

8.2 COVID-19 Dynamics in Central Asia

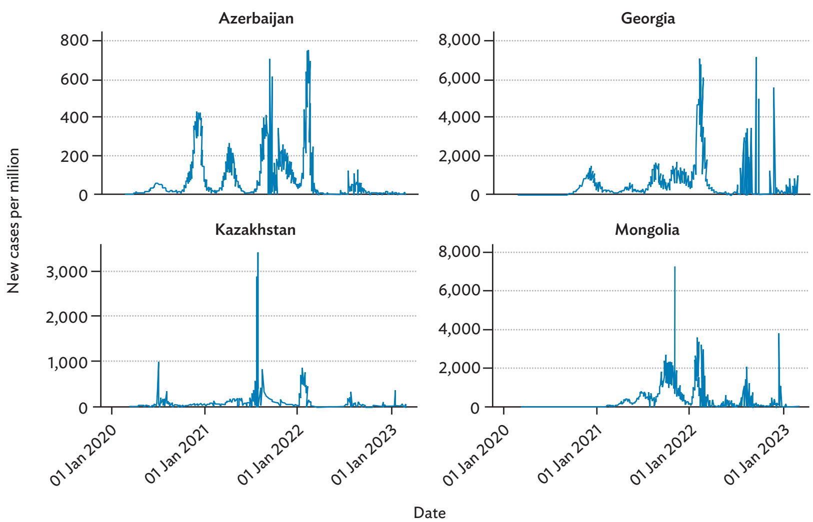
COVID-19 severely affected the CAREC countries. Cases of COVID-19 were high in the summer of 2021 in the four countries. Figure 8.1 illustrates the daily new confirmed COVID-19 cases per million people in the four countries with a 7-day rolling average. Due to limited testing, the number of confirmed cases could be lower than the true number of infections.

The daily new confirmed COVID-19 deaths per million people are illustrated in Figure 8.2 using a 7-day rolling average. Due to varying protocols and challenges in the attribution of the cause of death, the number of confirmed deaths may not accurately represent the true number of deaths caused by COVID-19.

The strictness of the "lockdown-style" policies that primarily restricted people's behavior, according to the COVID-19: stringency index, is provided in Figure 8.3. The stringency is measured from 0 (least strict restrictions) to 100 (strictest restrictions). The stringency index records the number and strictness of government policies. It does not measure the appropriateness or effectiveness of a response to the COVID-19 pandemic. The strictness of lockdown policies was at its highest in the first half of 2020 and gradually declined due to the spread of vaccination.

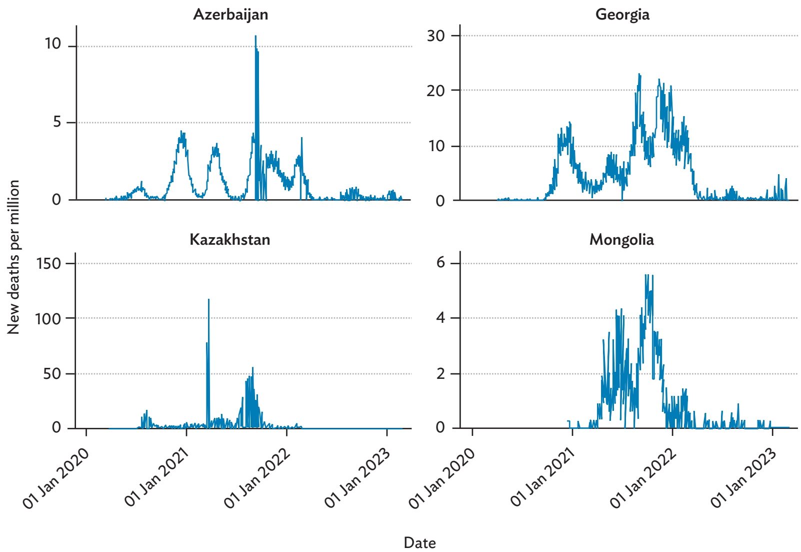
The daily share of the population receiving a COVID-19 vaccine dose is presented in Figure 8.4 and Figure 8.5. Figure 8.4 illustrates the 7-day rolling average of all doses, including boosters, which are counted individually, as a share of the population. Figure 8.5 shows that, in Mongolia, the majority of the population received a COVID-19 vaccination in the middle and at the end of 2021.

Figure 8.1: COVID-19 Cases



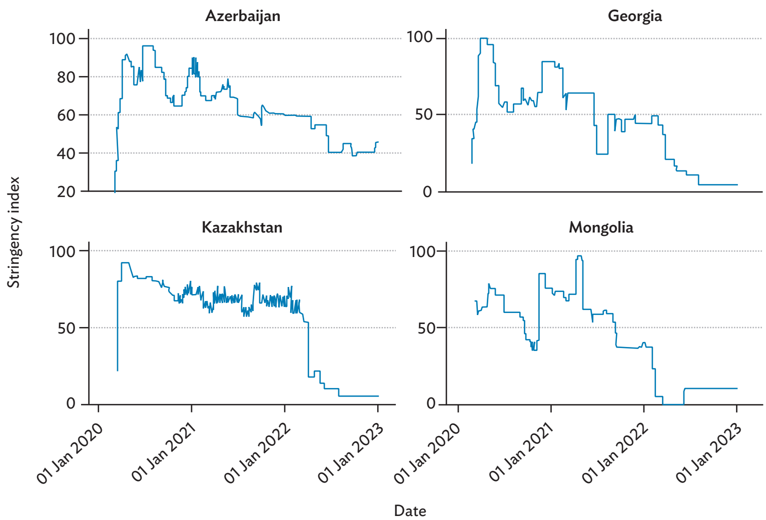
Source: Authors' elaboration using data from the COVID-19 Data Repository by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University.

Figure 8.2: COVID-19 Deaths



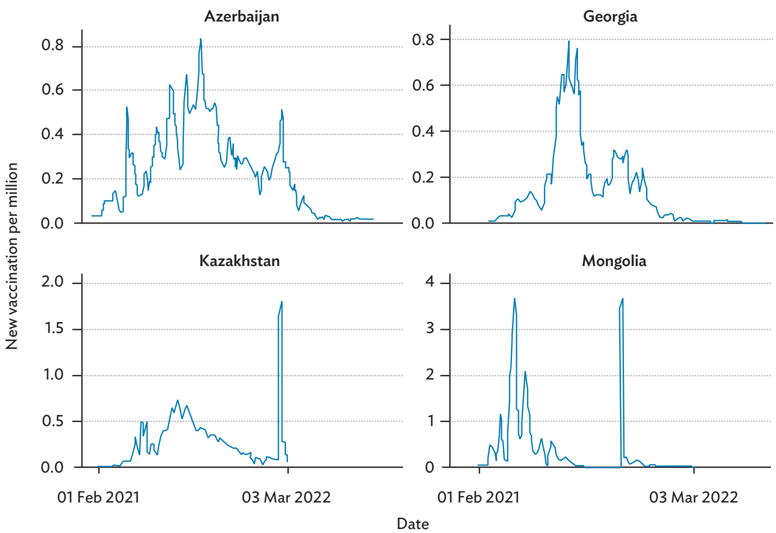
Source: Authors' elaboration using data from the COVID-19 Data Repository by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University.

Figure 8.3: Stringency Index



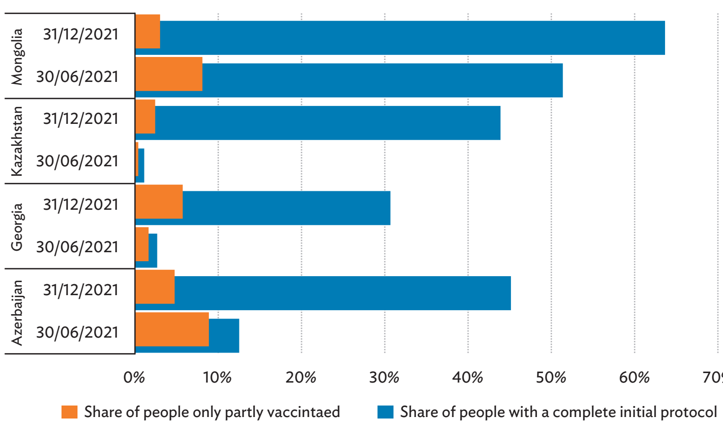
Source: Authors' elaboration using data from Hale et al. (2021).

Figure 8.4: Population Receiving a COVID-19 Vaccine Dose



Source: Authors' elaboration using data from the COVID-19 Data Repository by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University.

Figure 8.5: COVID-19 Vaccinations on 30 June 2021 and 31 December 2021



Source: Authors' elaboration using data from Our World in Data.

8.3 Data

8.3.1 Data Source

The main dataset employed in our study consists of firm-level survey data for four CAREC countries. The World Bank Enterprise Survey, conducted before the COVID-19 pandemic and considered as the baseline survey, and the follow-up surveys, carried out during the COVID-19 pandemic, are combined to obtain data on the performance and characteristics of firms in the CAREC countries. The baseline survey, conducted in the pre-pandemic period, focused on the business environment as well as the key characteristics and performance of firms. The follow-up surveys, conducted during the pandemic, essentially asked questions about the impact of COVID-19 on business operations and the behavior of firms during the pandemic.

After deleting responses with missing values, the total sample consists of 2,816 observations. The sample distribution by country for both baseline and follow-up surveys is presented in Table 8.1. Due to the lack of availability of follow-up survey data, our dataset covers only four CAREC countries. The dataset contains two waves of the follow-up surveys each for Georgia and Mongolia and one wave each for Azerbaijan and Kazakhstan.

Table 8.1: Dataset: Survey Dates and Waves

			Follow-Up Survey				Number of Observed Firms
	Baseline Survey		Wave I		Wave II		
Country	Date	N	Date	N	Date	N	N
Azerbaijan	July–Dec 2019	72	Apr, May 2021	105			105
	Jan–Feb 2020	33					
Georgia	Jan 2020	14	June 2020	614	Oct, Nov 2020	589	659
	Mar–Nov 2019	1187					
Kazakhstan	Jan–Oct 2019	871	Jan–May 2021	871			871
Mongolia	Dec 2018	19					
	Jan–June 2019	618	Aug. 2020	314	Feb 2021	323	329
Total		2,814		1,904		912	1,964

Note: N denotes the number of observations.

Source: Authors' elaboration using data from the World Bank Enterprise Survey.

The baseline survey covers the period from December 2018 to February 2020, that is, the pre-pandemic period, while the follow-up surveys are from the pandemic period. As can be seen from Table 8.1, about 37% of the follow-up surveys were performed during the period of severe restrictions and intensive spread of coronavirus in the countries under consideration, specifically from April to August 2020. The remaining follow-up surveys cover the period from October 2020 to May 2021. The dataset is supplemented with other variables of interest i.e., the monthly night-time illumination and hardness index, according to the World Bank Enterprise Survey interview date (month and year) of the corresponding survey, country, and region or province.

The World Bank Enterprise Survey claims to contain a representative sample of an economy's private sector: "a sample representative of the non-agricultural, non-extractive formal private economy." (World Bank 2022). The follow-up surveys follow firms included in the standard enterprise survey, which is the baseline survey in our case. Therefore, we assume that the dataset that we use for our estimations is representative (details on sample distributions are provided in Appendix Figures 1A–4A).

8.3.2 Summary Statistics

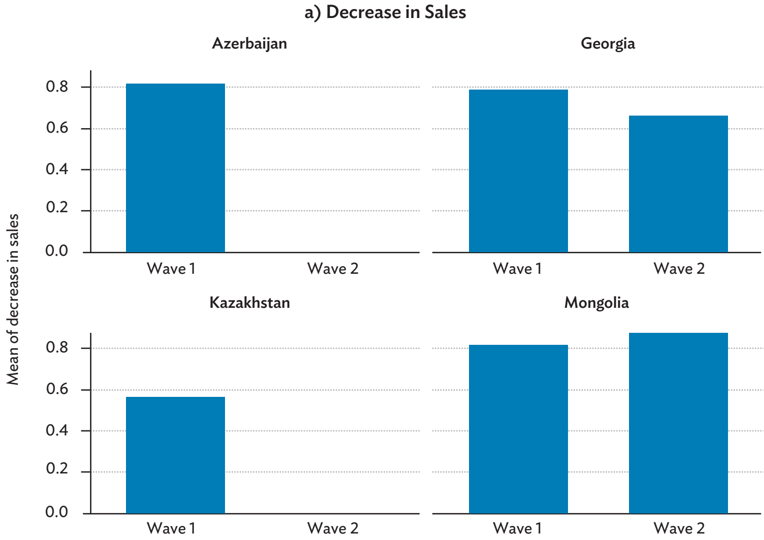
Table 8.2 reports the mean values of the variables used in the analysis. As can be seen from Table 8.2 and Figure 8.6, 70%, 60%, 51%, and 48% of the firms surveyed during the pandemic reported a decrease in their sales, the demand for their products and services, the total number of hours worked, and the share of exports in total sales, respectively. It should be noted here that the reduction in the share of exports in the follow-up data is only available for the first wave for Georgia and Mongolia. The proportion of firms that experienced sales declines is larger in the second wave of the follow-up survey than in the first wave. In terms of country differences, the performance of the surveyed firms in Kazakhstan is less affected by the pandemic than that of the firms in Georgia and Azerbaijan.

Table 8.2: Descriptive Statistics

Variables	Total Sample	Baseline Survey	Wave 1	Wave 2	Azerbaijan	Kazakhstan	Georgia	Mongolia
Sales (1 = decrease)	0.70		0.69	0.72	0.81	0.57	0.72	0.84
Demand (1 = decrease)	0.60		0.61	0.58	0.62	0.49	0.65	0.67
Worked hours (1 = decrease)	0.51		0.51	0.51	0.47	0.37	0.54	0.68
Export share (1 = decrease)			0.48				0.62	0.28
Night-time light (1 = increase)	0.8718	0.872	0.871	0.873	0.96	0.94	0.75	1.00
Stringency index (100 = strictest)	60.06		60.94	58.23	67.42	64.60	56.08	60.17
Competition (N)		445.70	460.80	414.70	371.50	513.30	585.60	117.80
Online business activity (1 = firm has started or increased)	0.25		0.28	0.18	0.58	0.31	0.17	0.29
KPI (1 = firm has key performance indicators)		0.37			0.64	0.46	0.22	0.43
Foreign ownership (%)		5.16			5.75	2.50	8.13	3.03
Female ownership (1 = yes)		0.33			0.08	0.33	0.29	0.46
Gender of manager (1 = female)		0.27			0.12	0.26	0.22	0.42
Industry (N)		2,812			105	871	1199	637
Food		398				138	260	
Retail		570			34	104	237	195
Manufacturing, Garments		720			31	222	257	210
Metal, Machinery, and Equip. Mineral		223				223		
Services		901			40	184	445	232
Firm size (N)		2,812			101	871	1,203	637
Micro		164				2	148	14
Small		1,366			46	450	544	326
Medium		890			37	286	374	193
Large		392			18	133	137	104

Sources: Hale et al. (2021), World Bank Enterprise Survey, and Google Earth.

Figure 8.6: Decrease in Sales, Demand, Working Hours, and Export Share (Wave 1 and Wave 2)



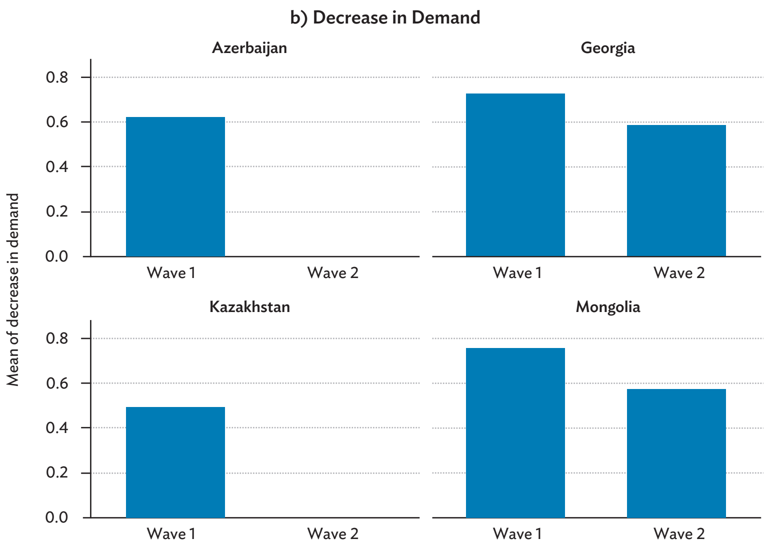


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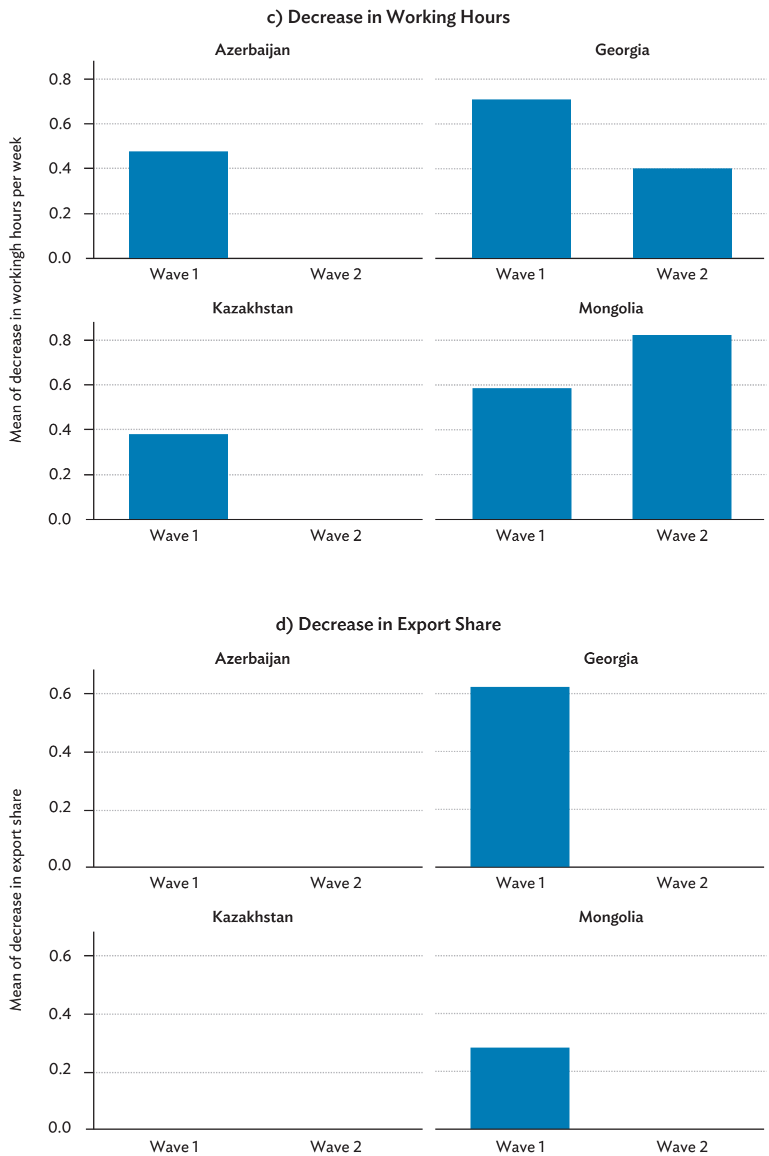
Figure 8.6 *continued*



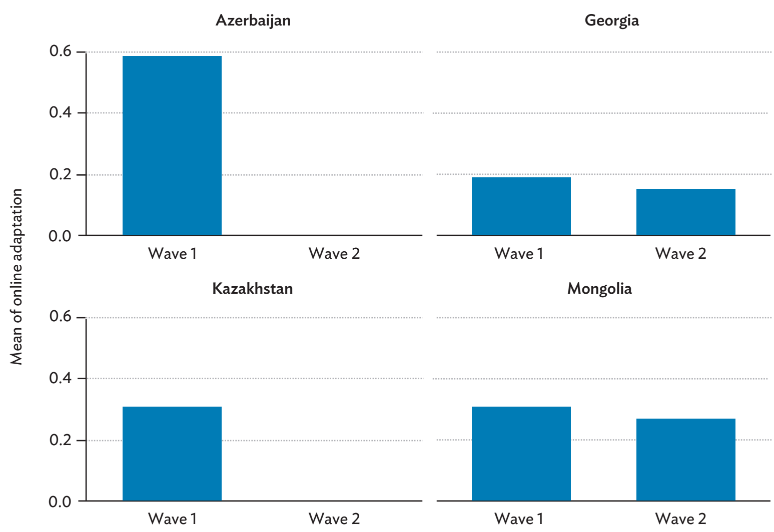
Note: There is no sample for wave 2 from Azerbaijan and Kazakhstan. The decrease in export share is only available from Georgia and Mongolia for wave 1.

Source: Authors' elaboration using data from the World Bank Enterprise Survey.

The differences in the averages between waves indicate that the pandemic-related restrictions, the number of competitors, and the number of firms that started or increased their online activity declined slightly during the second wave compared with the first wave in Georgia and Mongolia (Figure 8.7). A relatively large proportion of firms in Azerbaijan had key performance indicators and moved their activities online (nearly 60% of firms). However, it should be noted here that the number of firms observed is much smaller than that in other countries.

The average share of foreign ownership is generally low in Azerbaijan, Georgia, Kazakhstan, and Mongolia (Figure 8.8). The average share of foreign ownership is below 10% in all four countries. As regards the participation of foreign capital in ownership and the level of competition, Georgian firms are in the lead (Figure 8.8). A slight reduction in the average share of foreign ownership in wave 2 compared with wave 1 in Georgia and Mongolia is also observable.

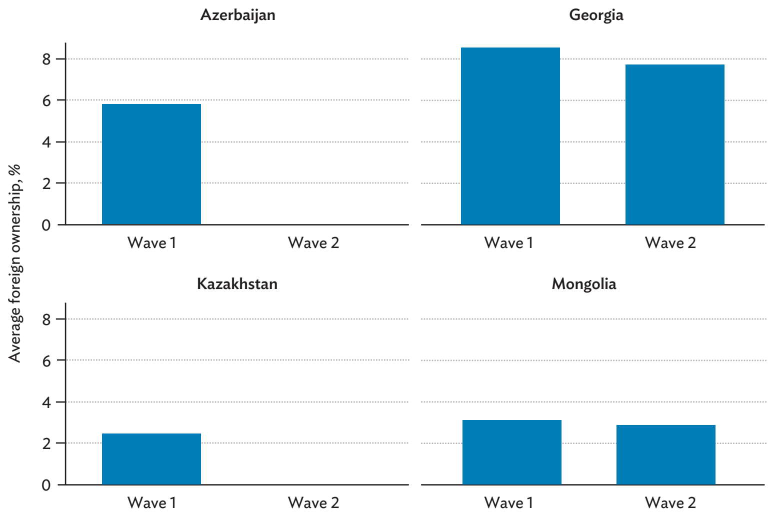
Figure 8.7: Average Online Business Activity (Wave 1 and Wave 2)



Note: There is no sample for wave 2 from Azerbaijan and Kazakhstan.

Source: Authors' elaboration using data from the World Bank Enterprise Survey.

Figure 8.8: Average Foreign Ownership (Wave 1 and Wave 2)

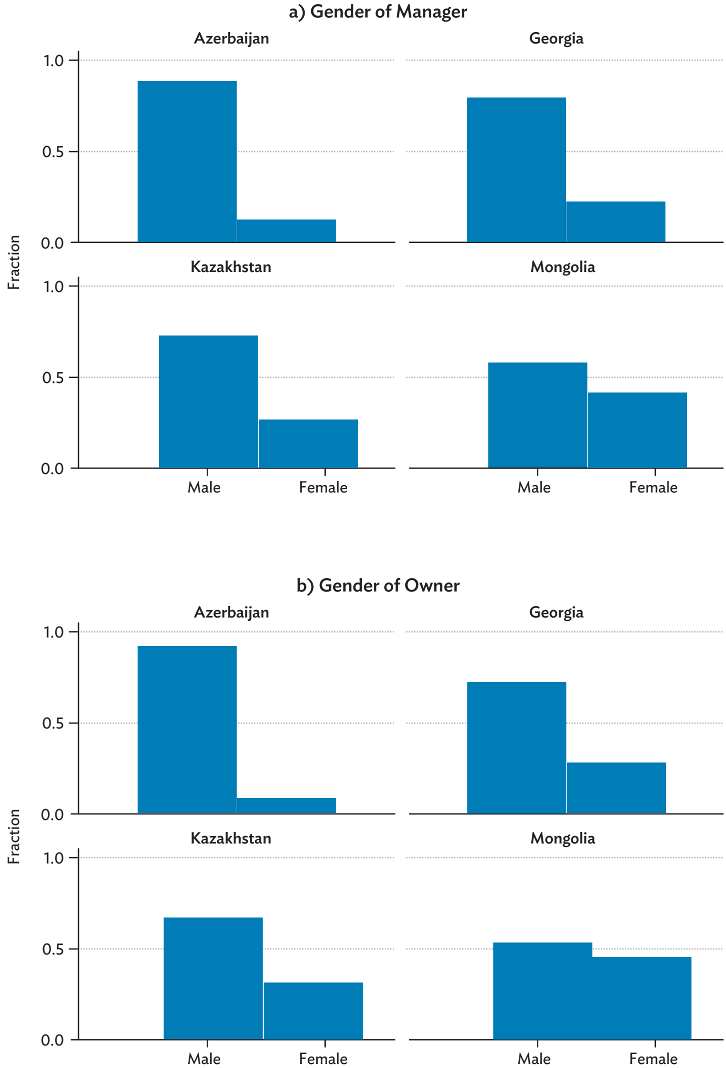


Note: There is no sample for wave 2 from Azerbaijan and Kazakhstan.

Source: Authors' elaboration using data from the World Bank Enterprise Survey.

On average, most firm owners and managers in Azerbaijan, Georgia, Kazakhstan, and Mongolia are male (Table 8.2 and Figure 8.9). The gender gap of firm owners and managers is notably large in Azerbaijan, Georgia, and Kazakhstan (in descending order). Table 8.2 and Figure 8.9 present noteworthy patterns of women's ownership and management among Mongolian firms. Women's participation in ownership and female top managers can be observed in 46% and 42% of Mongolian firms, respectively. The smallest gender gap of firm owners and managers among the four countries is in Mongolia.

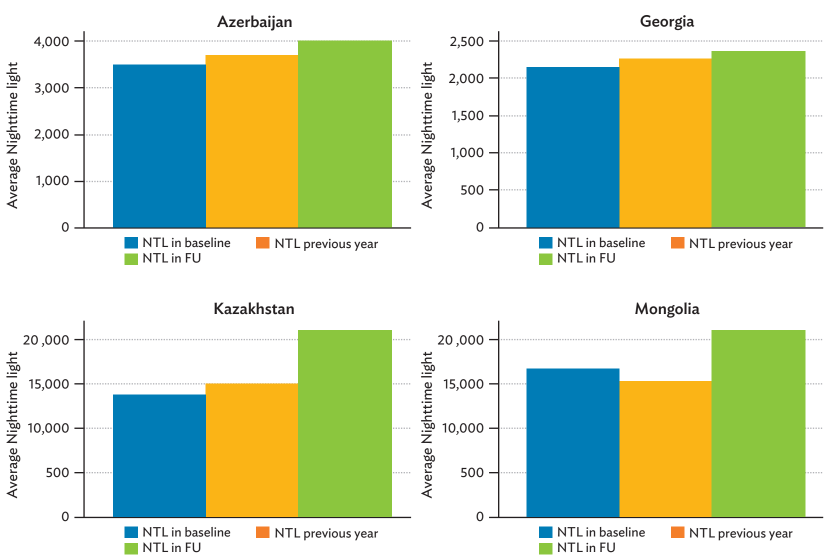
Figure 8.9: Gender of Firm Managers and Owners



Source: Authors' elaboration using data from the World Bank Enterprise Survey.

Night-time light data can be used as a proxy for a number of variables, including infrastructure, urbanization, density, and economic growth (Mellander et al. 2015; Kabanda 2022). We use the data from Google Earth on night-time light intensity.[2] Night-time light data are collected on a regional basis for each country and matched with the business survey dataset based on regions. Figure 8.10 shows the average night-time light for CAREC countries during the three survey periods. First, it refers to the average month in which the baseline interview was conducted. Second, the previous-year night-time light corresponds to the same month of the previous year in relation to the month of the subsequent survey. The third average refers to the month of the follow-up examination. Night-time light increased on average at a greater rate in Kazakhstan and Mongolia than in Azerbaijan and Georgia (Figure 8.10). It is interesting that night-time light increased during the

Figure 8.10: Average Night-Time Light



FU = follow-up survey, NTL = night-time light.

Source: Authors' elaboration using data from Google Earth.

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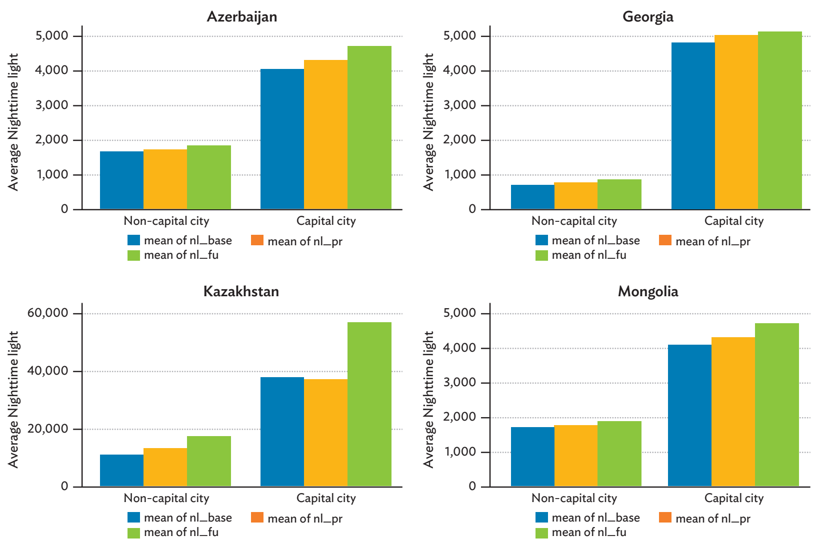
2 VIIRS Stray Light Corrected Nighttime Day/Night Band Composites Version 1, which consists of monthly average radiance composite images using night-time data from the Visible Infrared Imaging Radiometer Suite (VIIRS) Day/Night Band (DNB). https://developers.google.com/earth-engine/datasets/catalog/NOAA_VIIRS_DNB_MONTHLY_V1_VCMSLCFG (accessed 15 March 2022).

COVID-19 pandemic in Azerbaijan, Georgia, Kazakhstan, and Mongolia because it is believed that, during COVID-19, night-time light generally decreased due to lockdowns or did not increase (Beyer, Franco-Bedoya, and Galdo 2021; Xu et al. 2021). Since human activities and economic growth decreased during the COVID-19 pandemic due to lockdowns, the increases in night-time light in Azerbaijan, Georgia, Kazakhstan, and Mongolia could be explained by improvements in access to infrastructure and urbanization. Night-time light varies substantially between capital cities and other regions. The growth of night-time light is particularly noticeable in the capital city of Kazakhstan, Nur-Sultan (Figure 8.11). This could be due to urbanization and infrastructure construction.

Figure 8.11: Average Night-Time Light in Capital Cities and Other Regions



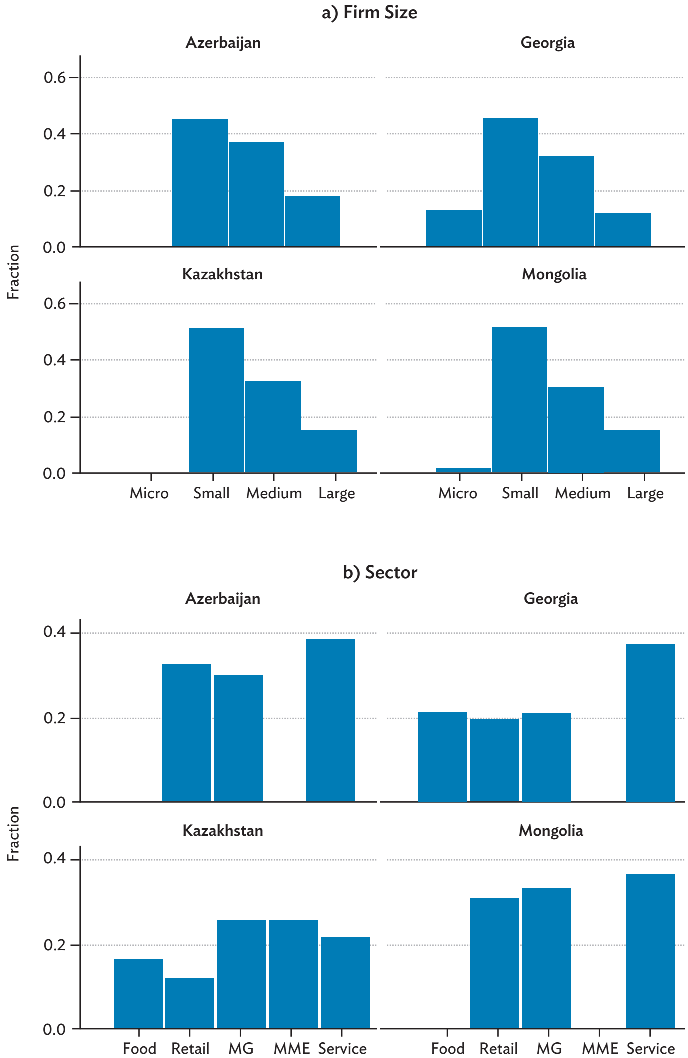
FU = follow-up survey, NL = night-time light.

Note: Radiance (nW).

Source: Authors' elaboration using data from Google Earth.

The sample includes mainly (around 80%) small and medium-sized enterprises in all four countries (Figure 8.12a). The remaining 20% consists of micro and large enterprises. The sample contains enterprises across five sectors: food; retail manufacturing and garments (MG); metal, machinery, and equipment (MME); and services. The share of firms across sectors varies across countries (Figure 8.12b).

Figure 8.12: Firm Sizes and Sectors

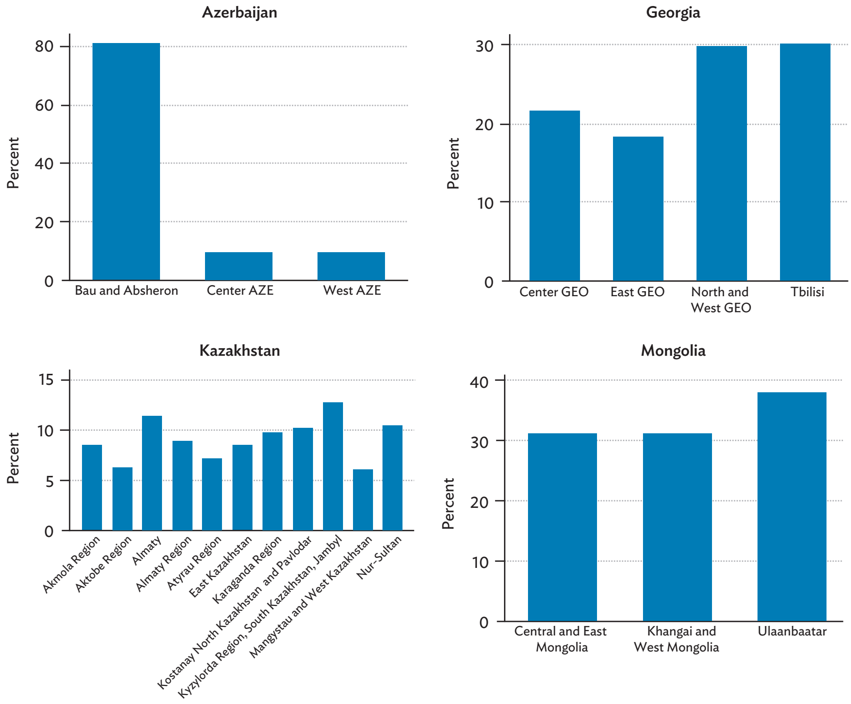


Note: Sectors are food; retail; manufacturing and garments (MG); metal, machinery, and equipment (MME); and services.

Source: Authors' elaboration using data from the World Bank (2022).

The distribution of firms across regions and/or provinces ("oblasts") is provided in Figure 8.13. Most of the firms in the sample from Azerbaijan (80%) are from Baku (the capital city) and Absheron. In the other three countries, the sample firms are more equally distributed across regions.

Figure 8.13: Distribution of the Sample across Regions



AZE = Azerbaijan, GEO = Georgia.

Notes: The capital cities are Nur-Sultan in Kazakhstan, Tbilisi in Georgia, Ulaanbaatar in Mongolia, and Baku in Azerbaijan.

Source: Authors' elaboration using data from the World Bank Enterprise Surveys.

8.4 Methodology

This study investigates the impact of COVID-19 on firm performance and night-time light in CAREC countries. The dependent variables used in our empirical models are measures of firm performance. These are dummy variables that take the value of 1 if a considered performance indicator has deteriorated and 0 if it has not. In such cases, a binary response probit regression model has generally been suggested as the appropriate specification (Horowitz and Savin 2001). Hence, this study employs the following probit regression model:

$$P\,(y_i = 1 \mid x_i) = F(\beta_0 + \beta_k\, x_k) \qquad (1)$$

where y_i is a dummy dependent variable indicating whether the firm performance measure has decreased. This specification considers the impact of the explanatory variables on the likelihood of a decrease rather than an increase in firm performance since firms' performance is likely to have declined due to the deteriorating business environment during the pandemic. In this context, the sales, demand, working hours, and share of exports in sales are defined as measures of firm performance. Hence, decreases in the sales, demand, working hours, and share of exports in sales in the last complete month compared with the relative month in 2019 are considered as outcome variables in our model specifications.

x_k is a vector of firm-specific and exogenous factors that influence firm performance. F(.) is the cumulative density function of the error term, which is standard normally distributed and evaluated at given values of the independent variables (Long and Freese 2014). The covariates controlled in the models are firm characteristic and environmental variables.

In this study, it is assumed that firm characteristics, such as ownership and management, size, industry, performance targets, and the ability of a firm to transform its operations online during the pandemic, have affected firms' performance. To control for the diversity of impacts of the participation of women in management and ownership, we include dummies indicating whether the top manager is female and whether there is a woman among the owners. A variable measuring foreign capital participation as a percentage is also included to control for differences in the impacts of domestic and foreign capital on firm performance. Other firm-specific dummies are the size of the firm and its ability to move its business online. We control for firm size as the COVID-19 crisis may affect larger firms differently from smaller firms. Moving their business operations online could allow firms to be less affected by COVID-19-related restrictions and to maintain or even increase their performance. The use of key performance indicators (KPIs) is to help managers obtain information about whether the organization is performing properly and then take appropriate actions to achieve better performance indicators (Nastasiea and Mironeasa 2016; Pîrlog and Balint 2016). Differences between firms in terms of the availability of KPIs are controlled by a dummy variable that is 1 if a firm has a formally documented business strategy with clear KPIs and 0 otherwise.

The competition in the main market, industry, and the strictness index reflecting the impact of pandemic-related restrictions are also included in the models as factors that are likely to influence the environment in which a firm operates. During the COVID-19 recession, some industries were hit harder than those dependent on the movement of information. Those industries that depend on face-to-face communication and cannot interact remotely suffered dramatically. To control for this, we include industry dummies in our models. We use the number of competitors that a firm faced in the main market in which it sells its main product to account for competition. A more convenient and briefer description of the variables is presented in Table 8.3.

The economic environment of firms has been significantly affected by the various types of restrictions introduced during the pandemic. Accounting for this impact in our models is important as economic circumstances and shocks are correlated with firm performance. In this context, the average stringency index value is used as a proxy for the impact of the COVID-19 outbreak on firms' operations. It is calculated based on the Oxford COVID-19 Government Response Tracker (OxCGRT) scores from 1 January 2020 to the date of the follow-up survey.

The methodology for calculating the index indicating the severity of restrictions on the mobility and activity of people and firms was described by Hale et al. (2021). The calculation of the index is based on recommendations and requirements for the closure of public institutions and transport; bans on travel and leaving the house; meetings and mass events; and the availability of information (Hale et al. 2021). The index takes a value from 0 to 100. An index value close to 0 indicates the softness of the restrictions applied, while an index value equal to 100 means the maximum possible rigidity of the restrictions.

Our model specifications suggest that changes in night-time light intensity, i.e., economic activity, along with other variables, can explain the likelihood of reduced performance due to the COVID-19 pandemic. In our models, night-time light intensity is used as a proxy for the economic activity of firms in some CAREC countries. This study applies one of the most commonly used sources of night-time light data, the Suomi National Polar-Orbiting Partnership-Visible Infrared Imaging Radiometer Suite (NPP-VIIRS). The data are also publicly available on the website of the National Oceanic and Atmospheric Administration's National Centers for Environmental Information (NOAA/NCEI). Night-time light data are used at the regional level since this is the lowest geographic level for which business survey data are available. VIIRS Stray Light Corrected Night-Time Day/Night Band Composites Version 1 is obtained through Google Earth Engine cloud computing

Table 8.3: Description of the Variables

Variables	Source	Description
Dependent Variables		
Sales (1=decrease)	FU	1 – if the firm's sales for the last completed month decreased from the same month in 2019
Demand (1=decrease)	FU	1 – if the demand for products and services of the firm for the last completed month decreased from the same month in 2019
Worked hours (1=decrease)	FU	1 – if the total number of hours worked by the firm per week for the last completed month reduced from the same month in 2019
Export share (1=decrease)	FU	1 – if the percentage of direct and indirect exports for the last completed month decreased from the same month in 2019
Explanatory variables		
Night-time light (1=increase)	NOAA/ NCEI	1 – if the difference between monthly VIIRS stray light on the date of the baseline survey and the date of the follow-up survey is positive
Stringency index	OxCGRT	Stringency index (Hale et al. 2021) calculated for the period from 1 January 2020 to the interview date of the follow-up survey
Online business activity	FU	1 – if the firm has started or increased online business activity during the pandemic
Firm size	BS	1 – micro; 2 – small; 3 – medium; 4 – large
Industry	BS	1 – food; 2 – retail; 3 – manufacturing, garments; 4 – metal, machinery, and equip. mineral; 5 – services
Competition	BS	Number of competitors faced in the main market in which the firm sells its main product
KPI	BS	1 – if the firm has a formalized, written business strategy with clear key performance indicators
Gender of manager	BS	1 – if the manager is female; 0 – if the manager is male
Female ownership	BS	1 – if there are any women among the owners of the firm
Foreign ownership	BS	Percentage of the firm owned by private foreign individuals, companies, or organizations (in %)

BS = baseline survey, FU = follow-up survey, OxCGRT = Oxford COVID-19 Government Response Tracker, NOAA/NCEI = National Oceanic and Atmospheric Administration's National Centers for Environmental Information, KPI = key performance indicator, VIIRS = Visible Infrared Imaging Radiometer Suite.

Notes: BS, FU, OxCGRT, NOAA/NCEI, and KPI indicate the baseline survey; the follow-up survey; the Oxford COVID-19 Government Response Tracker; the National Oceanic and Atmospheric Administration's National Centers for Environmental Information; and Key Performance Indicators, respectively.

Sources: World Bank Enterprise Surveys. http://www.enterprisesurveys.org (accessed 10 October 2021); Hale et al. (2021); and the National Oceanic and Atmospheric Administration's National Centers for Environmental Information. http://www.nsof.class.noaa.gov (accessed 15 March 2022).

technology to estimate the regional economic activity (development). The spatial granularity of night-time light data has been found to be very useful for regional studies.

In this regard, it is necessary to measure changes in the intensity of night-time light during the pandemic compared with the pre-pandemic period. To measure change in the night-time light intensity, we take the difference between the average night-time light on the date of the follow-up survey and that in the same month in 2019 for Georgia and Mongolia. For Azerbaijan and Kazakhstan, we take the difference between the dates of the follow-up survey and the baseline survey since the months of the previous period do not refer to the pre-pandemic period.

The difference values range from negative to positive. However, there are surprisingly few observations with a negative value. This study uses positive night-time light changes instead of negative ones as this approach provides greater variability among observations in these circumstances. Thus, we use a dummy variable that takes the value 1 if the intensity of night-time light was stronger than in the pre-pandemic period.

Our empirical strategy follows the previous literature to explain economic performance with night-time light data. However, it may be argued about the potential reverse causality from economic performance to night-time light. Thus, higher economic performance may lead to greater night-time light intensity. The solution to this issue requires the use of exogenous variables, which is non-trivial issue given the limited scope of the data at the firm level (Freedman and Sekhon 2010; Baum et al. 2012). Although this causality is potential and our empirical model may result in biased estimation results, the empirical literature has concluded that night-time light intensity successfully explains the level of economic activities both at the macroeconomic and at the firm level (Chen and Nordhaus 2011; Henderson, Storeygard, and Weil 2012; Tanaka and Keola 2017). In addition, as described in our analysis, both firm performance and night-time light take into account lagged values as they are measured in relative terms compared with the previous year or the pre-COVID-19 period. This may help to reduce the potential reverse causality.

8.5 Results

Two waves of survey data are only available for Georgia and Mongolia, and basic firm characteristics are available in the baseline survey only. Therefore, assuming that firms do not show much variability in their characteristics over the 2-year period of the follow-up survey, a cross-sectional approach is used. The marginal effects are reported in Table 8.4, and the coefficient estimates are presented in Appendix Table A8.1. The estimation results are for the outcome variables: dummy variables indicating whether the sales, demand, share of exports, and hours worked per week have declined.

The estimated coefficients for night-time light show a positive impact on the likelihood that firms' performance in sales and demand will improve. These results indicate that, as the night-time light increases, the likelihood of deterioration in the performance of sales and demand is reduced. Thus, our results are consistent with the existing literature showing that night-time light can be used as a proxy for a number of variables, including infrastructure, urbanization, density, and economic growth (Mellander et al. 2015; Li et al. 2017; Kabanda 2022). However, the impact of night-time light on the export share and working hours is not significant.

According to the results, the stringency index has a positive impact on the likelihood that firms' performance in sales, demand, and working hours will improve. This finding may suggest that firms gradually adapted to the new realities and reported less evidence of decreasing firm performance due to the strictness of lockdown-style policies (Aseinov et al. 2022) or due to the inappropriateness or effectiveness of a government response to the COVID-19 pandemic, i.e., of the strictness of "lockdown-style" policies.

Table 8.4: Estimation Results (Marginal Effects)

Variable	Decrease in Sales	Decrease in Demand	Decrease in Export Share	Decrease in Hours Worked per Week
Night-time light (1=increase)	−0.0907***	−0.0687**	−0.0437	−0.0107
	(0.0314)	(0.0336)	(0.0966)	(0.0332)
Stringency index	−0.0298*	−0.108***	−0.0158	−0.0762***
	(0.0173)	(0.0180)	(0.222)	(0.0182)
Online business activity	0.0184	0.0201	−0.0634	0.0145
	(0.0224)	(0.0239)	(0.0712)	(0.0243)
Gender of manager	0.0452	0.0874***	0.100	−0.000995
	(0.0285)	(0.0301)	(0.0803)	(0.0302)
Female ownership	0.0508*	0.00901	0.0930	0.0654**
	(0.0262)	(0.0280)	(0.0747)	(0.0281)
Foreign ownership	0.00066	0.0012**	0.00149	0.00046
	(0.000474)	(0.00052)	(0.0012)	(0.00051)
Competition	−2.12e-05	4.18e-06	−0.00018**	−2.74e-05
	(1.72e-05)	(1.95e-05)	(7.42e-05)	(1.95e-05)

continued on next page

Table 8.4 *continued*

Variable	Decrease in Sales	Decrease in Demand	Decrease in Export Share	Decrease in Hours Worked per Week
KPI	−0.0191	−0.0381*	0.0196	−0.00490
	(0.0209)	(0.0223)	(0.0704)	(0.0229)
Firm size (reference category: Micro)				
Small	−0.0473	−0.0383		−0.195**
	(0.0727)	(0.0807)		(0.0783)
Medium	−0.0733	−0.0611		−0.195**
	(0.0737)	(0.0818)		(0.0793)
Large	−0.129*	−0.165*		−0.273***
	(0.0771)	(0.0850)		(0.0823)
Industry (reference category: Food)				
Retail	0.0083	−0.0443	−0.327***	−0.0077
	(0.0354)	(0.0376)	(0.109)	(0.0376)
Manufacturing, Garments	0.0639**	0.0367	0.0695	0.0499
	(0.0326)	(0.0351)	(0.113)	(0.0356)
Metal, Machinery and Equipment, Mineral	0.0408	0.0212		0.0528
	(0.0430)	(0.0476)		(0.0487)
Services	0.0686**	0.0868**	0.0702	0.0829**
	(0.0315)	(0.0337)	(0.102)	(0.0343)
Country dummy	+	+	+	+
Observations	2,144	2,174	207	2,176

KPI = key performance indicator.

Notes: Standard errors are in parentheses. ***, **, and * represent statistical significance of 1%, 5%, and 10%, respectively. KPI stands for key performance indicators.

Source: Authors' elaboration using data from the World Bank Enterprise Surveys. http://www.enterprisesurveys.org (accessed 10 October 2021); Hale et al. (2021); and the National Oceanic and Atmospheric Administration's National Centers for Environmental Information. http://www.nsof.class.noaa.gov (accessed 15 March 2022).

Most female-led and/or foreign-owned firms experienced a decline in the demand for their products and services compared with male-led and/or domestic-owned firms. In addition, firms with female owners were more likely to experience declines in sales, although this effect is valid at a lower level of statistical significance. This particular finding that firms with female managers suffered most from a decrease in demand, might be related to the fact that the firms managed by women are in retail sales and services. These sectors suffered the most during the initial months of the COVID-19 pandemic with lockdown restrictions on mobility.

The presence of officially defined KPIs and more competitors is likely to have helped firms to maintain their performance, especially their demand and export share, during the pandemic. These results are consistent with the general expectation that effective coordination between the management and the production of a firm contributes to its performance.

As for the firm size covariates, they indicate that larger firms are more likely to maintain their performance than smaller firms. This result highlights that small and medium-sized firms are in a disadvantageous position when facing the challenges caused by COVID-19.

The marginal effects for industry dummies reveal interesting results. The sales volume of firms in the manufacturing, clothing, and service sectors were more likely to decline than that of firms in the food sector. Along with this, the results point to a significant decline in the performance of firms operating in the service sector compared with the food sector during the pandemic.

8.6 Conclusions and Policy Implications

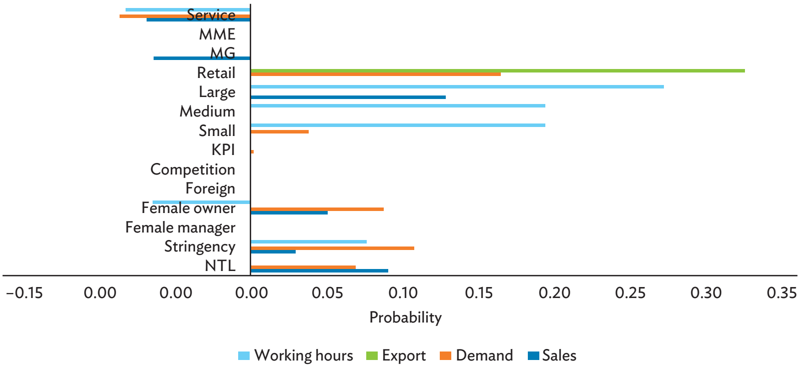
This study examines economic activity measured with firm performance indicators using the changes in intensity of night-time light in four CAREC economies: Azerbaijan, Georgia, Kazakhstan, and Mongolia. The empirical analysis is based on the World Bank Enterprise Survey (data for 2019 and the follow-up survey during the COVID-19 pandemic). The Enterprise Survey dataset is enhanced with data on night-time light intensity from Google Earth and the strictness of "lockdown-style" policies, i.e., the stringency index from Hale et al. (2021). Using the probit regression model, this study investigates the impact of COVID-19 on firm performance and night-time light in CAREC countries. Firm performance is measured using four variables: decreases in sales, demand, export share, and working hours. The study provides important results, which are summarized in Figure 8.14.

First, our results show that, as night-time light increases, firms' sales and demand are more likely to increase. Thus, night-time light can be used as a proxy for a number of variables, including infrastructure, urbanization, density, and economic growth (Mellander et al. 2015; Kabanda 2022). Second, the strictness of "lockdown-style" government policies, i.e., the stringency index, does not harm firm performance on average. Conversely, the stringency index even shows improvements to firm performance (sales, demand, and working hours). There could be several reasons for this result: firms were able to adjust to government measures to respond to COVID-19, less effective lockdown measures were imposed, or firms from areas with a higher stringency index received greater government support. Third, sales in the manufacturing, clothing, and service sectors are more likely to decline than those in the food sector. Along with this, the results point to a significant decline in the performance of firms operating in the service sector compared with the food sector during the pandemic. Finally, large firms are more likely to have a better performance than micro, small, and medium-sized enterprises (MSMEs).

However, three main limitations of this study can be mentioned. First, although night-time light data can provide detailed information on light intensity at higher frequency, the KPIs from the business survey data used in the study refer to a comparison with the previous year. This limits the use of fine-grained data at a higher frequency resolution to track firm performance. Second, the main characteristics of firms in the business survey data are from the baseline survey carried out before the COVID-19 pandemic. Although the basic characteristics of firms do not change very frequently, it would be interesting to take into account potential changes in those characteristics during the COVID-19 pandemic too. Third, limited data on firms and their history restrict the identification of a valid exogenous variable that would be useful for providing robust estimation results due to the potential reverse causality issue.

Despite its potential limitations, the findings of the study have several policy implications. First, the study highlights that night-time light intensity data are useful for understanding economic dynamics not only at the country level but also by regions within a country. This is particularly important in developing countries with less reliable statistics on economic performance. Second, the findings indicate that the severity of the challenges faced by firms differs by sectors of the economy. Thus, the manufacturing, clothing, and service sectors are in greater need of support than other sectors. Third, the results point out potential unequal recovery among firms during the post-COVID-19 period. MSMEs are in greater need of support than large firms. Therefore, special focus on micro and small firms for loans and other types of government support mechanism would increase the social and economic effects of the post-COVID-19 recovery policy.

Figure 8.14: Summary of the Results



KPI = key performance indicator, MG = manufacturing and garments, MME = metal, machinery, and equipment, NTL = night-time light.

Source: Authors' elaboration using data from the World Bank Enterprise Surveys. http://www.enterprisesurveys.org (accessed 10 October 2021); Hale et al. (2021); and the National Oceanic and Atmospheric Administration's National Centers for Environmental Information. http://www.nsof.class.noaa.gov (accessed 15 March 2022).

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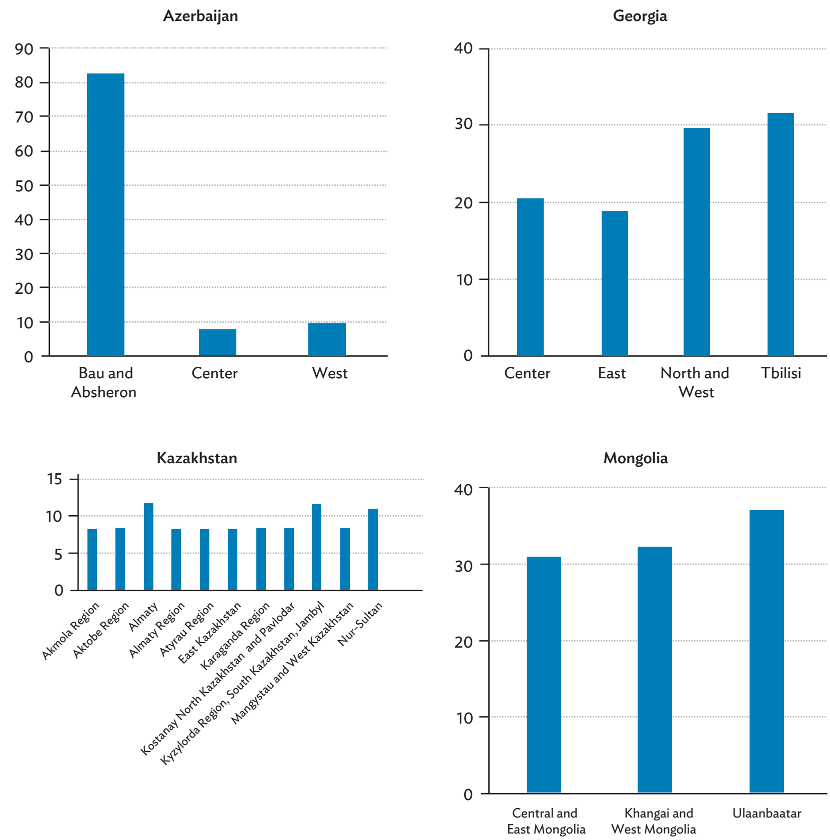
Appendix

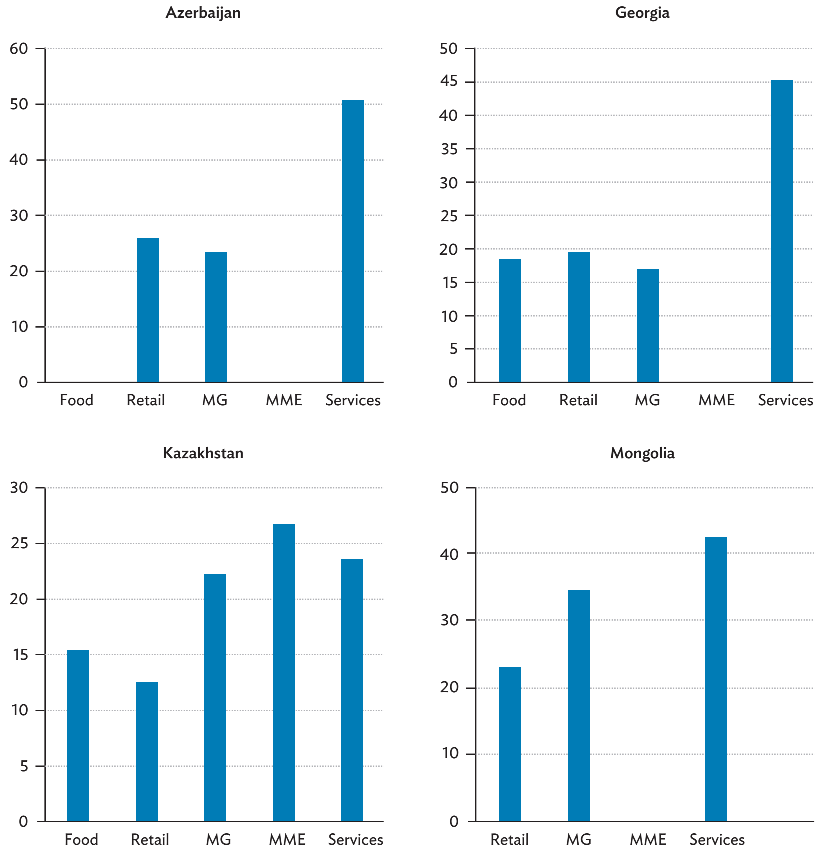
Figure A8.1: Distribution of the World Bank Full Sample across Sectors* (%)



* Statistics on the number of firms surveyed by company size, ownership characteristic, and line of business are provided by the World Bank. Download file (Excel, 342KB) (https://www.enterprisesurveys.org/en/survey-datasets).

Source: Authors, using data from the World Bank (2022) Business Enterprise Survey.

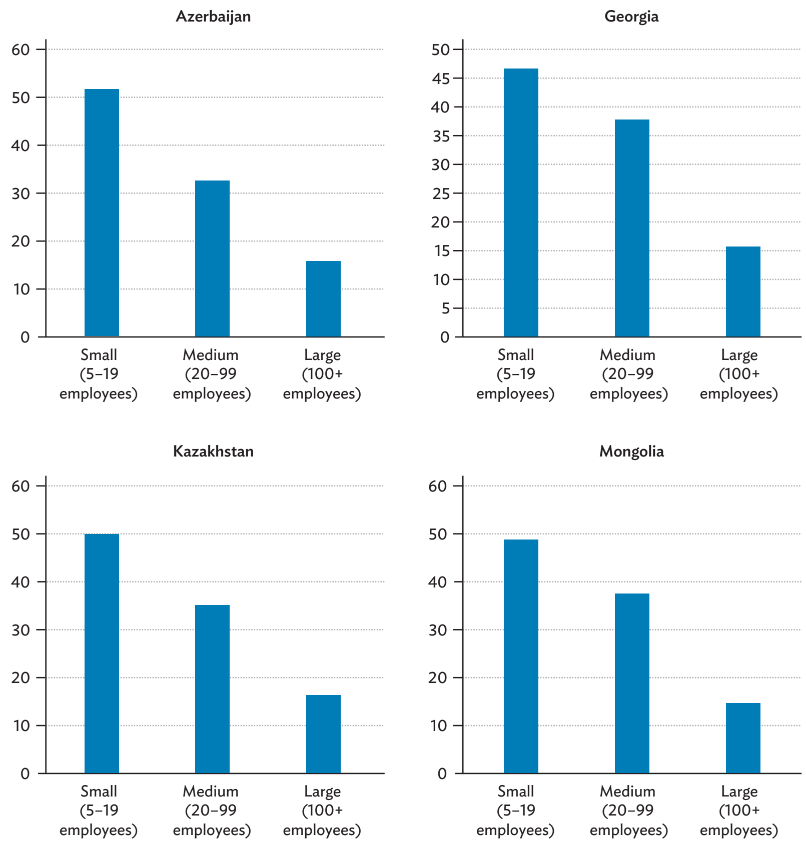
Figure A8.2: Distribution of the World Bank Enterprise Survey Sample across Sectors (%)



MG = manufacturing and garments, MME = metal, machinery, and equipment.

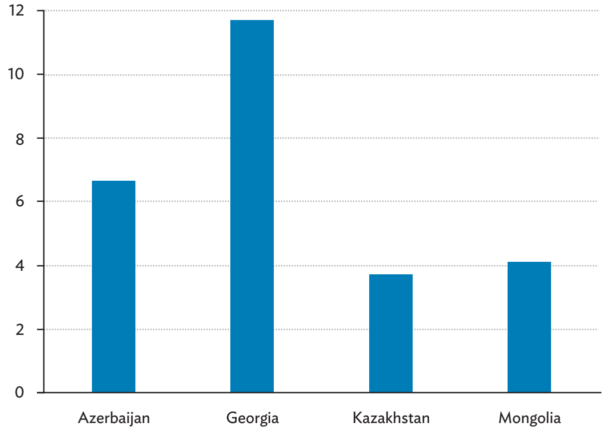
Source: Authors, using data from the World Bank (2022) Business Enterprise Survey.

Figure A8.3: Distribution of the World Bank Enterprise Survey Sample across Firm Sizes (%)



Source: Authors, using data from the World Bank Enterprise Survey.

Figure A8.4: Share of Firms with Foreign Ownership (%)



Note: Firms are considered as foreign owned when 10% or more of the firm is owned by foreign private individuals, companies, or organizations.

Source: Authors, using data from the World Bank Enterprise Survey.

Table A8.1: Estimation Results of Probit Models on the Probability of a Decrease in Firms' Performance during the COVID-19 Pandemic (Coefficients)

	Decrease in Sales	Decrease in Demand	Decrease in Export Share	Decrease in Hours Worked per Week
Night-time light (1=increase)	−0.283***	−0.189**	−0.147	−0.0287
	(0.0984)	(0.0928)	(0.326)	(0.0888)
Stringency index	−0.0931*	−0.299***	−0.0532	−0.204***
	(0.0541)	(0.0506)	(0.748)	(0.0494)
Online business activity	0.0574	0.0554	−0.213	0.0389
	(0.0697)	(0.0658)	(0.241)	(0.0650)
Gender of manager	0.141	0.241***	0.337	−0.00267
	(0.0890)	(0.0834)	(0.273)	(0.0809)
Female ownership	0.158*	0.0248	0.313	0.175**
	(0.0820)	(0.0771)	(0.255)	(0.0756)
Foreign ownership	0.00204	0.00335**	0.00503	0.00122
	(0.00148)	(0.00143)	(0.00408)	(0.00136)
Competition	−6.61e-05	1.15e-05	−0.000610**	−7.34e-05
	(5.36e-05)	(5.38e-05)	(0.000259)	(5.22e-05)
KPI	−0.0594	−0.105*	0.0660	−0.0131
	(0.0652)	(0.0617)	(0.237)	(0.0613)
Firm size (reference category: Micro)				
Small	−0.160	−0.109	−0.466	−0.551**
	(0.258)	(0.233)	(0.336)	(0.244)
Medium	−0.241	−0.172	−0.713**	−0.550**
	(0.260)	(0.236)	(0.334)	(0.247)
Large	−0.406	−0.450*		−0.758***
	(0.268)	(0.244)		(0.254)

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Table A8.1 *continued*

	Decrease in Sales	Decrease in Demand	Decrease in Export Share	Decrease in Hours Worked per Week
Industry (reference category: Food)				
Retail	0.0245	–0.118	–1.200***	–0.0206
	(0.104)	(0.101)	(0.404)	(0.101)
Manufacturing, Garments	0.196**	0.0996	0.212	0.133
	(0.0986)	(0.0951)	(0.350)	(0.0950)
Metal, Machinery, and Equipment, Mineral	0.123	0.0575		0.141
	(0.131)	(0.129)		(0.130)
Services	0.211**	0.240***	0.214	0.222**
	(0.0950)	(0.0923)	(0.316)	(0.0916)
Country dummy	+	+	+	+
Constant	7.498**	20.67***	4.069	14.18***
	(3.653)	(3.419)	(41.42)	(3.336)
Observations	2,144	2,174	207	2,176
Pseudo R-squared	0.0649	0.0563	0.244	0.0594
LR	168.4	164.8	69.67	179.2
P-value	0	0	2.21e-09	0
LogLik	–1,213	–1,381	–107.8	–1,418

KPI = key performance indicator, LR = likelihood ratio.

Notes: Standard errors are in parentheses. ***, **, and * represent statistical significance of 1%, 5%, and 10%, respectively.

Source: Authors' elaboration using data from the World Bank Enterprise Surveys. http://www.enterprisesurveys.org (accessed 10 October 2021); Hale et al. (2021); and the National Oceanic and Atmospheric Administration's National Centers for Environmental Information. http://www.nsof.class.noaa.gov (accessed 15 March 2022).

Infrastructure Spillover Impacts in Developing Asia

Quality infrastructure can give economies in developing Asia a critical boost by enhancing growth and reducing poverty, especially during times of economic crisis. However, the increasing demand for public funds for health, education, and social welfare programs diminishes their availability for infrastructure. Policy makers must therefore consider novel financing solutions to attract private investment essential for meeting the region's expanding infrastructure needs.

Harnessing the positive spillover effects of successful infrastructure projects on economies is an approach that can do just that. Its potential to support financing breakthroughs depends on factors, such as the quality of construction, operations, and maintenance of physical and digital infrastructure, interconnectivity, population density, income levels, and financing access.

Infrastructure Spillover Impacts in Developing Asia explores the role of information and communication technology, transport, and water infrastructure development in driving trade, business performance, and tax revenues in the region. The book describes how these dynamics can promote private sector investment in infrastructure projects by creating a steady stream of income for prospective investors, offering valuable insights for policy makers, investors, and practitioners.

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