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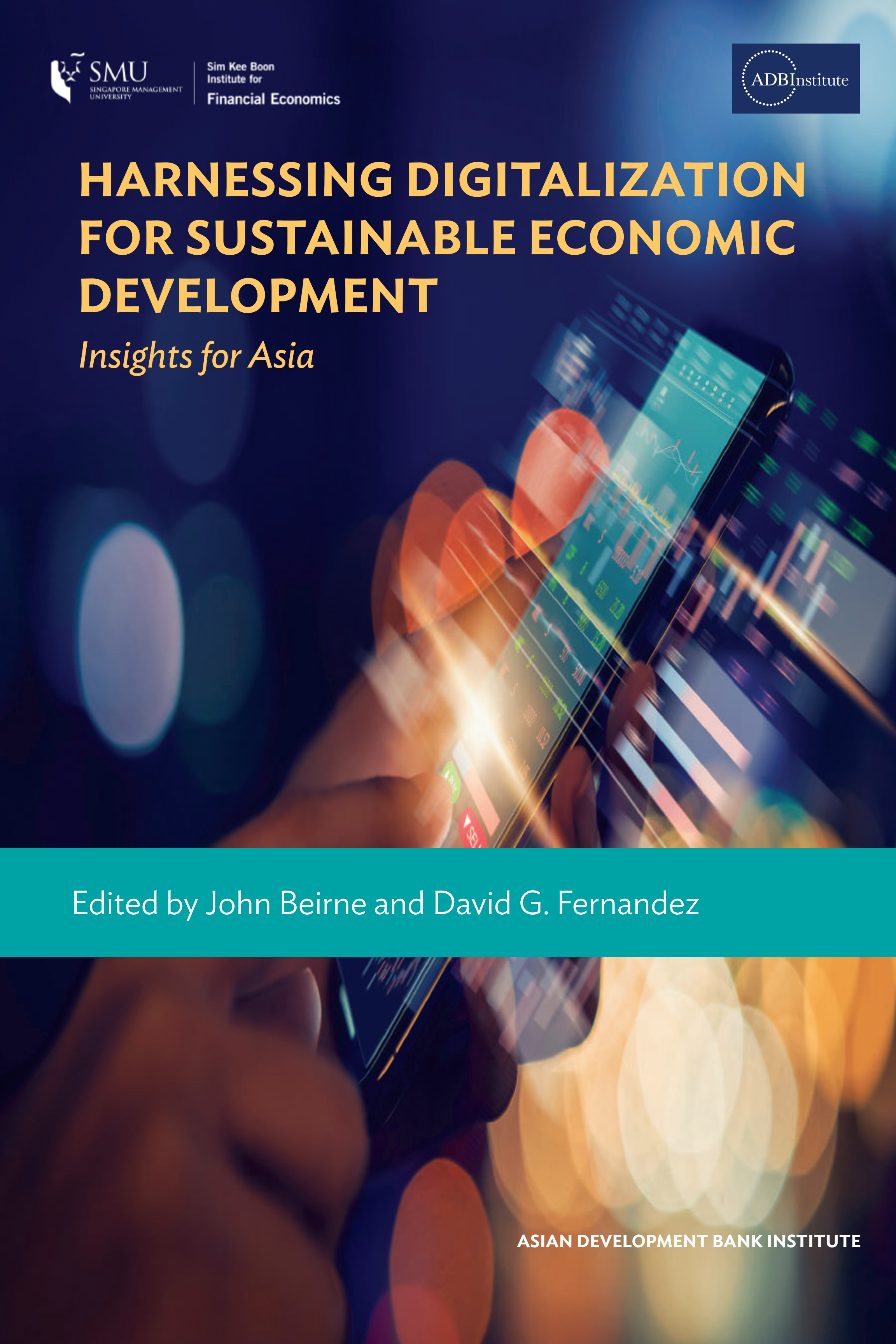
Chapter 8: Information Technology and the New Capitalism

James Bessen



SMU SINGAPORE MANAGEMENT UNIVERSITY
Sim Kee Boon Institute for Financial Economics
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HARNESSING DIGITALIZATION FOR SUSTAINABLE ECONOMIC DEVELOPMENT

Insights for Asia

Edited by John Beirne and David G. Fernandez

ASIAN DEVELOPMENT BANK INSTITUTE

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Harnessing Digitalization for Sustainable Economic Development

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Abbreviations

AAGR	annual average growth rate
ADB	Asian Development Bank
ADF	augmented Dickey-Fuller
AFTA	ASEAN Free Trade Area
AI	artificial intelligence
AIC	Akaike information criterion
AR	Autoregressive
ARDL	autoregressive distributed lag
ASEAN	Association of Southeast Asian Nations
B2B	business to business
B2C	business to consumer
Bps	basis points
BST	base transceiver station
CAGR	compound annual growth rate
CAPI	computer-assisted personal interview
CBDC	central bank digital currency
CEPII	Centre d'Études Prospectives et d'Informations Internationale
CIS	Commonwealth of Independent States
COVID-19	coronavirus disease 2019
CPI	consumer price index
CRSP	Center for Research in Security Prices
DBT	direct benefit transfer
DFI	digital financial inclusion
DFS	digital financial services
EF	economic freedom
EGDC	E-Government and Digital Economy Project Management Center
EGDI	E-Government Development Index
EME	emerging market economy
EX	exports
EYS	expected years of schooling
FD	fiscal deficit
FDI	foreign direct investment
FDII	foreign direct investment inflow
FI	financial inclusion
FOL	fiber-optic line
FTD	fixed telephone density

G2	Group of Two
G2B	government to businesses
G2C	government to citizens
G2G	government to government
GCF	gross capital formation
GDP	gross domestic product
GFCE	general government final consumption expenditure
GMV	gross merchandise value
ICT	information and communication technology
ICTSE	ICT service exports
ID	internet density
IDI	ICT Development Index
IFI	index of financial inclusion
IIP	Index of Industrial Production
ILO	International Labour Organization
IMF	International Monetary Fund
IoT	Internet of Things
ISCO	International Standard Classification of Occupations
IT	information technology
ITU	International Telecommunication Union
IV	instrumental variable
Lao PDR	Lao People's Democratic Republic
LATER	local average treatment effect
LFS	Labour Force Survey
M&A	mergers and acquisitions
MD	mobile density
MENA	Middle East and North Africa
MIDAS	mixed data sampling
MITC	Ministry for Development of Information Technologies and Communications
MNC	multinational corporation
MSEs	micro and small enterprises
NAPM	National Agency for Project Management
NPCI	National Payments Corporation of India
NPL	nonperforming loan
O*NET	Occupational Information Network
OCEN	Open Credit Enablement Network
OECD	Organisation for Economic Co-operation and Development
OEM	original equipment manufacturer
OLS	ordinary least squares
PCDGP	per capita gross domestic product
PEC	per capita electricity power consumption

POS	point of sale
PP	Philips-Perron
PPP	purchasing power parity
PRC	People's Republic of China
R&D	research and development
RBI	Reserve Bank of India
RCEP	Regional Comprehensive Economic Partnership Agreement
RE	revenue expenditure
RIF	recentered influence function
RTA	regional trade agreement
SAARC	South Asian Association for Regional Cooperation
SAFTA	South Asian Free Trade Area
SARS	severe acute respiratory syndrome
SDC	Securities Data Company
SDGs	Sustainable Development Goals
SMEs	small and medium-sized enterprises
STEM	science, technology, engineering, and mathematics
TFP	total factor productivity
TII	Telecommunication Infrastructure Index
UN	United Nations
UPI	Unified Payments Interface
US	United States
USPTO	United States Patent and Trademark Office
VECM	vector error correction model
WDI	World Development Indicators

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Introduction

John Beirne and David G. Fernandez

Digitalization has helped to transform economies by enhancing competitiveness and productivity across a wide range of sectors. The use of big data and the rise of online platforms have accelerated this process over the past decade. In addition, the adoption of digital solutions in the face of social distancing and lockdown measures introduced due to the coronavirus disease 2019 (COVID-19) pandemic has been integral to the economic recovery process. The shift to a digitalized economy has also reduced barriers to market entry for firms, lowered inequality, and led to a promotion of social and economic inclusion. Advances in digital technology have also had substantial positive impacts on the productive capacities of economies, helping to improve economic efficiency and long-run output growth potential. In addition, digitalization has contributed to rises in regional and global economic integration, including via international capital flow and trade dynamics. All of these have been important contributory factors in helping economies make progress toward achieving the United Nations Sustainable Development Goals. That said, while digitalization can have substantial positive effects on overall macroeconomic performance, there can also be labor market implications as automation and artificial intelligence (AI) replace workers. Ensuring a sufficient level of internet infrastructure development and digital education and reducing the digital divide are other factors driving the potential of digitalization as an input to economic progress. Policy makers therefore face challenges in order to harness the maximum benefits of digitalization for the competitiveness of their economies, including through appropriate education and labor market reforms, as well as digital infrastructure investment.

This book provides an overview of the implications of digitalization for sustainable economic development, with a focus on perspectives from Asia and the Pacific. It features new research on the role of digitalization in enhancing sustainable, inclusive, and balanced growth in the region. The objectives of the book are threefold: (i) to provide insights on the impact of digitalization on trade and economic performance, particularly in Asia; (ii) to improve our understanding of the channels through which digitalization affects firms and the labor market; and (iii) to highlight prevailing and future policy challenges posed by digitalization. It brings together a set of 14 papers, many of which were presented at a conference organized by the Asian Development Bank Institute and the Sim Kee Boon Institute for Financial Economics at Singapore Management University.[1]

The book is organized in three parts:

I. Digitalization, Economic Development, and Trade
II. Firms, Technology Spillovers, and the Labor Market
III. Digital Challenges and Opportunities for Macroeconomic Policy Makers

Part I of the book comprises five chapters and focuses on improving our understanding of the empirical relationship between the rising adoption of digitalization and overall macroeconomic development and performance, including through trade channels. Chapter 2 studies the impact of digitalization on economic development in the People's Republic of China (PRC) and India. The chapter finds an important role for telecommunications infrastructure in determining gross domestic product (GDP) per capita in the PRC and India. A panel model from 1990 to 2019 is estimated, also controlling for other factors such as human capital development, foreign direct investment, gross capital formation, electricity infrastructure, and research and development (R&D) expenditure. While the chapter shows that the elasticity of these economic development–enhancing factors has been more pronounced in the case of the PRC compared to India, which can be related to greater allocative efficiency, further investment in both technological infrastructure and labor market training is advocated to help these economies to reap further economic development gains ahead.

Chapter 3 provides empirical evidence to indicate that digital financial inclusion is positively related to stability in the banking sector. Drawing on its findings from a large panel of 574 banks in seven economies in emerging Asia from 2011 to 2018, the chapter highlights a number of important policy implications for sustainable economic development related to further enhancing digital financial education and greater efforts toward tackling cybercrime.

Chapter 4 examines the factors driving financial inclusion from 2004 to 2017 for 22 emerging economies, finding significant long-run relationships between financial inclusion, information and communication technology (ICT) development, economic freedom,

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1 Further details about the conference can be found at https://www.adb.org/news/events/digitalization-and-sustainable-economic-development.

financial development, and economic growth. The chapter discusses the implications of the findings in terms of ICT policies ahead that underpin financial development and, in turn, help to enhance further financial inclusion.

Chapter 5 uses a Bayesian gravity model to provide empirical evidence that digitalization in Asia is positively related to trade integration in the region. Controlling for a large set of macroeconomic fundamentals from 1995 to 2018 across 43 Asian economies, bilateral trade flows between countries are shown to be significantly influenced by factors reflecting digital technology, such as access to broadband internet and internet usage (both fixed and mobile). Advances in digital technology have helped to facilitate increased e-commerce and digital payment transactions, and have been important drivers of bilateral trade in Asia.

Chapter 6 focuses on the role of digital technology and e-commerce in affecting Indonesia's trade with other countries in the Association of Southeast Asian Nations (ASEAN). A panel analysis and gravity model approach, using data from 2010 to 2018, demonstrates a significant and positive impact by digitalization. In the model, digitalization is represented by two measures: a composite index that combines 11 digitalization indicators to reflect ICT capacity and an e-commerce measure based on business-to-business transactions.

Part II of the book comprises five chapters and focuses on the role of automation and the effect of digital technological advancement on firms, including via technology spillovers and labor market effects. Chapter 7 looks at the state of digitalization among the PRC's manufacturing small and medium-sized enterprises (SMEs), examining bottlenecks to further digitalization and potential pathways to greater automation adoption. In order to reduce the reliance on analog-era assets, the chapter advocates lowering transaction costs and streamlining procedures for AI subsidies to SMEs in the country; prioritizing government support toward investment in data-collection equipment, enabling a shift to digitalized production for targeted firms; and strengthening the requisite legal framework for contract enforcement throughout the manufacturing SME supply chain in the PRC.

Chapter 8 argues that proprietary investment in software, mainly by large firms, is transforming the nature of markets and technology diffusion, exacerbating economic inequality and undermining government regulation. The implications and challenges for sustainable economic development are drawn in terms of growing productivity gaps and income inequality caused by these new software technologies, which have been introduced at scale, increasing market power relative to both competitors and government regulators.

Chapter 9 examines the role of technology spillovers and their impact on financial leverage. This is due to the positive effect of technology spillovers on collateralized borrowing and asset transactions, as well as borrowing costs. By increasing asset redeployability in this manner, technology spillovers also help to limit the losses of a firm's creditors in the event of bankruptcy. In addition, an important role is found for R&D tax credits in underpinning technology spillovers.

Chapter 10 focuses on the occupational structure of the economy in Thailand and the role of automation on the labor market, notably in respect of AI and machine learning. The chapter shows that from 1985 to 2018, the latter half reflecting a period of substantial digital transformation of the economy, provincial GDP per capita increased with nonroutine cognitive analytical and interpersonal skills and routine cognitive skills in a monotonic way, while economic development has an inverse relationship with routine manual physical skills. Analytical work in the chapter reveals that the occupational skill content could be a useful predictor for hourly earnings, especially in relation to nonroutine cognitive skills. Moreover, it is demonstrated that the risks of automation are more likely to be harmful to the poor and low-skilled workers in Thailand from job replacement by AI and robots.

Chapter 11 examines the labor market impact of digitalization for women in Indonesia. Using a cross-section of micro survey data in January 2018, the analysis uses an instrumental variables approach to show that internet access increases the number of working hours for married women in Indonesia who are owners or managers of small or medium-sized firms. In addition, the effects of digitalization on female labor market participation are found to be more pronounced for married women in urban relative to rural areas.

Part III of the book comprises four chapters and focuses on highlighting the challenges and opportunities faced by policy makers in harnessing the benefits of digitalization for sustainable economic development. Chapter 12 investigates the factors underpinning recent economic development in ASEAN and the role played by digitalization. The chapter explains that further investment in digital infrastructure and wireless capability, as well as appropriate training and education for workers in a digital world will strengthen the maintenance of sustainable and inclusive development in ASEAN.

Chapter 13 examines new financial technology and sustainable development in the context of the international monetary system. In particular, the chapter highlights the policy challenges ahead for governments, central banks, and regulatory agencies in balancing the benefits of digital technology advancements against the potential costs. For emerging market and developing economies, while faster and cheaper cross-border remittances and financial inclusion will underpin more balanced and sustainable development going forward, caution needs to be exercised with potential threats related to vulnerability to capital flow volatility.

Chapter 14 examines the forecasting power of digital payment systems data in India, which are available at high frequencies, for lower frequency macroeconomic data. Using mixed data sampling (MIDAS) regressions to forecast quarterly consumption using monthly data on the digital payment system and other macroeconomic variables such as personal credit and the Index of Industrial Production, the empirical results show that digital payment systems data have strong predictive power in forecasting private consumption in India. Both in-sample and out-of-sample forecast evaluation assessments indicate that MIDAS provides a superior forecast evaluation over the standard time series models using a single frequency.

Chapter 15 provides an overview of the evolution of e-government in the post-Soviet transition countries, with a focus on Uzbekistan. This chapter highlights the benefits to digital transformation in the public sector, notably related to improving the efficiency of state services and reducing corruption, and overall more transparent and inclusive governance. While there has been progress on e-government in Uzbekistan, the chapter notes that greater efforts are needed to develop further e-government infrastructure and interoperability across government authorities, as well as investment in digital transactional services by government.

Overall, with a focus on Asian perspectives, this book provides important insights for policy makers on the role of digitalization in contributing to sustainable economic development in the region. The onset of the COVID-19 pandemic in 2020 led to an acceleration in the rate of digitalization and diffusion of digital solutions into business models and practices across a range of sectors. This has been instrumental to the recovery not only in Asia but also globally. The empirical evidence contained in the chapters demonstrates the material benefits for economies for improving overall macroeconomic performance through embracing digital technology. Moreover, enhanced economic development via productivity channels due to digitalization has helped to stimulate inflows of foreign investment and higher levels of trade integration across Asia and the Pacific. Digitalization in the region has also helped to enhance the competitiveness of firms, while also highlighting labor market frictions that need to be addressed. Such frictions mainly reflect the need for enhanced digital education, as well as digital financial education and training, to address the labor market challenges for economies in a more digitalized environment.

Looking ahead, to reap further benefits from digitalization, policy makers in Asia and the Pacific should be aware of the need for greater investment in information technology infrastructure to improve levels of internet connectivity in the region and to develop a more inclusive digital infrastructure landscape. Moreover, to achieve a sustainable contribution of digitalization to economic development in the region, greater efforts are needed to mitigate threats posed by cybercrime. Finally, and related to this, it will be important for policy makers to strike the right balance with regard to the regulation and supervision of financial technology to enable innovation but also to safeguard financial stability and consumer protection.

PART I

Digitalization, Economic Development, and Trade

2

Digitalization and the Economic Performance of Two Fast-Growing Asian Economies: India and the People's Republic of China

Dukhabandhu Sahoo, Suryakanta Nayak, and Jayanti Behera

2.1 Introduction

The literature has documented well the role of infrastructure in the growth process of any economy as it helps in diversifying production, expanding trade, coping with the pressure of demographic and environmental challenges, and ultimately improving the quality of human life. "Infrastructure is an umbrella term for many activities referred to as 'social overhead capital' by ... development economists" (World Bank 1994: 2). In addition to its role as an engine of growth, infrastructure also helps to maintain the growth of an economy. However, the macroeconomic policies of an economy determine the course of its infrastructure development and ultimate growth trajectory. Economies like the People's Republic of China (PRC) have been experiencing rapid growth, and India, with its moderate economic growth during the last few decades, needs not only to maintain the policy task at hand but also to work toward accelerating its growth further. The PRC, the most populous country, and India, the second-most populous country, are the two economic giants in Asia that have transitioned from a centrally planned socialistic economy to a market-led open economy. The PRC started economic reforms before India and registered high economic growth. India followed the PRC and opted for economic liberalization as a result of the economic crisis. The economic advancement of both countries will create a new milestone in the 21st century. Although the lack of adequate infrastructure seems to be exerting an adverse effect on the economic growth of India, there is a visible gap between the potential demand for infrastructure and the actual level of infrastructure in the country (Rastogi 2006). Both economies require adequate infrastructure to achieve sustainable economic growth since the lack of adequate infrastructure facilities creates an obstacle to their achievement of higher economic growth.

Against this backdrop, the chapter aims to analyze the role of infrastructure in the economic performance of two fast-growing countries, specifically India and the PRC, and the policy concerns that it engenders using annual data from 1990 onward, which we collected from the World Development Indicators (WDI) (World Bank 2020).

2.2 Review of the Literature

Although the indicators of infrastructure are different, several studies have identified the positive contribution of infrastructure to economic growth across the globe (Munnell 1990; Devarajan, Swaroop, and Zou 1996; Roller and Waverman 2001; Wang 2002; Canning and Pedroni 2004; Zhang and Fan 2004; Chakraborty and Guha 2009; Sahoo and Dash 2009; Sahoo 2012; Sahoo, Dash, and Nataraj 2012; Szymańska and Biegańska 2012; Batuo 2015; Mohanty and Bhanumurthy 2019). These studies have reinforced the importance of infrastructure across different regions over different periods with variations in the magnitude of their impact on various growth dynamics.

Sahoo and Dash (2009) found that infrastructure plays an important role in the economic growth of India. This study found unidirectional causality from infrastructure development and economic growth in India. Similarly, Sahoo, Dash, and Nataraj (2012) explained that the encouraging growth story of the PRC over the last 2 decades owes its origin to the physical and social infrastructure in the country. According to Elhance and Lakshmanan (1988), the infrastructure (both physical and social) investment in India is the main factor in the reduction of production costs in manufacturing. The state-level analysis that Ravallion and Datt (1999) conducted proved that the Indian states that have experienced significant growth have better infrastructure. Sahoo and Saxena (1999) also concluded that electricity, transport, water and gas supply, and communication facilities have significant positive effects on economic growth. According to Ghosh and De (2000), the different endowments of physical infrastructure are responsible for the regional disparity in South Asian countries. Sahoo (2006) also concluded that infrastructure is an important determinant of foreign direct investment (FDI) inflow in South Asian countries.

In addition to this physical infrastructure, studies have identified the positive and significant contribution of other infrastructure to the growth performance of economies. For example, see Levine (1999); Cooray (2009); Estrada, Park, and Ramayandi (2010); Bist (2018); Mohanty and Bhanumurthy (2019) on financial infrastructure and growth; Sridhar and Sridhar (2007); Veeramacheneni, Vogel, and Ekanayake (2008); Sahoo (2012); Chu (2013); Erumban and Das (2016); Hodrab, Maitah, and Smutka (2016); Pradhan et al. (2016); Sajjad (2016); Maurseth (2018); Haftu (2019) on information and communication technology (ICT) infrastructure and growth; Beenstock and Willcocks (1981); Samouilidis and Mitropoulos (1984); Yu and Choi (1985); Erol and Eden (1987); Asafu-Adjaye (2000); Stern (2000); Yang (2000); Ghosh (2002); Gylfason (2002); Gylfason and Zoega (2006); Kasperowicz (2014a); Sahoo, Sahoo, and Sahu (2014); Sahoo and Sahu (2014); Sahoo et al. (2014); Sahoo, Sahu, and Sahoo (2015); Sandonato and Willebald (2018); Iddrisu (2019) on natural infrastructure and capital, i.e., energy use and mineral resources and growth; Mincer (1981); Romer (1983, 1986, 1987, 1993); Lucas (1989); Fernandez and Mauro (2000); Pelinescu (2015); Dinda (2016); Altiner and Toktas (2017); Ali, Egbetokun, and Memon (2018) on human capital and growth; Helliwell and Putnam (1995); Rupasingha, Goetz, and Freshwater (2000); Hjerppe (2003); Chakrabarty (2013); Dinda (2016) on social capital and growth; and Stoneman (1975); Sahoo, Mathiyazhagan, and Parida (2002); Sahoo and Mathiyazhagan (2003); Prasad, Rajan, and Subramanian (2007); Leitão and Rasekhi (2013); Mowlaei (2018) on foreign capital and growth.

Biswas and Saha (2014) found that exports, gross domestic capital formation, employment, the money supply, and FDI positively affect the gross domestic product (GDP) growth of India. Marelli and Signorelli (2011) conducted a study on both India and the PRC that found that FDI and trade openness have positive impacts on the economic growth of both the economies. According to Bloom et al. (2006), the growth in India and the PRC was due to a rise in life expectancy, increased trade openness, and an expansion of the share of the working population.

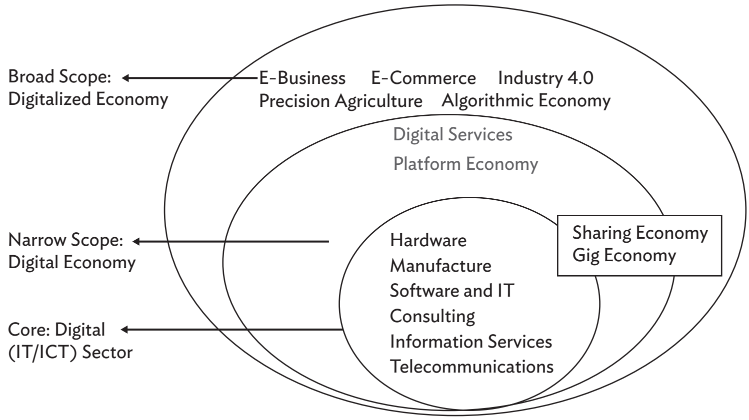
Most researchers have found a positive effect of ICT on economic growth (Joseph 2002 in India; Hodrab, Maitah, and Smutka 2016 in Arab countries). Joseph (2002) established the positive contribution of ICT to India's economy. A study by Heshmati and Yang (2006) inferred that the PRC has reaped huge benefits from ICT development. Torero, Chowdhury, and Bedi (2002) concluded that there is a positive causal link from telecommunications to GDP. Sridhar and Sridhar (2007) assessed the effects of ICT on the economic growth of developing economies and found that ICT is an effective enabler of economic development. Veeramacheneni, Vogel, and Ekanayake (2008) noted that ICT has a positive influence on the economic growth of India. A study by Erumban and Das (2016) concluded that ICT plays a significant role in driving the aggregate economic growth in India. Ghosh (2002) stated that, in India, Granger causality runs from economic growth to electricity consumption without any feedback effect.

However, the precise relationship between infrastructure development and economic growth in India is not yet clear. The objectives of this study are to analyze the economic growth process and the impact of infrastructure on the economic growth of India and the PRC. The above survey of the literature has highlighted the role of infrastructure in ushering in economic growth across different parts of the world through the creation, preservation, maintenance, and exploitation of different means of production (i.e., capital), and they fall broadly into the physical, financial, foreign, human, social, and natural capital categories. The literature has identified the key infrastructure variables for all these forms of capital as mobile density, internet density, fixed telephone density, ICT service exports, per capita electricity power consumption, research and development expenditure, general government final consumption expenditure (formerly general government consumption, gross capital formation, expected years of schooling, exports, and FDI inflows. With these identified variables, the following section develops an analytical framework to explain the growth dynamics of India and subsequently the PRC.

2.3 Conceptualizing Digitalization

As Bukht and Heeks (2017) discussed, the economic changes in the 1990s mainly concerned the emergence of the internet, and this remains a foundation for the growth of the digital economy. Further, we added that the meaning and metrics of the digital economy are both limited and divergent. Accordingly, the core of the digital economy is the "digital sector," which is the information technology (IT) or ICT sector that produces foundational digital goods and services. The true "digital economy" consists of the digital sector plus emerging digital and platform services, and the widest scope of the digital economy is the "digitalized economy," which implies the use of ICT in all economic fields (Bukht and Heeks 2017). The narrow definition of the digital economy includes digital services, and, due to the data access constraints on all aspects of the digital economy, this study considers this narrow concept of digitalization. The variables that the literature has used to capture this narrow concept of digitalization are the mobile density, internet density, fixed telephone line density, and ICT export services. Figure 2.1 shows this concept of digitalization, which Bukht and Heeks (2017) conceived.

Figure 2.1: Scoping the Digital Economy



IT = information technology, ICT = information and communication technology.

Source: Adapted from Bukht and Heeks (2017).

2.4 Theoretical Framework

GDP is a key indicator that most studies have used to measure the health of an economy (although some studies, such as those by Dua and Rasid [1998] and Sahoo and Mathiyazhagan [2003], used the Index of Industrial Production as a representative of GDP). It is the total value of all the goods and services produced within the geographic boundaries of a country during a specific period. GDP per capita, which measures the growth of an economy, is useful for comparing the relative economic performance of countries. This study takes per capita GDP to measure the economic growth of India and the PRC. The following paragraphs explain the theoretical relationship between the explanatory (infrastructure) variables (from the literature) and economic growth.

2.4.1 Mobile Density (MD)

The development of telecommunications is essential for the enhancement and improvement of the transaction process. According to Matalqah and Warad (2017), a 10% increase in telecom subscribers leads to 3% growth of GDP in non-oil-producing countries. Haftu (2019) found that 10% growth in mobile phone penetration results in a 1.2% change in per capita GDP. Wainaina (2012) identified bidirectional causality between mobile density and economic growth in sub-Saharan Africa. There is an expectation that the penetration rate of mobile services will enhance economic activities and therefore that mobile density will have a positive impact on economic growth.

2.4.2 Internet Density

The internet, through information dissemination, has transformed the production process and thus facilitated the improvement of efficiency and the expansion of economic activities through e-commerce, reducing the geographical barrier(s). The literature on internet density (ID) has argued that internet penetration makes a positive contribution to the achievement of higher economic growth (Pradhan et al. 2016).

2.4.3 Fixed Telephone Density

Fixed telephone density (FTD), an indicator of ICT, plays an important role in the economy. Andrianaivo and Kpodar (2011) found that the penetration of fixed telephones has a positive impact on the economic growth in Africa. Hence, we expect a positive impact of fixed telephone density on economic growth.

2.4.4 ICT Service Exports

ICT service exports (ICTSE) include computer and communication services and information services (World Bank 2020). Exports positively influence the income level of economies and play a comparatively better role in the growth of the Indian economy than FDI (Sahoo and Mathiyazhagan 2003). Therefore, we expect that ICTSE will promote the growth of an economy.

2.4.5 Per Capita Electricity Power Consumption

Economic growth is highly dependent on energy inputs; accordingly, electricity (from any source) plays an important role in economic growth as it is a crucial input into many productive activities. According to Kasperowicz (2014b), there is bidirectional causality between electricity consumption and economic growth in Poland. Both India and the PRC rely on electricity for manufacturing goods and services. Thus, per capita electricity power consumption (PEC) will fuel the growth of these two Asian economic powers.

2.4.6 Research and Development Expenditure

Investment in research and development (R&D) is a key input for economic growth. According to Romer (1994), R&D plays an important role in innovation, increased productivity, and economic growth. R&D expenditure has a statistically significant impact on the economic growth of the European Union (Freimane and Bālina 2016). Hence, theoretically, there is a positive effect of R&D expenditure on economic growth.

2.4.7 General Government Final Consumption Expenditure

The general government final consumption expenditure (GFCE, formerly general government consumption) consists of all the current expenditures of the government for the purchase of goods and services, including compensation for employees (World Bank 2020). It also includes expenditures on national security and defense but excludes government military expenditures, which are part of government capital formation (World Bank 2020). Since a higher GFCE is an indication of an expansionary fiscal policy, there is an expectation that it will boost the economic growth of any economy, though some empirical literature has found the opposite relationship (Devarajan, Swaroop, and Zou 1996).

2.4.8 Exports

Exports (EX) influence the level of economic growth, employment, and balance of payments. In the recent period, globalization, a reduction in transportation costs, and tariffs have made exports an important part of national incomes. The growth of exports has played a substantial role in the economic growth of India (Agrawal 2015). Studies such as Sahoo and Mathiyazhagan (2003) have suggested opening export-oriented sectors to achieve higher economic growth. Thus, the literature has supported the positive contribution of EX to the economic growth of any country.

2.4.9 Gross Capital Formation

Gross capital formation (GCF) consists of the outlays in addition to the fixed assets plus net changes in the level of inventories in the economy. The empirical literature has supported the view that GCF is the key driver of economic growth in many economies. Ongo and Vukenkeng (2014) revealed that private investment is a significant and positive determinant of economic growth in the Economic and Monetary Community of Central Africa subregion.

2.4.10 Expected Years of Schooling

Human capital is a critical factor for economic growth (Romer 1986; Lucas 1988; Barro 1996). Human capital may influence the growth of an economy by expanding the knowledge and skills of the people. Human capital has a positive impact on economic growth (Ojha and Pradhan 2010). Considering the expected years of schooling (EYS) as an important component of human capital, we expect it to exert a positive impact on economic growth.

2.4.11 Foreign Direct Investment Inflows

FDI is the preferred source of external funds for many developing economies because of the associated benefits. Along with financial capital, it brings technology and skills. Moreover, the non-debt nature of this investment has made it a safe source of foreign funds for the host economy. According to Sahoo, Mathiyazhagan, and Parida (2002), FDI is a positive and significant determinant of GDP in the PRC. Sahoo and Mathiyazhagan (2003) also found a long-term relationship between FDI and GDP in India. The Government of India has continued the reform process to attract more and more FDI and sustain higher economic growth. Thus, theoretically, a positive effect of the FDI inflow (FDII) on economic growth is likely.

Further, the macroeconomic policies (both fiscal and monetary) of the government affect these variables. Though fiscal consolidation is the call of the day for most of the economies across the world, indicating the downsizing of revenue expenditure (RE) and fiscal deficit (FD),[1] the RE of the government is essential in maintaining the capital expenditure (CE) under fiscal policies. Therefore, GCE, which is a fiscal policy variable, is essential to achieve and sustain economic growth. The literature has also supported the assertion that an expansionary monetary policy with controlled mild inflation acts as a tonic for economic growth by raising the business sentiment in the economy. On the other hand, hyperinflation can destabilize the economy by affecting the business environment (Mohanty and Bhanumurthy 2019). This chapter uses

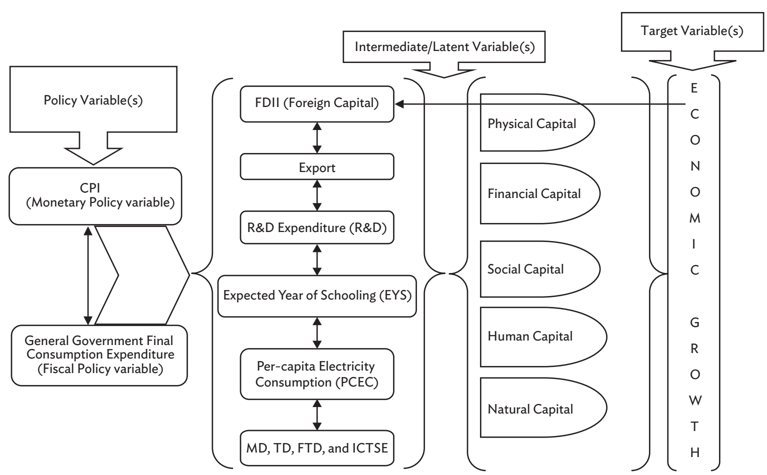
[1] The Government of India has a Fiscal Responsibility and Budget Management Act that requires the reduction of RE to 0% and FD to 3% of GDP.

the consumer price index (CPI) as one of the explanatory variables to account for the monetary policy.

2.4.12 Consumer Price Index

The price level of an economy influences its growth. As Fischer (1991) discussed, the growth of an economy has a negative association with rising price levels. The author argued that inflation deters growth by reducing investment and productivity. On a similar line, Barro (1996) argued that higher growth of economies is conditional on a lower level of inflation. Therefore, the assumption is that a higher price level, which a higher CPI indicates, will deter growth, though the literature has also supported the reverse relationship (Mahmoud 2015). The price of goods and services in an economy continues to fluctuate, but changes in the price that are too large and too fast are not favorable for the economy. Though research has not considered an increase in the price level to be good for an economy, a mild increase is beneficial for its growth. According to Mahmoud (2015), there is a positive relationship between the CPI and GDP, and unidirectional causality runs from inflation to economic growth in Mauritania. Figure 2.2 shows the theoretical relationship between the explanatory variables and per capita GDP:

Figure 2.2: Theoretical Relationship



CPI = consumer price index, FDII = foreign direct investment inflows, FTD= fixed telephone density, ICTSE = information and communication technology service exports, MD = mobile density, R&D = research and development, TD = teledensity.

Source: Authors' illustration from the literature.

The functional form below can express the relationship of the explanatory variables with per capita GDP or PCGDP (the key indicator of economic growth for any country):

$$PCGDP = F(MD, ID, FTD, ICTSE, PCEPC, R\&D, GFCE, EX, GCF, EYS, FDII, CPI) \quad (1)$$

Similarly, the literature on the determinants of FDII has supported the assertion that the size of the market, which the PCGDP indicates, attracts more FDI to a destination (Sahoo 2004). Therefore, it is possible to express the relationship of the explanatory variables with FDII as follows:

$$FDII = F(MD, ID, FTD, ICTSE, PCEPC, R\&D, GFCE, EX, GCF, EYS, PCGDP, CPI) \quad (2)$$

Equations 1 and 2 show the feedback relationship between PCGDP and FDII: the variables affect each other, resulting in a simultaneous relationship between the two. Table 2.1 shows the expected relationships of the explanatory variables with PCGDP and FDII.

Table 2.1: Expected Relationship of the Explanatory Variables with PCGDP and FDII

Dependent Variable(s)	Explanatory Variables	Expected Relationship with PCGDP
PCGDP	Mobile Density (MD)	+
	Internet Density (ID)	+
	Fixed Telephone Density (FTD)	+
	ICT Service Exports (ICTSE)	+
	Per Capita Electricity Power Consumption (PCEPC)	+
	Research and Development Expenditure (R&D)	+
	General Government Final Consumption Expenditure (GFCE)	+/-
	Exports (EX)	+
	Gross Capital Formation (GCF)	+
	Expected Years of Schooling (EYS)	+
	Foreign Direct Investment Inflow (FDII)	+
	Consumer Price Index (CPI)	+/–

continued on next page

Table 2.1 *continued*

Dependent Variable(s)	Explanatory Variables	Expected Relationship with PCGDP
FDII	Mobile Density (MD)	+
	Internet Density (ID)	+
	Fixed Telephone Density (FTD)	+
	ICT Service Exports (ICTSE)	+
	Per Capita Electricity Power Consumption (PCEPC)	+
	Research and Development Expenditure (R&D)	+
	General Government Final Consumption Expenditure (GFCE)	+
	Exports (EX)	+
	Gross Capital Formation (GCF)	+
	Expected Years of Schooling (EYS)	+
	Per Capita GDP (PCGDP)	+
	Consumer Price Index (CPI)	+/–

FDII = foreign direct investment inflows, PCGDP = per capita gross domestic product.
Source: Authors' compilation from the literature.

Equations 1 and 2 constitute a simultaneous structural equation system, and it is necessary to estimate them in their reduced form. After repeated cross-checking, the reduced-form estimable simultaneous equation system of the two equations is as follows:

$$\begin{aligned} LnPCGDP_{it} = {} & \delta + \gamma_1\, LnEX_{it} + \gamma_2\, LnEYS_{it} + \gamma_3\, LnFDII_{it} + \gamma_4\, LnID_{it} \\ & + \gamma_5\, LnMD_{it} + \gamma_6\, LnPCEPC_{it} + \gamma_7\, LnR\&D_{it} + \gamma_8\, LnCPI_{it} \\ & + \gamma_9\, (LnEYS_{it} \times LnR\&D_{it}) + \gamma_{10}\, (D_C \times LnEX_{it}) + \gamma_{11}\, (D_C \\ & \times LnEYS_{it}) + \gamma_{12}\, (D_C \times LnFDII_{it}) + \gamma_{13}\, (D_C \times LnID_{it}) \\ & + \gamma_{14}\, (D_C \times LnMD_{it}) + \gamma_{15}\, (D_C \times LnPCEPC_{it}) + \gamma_{16}\, (D_C \\ & \times LnR\&D_{it}) + \gamma_{17}\, (D_C \times LnCPI_{it}) + \gamma_{18}\, (D_C \times LnEYS_{it} \\ & \times LnR\&D_{it}) + \varepsilon_{it} \qquad (3) \end{aligned}$$

$$\begin{aligned} LnFDII_{it} = {} & \alpha + \beta D_C + \beta_1\, LnEX_{it} + \beta_2\, LnEYS_{it} + \beta_3\, LnGCF_{it} \\ & + \beta_4\, LnID_{it} + \beta_5\, LnMD_{it} + \beta_6\, LnPCEPC_{it} + \beta_7\, LnCPI_{it} \\ & + \beta_8\, LnR\&D_{it} + \beta_9\, LnDU_{it} + \varepsilon_{it} \qquad (4) \end{aligned}$$

where i refers to the country, that is India and the PRC, t is time, D_c is the dummy (1 for India and 0 for the PRC), and ε is the independently and identically distributed (IID) random error term. We estimated these equations using the data that we collected from secondary sources[2] through the statistical software STATA 13.0 edition (StataCorp 2013). However, before estimating the reduced form of the simultaneous equation system, it is pertinent to discuss the data sources and variable constructs. Additionally, an overview of the macroeconomic conditions of both economies through the macroeconomic variables would enrich the analysis.

2.5 Data Sources and Variable Constructs

This study used the data for the two fastest-growing economies of Asia: India and the PRC. All the data are secondary in nature and refer to the period 1990 to 2019. The annual data for the dependent variable, per capita GDP (in purchasing power parity or PPP terms, constant 2017) of India and the PRC, come from WDI (World Bank 2020). WDI also provided the data for the independent variables, such as MD, ID, FTD, ICTSE, PCEPC, R&D (% GDP), GFCE (% GDP), EX (% GDP), GCF (% GDP), and FDII (% GDP). We collected the data on the EYS from the United Nations Development Programme's Human Development Reports (UNDP 2020), and the CPI data from the United Nations Conference on Trade and Development (UNCTAD 2020). Table 2.2 provides the description of the variables that this study used.

Table 2.2: Variables Used and Data Sources

Economies	Variable	Measurement	Note	Data Source
India and the PRC	Per Capita GDP, PPP (PCGDP)	Constant 2017 $	GDP divided by midyear population	WDI, World Bank
	Mobile Density (MD)	Numeric	Number of mobile phones per 100 people	WDI, World Bank
	Internet Density (ID)	Numeric	Number of internet subscriptions per 100 people	WDI, World Bank

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2 See Section 2.4.

Table 2.2 *continued*

Economies	Variable	Measurement	Note	Data Source
	Fixed Telephone Density (FTD)	Numeric	Number of fixed telephone subscriptions per 100 people	WDI, World Bank
	ICT Service Exports (ICTSE)	% of service exports, balance of payments	Includes computer and communication services and information services	WDI, World Bank
	Per Capita Electricity Power Consumption (PCEPC)	kWh	Electric power consumption	WDI, World Bank
	Research and Development Expenditure (R&D)	% of GDP	Includes both capital and current expenditures	WDI, World Bank
	General Government Final Consumption Expenditure (GFCE)	% of GDP	Includes all govt. expenditures for the purchase of goods and services	WDI, World Bank
	Exports (EX)	% of GDP	Exports of goods and services	WDI, World Bank
	Gross Capital Formation (GCF)	% of GDP	Consists of outlays in addition to fixed assets + net changes in the level of inventories	WDI, World Bank
	Expected Years of Schooling (EYS)	Number of Years	Expected years of schooling in years	UNDP
	Foreign Direct Investment Inflow (FDII)	% of GDP	Net inflows of investment	WDI, World Bank
	Consumer Price Index (CPI)	Index	Price of a basket of consumer goods	UNCTAD

GDP = gross domestic product, kWh = kilowatt hour, PPP = purchasing power parity, PRC = People's Republic of China, UNCTAD = United Nations Conference on Trade and Development, WDI = World Development Indicators.

Source: Authors' compilation from various sources.

However, a few issues relating to the data are worth mentioning. Data on MD were not available for India for 1990–1994. Data on ID were unavailable for India for 1990, 1991, and 2019 and for the PRC from 1990 to 1992 and from 2018 to 2019. Further, the variables FTD and ICTSE have no impact on the dependent variables; thus, the subsequent discussions and models do not consider them.

2.6 Some Stylized Facts on the Economies of India and the People's Republic of China

To present the data that this study used in a meaningful way, Table 2.3 contains the calculations of the descriptive statistics.

Table 2.3: Descriptive Statistics

	PCGDP[a]	MD	ID	FTD	ICTSE[b]	PCEPC	R&D	GFCE	EX	GCF	EYS	FDII	CPI
India													
Mean	3,550.4	29.6	6.9	2.3	45.7	522.2	0.7	10.9	16.4	31.7	9.8	1.2	81.8
Standard Deviation	1,515.8	35.3	9.2	1.1	4.7	182.0	0.1	0.6	5.7	5.5	1.7	0.8	47.6
Kurtosis	−0.6	−1.5	0.6	−1.0	7.1	−1.5	−0.4	−0.5	−1.4	−1.2	−1.5	0.6	−0.8
Skewness	0.7	0.6	1.3	0.1	−2.1	0.4	0.7	0.4	0.0	0.4	0.3	0.7	0.7
Minimum	1,792.0	0.0	0.0	0.6	30.1	272.1	0.6	9.8	7.1	24.0	7.6	0.0	22.9
Maximum	6,754.3	87.3	32.0	4.4	52.1	804.5	0.9	12.2	25.4	41.9	12.3	3.6	180.4
PRC													
Mean	6,691.8	40.5	19.4	14.0	5.4	2,036.0	1.3	15.1	22.7	40.5	11.2	3.4	88.3
Standard Deviation	4,606.0	41.2	21.5	8.8	3.8	1,282.9	0.6	1.1	6.2	4.2	2.0	1.4	23.6
Kurtosis	−0.9	−1.2	−1.4	−1.2	−0.8	−1.6	−1.6	−1.1	−0.2	−1.2	−1.7	−0.5	−0.3
Skewness	0.7	0.6	0.6	−0.2	0.7	0.3	0.2	−0.1	0.8	−0.2	0.2	0.0	−0.5
Minimum	1,423.7	0.0	0.0	0.6	0.6	510.6	0.6	13.2	13.6	33.6	8.8	1.0	40.4
Maximum	16,116.7	120.4	54.3	27.5	12.7	3,927.0	2.2	16.8	36.0	46.7	13.9	6.2	125.1
Mean Difference[c]													
	3,141.47	10.97	12.49	11.7	40.3	1,513.77	0.57	4.24	6.25	8.78	1.42	2.14	6.43
t-statistics[d]	5.59*	5.99*	5.19*	8.09*	30.71*	7.53*	5.26*	22.51*	7.34*	11.21*	20.01*	6.70*	1.28

[a] In US dollars.

[b] The ICTSE data for India are available for the period 2000 to 2017, so the authors calculated the descriptive statistics only for this period.

[c] The difference results from deducting the mean of the variables of India from the mean of the variable of the People's Republic of China.

[d] The authors calculated the t-statistics for the mean difference through the formula:

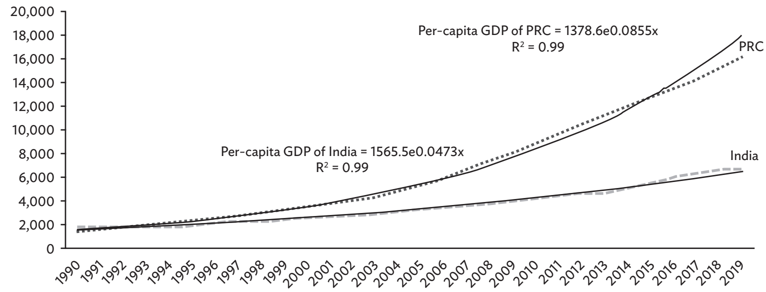
$$t = \frac{\bar{x}_1 - \bar{x}_2}{s_V\sqrt{\frac{1}{n_1}+\frac{1}{n_2}}}\quad S_V = \sqrt{\frac{(n_1-1)S_1^2 + (n_2-1)S_2^2}{n_1+n_2-2}}$$

, where $\bar{x}_1 s_1$, and n_1 are the mean, standard deviation, and sample size in sample one and $\bar{x}_2$, s_2, and n_2 are the mean, standard deviation, and sample size in sample two, respectively. S_V is the pooled standard deviation and $n_1 + n_2 - 2$ is the degrees of freedom.

* indicates significance at the 1% level.

Source: Authors' computation from the World Development Indicators, United Nations Conference on Trade and Development, and United Nations Development Programme data.

Figure 2.3: Per Capita GDP (PPP) at Constant Prices, 1990–2019 ($)



GDP = gross domestic product, PPP = purchasing power parity, PRC = People's Republic of China.

Note: The dotted lines show the actual values. The solid lines indicate the fitted/estimated values.

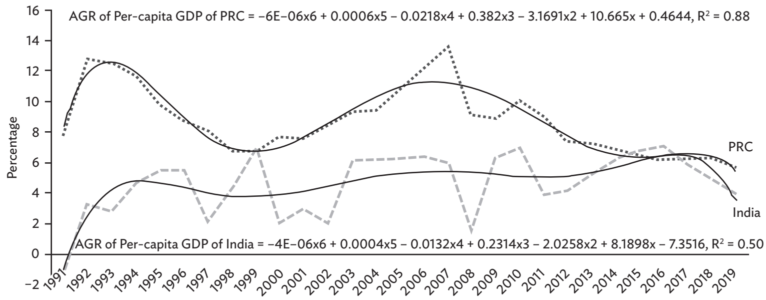
Source: Authors' illustration based on data from the World Development Indicators.

Table 2.3 shows the descriptive statistics of the variables that this study considered. It shows the characteristics of the data over 30 years from 1990 to 2019. The average per capita GDP of India is $3,550.4, the minimum value is $1,792.0, and the maximum value is $6,754.3. Similarly, the average per capita GDP of the PRC is $6,691.8, the minimum value is $1,423.7, and the maximum value is $16,116.7. Table 2.3 reveals that there is a significant difference between the respective means of per capita GDP of the two economies. The absolute difference between the mean values of the variables of both countries, which the mean difference indicated, shows that the gap is significant for all the variables except the CPI.

Figure 2.3 shows the trends of per capita GDP (PPP) in India and the PRC. Measured in constant United States dollars, the PCGDP of India was $1,809.80 in 1990, rising to $6,754.28 in 2019. Likewise, the PCGDP of the PRC increased from $1,423.70 in 1990 to $16,116.70 in 2019. In 1990, the PCGDP of India was higher than that of the PRC. However, in 2019, the PRC's PCGDP was around 2.38 times greater than that of India.

Figure 2.4 shows the annual growth rates of the PCGDP of India and the PRC. India attained a maximum growth rate of 7.08% in 2016 and a minimum of –0.98% in 1991. Similarly, the PRC attained a maximum growth rate of 13.63% in 2007 and a minimum of 5.73% in 2019. Both countries are prominent economies in Asia. The annual average growth

Figure 2.4: Annual Growth Rate of Per Capita GDP (PPP)



AGR = annual growth rate, GDP = gross domestic product, PPP = purchasing power parity, PRC = People's Republic of China.

Note: The dotted lines show the actual values. The solid lines indicate the fitted/estimated values.

Source: Authors' illustration based on data from the World Development Indicators.

rates (AAGRs) of the PCGDP of both India and the PRC over the period 1990–2019 are ahead of those of economies like Brazil, the Russian Federation, South Africa, Japan, and the United States as well as the world economy (see Tables 2.4 and 2.5).

Table 2.4: Annual Average Growth Rates of Some Variables of Selected Economies (%)

Period	Brazil	Russian Federation	South Africa	Japan	United States	World
Per Capita Gross Domestic Product (PCGDP)						
1991–2000	1.00	–3.52	–0.18	1.04	2.19	1.39
2001–2010	2.54	5.21	2.14	0.57	0.82	2.31
2011–2019	–0.13	1.34	0.03	1.12	1.55	2.23
1991–2019	1.18	1.00	0.69	0.90	1.52	1.96
Mobile Density (MD)						
1991–2000	242.97	281.27	144.49	61.04	34.26	50.00
2001–2010	22.73	61.52	19.19	6.26	9.12	20.33
2011–2019	1.14	0.07	6.27	4.00	3.51	3.50
1991–2019	91.97	118.23	58.39	24.45	16.05	25.34

continued on next page

Table 2.4 *continued*

Period	Brazil	Russian Federation	South Africa	Japan	United States	World
Internet Density (ID)						
1991–2000	111.10	271.14	86.83	118.19	52.01	110.26
2001–2010	33.15	38.39	20.87	10.54	5.44	15.75
2011–2019	5.69	7.85	10.28	1.88	2.33	5.58
1991–2019	51.51	109.17	40.33	44.98	20.53	45.19
Per Capita Electricity Power Consumption (PCEPC)						
1991–2000	2.656	–2.41	0.89	2.02	1.56	1.16
2001– 2010	2.35	2.15	–0.02	0.40	–0.16	2.19
2011–2019	0.96	0.30	–0.71	–0.90	–0.33	0.57
1991–2019	2.02	0.006	0.08	0.55	0.38	1.33
Research and Development Expenditure (R&D)						
1991–2000	0.01	0.70	1.80	0.58	0.64	–
2001–2010	1.11	1.17	–0.07	0.80	0.43	–
2011–2019	1.11	–0.49	1.25	0.29	0.29	–
1991–2019	0.73	0.49	0.99	0.57	0.46	–
General Government Final Consumption Expenditure (GFCE)						
1991–2000	0.29	–1.63	–0.03	2.21	–1.23	–0.07
2001–2010	0.17	2.43	1.02	1.49	1.81	0.95
2011–2019	0.73	–0.19	0.58	0.17	–1.81	–0.33
1991–2019	0.39	0.22	0.52	1.33	–0.36	0.20
Exports (EX)						
1991–2000	3.40	33.26	1.62	0.53	1.52	3.05
2001–2010	1.31	–3.79	1.18	4.41	1.74	1.26
2011–2019	3.46	–0.06	0.52	1.90	–0.44	0.67
1991–2019	2.70	10.14	1.13	2.30	0.99	1.70
Gross Capital Formation (GCF)						
1991–2000	–0.11	–3.28	–1.38	–2.27	1.00	–0.58
2001–2010	1.80	2.79	2.00	–2.36	–2.12	–0.03
2011–2019	–3.78	0.35	–1.07	1.32	1.13	–0.01
1991–2019	–0.60	–0.06	–0.12	–1.19	–0.04	–0.22

continued on next page

Table 2.4 *continued*

Period	Brazil	Russian Federation	South Africa	Japan	United States	World
Expected Years of Schooling (EYS)						
1991–2000	1.60	−0.22	1.33	0.73	−0.17	0.95
2001–2010	−0.18	1.15	−0.15	0.48	0.71	1.57
2011–2019	1.10	1.14	0.76	0.15	0.07	0.82
1991–2019	0.83	0.67	0.64	0.46	0.20	1.12
Foreign Direct Investment Inflow (FDII)						
1991–2000	51.02	29.02	338.82	−688.02	16.93	17.90
2001–2010	6.80	16.70	202.91	122.52	5.60	0.06
2011–2019	2.54	50.78	21.33	290.24	2.75	−3.47
1991–2019	20.72	31.52	193.42	−189.4	8.62	5.12
Consumer Price Index (CPI)						
1991–2000	549.18	156.51	8.99	0.83	2.80	–
2001–2010	6.69	12.58	5.30	−0.26	2.39	–
2011–2019	5.91	6.85	5.28	0.60	1.79	–
1991–2019	193.51	60.44	6.57	0.38	2.35	–

Source: Authors' computation from the World Development Indicators, United Nations Conference on Trade and Development, and United Nations Development Programme data.

Further, we tested the relative performance of both the economies with respect to the PCGDP using the dummy variable regression technique.[3]

Table 2.5 depicts the AAGRs of the PCGDP of India and the PRC during different periods. From 1991 to 2019, the AAGR of India and the PRC is 4.66% and 8.74%, respectively. During 1991–2000, the PCGDP of India grew at an average rate of 3.60% and that of the PRC grew at an average rate of 9.27%. India was able to raise the growth rate steadily over the period, whereas the PRC maintained its high growth rate,

[3] The estimated regression equation for the dummy variable technique is $y = \alpha + \beta D + \varepsilon$, where y represents the variable concerned in the difference test; D is the dummy variable, 0 for India and 1 for the PRC; and ε is the error term. This dummy variable technique tests the difference in the performance for digitalization for the whole period (1990–2019) and for the different subperiods (1990–2000, 2001–2010, and 2011–2019). This exercise will provide an understanding of the temporal variation in the performance of y.

Table 2.5: Annual Average Growth Rates of PCGDP (PPP) of India and the PRC (%)

Period	India	PRC	Difference/Intercept	Coefficient
1991–2000	3.60	9.27	3.60* (4.96)	5.67* (5.52)
2001–2010	5.10	9.92	5.10* (8.38)	4.82* (5.60)
2011–2019	5.35	6.84	5.35* (14.68)	1.49** (2.89)
1991–2019	4.66	8.74	4.66* (11.94)	4.08* (7.39)

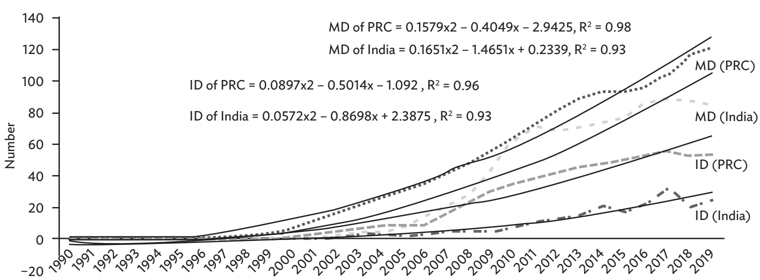
GDP = gross domestic product, PCGDP = per capita gross domestic product, PPP = purchasing power parity, PRC = People's Republic of China.

Notes: * and ** indicate significance at the 1% and 5% levels, respectively. The figures in parentheses represent the t-statistics.

Source: Authors' estimation from the World Development Indicators data.

albeit showing some periodic fluctuations. Further, there is significant difference in the growth performance (the AAGR of the PRC is higher than that of India) of the two economies across different subperiods.

Figure 2.5: Trend of Mobile and Internet Density



ID = internet density, MD = mobile density, PRC = People's Republic of China.

Note: The dotted lines show the actual values. The solid lines indicate the fitted/estimated values.

Source: Authors' illustration based on World Development Indicators data.

Figure 2.5 shows the trends of the mobile density and internet density of both India and the PRC, and Table 2.6 provides the AAGR of the digitalization variables (i.e., MD and ID) for both India and the PRC. Further, we used a dummy variable regression technique to test

Table 2.6: Annual Average Growth Rates of MD and ID

	India		PRC		Difference/Intercept		Coefficient	
Period	MD	ID	MD	ID	MD	ID	MD	ID
1991–2000	62.94	325.36	138.71	211.15	62.94** (2.14)	325.36 *** (1.94)	75.77*** (1.82)	−114.21 (−0.48)
2001–2010	70.93	33.83	26.17	35.54	70.93* (8.09)	33.83* (3.66)	−44.76* (−3.61)	1.71 (0.13)
2011–2019	3.87	17.75	7.59	5.12	3.87** (1.96)	17.75** (2.69)	3.72 (1.34)	−12.63 (−1.35)
1991–2019	47.36	129.37	59.20	126.66	47.36* (3.52)	129.37** (2.14)	11.84 (0.62)	−42.71 (−0.50)

ID = internet density, MD = mobile density, PRC = People's Republic of China.

Notes: *, **, and *** indicate significance at the 1%, 5%, and 10% levels, respectively. The figures in parentheses represent the t-statistics.

Source: Authors' estimation from the World Development Indicators data.

the difference in digitalization performance of the two economies. Figure 2.5 reveals that the PRC is ahead of India in absolute digitization, and a further perusal of Table 2.6 shows that the growth performance of the PRC in digitization is significantly higher than that of India during all subperiods.

The expansion of digitalization measured in terms of mobile density and internet density in Table 2.6 shows that the AAGR of these two variables in the PRC are higher than those in India during 1991–2019. However, the gap in the growth rates of MD in the two economies is smaller than those of ID. During the first decade of the 21st century, the growth of mobile penetration in India was far ahead that of the PRC. However, during 2011–2019, both economies faced low growth of mobile penetration. Similarly, Figures A2.1.1 to A2.1.5 in Appendix A2.1 depict the trends of the remaining explanatory variables, like PCEPC, R&D, EYS, GFCE, GCF, EX, FDII, and CPI, of both India and the PRC. Tables 1–5 in the same appendix report the AAGRs of the same explanatory variables and the results of their dummy variable regression model.

To sum up, it is possible to state that the economic performance of India and the PRC has been better than that of other major economies of the world (Table 2.4). The performance of these two rising economic giants is associated with their relatively better performance in ushering in other proactive policies to create growth-promoting capital. As Table 2.4 revealed, both India and the PRC have been well ahead of other economies in the key variables for promoting growth. Thus, it is pertinent to explore the impact of these key variables on the growth performance of India and the PRC, which the following section reports.

2.7 Results and Discussion

We explored the impact of the explanatory variables on the economic performance of India and the PRC by estimating equations 3 and 4. However, before discussing the estimated result of the two equations, we studied the coefficient of correlation between the variables to obtain a preliminary understanding of the relationship between the explanatory variables and PCGDP. This would also help in quantifying the degrees to which PCGDP is related to the other variables. Table 2.7 presents the correlation coefficients of PCGDP with the other variables.

Table 2.7 shows that both MD and ID have a high positive correlation with PCGDP in both India and the PRC. Likewise, CPI has a very high positive correlation with PCGDP in both countries. The relationship between PCEPC and PCGDP is stronger in the PRC than in India. There is a negligible positive relationship between R&D and PCGDP, whereas, in the case of the PRC, the relationship is very strong. There is a negative relationship between GFCE and PCGDP in both countries. EX and GCF have a positive relationship with PCGDP in both countries. FDII has a positive relationship with PCGDP in India, whereas, in the case of the PRC, there is a negative relationship between these two variables.

Table 2.7: Correlation between PCGDP and Macroeconomic Variables

Variables	PCGDP: India	PCGDP: PRC
MD	0.95*	0.99*
ID	0.94*	0.98*
PCEPC	0.97*	0.97*
R&D	0.003	0.97*
GFCE	–0.155	0.62*
EX	0.74*	0.26
GCF	0.44**	0.72*
EYS	0.97*	0.97*
FDII	0.65*	–0.54*
CPI	0.99*	0.91*

PCDGP = per capita gross domestic product, PRC = People's Republic of China.

Note: * and ** indicate that the correlation coefficient is significant at the 1% and the 5% levels, respectively.

Source: Authors' computation from the World Development Indicators, United Nations Conference on Trade and Development, and United Nations Development Programme data.

The correlation analysis gives only the mere associations among the variables. To determine the impact of these explanatory variables on economic growth, we estimated equations 3 and 4 within a simultaneous framework. Additionally, we subjected the data to time series analysis to draw a relevant conclusion. For the simultaneous equation framework, since we performed the estimation for balanced panel data, we carried out the test for the poolability of data and the Hausman test for the choice of models (fixed effect [FE] and/or random effect [RE]); Table 2.8 presents the results. The result of the poolability test confirmed that the coefficients are stable across cross-section units (thus, they are poolable), and the result of the Hausman test revealed that the RE model is preferable to the FE model. However, this chapter presents the results of both the RE and the FE model. Further, it reports the results of the first-difference model (this will give an idea about the short-run effect of the explanatory variables on the dependent variable[s]). Further, before carrying out the time series analysis of the data, we tested the time series properties (i.e., through the unit root test) of all the variables. Appendix A2.2 presents the results of the unit root test of all the variables.

Table 2.8: Results of the Poolability Test and the Hausman Test for Equations 3 and 4

	Poolability Test	Hausman Test
For Equation 3	$F(1, 37) = 1.94$ $Prob > F = 0.172$	$\chi^2 = 1.94$ $Prob > \chi^2 = 1.000$
For Equation 4	$F(1, 38) = 0.40$ $Prob > F = 0.5307$	$\chi^2 = 0.40$ $Prob > \chi^2 = 1.000$

Source: Authors' computation from the World Development Indicators data.

Since the study estimated equations 3 and 4 within a simultaneous equation framework, we performed a test of endogeneity of the two variables PCGDP and FDII; Table 2.9 reports the results. Although the test results do not confirm the endogeneity of the variables, the literature has supported the simultaneous feedback relationship between the two. Therefore, the study estimated both equations 3 and 4; Tables 2.10 and 2.11 present the results.

Table 2.9: Test for Endogeneity of PCGDP and FDII

Wald Test for PCGDP			
Test Statistic	**Value**	**Df**	**Probability**
t-statistic	−1.003	19	0.328
F-statistic	1.007	(1, 19)	0.328
Chi-square (χ^2)	1.007	1	0.316
Null Hypothesis: Coefficient of the residual is zero			
Null Hypothesis Summary:			
Normalized Restriction (= 0)		**Value**	**Std Err.**
Coefficient		−3.577	3.565
Restrictions are linear in coefficients.			
Wald Test for FDII			
Test Statistic	**Value**	**Df**	**Probability**
t-statistic	−1.003	19	0.328
F-statistic	1.007	(1, 19)	0.328
Chi-square (χ^2)	1.007	1	0.316
Null Hypothesis: Coefficient of the residual is zero			
Null Hypothesis Summary:			
Normalized Restriction (= 0)		**Value**	**Std Err.**
Coefficient		−0.014	0.014
Restrictions are linear in coefficients.			

FDII = foreign direct investment inflows, PCGDP = per capita gross domestic product.
Source: Authors' computation from the World Development Indicators data.

Table 2.10 shows the results of the two-stage least square estimates of equation 3. The high values of R^2 and Wald χ^2, for both the FE and the RE model, suggest the goodness of fit of the models. The study found that EYS, FDII, GCF, ID (in FE model), MD, PCEPC, and R&D have a positive impact on PCGDP of India and the PRC. However, CPI promotes growth in the short run in the PRC but retards the growth in India. The impact of EX, MD, R&D, and EYS on growth performance is comparatively greater in the PRC, indicating better productivity of human capital in the PRC. However, FDII exerts a relatively stronger impact on the growth performance of India than on that of the PRC. This may be because the FDII into India is comparatively low, resulting in higher marginal productivity.

Table 2.10: Two-Stage Least Square Estimate of Equation 3

	Dependent Variable: LOG (PCGDP)		
Independent Variables	**Random Effect**	**Fixed Effect**	**First Differenced**
Constant	5.745* (0.64)	5.633* (0.659)	0.055* (0.006)
LOG(FDII)	0.108* (0.037)	0.110* (0.037)	0.023 (0.016)
LOG(EX)	0.326* (0.108)	0.276** (0.125)	−0.008 (0.055)
LOG(EYS)	2.210* (0.608)	2.258* (0.614)	0.530*** (0.272)
LOG(R&D)	7.669* (1.423)	6.658* (1.921)	−0.637 (0.888)
LOG(ID)	0.013 (0.011)	6.017* (0.012)	0.001 (0.004)
LOG(PCEPC)	0.572** (0.268)	0.507*** (0.282)	0.120 (0.111)
LOG(MD)	0.161* (0.024)	0.152* (0.027)	0.009 (0.015)
LOG(CPI)	0.046 (0.164)	0.103 (0.180)	0.161** (0.076)
DU × LOG(EX)	−0.591* (0.126)	−0.532* (0.147)	−0.115*** (0.066)
DU × LOG(EYS)	−0.678 (0.782)	−0.897 (0.833)	−0.356 (0.355)
DU × LOG(FDII)	0.0115* (0.039)	0.119* (0.040)	−0.023 (0.018)
DU × LOG(ID)	0.018 (0.013)	0.022 (0.014)	0.002 (0.006)
DU × LOG(MD)	−0.150* (0.025)	−0.139* (0.029)	−0.013 (0.015)
DU × LOG(PCEPC)	0.260 (0.358)	0.203 (0.366)	0.055 (0.162)
DU × LOG(R&D)	10.124* (3.514)	10.171* (3.531)	1.708 (1.630)
DU × LOG(CPI)	0.335 (0.205)	0.254 (0.230)	−0.369* (0.113)
LOG(EYS) × LOG(R&D)	3.355* (0.599)	2.923* (0.814)	0.274 (0.379)

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Table 2.10 *continued*

Dependent Variable: LOG (PCGDP)			
Independent Variables	**Random Effect**	**Fixed Effect**	**First Differenced**
DU × LOG(EYS) × LOG(R&D)	−4.318* (1.528)	−4.364* (1.537)	−0.773 (0.714)
R^2 (Within)	0.998	0.998	0.473
R^2 (Overall)	0.998	0.745	0.208
Wald χ^2	30,549.57	5.11e+06	182.50

Notes:*, **, and *** indicate significance at the 1%, 5%, and 10% levels. The numbers in parentheses are standard errors.

Source: Authors' computation from the World Development Indicators, United Nations Conference on Trade and Development, and United Nations Development Programme data.

Table 2.11 provides the results of the two-stage least square estimate of equation 4. The values of R^2 and Wald χ^2 are indicative of the goodness of fit of the models. The results show that EX, GCF, and CPI are positive determinants of the inward FDI flows to India and the PRC. This implies that the FDI inflows to these economies are export-promoting in both the short and the long run. Higher revenue/profit due to increased prices also attracts FDI to India and the PRC. Further, the promotion of infrastructure through capital formation makes these two economies favorable FDI destinations.

As mentioned earlier, the data are a panel set—and thus we conducted panel unit root tests of all the variables before analyzing the data through an appropriate model(s). They undertook a total of seven panel unit root tests for all the variables: (i) augmented Dickey–Fuller (ADF) (Fisher χ^2), (ii) augmented Dickey–Fuller (Choi Z stat), (iii) Levin–Lin–Chu, (iv) Im–Pesaran–Shin, (v) Breitung, (vi) Philips–Perron (Fisher χ^2), and (vii) Philips–Perron (PP) (Choi Z stat) tests. Appendix A2.2 presents the panel unit root test results. The first, second, fourth, sixth, and seventh tests assumed the null hypothesis of a unit root with an individual unit root process, whereas the third and fifth tests assumed the null hypothesis of a unit root with a common unit root process.

The results of the panel unit root test reveal that PCGDP and R&D are stationary at first difference I (1) in all the seven tests. MD is stationary at level I (0) according to the ADF (Fisher χ^2), ADF (Choi Z stat), Im–Pesaran–Shin, PP (Fisher χ^2), and PP (Choi Z stat) tests, while it is stationary at first difference according to the ADF (Fisher χ^2),

Table 2.11: Two-Stage Least Square Estimate of Equation 4

Dependent Variable: LOG (FDII)			
Independent Variables	**Random Effect**	**Fixed Effect**	**First Differenced**
Constant	−12.419** (5.482)	−12.364** (5.510)	0.056 (0.173)
LOG(PCGDP)	−0.034 (1.159)	−0.034 (1.159)	0.943 (2.528)
LOG(EX)	1.369** (0.541)	1.369** (0.541)	1.394** (0.687)
LOG(EYS)	−7.632* (1.702)	−7.632* (1.702)	−3.859 (3.825)
LOG (GCF)	2.805* (0.618)	2.805* (0.618)	1.599*** (0.871)
LOG(ID)	0.040 (0.056)	0.040 (0.056)	−0.092 (0.072)
LOG(MD)	−0.204* (0.077)	−0.204* (0.077)	−0.094 (0.120)
LOG(PCEPC)	0.732 (0.964)	0.732 (0.964)	−0.332 (1.833)
LOG(CPI)	2.816* (0.830)	2.816* (0.830)	0.974 (1.435)
LOG(R&D)	−0.069 (1.105)	−0.069 (1.105)	−0.281 (1.202)
DU	0.110 (0.606)	–	–
R-squared (Within)	0.850	0.850	0.381
R-squared (Overall)	0.905	0.903	0.447
Wald χ^2	466.81	370.14	11.61

Notes: *, **, and *** indicate significance at the 1%, 5%, and 10% levels. The numbers in parentheses are standard errors.

Source: Authors' computation from the World Development Indicators, United Nations Conference on Trade and Development, and United Nations Development Programme data.

ADF (Choi Z stat), Levin–Lin–Chu, Im–Pesaran–Shin, PP (Fisher χ^2), and PP (Choi Z stat) tests. The results for ID are mixed; that is, it is stationary both at level and at first difference in all the tests except ADF (Choi Z stat), in which it is not stationary at first difference. However, PCEPC is only stationary at first difference according to the PP (Fisher χ^2), and PP (Choi Z stat) tests. GFCE is stationary at level in all the tests except the Breitung, PP (Fisher χ^2), and PP (Choi Z stat) tests and stationary at first difference in all the tests. In addition, the Levin–Lin–Chu test supports EX as being stationary at level, but all the other tests support it as stationary at first difference. GCF is stationary at first difference according to all the tests except the Levin–Lin–Chu and Breitung tests, while EYS is stationary at first difference according to all the tests except the Levin–Lin–Chu test. Besides, the result for FDII, CPI, FTS, and ICTSE are mixed. Since the model includes a combination of I (0) and I (1) variables, it was appropriate to use the panel nonlinear autoregressive distributed lag (panel NARDL) model to analyze the data and draw the relevant conclusions and policy implications.

Table 2.12 shows the results of the panel NARDL model for equations 3 and 4. In equation 3, the positive change in FDII and negative change in MD lead to a negative impact on PCGDP in the long run. Both positive and negative changes in EX tend to have a positive and significant impact on PCGDP. Besides, the positive change in ID has a positive impact on PCGDP in the long run. In the short run, both positive and negative changes in FDII have a positive impact on PCGDP. On the other hand, a positive change in R&D has a negative impact on PCGDP in the short run. In equation 4, positive changes in ID and CPI lead to a negative effect on FDII in the long run. In addition, in the long run, both positive and negative changes in GCF have a negative effect on FDII. In the short run, a negative shock to R&D leads to a negative impact on FDII. Similarly, both positive and negative changes in ID and GCF lead to a negative impact on FDII in the short run. Moreover, in both equations 3 and 4, long-run relationships exist between the variables; that is, the cointegration equation coefficients in equation 3 (–0.091) and equation 4 (–0.403) are negative and significant.

Table 2.13 evaluated the long-run and short-run asymmetric relationships. The result of equation 3 reveals the long-run asymmetric relationships between positive shocks and negative shocks in ID, PCEPC, and FDII and short-run asymmetric relationships between positive shocks and negative shocks in MD and R&D. In equation 4, long-run asymmetric relationships exist between positive shocks and negative shocks in GCF, while short-run asymmetric relationships exist between positive shocks and negative shocks in ID.

Table 2.12: Panel Nonlinear Autoregressive Distributed Lag Model of Equations 3 and 4

	Dependent Variable: LPCGDP		Dependent Variable: LFDII	
Variables	**Coefficients**	**Probability**	**Coefficients**	**Probability**
Long run				
FDII_POS	−0.488	0.004*	–	–
FDII_NEG	−0.598	0.125	–	–
EX_POS	1.346	0.000*	13.188	0.223
EX_NEG	1.246	0.000*	12.371	0.206
EYS_POS	4.099	0.317	−0.471	0.317
EYS_NEG	4.057	0.317	0	0
RD_POS	0	0	−4.589	0.317
RD_NEG	−1.439	0.704	5.471	0.190
ID_POS	0.351	0.016*	−1.752	0.034**
ID_NEG	0.243	0.346	−28.780	0.313
PCEPC_POS	−3.631	0.420	−14.121	0.485
PCEPC_NEG	−3.566	0.473	−2.731	0.683
MD_POS	−0.216	0.155	0.209	0.942
MD_NEG	−0.806	0.097***	1.144	0.848
CPI_POS	1.310	0.335	−0.898	0.002*
CPI_NEG	0	0	0	0
PCGDP_POS	–	–	18.453	0.308
PCGDP_NEG	–	–	−19.784	0.317
GCF_POS	–	–	−3.185	0.002*
GCF_NEG	–	–	−3.345	0.001*
Short run				
DFDII_POS(-1)	0.045	0.000*	–	–
DFDII_NEG(-1)	0.056	0.000*	–	–
DEX_POS(-1)	−0.323	0.387	0.122	0.770
DEX_NEG(-1)	−0.328	0.395	0.238	0.317
DEYS_POS(-1)	0.048	0.275	−0.366	0.489
DEYS_NEG(-1)	0	0	0	0
DRD_POS(-1)	−0.492	0.088***	−6.306	0.339
DRD_NEG(-1)	−0.335	0.399	−7.380	0.011*
DID_POS(-1)	−0.002	0.907	−2.190	0.000*
DID_NEG(-1)	0.017	0.638	−2.390	0.000*

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Table 2.12 *continued*

	Dependent Variable: LPCGDP		Dependent Variable: LFDII	
Variables	Coefficients	Probability	Coefficients	Probability
DPCEPC_POS(-1)	−0.092	0.296	−0.307	0.277
DPCEPC_NEG(-1)	−0.115	0.317	0	0
DMD_POS(-1)	0.051	0.617	0.640	0.760
DMD_NEG(-1)	0.106	0.424	0.253	0.852
DCPI_POS(-1)	−0.257	0.187	0.076	0.317
DCPI_NEG(-1)	−0.225	0.317	0	0
DPCGDP_POS(-1)	–	–	−10.279	0.317
DPCGDP_NEG(-1)	–	–	0	0
DGCF_POS(-1)	–	–	−6.864	0.000*
DGCF_NEG(-1)	–	–	−6.976	0.000*
Constant	0.992	0.318	−28.077	0.000*
ECT	−0.091	0.000*	−0.403	0.001*

Note: *, **, and *** indicate significance at the 1%, 5%, and 10% levels, respectively.

Source: Authors' computation from the World Development Indicators, United Nations Conference on Trade and Development, and United Nations Development Programme data.

Table 2.13: Long-Run and Short-Run Asymmetric Tests

	Dependent Variable: LPCGDP				Dependent Variable: LFDII			
	Long-run Asymmetry		Short-run Asymmetry		Long-run Asymmetry		Short-run Asymmetry	
Variables	χ^2	Probability	χ^2	Probability	χ^2	Probability	χ^2	Probability
LPCGDP	–	–	–	–	1.02	0.313	1.00	0.317
LMD	0.64	0.423	3.76	0.053**	0.09	0.764	0.27	0.602
LID	2.61	0.106***	0.89	0.344	0.85	0.358	10.03	0.001*
LPCEPC	3.49	0.062***	0.80	0.370	0.71	0.399	1.18	0.277
LR&D	1.18	0.278	5.34	0.021**	1.32	0.251	0.08	0.772
LEX	0.05	0.826	0.13	0.722	0.62	0.432	0.41	0.523
LEYS	1.00	0.317	1.00	0.318	1.00	0.317	0.48	0.489
LFDII	36.32	0.000*	0.69	0.406	–	–	–	–
LCPI	0.22	0.638	0.98	0.323	9.21	0.002	1.00	0.317
LGCF	–	–	–	–	6.09	0.014*	0.67	0.412

Note: *, **, and *** indicate significance at the 1%, 5%, and 10% levels, respectively.

Source: Authors' computation from the World Development Indicators, United Nations Conference on Trade and Development, and United Nations Development Programme data.

2.8 Conclusions and Policy Implications

To conclude, it is possible to state that both internet and mobile density (proxies for telecommunication infrastructure/digitization) have significant positive impacts on the economic growth of India and the PRC. The study found that the expected years of schooling (a proxy for human capital), foreign direct investment inflow, gross capital formation, per capita electricity power consumption (a proxy for electricity infrastructure), research and development expenditure, and consumer price index have positive impacts on the per capita GDP of India and the PRC. It also showed that the PRC extracts relatively more from these growth-promoting factors than India, probably indicating greater allocative efficiency.

The findings of the study may have some policy implications for both the upcoming giant economies of Asia. Both countries should enhance their digitization movement to provide internet facilities. Both the economies have huge population strength, which they should transform into human resources through education and by imparting skills. India needs to attract a huge amount of FDI inflows to develop its physical infrastructure, which will boost the economic growth. Further, India and the PRC need to increase their R&D expenditure to achieve innovation and economic development.

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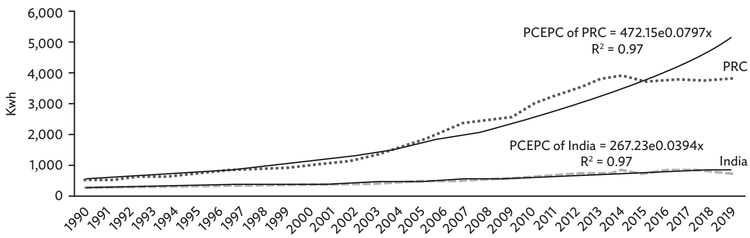
Appendix A2.1

Figure A2.1.1: Trend of Per Capita Electricity Power Consumption



kWh = kilowatt-hour, PCEPC = per capita electricity power consumption, PRC = People's Republic of China.

Note: The dotted lines show the actual values. The solid lines indicate the fitted/estimated values.

Source: Authors' illustration based on the World Development Indicators data.

Table A2.1.1: Annual Average Growth Rate of PCEPC

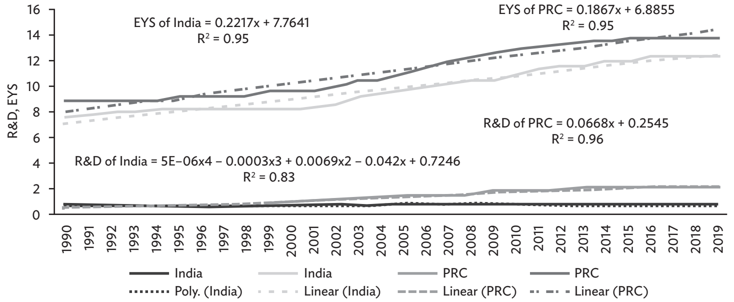
	India	PRC		
Period	PCEPC	PCEPC	Difference/ Intercept	Coefficient
1991–2000	3.79	6.91	3.79* (4.68)	3.12**(2.72)
2001–2010	5.01	11.53	5.01* (5.18)	6.52 (4.76)
2011–2019	2.26	3.00	2.26(1.45)	0.74 (0.34)
1991–2019	3.74	7.29	3.74* (4.71)	3.55* (3.17)

PCEPC = per capita electricity power consumption, PRC = People's Republic of China.

Note: * and ** indicate significance at the 1% and 5% levels, respectively. (The figures in parentheses represent the t-statistics.)

Source: Authors' estimation from the World Development Indicators data.

Figure A2.1.2: R&D and EYS Trends



EYS = expected years of schooling, PRC = People's Republic of China, R&D = research and development.

Source: Authors' illustration based on data from the World Development Indicators and United Nations Development Programme.

Table A2.1.2: Annual Average Growth Rate of R&D and EYS

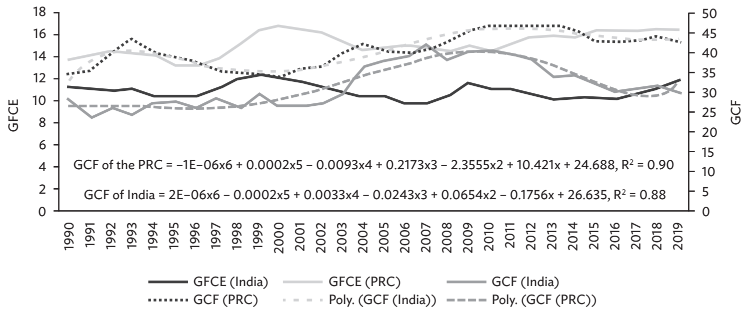
	India		PRC		Difference/ Intercept		Coefficient	
Period	**R&D**	**EYS**	**R&D**	**EYS**	**R&D**	**EYS**	**R&D**	**EYS**
1991–2000	1.35	0.89	4.35	0.88	1.35 (0.64)	0.89** (2.58)	3.00 (1.01)	−0.007 (−0.014)
2001–2010	0.51	2.68	6.81	3.00	0.51 (0.35)	2.68* (5.19)	6.30* (3.09)	0.32 (0.44)
2011–2019	−1.90	1.47	2.58	0.84	−1.90** (−2.47)	1.47* (3.62)	4.48* (4.11)	−0.63 (−1.10)
1991–2019	0.05	1.69	4.65	1.60	0.05 (0.06)	1.69* (5.75)	4.60* (3.50)	−0.09 (−0.21)

EYS = expected years of schooling, PRC = People's Republic of China, R&D = research and development.

Notes: * and ** indicate significance at the 1% and 5% levels, respectively. The figures in parentheses represent the t-statistics.

Source: Authors' estimation from the data from the World Development Indicators and United Nations Development Programme.

Figure A2.1.3: Trends of GFCE and GCF



GCF = gross capital formation, GFCE = government final consumption expenditure, PRC = People's Republic of China.

Source: Authors' illustration based on the World Development Indicators data.

Table A2.1.3: Annual Average Growth Rate of GFCE and GCF

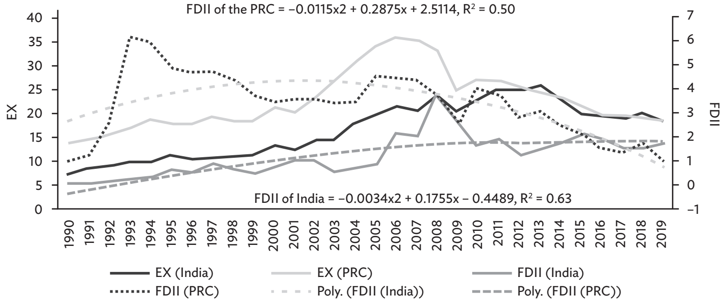
	India		PRC		Difference/ Intercept		Coefficient	
Period	**GFCE**	**GCF**	**GFCE**	**GCF**	**GFCE**	**GCF**	**GFCE**	**GCF**
1991–2000	0.65	−0.31	2.21	0.01	0.65 (0.47)	−0.31 (−0.13)	1.56 (0.80)	0.32 (0.09)
2001–2010	−0.71	4.47	−1.40	3.39	−0.71 (0.59)	4.47** (2.20)	−0.69 (−0.41)	−1.08 (−0.38)
2011–2019	0.79	−3.03	6.32	−0.82	0.79 (0.88)	−3.03** (−2.54)	5.53 (0.42)	2.21 (1.31)
1991–2019	0.22	0.49	0.69	0.91	0.22 (0.32)	0.49 (0.40)	0.47 (0.47)	0.42 (0.24)

GCF = gross capital formation, GFCE = government final consumption expenditure, PRC = People's Republic of China.

Notes: ** indicates significance at the 5% level. The figures in parentheses represent the t-statistics.

Source: Authors' illustration based on the World Development Indicators data.

Figure A2.1.4: Trends of EX and FDII



EX = exports, FDII = foreign direct investment inflows, PRC = People's Republic of China.

Source: Authors' illustration based on the World Development Indicators data.

Table A2.1.4: Annual Average Growth Rate of EX and FDII

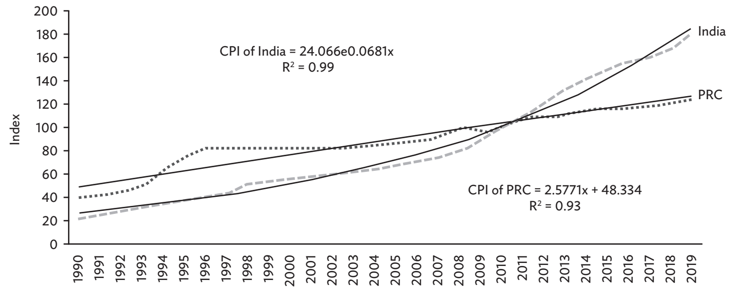
	India		PRC		Difference/ Intercept		Coefficient	
Period	EX	FDII	EX	FDII	EX	FDII	EX	FDII
1991–2000	6.52	49.90	4.58	23.04	6.52* (2.20)	49.90*** (2.07)	−1.94 (−0.62)	−26.86 (−0.79)
2001–2010	6.08	18.30	3.45	3.71	6.08 (1.64)	18.30 (1.34)	−2.63 (−0.50)	−14.59 (−0.76)
2011–2019	−1.76	2.83	4.20	−11.82	−1.76 (−0.93)	2.83 (0.43)	−2.44 (−0.91)	−14.65 (−1.59)
1991–2019	3.80	24.40	1.47	5.56	3.80** (2.24)	24.40** (2.45)	−2.33 (−0.97)	−18.84 (−1.34)

EX = exports, FDII = foreign direct investment inflows, PRC = People's Republic of China.

Notes: *, **, and *** indicate significance at the 1%, 5%, and 10% levels, respectively. The figures in parentheses represent the t-statistics.

Source: Authors' illustration based on the World Development Indicators data.

Figure A2.1.5: Trend of CPI



CPI = consumer price index, PRC = People's Republic of China.

Note: The dotted lines show the actual values. The solid lines indicate the fitted/estimated values.

Source: Authors' illustration based on the United Nations Conference on Trade and Development data.

Table A2.1.5: Annual Average Growth Rate of CPI

	India	PRC		
Period	CPI	CPI	Difference/ Intercept	Coefficient
1991–2000	9.05	7.48	9.05* (4.40)	−1.57 (−0.54)
2001–2010	6.33	1.56	6.33* (7.44)	−4.17* (−3.47)
2011–2019	6.81	2.53	6.81* (9.96)	−4.28* (−4.43)
1991–2019	7.41	3.26	7.41* (8.71)	−3.31* (−2.75)

CPI = consumer price index, PRC = People's Republic of China.

Notes: * indicates significant at the 1% level. The figures in parentheses represent the t-statistics.

Source: Authors' illustration based on the World Development Indicators data.

Appendix A2.2

Table A2.2.1: Results of the Panel Unit Root Tests

Variables	ADF (Fisher χ^2)		ADF (Choi Z stat)		Levin–Lin–Chu		Im–Pesaran–Shin	
	Level	First Difference	Level	First Difference	Level	First Difference	Level	First Difference
LPCGDP	0.830	17.725*	2.970	−2.549*	−0.139	−2.322*	2.952	−2.932*
LMD	13.627*	12.883*	−2.576*	−2.195*	−0.801	−3.378*	−2.516*	−2.304*
LID	39.400*	14.326*	−5.426*	−2.698	−7.252*	−1.940**	−6.459*	−2.656*
LPCEPC	0.910	6.223	1.238	−0.917	−0.820	0.570	0.751	−0.100
LR&D	1.027	25.461*	1.206	−4.135*	0.119	−3.166*	1.173	−4.568*
LGFCE	10.224**	11.184**	−2.010**	−2.029**	−1.240***	−1.616**	−1.908**	−2.017**
LEX	5.815	13.687*	−0.951	−2.493*	−1.970**	−1.432***	−0.901	−2.508*
LGCF	3.582	13.336*	−0.214	−2.525*	−0.683	−1.090	−0.221	−2.499*
LEYS	1.099	11.025**	1.270	−1.301***	−0.700	−1.031	1.036	−1.479***
LFDII	3.094	29.956*	1.642	−4.443*	1.759*	−5.460*	1.588	−5.237*
LCPI	0.226	27.252*	2.261	−4.060*	0.834	−4.576*	1.769	−4.596*

Variables	Breitung		PP (Fisher χ^2)		PP (Choi Z stat)	
	Level	First Difference	Level	First Difference	Level	First Difference
LPCGDP	1.400	−1.483***	2.379	19.065*	3.124	−2.775*
LMD	0.893	−1.017	18.882*	18.291*	−2.050**	−2.244*
LID	−1.463***	−6.735*	12.898*	24.752*	−1.981**	−4.023*
LPCEPC	1.238	−1.017	1.983	10.053**	0.397	−1.773**
LR&D	0.804	−3.568*	1.355	26.214*	0.980	−4.219*
LGFCE	−0.930	−3.471*	3.807	13.169*	−0.408	−2.471*
LEX	2.216	−5.545*	5.926	28.323*	−1.015	−4.365*
LGCF	−0.670	−2.856*	3.063	28.723*	−0.075	−4.289*
LEYS	1.506	0.132	0.338	15.570*	1.978	−2.809*
LFDII	2.292	−2.393*	8.612***	28.531*	−1.658**	−4.286*
LCPI	−1.313***	−1.165	8.941***	9.744**	−1.271***	−1.831**

Note: *, **, and *** indicate significance at the 1%, 5%, and 10% levels, respectively.

Source: Authors' computation from the World Development Indicators, United Nations Conference on Trade and Development, and United Nations Development Programme data.

3

Is Digital Financial Inclusion Good for Bank Stability and Sustainable Economic Development? Evidence from Emerging Asia

Hasanul Banna and Md Rabiul Alam

3.1 Introduction

Digital financial inclusion (DFI) is not very different from the notion of financial inclusion (FI): It is the extension phase of FI where the notion of advanced technology is entertained. It has been widely discussed as a global issue in recent years (Ozili 2018) as it is seen as a change agent that can bring about a revolutionary development in the overall global financial sector. In this regard, Jamie Caruana, the General Manager of the Bank for International Settlements, told world financial analysts, "(they) have the opportunity—and indeed the responsibility—to prepare the standard-setting world for both the risks and the rewards of the digitization of financial services" (CGAP 2015). Basically, DFI denotes financial services that are carried out remotely in a cashless manner using different electronic devices from which both parties (e.g., providers and receivers) gain benefits (Klapper 2017).

Considering the undeniable importance and the prospects of DFI, banks of emerging Asian countries are on their way to implementing digital financial services (DFS) (e.g., fintech, e-wallet, and other cashless transactions) in a full-fledged manner, although many banks from different countries have already launched DFS in a minimal way and others are paving the way to doing so. This is because wider inclusion of easily accessible financial services helps banks attain stability (Ahamed and Mallick 2019), financial advancement (Demirgüç-Kunt et al. 2015), and a flourishing global financial sector (Iqbal and Llewellyn 2002). Like the global banking sector, banks in emerging Asian economies are also considering including DFS as they ensure banking stability, which sends out a message about the economic stability of any country and will consequently lead toward achieving the Sustainable Development Goals (SDGs) by 2030 (Banna et al. 2020). To attain the SDGs, economic sustainability is a must that can be ensured through the banking sector along with other financial sectors. Attainment of the SDGs becomes impossible without filling a huge investment gap. There is a $2.5 trillion investment gap to achieve the SDGs by 2030 (Wilson 2016), which can be reduced by the banking sector along with other financial institutions (Niculescu 2017).

To meet this huge investment gap for attaining the SDGs, scholars, and in particular financial analysts, foresee the prospects of DFI through a wider lens as it is the recent phase of FI, which played a great role during the 2007–2009 global financial crisis. The crisis caused a $15 trillion loss in the global financial sector (Ahmed et al. 2015). At that time, FI played a major role in retaining banking stability (Ahamed and Mallick 2019). Although FI has brought a myriad of positive changes and benefits for underprivileged and less developed people, sometimes its proper implementation and utilization has become a burden for those who are unable to afford it. Therefore, as well as its positive impacts, it also has negative impacts on the financial system, which could be distressingly affected by excessive financial innovations (Mani 2016). However, both the negative and positive effects of FI raise the question of whether the implementation of digital finance, the latest innovation of FI, in the emerging Asian banking sector can be a solution for attaining banking stability through ensuring sustainable economic development or not. Hence, this chapter aims to investigate, in the context of the emerging Asian banking industry, how DFI promotes banking stability through ensuring sustainable economic development.

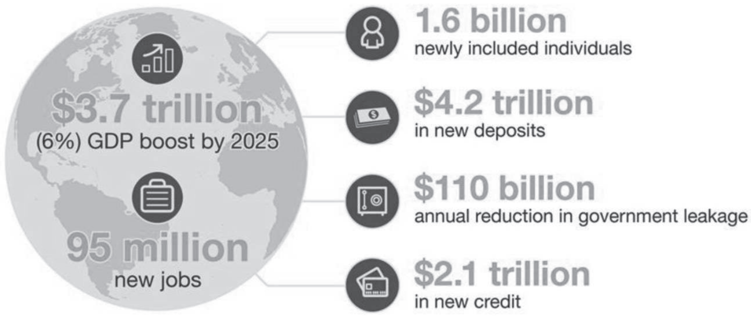
Despite general awareness of the unavoidable importance of the implementation of DFI, studies are very rarely found on this issue, except for a few like Ahamed and Mallick (2019), who demonstrate the impact of FI (but not DFI) in general on bank stability, and Ozili (2018) and Koh, Phoon, and Ha (2018), who outline the prospects and challenges of DFI, while Arner, Buckley, and Zetzsche (2018) sketch a framework for digital financial transformation. However, to the best of our knowledge, no such studies have yet attempted to investigate empirically the impact of DFI on emerging Asian banking stability through ensuring sustainable economic development. Thus, this empirical study fills the gap by examining the role of DFI, in the context of the emerging Asian banking sector, in spurring banking stability through ensuring sustainable economic development. The study has used the data of 574 banks from seven emerging Asian countries (the People's Republic of China [PRC], India, Indonesia, Malaysia, Pakistan, Thailand, and the Philippines) from 2011 to 2018 from the Orbis Bank Focus, Global Findex, and Financial Access Survey databases by deploying instrumental variable techniques using panel-corrected standard errors and two-stage least-squares. The results suggest that DFI brings banking stability and an integrated inclusion of digital finance by the emerging Asian banks is not merely a way of ensuring banking stability; rather, it ensures sustainable economic development that will ultimately lead to achieving the SDGs.

3.2 Literature Review

3.2.1 The Prospects of Digital Financial Inclusion at a Glance

The impacts and prospects of DFI are no longer abstract notions, and time demands their proper execution. The Executive Director of the Alliance for Financial Inclusion Alfred Hannig (2017) says: "The adoption of digital finance will have a significant impact not only on financial inclusion, but also inclusive economic growth." Highlighting the importance of DFI in their report, Manyika et al. (2016) present some important notes based on the findings of field visits to seven countries—Brazil, the PRC, Ethiopia, India, Mexico, Nigeria, and Pakistan—and more than 150 expert interviews. They report (as shown in Figure 3.1): "Digital finance has the potential to provide access to financial services for 1.6 billion people in emerging economies, more than half of them women. Widespread adoption and use of digital finance could increase the GDP of all emerging economies by 6%, or USD3.7 trillion, by 2025," which is equivalent to the size of the economy of Germany. Moreover, 95 million new jobs would be created in all sectors across the world through this additional gross domestic product (GDP). Since GDP is seen as a key development index of an economy, the implementation of DFI in the Islamic banking sector will contribute to enhancing GDP, which will help to alleviate poverty and ultimately lead to inclusive economic growth to achieve the SDGs.

Figure 3.1: The Impacts and Prospects of Digital Finance Inclusion



GDP = gross domestic product.

Source: Manyika et al. (2016).

3.2.2 Relevant Studies

Since DFI is the most updated phase of FI, and they both are interconnected, this section gives an account of both the terms and their relation to bank stability and sustainable economic growth. In recent years, DFI has been a much discussed issue in the world and is seen as a revolutionary innovation in the field of finance and banking. In their study, Siddik and Kabiraj (2020) show the impact of digital finance on FI and proper implementation of DFI can spur sustainable economic growth by eradicating poverty. Poverty is more visible among rural and underprivileged people, who are usually neglected in most of the developed society, which hinders the ultimate financial growth of any country. These types of deprived people can be included in formal financial services by implementing DFI properly. Ozili (2018) illustrates that the key aim of DFI is to provide formal financial services to the poor, rural, and underprivileged or unbanked people, which has a long-run impact on banking performance. Inclusion of people in formal financial services helps banks to be financially stable and consequently benefits the government through generating higher tax revenue (Manyika et al. 2016). Such types of financial services are delivered via smartphones, personal computers, or laptops, which need an internet connection (Manyika et al. 2016).

According to Gomber, Koch, and Siering (2017), DFS include innovative financial products, finance-related software, and a great way of interacting and communicating with customers provided by fintech and other finance-related service providers (e.g., BigTech firms). They can transform operations from cash-based to cashless transactions where people need a mobile phone, which almost 50% of people in developing countries own (World Bank Group 2013). Most of the countries of the world are turning to these services. According to Pénicaud and Katakam (2019), more than 80 countries around the world are launching DFS through mobile phones as they bring welfare to the people (CGAP 2015).

Proper application of DFI increases the profitability of banks, which brings financial growth and stability (Ozili 2018). García and José (2016) show that FI and financial stability move in parallel and financial stability is an indicator of banking stability. Reviewing the existing literature, they also show the nexus between FI and financial stability. Being the recent phase of FI, scholars reckon that DFI is more effective in terms of ensuring financial stability, which indicates banking stability.

As DFI is an ongoing research topic, empirical studies showing the impact of DFI are very scarce. A recent study by Klapper, Miller, and Hess (2019) shows that through DFS, informal business institutions can be registered as formal business institutions and help the government to collect taxes more easily by enforcing laws since all records are available in the database with no way to evade payment. More tax collection contributes to the national revenue sector and eventually makes the country's economic growth stable.

Before launching DFI in full swing, the prime focus should be on financial literacy. Financial literacy is an inseparable part of DFI that enables individuals to enhance financial resilience. In fact, globally only 33% of all adults have financial knowledge—that is, they understand at least three out of four main financial literacy issues, such as knowledge of inflation, interest rates, risk diversification, and compounding interest, which are essential for decision-making in financial affairs (Klapper and Lusardi 2020). Moreover, through the proper application of DFI, the gender gap in FI can be minimized. In most developing economies, women are still lagging in terms of having a formal bank account. In this regard, the study of Sioson and Kim (2019) shows that DFI plays a significant role in reducing the gender gap in financial services.

Moreover, inclusive finance brings banking stability and economic sustainability. Taking a sample of 31 Asian countries from 2004 to 2016, the empirical study of Li, Wu, and Xiao (2020) finds that FI has an enormous positive influence on financial sustainability. The empirical study of Neaime and Gaysset (2018) on countries in the Middle East and North Africa shows a very close association between FI and bank stability. Beck, Senbet, and Simbanegavi (2014) say that FI is viewed as an important driver of the financial growth and stability of the banking sector. The empirical study of Ahamed and Mallick (2019) also finds a very significant impact of FI on bank stability. In some cases, FI seems to be incomplete without the implementation of DFI, which plays a key role in accelerating financial inclusion. The empirical study of Senou, Ouattara, and Acclassato Houensou (2019) in the context of West Africa shows that the affordability, accessibility, and availability of DFI should be taken into account to accelerate FI in that region. Moreover, DFI strengthens the functions of FI since, as already stated, the nexus between FI and DFI is very strong, and DFI fills the gap of FI by implementing the latest technological innovation (Moufakkir and Mohammed 2020). Another study by Banna et al. (2020) shows that FI after the global financial crisis played a very significant role in promoting banking efficiency where it was eventually suggested that DFI should be implemented in the banking sector to keep pace with the competitive world that will help ensure banking stability and spur sustainable economic development.

So, realizing the impact of DFI found through previous studies, emerging Asian banks are on the way toward implementing DFI in full. Although a considerable number of empirical and theoretical studies pertinent to the role of FI, DFI, banking stability, and sustainable economic development exist, very few studies, in the context of emerging Asian banks, have attempted to empirically investigate the impact of DFI on banking stability that eventually leads to sustainable economic development. Since it is evident from the existing literature that the integration of digitalization in financial inclusion is a noble mechanism for reaching out to the people with more convenient financial support through the utilization of technologies, the current study endeavors to dig deep into the opportunities and impacts of DFI to achieve banking stability through sustainable economic development. The existing literature, however, has limitations in exploring the impacts of DFI on banking stability through sustainable economic development, although there are a few studies measuring the impact of financial inclusion on banking stability through sustainable economic development. Thus, it is hoped that the proposed study will add value to the prompt implementation of DFI in the emerging Asian banking sector that will ultimately facilitate the achievement of sustainable operations of financial institutions and ensure banking stability through sustainable economic development.

3.3 Methodology

This study examines the impact of DFI and the effect of its interaction with GDP on banking stability in emerging Asia to see how DFI helps to achieve banking stability through sustainable economic development. The following data and methods have been used to analyze the relationships.

3.3.1 Data

Although a good number of financial companies along with the banking sector render finance-related services, this study only considers the data of the banking sector—and more specifically, the emerging Asian banking sector. This is because, the Asian financial crisis was mainly the result of banking and currency problems that attracted the interest of the concerned authorities to surmount the crisis by ensuring Asian banking stability. This region has also drawn the attention of scholars as it has experienced rapid growth in different sectors such as industrialization, trade, and commerce, etc., where the PRC and India are in leading positions. The study considers seven emerging Asian countries: the PRC, India, Indonesia, Malaysia, Pakistan, the Philippines, and Thailand. We consider these emerging Asian countries as their main agenda is to perform financial activities in a cashless manner, which is also the prime aim of DFI. More specifically, the governments of these countries are willing to implement the digital banking system in full swing. Thus, many of these countries' financial institutions have started to provide digital financial services, for example, Alipay, Wechat pay, etc. (PRC); PayTM, Yono by SBI, ICICI pockets, etc. (India); QR pay, Boost pay, etc. (Indonesia); May Bank QR pay, CIMB pay, TnG E-wallet, etc. (Malaysia); EasyPaisa, JazzCash, UBL Omni, etc. (Pakistan); Banko, BDO, Bitbit, etc. (Philippines); and True Money wallet, Omise, etc. (Thailand).

Initially, the study took the annual data of 600 commercial banks from all seven emerging Asian countries. After that, due to data unavailability and missing values, some banks were excluded from the sample. Finally, the unbalanced panel data of 574 banks over the 2011–2018 period were considered. The reason for considering this period is that we want to study the aftereffects of the global financial crisis on banking stability, and data on DFI or FI are available from 2011 and onward. The proportions of the sample size in our analysis are given in Table 3.1, in which the PRC carries the highest percentage (40%), followed by Indonesia (20%) and the Philippines (12%). Data were taken from various sources: (i) the Orbis Bank Focus database for bank-specific data; (ii) the Financial Access Survey, International Monetary

Fund, and Global Findex databases for DFI data; and (iii) the World Development Indicators, World Bank database, and previous literature for macroeconomic variables and instrument data.

Table 3.1: List of Countries and Number of Banks in the Study

Country	Number of Banks	Observations	Sample %
People's Republic of China	229	1,832	40
India	55	440	10
Indonesia	114	912	20
Malaysia	48	384	8
Pakistan	33	264	6
Philippines	69	552	12
Thailand	26	208	5
Total	**574**	**4,592**	**100**

Source: Authors' compilation.

3.3.2 Methods

Bank Stability

Following Kim, Batten, and Ryu (2020), this study uses two financial stability measures: Z-score and Sharpe ratio. The Z-score has gained wider acceptance in the banking and finance literature and has been considered an unbiased parameter of bank riskiness (Fang, Hasan, and Marton 2014), also called "distance to default." It is measured in the following way:

$$Z - score_{it} = \frac{ROAA_{it} \ + EQT_{it}}{\sigma(ROAA)_{it}} \tag{1}$$

where $ROAA_{it}$ is the return on average assets, EQT_{it} the equity-to-assets ratio, and $\sigma(ROAA)_{it}$ the standard deviation of the ROAA of bank i in year t, respectively. The score can be interpreted in such a way that if the mean is higher than the number of standard deviations, the returns will have to fall down before all equity in the bank becomes depleted (Ahamed and Mallick 2019). The natural logarithm of the Z-score has been used in this study in order to minimize the skewness.

Furthermore, following Yin (2019), this study also considers the Sharpe ratio as another proxy for bank stability in the following way:

$$Sharpe\ ratio_{it} = \frac{ROAE_{it}}{\sigma(ROAE)_{it}} \quad (2)$$

where $ROAE_{it}$ is the return on average equity and $\sigma(ROAE)_{it}$ the standard deviation of the ROAE of bank i in year t, respectively. The higher the ratio, the higher the banking stability, similar to the Z-score. Apart from these, the nonperforming loans (NPL) ratio is also considered an alternative proxy for bank stability in which a lower ratio represents higher stability.

Digital Financial Inclusion Proxies

As the purpose of this study is to test the effect of DFI on the stability of emerging Asian banks to promote inclusive economic growth, digital financial proxies have been measured using the data from the Financial Access Survey database over the 2011–2018 period. In this regard, both the digital financial outreach and usage penetrations have been considered for DFI based on previous studies (e.g., Ahamed and Mallick 2019; Banna and Alam 2020; Banna et al. 2020; Banna, Hassan, and Alam 2020). However, the selection of proxies is different from the previous studies as they considered FI, whereas this study considers DFI. As a part of geographic and demographic outreach penetration (known as "supply side"), the number of ATMs and mobile money agent outlets per 100,000 adults and per 1,000 square kilometers (km^2) have been considered, while the number of mobile money accounts per 1,000 adults and the number of mobile and internet banking transactions per 1,000 adults have been considered as a part of the usage of digital financial service penetration (known as "demand side"). In addition, we consider "Made or received digital payments in the past year (% age 15+)" as a proxy for DFI to discover the robustness of our study. However, due to data unavailability of some DFI components we could not develop a single index of DFI using principal component analysis.

Bank-Specific and Macroeconomic Variables

We control both the bank-specific and macroeconomic variables. Following Fang, Hasan, and Marton (2014), the ratio of total loans to total assets (Loan ratio – *B_LR*) has been used to account for the liquidity risk of a particular bank. To control the potential size effect and the loan portfolio risk of an individual bank, the study has considered the logarithm of total assets (Bank size – *B_SIZE*) and the ratio of loan loss provision to total loans (Loan loss provision – *B_LLP*), respectively.

The ratio of other operating income to total operating income (Revenue diversification – *B_RD*) has been considered to control the ambiguous effect of off-balance sheet activities. Since excessive risk-taking tendency can be reduced by better management quality, the ratio of total earning assets to total assets (Management quality – *B_MQ*) has been taken into consideration. The equity ratio (Capitalization – *B_CAP*) has been used to control the capital risk as well-capitalized banks have a lower risk-taking tendency. The Herfindahl-Hirschman Index (*B_HHI*) has been used for controlling market concentration. The specialization (*B_SP* – whether an Islamic or conventional bank) and listing (*B_LIST* – whether the bank is listed with the stock market or not) have also been controlled. This chapter uses several macroeconomic variables, such as consumer price index to control inflation (*B_INF*) and good governance (*B_GG*) to control institutional effect. A good governance index is constructed using the standardized approach of Kaufmann, Kraay, and Mastruzzi's (2010) governance indicators, which consist of six components: Government Effectiveness, Control of Corruption, Regulatory Quality, Political Stability and Absence of Violence/Terrorism, Voice and Accountability, and Rule of Law.

For the economic growth or development proxy, this study uses annual GDP growth (*B_GDP*), which is also considered as business cycle and economic growth. The interaction between DFI and GDP is considered as an inclusive economic growth or sustainable economic development like in Banna and Alam (2020).

Estimation Technique

To examine the impact of DFI and the effect of its interaction with GDP on emerging Asian banking stability, the following baseline regression analysis has been used in this study:

$$Y_{ijt} = \alpha + \beta DFI_{jt} + \gamma Z_{ijt} + \vartheta M_{jt} + \varphi(B\_GDPxDFI)_{j,t} + \varepsilon_{ijt} \quad (3)$$

where, Y_{ijt} = *ln*(Z-score) and *ln*(*Sharpe ratio*) are dependent variables that are considered as a proxy for bank stability of bank *i* of country *j* in year *t*. DFI_{jt} is the DFI proxy in which the individual components of country *j* in year *t* have been considered for the analysis. Z_{ijt} are s the bank-specific factors of bank *i* of country *j* in year t (such as *B_SIZE*, *B_LR*, *B_LLP*, *B_RD*, *B_MQ*, *B_CAP*, *B_HHI*, *B_SP*, and *B_LIST*). M_{jt} are the macroeconomic factors of country *j* in year *t* (such as *B_INF*, *B_GDP*, and *B_GG*). $(B\_GDPxDFI)_{j,t}$ is the interaction effect of GDP and DFI of country *j* in year *t*. And β, γ, ϑ, φ are coefficients of the variables, and ε_{ijt} the error term.

Following Alfadli and Rjoub (2019), this study uses the panel-corrected standard errors method of Beck and Katz (1995) to examine the fundamental relationship between the variables. This method is used for two main reasons: i) it minimizes the existing problems of cross-sectional dependency and sequential correlation; and ii) it determines the likelihood of endogeneity among some of the regressors as well as regress and factors in a certain model using an appropriate instrument (Alfadli and Rjoub 2019). Moreover, following Kim, Batten, and Ryu (2020), the panel two-stage least-squares – instrumental variables (2SLS-IV) method has been used to mitigate possible endogeneity issues for the robustness of the results.

3.4 Results and Analysis

The outcomes of the analysis of the relationship between bank stability as well as DFI and the interaction effect with GDP on bank stability are illustrated in this section.

3.4.1 Digital Financial Inclusion and Bank Stability

Descriptive Statistics

The descriptive statistics of bank stability, *B_SIZE*, *B_LR*, *B_LLP*, *B_MQ*, *B_CAP*, *B_RD*, *B_HHI*, *B_GDP*, *B_GG*, *B_INF*, and *DFI* are illustrated in Table 3.2. The table exhibits the descriptive statistics (mean, standard deviation [SD], and minimum–maximum values) of each variable in the sample. From this table, a few observations are particularly worthy of note. First, the *ln(Z-score)* has an average value of 4.53 with an SD of 1.48, indicating that to deplete bank equity, on average the ROAA would have to drop by 4.53 times their SD. The SD suggests that every year the level of bank stability varies among the sample countries. Moreover, the mean values of the bank size and SD are 8.61 and 2.32, respectively. Hence, such a high yearly variation can be seen in these results. The sample countries, on average, achieved 6.28% growth in their GDP over the period 2011 to 2018. Furthermore, the sample countries, on average, had 89 and 64 ATMs and mobile money agent outlets per 1,000 km^2 and per 100,000 adults, respectively. Moreover, the number of mobile money accounts and the number of mobile and internet money transactions per 1,000 adults were approximately 198 and 33,411, respectively.

In order to see the link between bank stability and DFI and the interaction effect of DFI with GDP on bank stability, initially the panel-corrected standard errors regression was considered. The study controls bank-specific variables such as *B_SIZE, B_LR, B_LLP, B_MQ, B_CAP, B_RD*, and *B_HHI* and macroeconomic variables such as *B_GDP*, *B_GG, and B_INF* for our analysis.

Table 3.2: Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Bank Stability					
Ln (Z-score) using ROAA	2,673	4.533	1.477	−2.748	10.28
Ln (Sharpe ratio) using ROAE	2,470	2.098	1.607	−4.882	8.781
Digital Financial Inclusion (DFI)					
Number of ATMs and mobile money agent outlets per 1,000 km^2	4,592	88.942	84.716	15.907	570.205
Number of ATMs and mobile money agent outlets per 100,000 adults	4,592	63.737	48.94	8.83	317.035
Number of mobile money accounts per 1,000 adults	2,760	198.218	201.976	.393	855.869
Number of mobile and internet money transactions (during the reference year) per 1,000 adults	2,760	33,411	71,757.85	36.251	400,000
Made or received digital payments in the past year (% age 15+)	4,592	39.892	18.098	7.76	70.42
Bank-Specific					
Bank size (B_SIZE)	3,372	8.61	2.321	−1.941	15.212
Loan ratio (B_LR)	3,354	.532	.174	0	1.747
Loan loss provision ratio (B_LLP)	3,005	.006	.014	−.079	.426
Management quality (B_MQ)	3,367	.839	.1	.006	.997
Capitalization (B_CAP)	3,372	.135	.144	−2.236	.997
Revenue diversification (B_RD)	3,222	29.421	29.239	−178.056	553.863
Herfindahl-Hirschman index (B_HHI)	4,592	.095	.02	.063	.138
Macroeconomic					
Good governance index (B_GG)	4,592	.417	.131	.064	.801
GDP growth (B_GDP)	4,592	6.277	1.493	.84	9.55
Inflation (CPI) (B_INF)	4,592	3.605	2.266	−.9	11.92
Instrumental Variables					
Mobile cellular subscriptions (per 100 people) – Mobile Share	4,592	.903	.011	.868	.92
Borrowed from family or friends (% age 15+)	4,592	32.048	7.847	7.65	48.65

GDP = gross domestic product, ROAA = return on average assets, ROAE = return on average equity.
Source: Orbis Bank Focus, World Development Indicators, and Financial Access Survey.

We designed our analysis based on two main dimensions of bank stability: ln(z-score) (models 1–4) and ln(Sharpe ratio) (models 5–8). Based on DFI, we designed two main penetrations and four subpenetrations: financial outreach (both geographic and demographic) penetrations, with ATMs and mobile money agent outlets per 1,000 km^2 (models 1 and 5) and per 100,000 adults (models 2 and 6); and financial usage penetration of the customers, with number of mobile money accounts per 1,000 adults (models 3 and 7) and money transactions per 1,000 adults (models 4 and 8).

The findings (in Table 3.3) show that DFI has a positive relationship with emerging Asian banking stability for both the measures of bank stability. The results suggest that a higher level of DFI is significantly related to a higher level of banking stability (a high Z-score and Sharpe ratio indicate greater stability, i.e., less risk taking). Although the usage penetrations have an insignificant positive relationship in most cases, the financial outreach penetrations (both geographic and demographic) have a stronger association with bank stability. This suggests that DFI enriches the soundness of individual banks in the sample countries. These findings are similar to those of previous studies (e.g., Ahamed and Mallick 2019; Banna, Hassan, and Alam 2020; Morgan and Pontines 2014) that show that a financial system with inclusive DFS tends to strengthen banking stability, and that a greater implementation of DFI reduces the excessive risk-taking tendency of a particular bank.

However, the insignificant positive effect of usage dimensions of DFI suggests that in the sample countries, banks and other fintech companies have provided sufficient access to finance but people are still lagging behind in adopting it. This can be explained by the following facts. First, the practice of digital finance among the citizens of the sample countries is at a very early stage and it takes some time to impact significantly on banking stability and consequently the economy as a whole. This is because when a country adopts a new technology, it takes a long drive to reach maturity level or to cope with the existing development patterns (Banna 2020), which is also referred to as “drive to maturity” by the Stages of Economic Growth model of Rostow (1959). Second, this could be due to a lack of financial literacy among people. This is because, to digitalize financial services and bring consumers and businesses under this digitalization, it is necessary to promote and strengthen digital financial literacy among people (Morgan, Huang, and Trinh 2019). Third, BigTech financial companies dominate the digital financial market by making lucrative offers to their clients (e.g., no credit score required to get loans, consumer finance service facilities, etc.) (Stulz 2019), which can discourage them from using banking services and/or products. Fourth, high-speed or uninterrupted internet, like 3G, 4G, or 5G, which is the latest internet connection, is required for smooth operation of DFI, but this is still unavailable in many countries around the world (Ozili 2018), and internet facilities in some countries are not up to the mark or they have slower internet, resulting in buffering,

Table 3.3: Panel-Corrected Standard Errors Regression

	Ln (Z-score)				Ln (Sharpe ratio)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
DFI	0.877***	1.389***	0.118	0.457***	0.665***	1.237***	−0.195	0.196
	(0.200)	(0.212)	(0.139)	(0.156)	(0.217)	(0.246)	(0.159)	(0.185)
GDP growth	−0.750***	−1.067***	0.022	0.348*	−0.436*	−0.835***	−0.224	0.015
	(0.214)	(0.151)	(0.127)	(0.200)	(0.237)	(0.185)	(0.146)	(0.245)
DFI*B_GDP	0.129***	0.237***	−0.032	−0.052**	0.082*	0.194***	0.028	−0.006
	(0.045)	(0.035)	(0.026)	(0.024)	(0.048)	(0.042)	(0.030)	(0.029)
B_SIZE	0.198***	0.207***	0.149***	0.166***	0.255***	0.262***	0.265***	0.280***
	(0.021)	(0.021)	(0.030)	(0.030)	(0.022)	(0.021)	(0.031)	(0.031)
B_LR	0.947***	0.988***	0.733	0.640	1.893***	1.926***	1.843***	1.658***
	(0.325)	(0.321)	(0.469)	(0.441)	(0.279)	(0.277)	(0.372)	(0.369)
B_LLP	−27.999***	−27.074***	−26.827***	−26.024***	−71.760***	−69.501***	−70.903***	−66.546***
	(3.840)	(3.687)	(3.648)	(3.548)	(6.963)	(7.015)	(7.819)	(7.660)
B_MQ	0.839**	1.108**	0.464	0.952*	0.118	0.299	−0.023	0.674
	(0.425)	(0.434)	(0.538)	(0.553)	(0.478)	(0.488)	(0.586)	(0.600)
B_CAP	2.635***	2.690***	2.771***	2.746***	−0.623	−0.560	0.042	−0.113
	(0.382)	(0.379)	(0.460)	(0.460)	(0.404)	(0.393)	(0.437)	(0.419)
B_RD	−0.003**	−0.003*	−0.005**	−0.005**	−0.003	−0.003	−0.006*	−0.006*
	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)
B_HHI	7.901**	1.280	0.202	7.987*	1.686	−3.479	−0.124	8.606*
	(3.501)	(2.999)	(4.750)	(4.569)	(3.791)	(3.187)	(5.314)	(4.778)
B_GG	−0.104	0.327	1.045**	0.201	−1.452***	−1.141***	−1.246***	−1.951***
	(0.301)	(0.280)	(0.427)	(0.438)	(0.329)	(0.292)	(0.438)	(0.491)
B_INF	−0.087***	−0.075***	−0.035	0.029	−0.068***	−0.072***	−0.098***	−0.045
	(0.017)	(0.019)	(0.029)	(0.028)	(0.020)	(0.022)	(0.033)	(0.033)
B_SP	0.344*	0.273	0.504**	0.460**	−0.078	−0.102	0.012	−0.026
	(0.176)	(0.175)	(0.203)	(0.202)	(0.195)	(0.195)	(0.234)	(0.229)
B_LIST	0.087	0.102*	−0.013	−0.025	0.064	0.081	0.106	0.094
	(0.061)	(0.060)	(0.076)	(0.075)	(0.067)	(0.066)	(0.087)	(0.086)
Year fixed effect	Included	Included	Included	Included	Included	Included	Included	Included
Country fixed effect	Included	Included	Included	Included	Included	Included	Included	Included
Wald chi^2	355.28***	382.62***	286.90***	307.97***	423.24***	422.79***	247.63***	279.10***
Obs.	2,566	2,566	1,502	1,502	2,381	2,381	1,332	1,332
R-squared	0.177	0.181	0.204	0.213	0.166	0.167	0.163	0.172

Notes: Standard errors are in parenthesis. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Number of ATMs and mobile money agent outlets per 1,000 square kilometers (models 1 and 5). Number of ATMs and mobile money agent outlets per 100,000 adults (models 2 and 6). Number of mobile money accounts per 1,000 adults (models 3 and 7). Number of mobile and internet money transactions (during the reference year) per 1,000 adults (models 4 and 8).

Source: Authors' compilation.

server downtime, and network problems, which makes people reluctant to use DFS. Finally, account hacking and ATM card or SIM card cloning (ADB and Oliver Wyman 2017); forgetting the password of one's own card, e-wallet, or account; data privacy issues; loss of mobile phone; and cyber insecurity (Adeoti 2011) may prevent people from using the full-fledged facilities of DFS (Obiano 2009).

The study has found a positive association between economic growth (*B_GDP*) and banking stability as growth influences banking stability. However, the findings denote that, in most cases, GDP alone is negatively associated with banking stability in emerging Asian countries. Surprisingly, the interaction of *DFI* and *B_GDP* has a significantly positive relationship with banking stability. Such findings suggest that when *B_GDP* is associated with banking stability, it reflects a negative relation. However, when *DFI* interacts with *B_GDP*, the relationship with banking stability becomes strong and positive. The effect of interaction of DFI with GDP growth is considered because, while talking about the real or inclusive economic growth or sustainable economic development of any country, GDP emerges as one of the main determinants (Banna and Alam 2020; Banna, Hassan, and Alam 2020). GDP is considered a key indicator for a country's economic sustainability (Ben-David and Papell 1995) and GDP growth, for most countries, means overall economic development. However, for high-income countries, an increase or decrease in GDP does not necessarily have an impact, or has minimal impact, on their economic development. As both GDP and inclusive digital finance determine a country's economic growth, both of their interaction effects are thought to bring inclusive economic growth or sustainable economic development in an increasing manner.

The economic impact of the results, in particular, suggests that inclusive digital finance may help Asian banks lower costs by minimizing manual paperwork and documentation as well as maintaining fewer bank branches (Banna 2020; Banna, Hassan, and Alam 2020; Manyika et al. 2016). DFI, as an instrument, helps financial and monetary system regulators to reduce the level of inflation in both poor and developing countries by restricting the circulation of the amount of physical cash. Furthermore, DFI plays a significant role in enhancing the welfare of individuals and business sectors through which individuals can easily access funds in their bank accounts to perform financial transactions (CGAP 2015). Therefore, with an inclusive digital financial system, Asian banks enjoy greater financial stability through ensuring sustainable economic development.

In addition, *B_SIZE, B_LR, B_LLP, B_RD, B_HHI, B_CAP, B_INF*, and *B_*GG are also significant determinants of banking stability in emerging Asian economies.

Robustness Test: Instrumental Variables

Although possible reverse causality (endogeneity) is a common identification issue in any banking study, this study might be less concerned about endogeneity issues as it investigates the effect of DFI (a country-level indicator) on Asian banking stability (bank-level indicator). Nevertheless, in order to make the results more robust, following Kim, Batten, and Ryu (2020), this study used the 2SLS-IV technique.

We search the recent empirical studies on banking stability and financial inclusion to choose instrumental variables in order to address any potential endogeneity issue. Following Ahamed and Mallick (2019), this study considers the proportion of mobile cellular subscriptions (per 100 people) in other countries in the same region as an instrumental variable for the 2SLS-IV technique. We consider countries from East Asia, Southeast Asia, and South Asia. It is argued that banking operational costs as well as physical and financial infrastructural deficiencies can be reduced through good communication infrastructure (Beck, Demirgüç-Kunt, and Martínez-Pería 2007) and mass use of mobile phones (Allen et al. 2014). Hence, countries with a larger number of mobile subscriptions help to enable unbanked people to be banked, which will not directly affect bank stability but may influence DFI.

In addition, we consider the "percentage of adults borrowing from friends and family" as an instrumental variable. It is found that the key source of borrowing money in the developing countries is friends and family (Demirgüç-Kunt and Klapper 2012), and it is also evident that only 9% of adults borrow from formal financial sectors and 29% of adults borrow from friends and family. A higher percentage of adults borrowing from friends and family may influence DFI but does not directly affect bank stability (Ahamed and Mallick 2019).

The 2SLS-IV regression model does not change any result from the above analysis. Rather, it shows a stronger relationship between DFI and banking stability by providing a higher coefficient (Table 3.4). These findings make the panel-corrected standard errors regression results more robust and suggest that an inclusive digital financial system is positively associated with banking stability in emerging Asian countries. The interaction effect of *DFI* and *B_GDP* also make the above results more robust, which suggests that accelerating digital finance in the sample countries through ensuring sustainable economic development is a significant way of stabilizing the banking sector.

Apart from this, we also consider "the percentage of adults that made or received digital payments in the past year" as an alternative proxy of DFI from the Global Findex database. The results using an alternative proxy (Table 3.5) also make the previous results more robust.

Table 3.4: Instrumental Variables and 2SLS Regression – Robustness

	Ln (Z-score)				Ln (Sharpe Ratio)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
DFI	1.800*	2.603***	–3.207**	–2.556**	2.656**	2.975***	–2.886**	–2.392*
	(0.961)	(0.849)	(1.428)	(1.240)	(1.042)	(0.964)	(1.329)	(1.356)
GDP growth	–1.867**	–1.950***	–2.883**	–3.331**	–2.652**	–2.067***	–2.431**	–3.152*
	(0.950)	(0.558)	(1.216)	(1.503)	(1.041)	(0.644)	(1.153)	(1.692)
DFI*B_GDP	0.354*	0.486***	0.625**	0.374**	0.542**	0.503***	0.549**	0.362*
	(0.199)	(0.130)	(0.281)	(0.174)	(0.216)	(0.148)	(0.265)	(0.190)
B_SIZE	0.218***	0.213***	0.133**	0.145***	0.241***	0.240***	0.211***	0.244***
	(0.030)	(0.030)	(0.053)	(0.050)	(0.035)	(0.035)	(0.061)	(0.053)
B_LR	0.757**	0.786**	0.652	–0.211	2.061***	1.948***	2.834***	1.543**
	(0.326)	(0.322)	(0.566)	(0.528)	(0.388)	(0.387)	(0.671)	(0.629)
B_LLP	–20.492***	–19.674***	–19.615***	–19.698***	–72.077***	–71.027***	–79.686***	–81.399***
	(2.044)	(2.040)	(2.438)	(2.365)	(7.533)	(7.320)	(9.213)	(9.081)
B_MQ	1.547**	2.068***	0.267	1.865**	1.029	1.460*	–1.038	0.887
	(0.608)	(0.622)	(0.862)	(0.816)	(0.726)	(0.750)	(1.000)	(0.943)
B_CAP	2.268***	2.215***	2.663***	2.102***	–1.218**	–1.376***	–0.340	–0.863
	(0.435)	(0.432)	(0.717)	(0.640)	(0.517)	(0.516)	(0.830)	(0.725)
B_RD	–0.002	–0.001	–0.004*	–0.005**	0.000	0.000	–0.001	–0.003
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)
B_HHI	11.283	0.058	–28.832	–20.638	6.146	0.024	–36.452*	–23.362
	(10.117)	(8.273)	(18.219)	(16.703)	(11.661)	(9.715)	(18.874)	(17.461)
B_GG	1.239	2.079***	3.049***	8.358**	0.852	–0.076	–0.523	4.699
	(0.946)	(0.620)	(0.910)	(3.394)	(1.040)	(0.719)	(0.992)	(3.633)
B_INF	–0.030	–0.014	0.144**	0.090*	–0.030	–0.030	0.006	–0.028
	(0.038)	(0.034)	(0.063)	(0.049)	(0.045)	(0.040)	(0.060)	(0.056)
B_SP	0.115	0.035	0.350	0.833**	–0.552**	–0.524**	–0.497	0.018
	(0.233)	(0.220)	(0.313)	(0.324)	(0.268)	(0.256)	(0.355)	(0.331)
B_LIST	0.148	0.076	0.056	0.050	–0.027	–0.051	0.166	0.126
	(0.104)	(0.099)	(0.158)	(0.150)	(0.113)	(0.109)	(0.174)	(0.149)
Year fixed effect	Included	Included	Included	Included	Included	Included	Included	Included
Country fixed effect	Included	Included	Included	Included	Included	Included	Included	Included
Wald chi^2	276.97***	304.56***	143.35***	155.86***	269.77***	279.91***	134.08***	147.50***
Obs.	1,827	1,827	1,012	1,012	1,669	1,669	867	867
R^2	0.1909	0.1936	0.1224	0.1605	0.1605	0.1624	0.1271	0.1345

Notes: Standard errors are in parenthesis. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

DFI: Number of ATMs and mobile money agent outlets per 1,000 square kilometers (models 1 and 5). Number of ATMs and mobile money agent outlets per 100,000 adults (models 2 and 6). Number of mobile money accounts per 1,000 adults (models 3 and 7). Number of mobile and internet money transactions (during the reference year) per 1,000 adults (models 4 and 8).

Source: Authors' compilation.

Table 3.5: Alternative DFI Proxy – Robustness

	Ln (Z-score)		Ln (Sharpe Ratio)	
	(1)	(2)	(3)	(4)
DFI	0.035***	0.059**	0.042***	0.058**
	(0.011)	(0.023)	(0.012)	(0.026)
GDP growth	−0.300***	−0.435***	−0.254***	−0.342**
	(0.074)	(0.131)	(0.088)	(0.150)
DFI*B_GDP	0.008***	0.011***	0.007***	0.009**
	(0.002)	(0.004)	(0.002)	(0.004)
B_SIZE	0.182***	0.200***	0.260***	0.261***
	(0.022)	(0.026)	(0.022)	(0.030)
B_LR	1.162***	1.132***	1.980***	2.176***
	(0.329)	(0.274)	(0.277)	(0.324)
B_LLP	−27.557***	−23.740***	−72.006***	−76.551***
	(3.724)	(1.916)	(6.924)	(6.003)
B_MQ	0.489	1.038**	0.057	0.450
	(0.440)	(0.471)	(0.495)	(0.553)
B_CAP	2.658***	2.541***	−0.549	−0.675
	(0.376)	(0.369)	(0.397)	(0.436)
B_RD	−0.003*	−0.003*	−0.003	−0.001
	(0.001)	(0.001)	(0.002)	(0.002)
B_HHI	−2.750	−0.006	−3.510	−0.352
	(3.256)	(4.120)	(3.567)	(4.741)
B_GG	0.573	1.166*	−0.176	0.052
	(0.407)	(0.625)	(0.399)	(0.729)
B_INF	−0.027	−0.016	−0.065***	−0.063***
	(0.021)	(0.020)	(0.024)	(0.023)
B_SP	0.362**	0.283	−0.067	−0.072
	(0.176)	(0.186)	(0.197)	(0.214)
B_LIST	0.067	0.081	0.090	0.090
	(0.061)	(0.084)	(0.067)	(0.095)
Year fixed effect	Included	Included	Included	Included
Country fixed effect	Included	Included	Included	Included
Wald chi^2	394.84***	369.18***	407.53***	334.15***
Obs.	2,566	2,566	2,381	2,381
Pseudo R^2	0.1797	0.1754	0.1622	0.1610

Notes: Standard errors are in parenthesis. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

DFI: The percentage of adults that made or received digital payments in the past year.

Panel-corrected standard errors regression (models 1 and 3); two-stage least-squares – instrumental variables (2SLS-IV) regression (models 2 and 4).

Source: Authors' compilation.

Therefore, it is evident that with an inclusive digital financial system, banks enjoy greater financial stability through ensuring sustainable economic development.

Next, we have taken NPL as an alternative proxy for bank stability. The lower the ratio, the higher the stability – hence, the study finds a negative association between DFI and NPL. The results in Table 3.6 suggest that *DFI* has a negative relationship with *NPL*, which means that DFI positively affects banking stability in emerging Asian countries. Again, the demand side of DFI is insignificant, although the alternative DFI proxy is significant. These findings make the above results more robust and suggest that an inclusive digital financial system is significantly and positively associated with banking stability in emerging Asian countries. The interaction effect of *DFI* and *B_GDP* also makes the above results more robust, which suggests that accelerating digital finance in the sample countries through ensuring sustainable economic development is a significant way of stabilizing the banking sector.

Table 3.6: Alternative Bank Stability Proxy – Robustness

	Dependent Variable: NPL				
	(1)	(2)	(3)	(4)	(5)
GDP growth	5.604***	4.799***	−1.707**	−0.840	3.612***
	(1.812)	(1.483)	(0.721)	(0.930)	(1.265)
DFI1	−9.688***				
	(3.239)				
DFI1 x B_GDP	−1.257***				
	(0.431)				
DFI2		−7.374**			
		(2.869)			
DFI2 x B_GDP		−1.175***			
		(0.366)			
DFI3			−1.111		
			(0.866)		
DFI3 x B_GDP			0.188		
			(0.154)		
DFI4				0.136	
				(0.779)	
DFI4 x B_GDP				−0.001	
				(0.111)	

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Table 3.6 *continued*

	Dependent Variable: NPL				
	(1)	(2)	(3)	(4)	(5)
DFI5					–0.514**
					(0.205)
DFI5 x B_GDP					–0.097***
					(0.031)
Obs.	2,330	2,330	1,357	1,357	1,266
R-squared	0.185	0.185	0.161	0.161	0.169
Control variables	Included	Included	Included	Included	Included
Year Fixed Effect	Included	Included	Included	Included	Included
Country Fixed Effect	Included	Included	Included	Included	Included

Notes: Standard errors are in parenthesis. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

DFI1: Number of ATMs and mobile money agent outlets per 1,000 square kilometers; DFI2: Number of ATMs and mobile money agent outlets per 100,000 adults; DFI3: Number of mobile money accounts per 1,000 adults; DFI4: Number of mobile and internet money transactions (during the reference year) per 1,000 adults; DFI5: The percentage of adults that made or received digital payments in the past year.

Source: Authors' compilation.

Finally, we split the sample into two parts—Panel A: 2011–2015 and Panel B: 2016–2018—to compare between two time periods. As our findings indicate that the demand side has an insignificant relationship with banking stability, we would like to see whether the present situation has changed due to banks' adoption of the latest fintech-based technology and the Industrial Revolution 4.0 effect. The results are presented in Table 3.7.

The results in Table 3.7 show that during the initial period (2011–2015) of digital finance, the DFI-bank stability nexus was weak, especially the demand side of DFI. However, the nexus has become stronger as time (2016–2018) has passed. The interaction effect of *DFI* and *B_GDP* on banking stability was stronger during 2016–2018 than in 2011–2015. This is because the banking sector was undergoing a transformation from being traditional to digitalized together with highly dedicated human capital in the initial stage (Vives 2019)—at that time, BigTech companies were dominating (especially in the PRC and India). However, with the passage of time, banks have taken over that dominance by adopting financial technology.

Table 3.7: Split Sample Based on Time Periods – Robustness

	Dependent Variable: Ln (Z-score)							
	Panel A: 2011–2015				Panel B: 2016–2018			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
GDP growth	−0.417	−0.631***	−0.341**	−0.296	−1.514***	−1.034***	1.337***	0.158
	(0.328)	(0.221)	(0.164)	(0.314)	(0.468)	(0.344)	(0.448)	(0.424)
DFI1	0.975**				1.383**			
	(0.455)				(0.694)			
DFI1 x B_GDP	0.088				0.255**			
	(0.072)				(0.110)			
DFI2		1.093***				1.934***		
		(0.389)				(0.612)		
DFI2 x B_GDP		0.135***				0.233***		
		(0.052)				(0.089)		
DFI3			−0.365*				1.751***	
			(0.219)				(0.477)	
DFI3 x B_GDP			0.054				0.353***	
			(0.034)				(0.095)	
DFI4				−0.109				0.388
				(0.258)				(0.308)
DFI4 x B_GDP				0.028				−0.030
				(0.039)				(0.045)
Obs.	1,116	1,116	714	714	1,381	1,381	788	788
R-squared	0.174	0.171	0.189	0.191	0.206	0.216	0.256	0.247
Control variables	Included	Included	Included	Included	Included	Included	Included	Included
Year Fixed Effect	No	No	No	No	No	No	No	No
Country Fixed Effect	Included	Included	Included	Included	Included	Included	Included	Included

Note: Standard errors are in parenthesis. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Source: Authors' compilation.

3.5 Conclusion and Policy Recommendations

This study provides empirical evidence that greater DFI has a significantly positive impact on banking stability, indicating that DFI stabilizes the banking sector and an integrated inclusion of digital finance by the emerging Asian banks is not merely a channel of ensuring banking stability. Rather, it ensures inclusive and sustainable economic development. Such economic sustainability eventually helps in achieving the SDGs. Therefore, governments, policy makers, standard setters, and regulatory bodies can see DFI as a change agent that can bring about revolutionary development in the overall financial sector of the banking industry. In this regard, the implementation of the following policies can be taken into consideration.

First, digital financial literacy for all should be ensured along with ensuring that people have electronic devices supported by the latest technology and different applications germane to DFI that must have an uninterrupted internet connection. Insufficient or a lack of seamless internet connection may discourage people from enjoying digital financial services. For smooth operation of DFI, financial literacy is a must (Klapper and Lusardi 2020), as our findings also show that countries have sufficient access to DFI, but people cannot utilize it properly because of their lack of financial literacy. To make people financially literate, campaigns, seminars, and workshops should be arranged. Then, unbanked people living mostly in rural areas should be encouraged to become banked. Banks should review their requirement of a minimum amount when opening an account, as exists in most banks, so that poor people can open an account smoothly. Then, banks should provide services through which people can remotely open an account and enjoy all sorts of banking facilities. An awareness campaign regarding the prospects of the use of digital finance should be arranged. Timely DFS (e.g., fintech using artificial intelligence and machine learning) should be introduced that will enhance banking stability and efficiency, which will spur inclusive economic growth. Such types of DFS will inspire people to be more savings-minded, and more savings will lead to sustainable economic growth.

Moreover, banks, in order to tackle the cloning of ATM cards, debit cards, credit cards, hacking, and other technological threats, should implement updated software and a database so that hackers cannot breach the data. To prevent card cloning, banks should launch a money withdrawal facility via scanning a QR code with a mobile phone, which already operates in countries like Singapore, Turkey, and so on. Banks must have a strong team ready with vast and sound technical knowledge to provide clients with an uninterrupted and painless service, which will stimulate people en masse to come under the umbrella of DFI. After all, there will be a strong, independent, proficient, and unbiased regulatory body that will supervise all the activities in terms of DFI and adopt innovative and time-tested policies to make it a successful journey.

Finally, our study has some limitations. For example, we could not compare our findings with banks from other regions and other BigTech firms from emerging Asian countries due to data unavailability. Future studies can be extended to compare banks with BigTechs and show how banks collaborate with BigTechs or whether banks themselves improve the digitalization or improve productivity or lower the cost of services.

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4

Digital Financial Inclusion, Economic Freedom, Financial Development, and Growth: Implications from a Panel Data Analysis

AG Rekha, K. Rajamani, and AG Resmi

4.1 Background

Research has considered financial inclusion as a significant catalyst for economic development (Claessens 2006). Financial inclusion refers to the availability of formal financial services to everyone, including deprived households and microenterprises (ADB 2000). Although an inclusive financial system has several merits, according to the Global Findex Database (2017), 50% (around 2 billion people) of the total global adult population does not have access to formal financial services. As the World Bank reported, more than 50 countries are actively developing plans and policies for achieving financial inclusion to achieve universal financial access.

Although financial inclusion is a global socioeconomic challenge, its impact will be greater for less-developed countries than for developed countries since research has determined that financial inclusion is fundamental for growth and poverty alleviation (Kim 2016). The experience of emerging nations such as India is unique and severe, and growth has been non-inclusive, one of the key reasons being the failure to achieve greater financial inclusion (Shafi and Medabesh 2012). Since the situation in emerging economies is different, it is imperative to study the dynamics in that context.

Two critical types of factors that the literature has identified as driving financial inclusion across countries is structural and policy-related factors. While structural factors primarily decide the cost of delivering financial services to the population, policy-related factors are essential in creating a facilitating environment for financial inclusion. One of the primary structural factors is the information and communication technology (ICT) infrastructure. The diffusion of ICT has caused an intensive transformation of the world and allowed more access to finance.

Technological innovation plays a vital role in economic growth. ICT reduces income disparities by formalizing the financial sector, and the literature has argued that financial inclusion is one of the ways in which ICT facilitates economic growth (Kpodar and Andrianaivo 2011; Tchamyou, Erreygers, and Cassimon 2019). Digital financial inclusion refers to leveraging ICT to enhance financial inclusion meaningfully. It is an evolving phenomenon and understanding its associations with financial inclusion has many policy implications. Economic models indicate that economic freedom can influence production and resource efficiency. Countries with low levels of regulations will have more economic freedom than countries with more regulations—the greater the economic freedom, the greater the income and growth of a society. Economic researchers have reported that freedom of choice and a supply of resources, rivalries between enterprises, and the trade and safety of private liberties are crucial to economic progress (North and Thomas 1973).

In economically free societies, governments permit free mobility of labor, capital, and other resources, and refrain from imposing constraints on liberty beyond a degree that is necessary to defend and preserve democracy itself (Heritage Foundation 2019). The Economic Freedom Index indicates that a total of 90 countries (50%) offer organizational conditions in which private firms enjoy at least a reasonable degree of economic freedom to achieve greater wealth and accomplishments. Furthermore, economic freedom is one of the significant factors affecting financial development and growth. Hence, there is a strong rationale for examining the effect of economic freedom on financial inclusion. However, there is no empirical evidence on the linkages between economic freedom and financial inclusion.

The critical question facing practitioners and researchers regarding how to achieve an all-inclusive financial system remains unanswered. In this context, this chapter aims to explore the linkages among ICT diffusion, economic freedom, financial development, and financial inclusion by empirically examining a panel dataset pertaining to 22 emerging economies.

4.2 Brief Review of the Literature

Both theoretical and empirical studies have observed that economies with higher degrees of financial inclusion have higher rates of gross domestic product (GDP) growth as well as lower income disparities (King and Levine 1993; Beck et al. 2007; Demirgüç-Kunt and Levine 2009; Demirgüç-Kunt, Klapper, and Singer 2017). Studies have presented empirical evidence on the financial inclusion–economic development nexus. Financial inclusion in developed economies primarily focuses on awareness of equal and affordable financial services, whereas, in developing economies, both access to financial services and financial literacy are involved. Financial exclusion focuses primarily on issues related to access, in particular the availability of banking outlets (Leyshon and Thrift 1995).

Neaime and Gaysset (2018) observed that financial inclusion exerts a positive impact on financial stability and reduces income disparities in countries in the Middle East and North Africa (MENA). The numbers of loans and/or savings accounts and ATMs have unidirectional causation effects on the growth of the economy (Sharma 2016). Kim, Yu, and Hassan (2018) investigated the link between financial inclusion and economic growth in 57 companies through a panel regression analysis. They argued that financial inclusion has a positive impact on economic growth. Sarma and Pais (2011) examined the relationship between financial inclusion and development using country-specific factors related to financial inclusion. They proposed that variables such as income, discrimination, literacy, urbanization, communication networks, and knowledge play a significant part in financial inclusion.

Sethi and Sethy (2019) confirmed that financial inclusion positively influences economic growth by analyzing both the demand and the supply side of financial services. The study also indicated that improving financial inclusion makes economic growth possible in the long run. Kumar (2013) investigated the availability of financial inclusion indicators in 29 Indian states using fixed effects and the generalized method of moments. The study suggested that the branch network is an important indicator of financial inclusion in India. Anarfo et al. (2019) examined the triadic connection between financial inclusion, financial sector development, and economic growth pertaining to sub-Saharan Africa, employing a vector autoregressive estimation method. It is evident from the study that financial inclusion is a critical factor in financial sector development.

Further, evidence from the literature has suggested that financial inclusion supports economic growth through ICT. ICT in financial inclusion facilitates digital access to the use of formal financial services for excluded and underserved populations. Joia and dos Santos (2017) determined that e-government ventures fulfill the population's need to access financial products and services. Another study suggested that the government could create central information repositories to provide the general public with general information about financial service providers to facilitate financial inclusion (Bongomin, Ntayi, and Munene 2016). Andrianaivo and Kpodar (2012) investigated the impact of ICT, especially that of mobile and fixed telephone penetration, on growth on a panel of African countries using the generalized method of moments estimator. A similar study by Mihasonirina and Kangni (2011) also confirmed the importance of communication technologies for financial inclusion. Tchamyou, Erreygers, and Cassimon (2019) investigated the effect of ICT on economic disparity through the dimensions of depth, efficiency, activity, and size of the financial sector in African countries. The result showed that ICT lessens income disparity by formalizing the financial services sector. Another work based on the MENA region suggested that a high degree of ICT diffusion influences financial development favorably and enhances economic growth (Sassi and Goaied 2013). Falahaty and Jusoh (2013) also highlighted the significance of ICT in the financial growth of MENA countries.

Earlier research has considered financial intermediaries as critical catalysts for innovation and economic growth. Schumpeter (1911) and Robinson (1952) argued that finance has no causal effect on development. Instead, financial development follows economic development as a consequence of the increased need for financial services. In the context of the increasing demand for financial services, more financial institutions, financial goods, and services arise in the markets. Ang and McKibbin (2007) investigated the impact of financial development on growth by analyzing Malaysian data from 1960 to 2001. The result indicated that financial liberalization has a significant influence on financial sector development.

Many theoretical and empirical studies have supported the causal linkage between financial development and economic growth, indicating that established financial institutions and markets improve service availability, leading to economic development (King and Levine 1993; Neusser and Kugler 1998; Levine, Loayza, and Beck 2000), whereas some of the empirical research has also supported the hypothesis of a causal relationship between economic growth and financial development. Here, the growing demand for financial services could cause financial sector development as the real economy grows. Here, the need for financial services could contribute to the development of the financial sector when the overall economy develops (Goldsmith 1969; Jung 1986).

In an economically free society, there will be freedom to work, produce, consume, and invest in any manner.

Hafer (2013) argued that research has identified a substantial link between economic and financial development and economic freedom (EF). The study further revealed that countries with greater economic freedom exhibit a higher degree of development in financial intermediaries, resulting in rapid economic growth. The findings from this research partly justify the association between economic freedom and growth. Carlsson and Lundström (2002) suggested that economic freedom has a strong association with development. Financial freedom, which is one of the factors of economic freedom, has a significant long-run relationship with financial inclusion (Rekha, Rajamani, and Resmi 2020). However, there are no empirical studies in the literature on the linkages between economic freedom and financial inclusion.

4.3 Methodology

4.3.1 Data and Sources

The study used annual data covering the period 2004–2017 pertaining to 22 emerging economies, which the availability of data dictated. We developed an index of financial inclusion (IFI) with three dimensions—penetration, availability, and usage—following a method similar to the one that Sarma and Pais (2011) explained, using World Bank data. The ICT Development Index, which measures the digital divide and enables the comparison of ICT performance across countries, comes from the United Nations International Telecommunication Union (ITU 2017). The index uses 11 ICT metrics (Table 4.1) in three subindexes (ICT access, ICT use, and ICT skills) and aggregates the weighted values. The normalized and averaged indicators provide the subindex values.

The Heritage Foundation (2019) provided the Economic Freedom Index, which measures the economic freedom in a country. The index covers 12 freedoms, from property rights to financial freedom (Table 4.2).

We obtained the Financial Development Index, an aggregate of the Financial Institutions Index and the Financial Markets Index, based on depth, access, and efficiency, from the International Monetary Fund database (IMF 2019). We employed GDP converted into international dollars using purchasing power parity rates (GDP PPP) as a proxy for economic development (World Bank 2018).

Table 4.1: Indicators for the ICT Development Index

	Weights (Indicators)	Weights (Subindexes)
ICT access		0.40
Fixed telephone subscriptions per 100 inhabitants	0.20	
Mobile-cellular telephone subscriptions per 100 inhabitants	0.20	
International internet bandwidth per internet user	0.20	
Percentage of households with a computer	0.20	
Percentage of households with internet access	0.20	
ICT use		0.40
Percentage of individuals using the internet	0.33	
Fixed-broadband internet subscriptions per 100 inhabitants	0.33	
Active mobile-broadband subscriptions per 100 inhabitants	0.33	
ICT skills		0.20
Mean years of schooling	0.33	
Secondary gross enrollment ratio	0.33	
Tertiary gross enrollment ratio	0.33	

ICT = information and communication technology.
Source: International Telecommunication Union.

Table 4.2: Economic Freedom Factors

Category	Factors
Rule of Law	Property rights, government integrity, judicial effectiveness
Government Size	Government spending, tax burden, fiscal health
Regulatory Efficiency	Business freedom, labor freedom, monetary freedom
Open Markets	Trade freedom, investment freedom, financial freedom

Source: Heritage Foundation.

4.3.2 Model

Following established procedures, we evaluated the causal interaction between the variables in four stages. Initially, we performed tests for the order of integration of the variables Index of Financial Inclusion (IFI), Foreign Direct Investment (FDI), Economic Freedom (EF), Information and Communication Technology (ICT), and GDP. Next, we performed panel cointegration tests to check for long-run relationships among the variables. Then, we applied the vector error correction model (VECM) to evaluate the long-run cointegration among the variables. Finally, we conducted the Wald test to assess the short-run causality of the variables. The empirical model that we used in the study is as follows:

$$IFIt = \alpha_1 + \beta_1 ICT_t + \beta_2 EF_t + \beta_3 FDI_t + \beta_4 LGDP_t + \varepsilon_t$$

where t represents the time from 2004 to 2017, ε represents the error correction term, α_1 is the intercept term, and β_1, β_2, β_3, and β_4 are the relevant parameters.

4.4 Results

4.4.1 Panel Unit Root Tests

To check the unit root properties of the data, we used the Levin–Lin–Chu (2002), Im–Pesaran–Shin (2003), and Fisher–ADF and Fisher–PP tests; Table 4.3 presents the results.

Table 4.3: Panel Unit Root Tests

Variable	ICT	EF	FDI	GDP	IFI
Levels					
Levin, Lin, and Chu t	−2.74968	−0.20612	−5.11484***	5.93692	−2.96182**
Im, Pesaran, and Shin W-stat.	0.9950	1.02543	−1.48781	6.66121	1.05448
ADF–Fisher chi-square	0.8187	38.5469	57.5040	27.5161	41.3434
PP–Fisher chi-square	0.3391	51.1875	86.4554***	42.9968	36.6331
First difference					
Levin, Lin, and Chu t	−14.7119***	−12.6112	−14.8947***	−6.67862***	−8.16149***
Im, Pesaran, and Shin W-stat.	−10.7246***	−10.2551***	−10.2270***	−4.63524***	−5.84759***
ADF–Fisher chi-square	181.057***	173.217***	171.164***	99.2783***	109.321***
PP–Fisher chi-square	229.778***	184.091***	194.987***	93.9469***	118.330***

Source: Authors' compilation.

The results indicate the presence of a unit root in all the series at level, and hence they are non-stationarity at level. Table 4.3 also shows the results of the tests using first differences, which indicate that the variables follow an I(1) process. Having established that all the variables are integrated to the order I(1), we examined the cointegration among the variables to decide whether to control for long-run relationships in the econometric specifications.

4.4.2 Cointegration among Variables

Tables 4.4 and 4.5 present the results of the panel cointegration tests for the data (Kao 1999; Pedroni 1999). The null hypothesis for these tests is that there is no cointegrating relationship. According to the Pedroni test, as Table 4.4 shows, four out of the seven statistics provide evidence for cointegrating relationships. The Kao test result also suggests panel cointegration at the 1% significance level (Table 4.5).

Table 4.4: Pedroni Panel Cointegration Test

(Series: IFI ICT EF FDI LGDP)			
Panel Statistic (Within Dimension)		Group Statistic (Between Dimension)	
V	−1.325269	Rho	4.614325
Rho	3.040432	PP	−7.461744***
PP	−3.732644***	ADF	−5.092943***
ADF	−4.202287***		

Source: Authors' compilation.

Table 4.5: Kao Test

Series: IFI ICT EF FDI LGDP	
ADF	−2.611245**
Residual variance	0.000122
HAC variance	0.000157

Source: Authors' compilation.

4.4.3 Panel Vector Error Correction Model

Since we found that the variables are cointegrated, we applied VECM to analyze the panel. This technique adjusts to short-run changes in variables as well as to deviations from the equilibrium. We used the Akaike information criterion (AIC) values to arrive at a suitable lag length (Table 4.6); for our model, it was two.

Table 4.6: Lag Order Selection Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	–405.8966	NA	0.001208	7.470848	7.593597	7.520636
1	710.9323	2,111.822	2.89e-12	–12.38059	–11.64409	–12.08186
2	777.3900	119.6240	1.36e-12*	–13.13436*	–11.78412*	–12.58670*
3	793.3965	27.35642	1.62e-12	–12.97084	–11.00686	–12.17424
4	815.9359	36.47291	1.71e-12	–12.92611	–10.34838	–11.88057

NA = not available.

Source: Authors' compilation.

Table 4.7 contains the result from the panel VECM. The results confirm the long-run equilibrium association between the variables. They imply that all of the independent variables jointly influence the dependent variable *IFI*.

Table 4.7: VECM Long-Run Representations: IFI as the Dependent Variable

(Series IFI ICT EF FDI LGDP)			
Coefficient	**Std Error**	**t-Statistic**	**Probability Value**
-0.005649	0.002595	-2.177062	0.0297

VECM = vector error correction model.

Source: Authors' compilation.

The Wald statistic (Table 4.8) shows that there is no significant short-run causality running from the independent variables to IFI. Further, it is apparent that FDI, EF, ICT, and GDP have a significant effect on IFI only in the long run. However, when treated independently, EF does not have any significant impact on IFI in either the long or the short run.

Table 4.8: VECM Short-Run Representations: Wald Test

Variable	Value	Probability Value
ICT	0.984579	(0.6112)
EF	0.437569	(0.8035)
FDI	1.256267	(0.5336)
LGDP	2.151797	(0.3410)

VECM = vector error correction model.

Note: Test statistic: Chi-square independent variable IFI.

Source: Authors' compilation.

4.5 Discussion and Implications

The evidence for a significant long-run association between ICT diffusion and financial inclusion suggests the necessity to strengthen the ICT infrastructure, the rollout of digital banking, and e-commerce services. Policy makers must strengthen the ICT policy measures and concentrate on the promotion of e-governance and e-commerce. For emerging economies, ICT sector investment is critical for advancing even with a weak economic status. Improving access and connectivity, primarily through mobile phone and internet connections, enhances financial depth, which is vital for any economy to develop. The growth of financial intermediaries, such as banks and capital markets, stimulates the overall growth based on ICT. To ensure a long-term sustained effect of ICT diffusion, the role of the government is significant in designing new policies and investment and development strategies to build up the ICT infrastructure.

This will enable citizens to benefit from low-cost and high-speed internet services. Further, it will make e-finance easier for businesses and other industries. Policies aiming to strengthen a country's ICT ecosystem would undoubtedly promote greater financial growth and further resources for developing countries to experience e-financing.

With regard to economic freedom, it is apparent that strategies aim to promote and foster financial access by creating competitiveness and eliminating excessive entry barriers as well as by improving the availability of credit information. Efforts should focus on minimizing government involvement in the financial system through a reassessment of the role of financial institutions. Governments should also minimize restrictive practices in the financial services sector and encourage reforms like providing cheaper bank accounts for the unbanked population. Apart from policies for expanding banking penetration, there should be policies for improving the infrastructure to increase availability and usage. It is also necessary to reduce income inequalities, enhance literacy levels, and improve the communication infrastructure to build financially inclusive societies.

Further, policy makers should recommend introducing comprehensive financial reforms leading to economic freedom that would create favorable outcomes to boost financial inclusion and growth. In addition to the analytical findings favoring the relationship between financial development and financial inclusion, it seems that improving the quality of financial institutions is necessary to strengthen the relationship between financial development and economic growth.

The results highlight that, in emerging markets, financial sector development has a significant role in inclusive growth and financial markets and institutions strongly influence sustainable development. It is possible to access informal markets by improving the degree of e-governance and economic freedom. At a broader level, our findings suggest that careful alignment between the ICT policy and the growth policy is critical for addressing financial development, which in turn will reflect favorably on financial inclusion.

4.6 Conclusion

This chapter examined the interlinkages of ICT diffusion, economic freedom, financial development, and economic growth with financial inclusion using a panel data analysis of 22 emerging economies. We found that the variables are cointegrated and applying a VECM approach indicated the presence of a long-run relationship between the variables. The literature has shown that financial inclusion and economic growth have a positive association, but, apart from the conventional findings, our results indicate that growth leads to greater financial inclusion in the long run. The other factors, ICT, economic freedom, and financial development are also positively related to financial inclusion in the long run. These findings have significant policy implications and stress the importance of creating an economic environment that is conducive to sustained economic growth. Future research could analyze the impact of individual factors of economic freedom on financial inclusion using more robust tests to gain further insights.

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5

Bayesian Gravity Model for Digitalization on Bilateral Trade Integration in Asia

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5.1 Introduction

Impacts of globalization result in trade integration since it is advantageous in many developing economies. Adapting to bilateral trade is fundamental for the trade facilitation and integration process by digitizing, which is considered a key determinant for international trade policies, and the potential of digitizing is an essential source of comparative advantage for Asia. Theoretical structures for the nexus between trade flow and trade integration determinants are studied in a number of seminal studies using the gravity model. Increased import and export has accelerated the integration of trade among countries in Asia, where countries have continued to implement open economic policies with a greater direction to open the markets. They have made extensive efforts to implement economic integration not only with their neighboring countries but also with other countries in different regions of Asia. Since 1990, many Asian countries have been involved in regional trade agreements (RTAs), with more than 30 agreements, including multilateral and bilateral RTAs. Among these agreements, the ASEAN Free Trade Area (AFTA) of the Association of Southeast Asian Nations (ASEAN) and the South Asian Free Trade Area (SAFTA) of the South Asian Association for Regional Cooperation (SAARC), with a focus on trade volume and economic growth, are significant in terms of integration. Within the wide range of literature, Frankel (1994), Ramasamy (1995), Endoh (1999), Thorn and Goglio (2002), Elliott and Ikemoto (2004), investigated the effects of ASEAN and AFTA, while Hassan (2001), Hirantha (2004), Batra (2004), Rahman, Shadat, and Das (2006), and Gul and Yasin (2011) examined SAARC and SAFTA.

To facilitate open economic policies in terms of trade integration, this study analyzes the Bayesian gravity model for Asian countries to thoroughly evaluate the determinants of import volume. From an economic growth standpoint, open economic policy analysis has been devoted to explaining the relationships with trade integration at the aggregate level. Nevertheless, the literature shows a gap in Asian countries in providing empirical evidence to foster open economic policies for trade integration.

International trade is associated with individuals, sectors, and regions in increasing prosperity for long-term economic growth. Opening the national economy always consists of winning parties as well as losing parties with a focus on trade policy makers attempting to maximize the positive net gains. This suggests that the integration of trade sectors needs to be considered with careful analysis and evaluation of policies for open economic scenarios, mainly because of the high risks and heterogeneous impacts of the countries in economically opening to the distribution of income, assets, and opportunities. Free trade can be slowed down, stopped, or prevent others from benefiting due to political influences. Nonetheless, if potential adverse effects are controlled, an open economy can achieve positive impacts at national, sectoral, and individual levels. Generally, these kinds of policies are related to trade integration, enhancing the distribution of benefits from economic opening.

5.1.1 Targeting Trade-Related Integration

Open economic policies have been applied in many Asian economies with different intensities, frameworks, and strategies. However, a limited review of trade integration with open economic policy for developing countries is apparent in the underpinning literature. Trade integration is defined as measures and policies, including financial factors, focusing on the implementation of trade reforms and trade policies between countries. Trade integration measures and policies include using other measures to eradicate the deficit in the balance of payments, adjusting to the world trading conditions and changing commodity prices. Further, trade integration supports activating target transformation and enhancing the competitiveness of import while measuring the burden of trade liberalization.

This study aimed to provide pragmatic evidence of trade policies in the Asian countries for already established trade agreements. The quality of the executed policies and reforms is highly varied among these countries that need trade integration studied. Based on the above discussion, the purpose of this chapter is to examine the trade integration with the evidence of trade policies under the digitalization of Asian countries. It investigates the contribution of trade facilitation and integration in promoting a country's trade integration for fostering growth.

5.2 Literature Review

International trade is accelerated under multilateral free trade negotiations providing a theoretical foundation for accepting that a substantial part of trade is bilateral among developed countries, which makes the impact of trade liberalization uncertain. Thus, the literature proposes numerous theories for trade integration in line with digitalization. Numerous theories and models on trade integration explain the advantage of bilateral trade in developed and developing economies for gaining maximum benefits with open economic policies. The gravity model, at the macroeconomic level, predicts the effects of trade liberalization on the economies, fostering economic growth. The literature provides a number of seminal studies on the application of the gravity-based model for trade integration. The literature includes the contributions of Tinbergen (1962) and Pöyhönen (1963). Accordingly, the new trade theory supports validations of the theories for building models with increasing returns of scale, competition, and transport costs (Anderson 1979; Bergstrand 1989; Helpman and Krugman 1985). Tinbergen (1962), Pöyhönen (1963), and Linnemann (1966) applied the gravity model analogy for trade relationships among various countries. Furthermore, Bayoumi and Eichengreen (1995) designed the model that was used for an expanded period to determine the variations of trade in numerous studies. Therefore, the empirical results of the overall gravity model are considered robust and best fitted to the data for empirical evidence and open economic policies.

Although the empirical progress of the gravity model has been advanced over time, Baldwin (1994) and Leamer (1994) disapproved of the gravity model on the basis of lacking theoretical insight of the relationships. In general, the gravity model determines the trade patterns and potentials of factors such as transport costs, border and non-border barriers, geographical and cultural features, and other regulatory constraints that impact the trade between countries. Therefore, a theoretical foundation for the gravity model was developed to best-fit results. Thus, a reduced form of the gravity model based on trade theories such as Heckscher-Ohlin is developed.

Many economists derive the foundation for the gravity model using the theoretical perspective of trade, including Ricardian, Heckscher-Ohlin, and New International Trade Theory (Anderson 1979; Helpman and Krugman 1985; Deardorff 1995, 1998; Feenstra, Markusen, and Rose 2001; Anderson and van Wincoop 2003). But Anderson (1979) presented a gravity model from all types of product differential models. Later, Bergstrand (1989) derived the Heckscher-Ohlin model. Helpman and Krugman (1985) developed the monopolistic competition model with increasing returns and transport costs. Recently, the gravity model has been extended on the basis of traditional models and reached more robust and consistent conclusions (Deardorff 1995; Anderson and van Wincoop 2003; Helmers and Pasteels 2005). The gravity model is used in data samples to investigate bilateral trade flows considering their incomes, bilateral distance, and dummy variables for a common language, common borders, and any of the regional or bilateral agreements. Last, trade potential between partner countries at the sectoral level is estimated by Baroncelli, Fink, and Javorcik (2005) by incorporating the simulated SAFTA-bound future tariffs. However, it contains some methodological flaws such as endogeneity and violations of assumptions of Jensen's inequality.

On the other hand, digitalization has made an enormous impact on the trade between countries. Digital trade includes digitally enabled transactions in goods and services. Thus, growing digital connectivity is also enabled, increasing radiational or supply chain trade in goods. According to Miroudot and Cadestin (2017), as a consequence of digitalization, trade in minor, low-valued physical packages and digitally delivered services is growing. In addition, digitalization changes how companies interact with their customers, other companies, and government; a globalized world with hyperconnectivity, production, design, delivery, and consumption is geographically detached through trade and constantly connected through digital networks (López González and Jouanjean 2017). The digitalization of trade has brought changes in terms of the scope, scale, and speed of trade.

Undoubtedly, digitalization changes the many economic activities of the industries through digital retailers and associated firms with supply and demand matching services who are increasingly providing or facilitating access to warehousing, logistic, e-payment, credit, and insurance services with a supportive environment. Asian open economies are largely dependent on the integration of bilateral trade for economic growth. Overall, this has the effect of boosting the efficiency and production capacity of domestic firms, thereby enhancing their competitiveness in the global markets. Digitalization has become the key factor on this basis, which helps international trade to be smooth and fast.

5.3 Data and Empirical Method

5.3.1 Data

The database includes 43 countries in Asia over the period 1995–2018. Based on the availability of data, annual data on GDP, population, area, exchange rates, and other influential variables and trade agreements of the country of origin and destination are generated for assorted years from the World Bank database. All nominal values of the variables are converted to constant 2015 United States dollars using the consumer price index or CPI; all nominal variables are expressed in real terms. Under this study, data from the Centre d'Études Prospectives et d'Informations Internationales or CEPII Bilateral Trade Database from 1995 to 2018 are compiled and the World Development Indicators of the World Bank used, with bilateral import flow as the key dependent variable. Further, those data are supported by the CEPII Geodist dyadic data set and the CEPII gravity data set (Head and Mayer 2013). The data on GDP and population have been updated using the World Bank Development Indicators. The areas of the country of origin and destinations were measured in square kilometers. Dummy variables are used to measure whether two countries are contiguous and share a common language or religion. Additionally, data were gathered on five variables measuring digitalization data from the Global Competitiveness Index Report of the World Economic Forum: (i) mobile telephone subscriptions per 100 people; (ii) mobile-broadband subscriptions per 100 people; (iii) fixed-broadband internet subscriptions per 100 people; (iv) fixed telephone lines per 100 people; and (v) internet users as percentage of the adult population.

5.3.2 Empirical Method

This empirical method follows the previous empirical studies on the gravity application and is then extended to the estimation of the Bayesian approach with econometric specifications. The empirical method is employed to control for econometric issues for robust estimations. The trade flows in Asian economies are not necessarily related to the long-run equilibrium since Asian economies are still transition market economies.

In this section, the "gravity" specification model for trade volumes and trade partners is used to estimate the equation to provide a benchmark. Much of the economic literature has devoted substantial efforts to producing trade theories, and describing and predicting the subsequently observed export and import flows. One such empirical attempt is the gravity models, which have become the pillar of the empirical literature on the determinants of international trade (Anderson 2011). The standard gravity model provides all bilateral flows of trade at time *t* between the reporter and the partner. In brief, a gravity equation explains the trade with the size of the economies and their distances, suggesting a stable relationship between the size of the economies, proximity, and trade among countries to infer trade flow potentials and to estimate the effects on trade of institutions such as customs unions, monetary agreements, exchange rate mechanisms, ethnic ties, linguistic identity, and international borders. Physical distance is an explanatory variable for trade measure resistance issues such as transaction costs, transport costs, perishability and/or loss of goods during transport, synchronization costs, communication costs, and cultural distance.

5.3.3 Gravity Model

A number of theoretical frameworks and models are presented in the literature to show the determinants of trade flow. Although the gravity model is designed on the basis of Newton's gravity law, several adjustments to the model are made in the form of trade integration analysis (Grogger and Hanson 2007). These approaches are widely used in the analysis of trade exports or imports because of their robust forecasting characteristics (Fertig and Schmid 2000; Karemera, Oguledo, and Davis 2000; Kim and Cohen 2010). With the use of different pull and push factors, gravity models are deepened by the inclusion of more variables (Vogler and Rotte 2000; Hatton and Williamson 2002; Gallardo-Sejas et al. 2006; Mayda 2010; Ortega and Peri 2013). The gravity model is widespread with the specification of the time invariant fixed effects with the time shocks, and origin and destination country to account for the unobserved heterogeneity. Bertoli, Fernández-Huertas Moraga, and Ortega (2013) found that, without specifying the fixed effects, the models suffer biases because of multilateral resistance to trade.

Considering all the factors, the model specification for the gravity model is as follows:

$$\begin{aligned} logImport_{odt} = {} & a_0 + a_1 logGDP_{ot} + a_2 logGDP_{dt} + a_3 logPop_{ot} + a_4 logPop_{dt} \\ & + a_5 logDis_{od} + a_6 logDigitization\ Index_{odt} + a_7 logArea_o \\ & + a_8 logArea_d + a_9 logExch_{ot} + a_{10} logExch_{dt} + a_{11} {Sib_{conflict}}_{dt} \\ & + a_{12} Conrelig_{dt} + a_{13} Comlan_{dt} + m_{odt} \end{aligned}$$

where $logImport_{odt}$ signifies the natural logarithm of the imports from country of origin *o* to country of destination *d* at time *t*; $logGDP_{ot}$ and $logGDPd_t$ indicate the logarithm of the GDP in the country of origin *o* and destination *d* at time *t*, respectively; $logPop_{ot}$ and $logPop_{dt}$ denote, respectively, the logarithm of the population in the country of origin *o* and *d* at time *t*; $logDist_{od}$ is the logarithm of geographical distance between capital cities of countries; *DigitalizationIndex* is composed of the log of mobile telephone subscriptions per 100 people, the log of mobile-broadband subscriptions per 100 people, the log of fixed-broadband internet subscriptions per 100 people, the log of fixed telephone lines per 100 people, and the log of internet users as a percentage of the adult population, respectively; $logArea_o$ and $logArea_d$ indicate the natural logarithm of the area of the country of origin *o* and destination *d*; and $logExch_{ot}$ and $logExch_{dt}$ denote, respectively, the logarithm of the exchange rate in the country of origin *o* and destination *d* at time *t*. The remaining variables are dummy variables indicating whether the two countries share a common official language (*comlan*), share a language spoken by at least 9% of the population in both countries (*comlangethno*), and have a common religion (*comrelig*). As previously mentioned, time fixed effects as well as origin and destination country fixed effects are also included in the model. Last, u_{odt} denotes a random error term.

However, the gravity model suffers from issues such as how to deal with zero trade and bias for the log model estimation in the presence of heteroskedasticity; endogeneity in the gravity equation, i.e., causation between trade and trade policy could be reversed when, in the case of signing a free trade agreement, there exists a selection of countries based on the intensity of trade, and not the other way round; spatial correlation; and omitted variables biasing coefficients systematically. In order to address these issues for robust estimation, the study in this chapter applies the Bayesian approach for the gravity model in the econometric specification.

5.3.4 Bayesian Approach

The Bayesian statistical inference is based on Bayes' Theorem (Bayes 1763). The study of the Bayesian approach used the sample information transforming the prior knowledge of the researchers into posterior knowledge. Despite the subjective measures such as beliefs and intuition, without considering the observations, the base theorem is conditional on the sample data. The theorem makes inferences about the unknown parameters such as θ and conditionally about the sample statistical information x. The Bayesian statistics complete the theoretical overview, for example in Bernardo and Smith (1994). The scheme of Bayesian inference and Bayes' Theorem are presented in Table 5.1.

Table 5.1: Bayes' Theorem and the Bayesian Statistical Inference

Posterior knowledge = prior knowledge	Likelihood of the data
p(θ | x) = p(θ)	p(x|θ) / p(x)

Source: Author's compilation.

The empirical issue of collecting the prior distribution of the probabilities in the model as estimated parameters p(θ) shows that the knowledge of the researcher needs to be considered. Expert judgment supports the selection of the prior distribution in the Bayesian inference. The natural results of the analysis of the posterior distribution p(θ|x) can be summarized by the mean, median, etc. In the statistics, the major concept is the subjective probabilities (Ramsey 1926; De Finetti 1937).

5.3.5 Poisson Pseudo-Maximum Likelihood Estimator

A robustness check of the gravity model can be applied using the Poisson pseudo-maximum likelihood estimator with the fixed effect model. On the basis of the nonlinear form of the gravity model derived by Anderson and van Wincoop (2003), a multiplicative disturbance term can be written as:

$$X_{ij}^k = \frac{Y_i^k E_j^k}{Y^k} \left(\frac{\tau_{ij}^k}{\Pi_i^k P_j^k} \right)^{1-\alpha_k} e_{ij}^k$$

The standard gravity model in linearized form can be derived from natural logarithms, but with the logarithmic error term.

$$logX_{ij}^k = logY_i^k + logE_i^k - logY^k + (1 - s_k)\left[log\tau_{ij}^k - logP_i^k - logP_j^k\right] + loge_{ij}^k$$

The mean value of $loge_{ij}^k$ depends on higher moments of e_{ij}^k, and hence includes the variance. The expected value of the disturbance term depends on one or more independent variables because of the inclusion of the variance, if e_{ij}^k is heteroskedastic. Under heteroskedasticity, it is assumed that the multiplicative errors in the nonlinear model require the adoption of a different approach.

5.4 Results and Discussion

This section presents the results of the Bayesian gravity model analysis. The annual data from 1995 to 2018 were collected from 43 Asian countries for the study. These Asian economies have bilateral trade relationships within the region and also with the rest of the world. The gravity model is estimated for imports—instead of the total trade turnover—with every trading partner of the Asian economies. The estimations are based on annual values of real trade of the Asian economies with whole-world bilateral partners in each country. Consequently, the gravity model predicts trade in each economy in Asia with every trading partner in the world.

Table 5.2 shows the summary statistics of the variables used in the gravity model analysis.

Table 5.2: Summary Statistics of the Variables

Variable	Mean	Std. Dev.	Observations
Trade inflow (import of the trade)	78.64	1,836.82	34,278
GDP of country of origin	2.38e+11	8.11e+11	31,114
GDP of country of destination	1.97e+10	1.84e+10	31,069
Population of country of origin	41.84	192.73	34,278
Population of country of destination	31.37	29.72	32,245
Distance between countries	8,365.86	3,739.20	34,278
Mobile telephone subscriptions per 100 people	86.59	39.15	2,536
Mobile-broadband subscriptions per 100 people	35.08	36.41	4,365
Fixed-broadband internet subscriptions per 100 people	6.78	9.18	3,578
Fixed telephone lines per 100 people	18.23	16.62	3,535
Internet users' percentage of adult population	31.74	24.50	2,535
GDP per capita of the country of origin	9,428.39	13,003.92	31,746
GDP per capita of the country of destination	7,291.87	10,382.11	31,661
Area of country of origin	788,241.50	227,143.91	34,278
Area of country of destination	542,981.60	529,674.86	34,278

GDP = gross domestic product.

Source: Author's estimations.

5.4.1 Gravity Model Estimator

The results of the basic gravity model in Table 5.3 report the estimation of coefficients on the bilateral trade integration in Asia. In general, these equations fit the data well, indicating that the proposed explanatory variables were significantly related to bilateral trade. The coefficients of determination (R^2) range from 62% to 76%. The F-test (p-value) results show that collectively the models were highly significant. These results are in line with the usual gravity model findings from other papers. Starting from the simple standard model, Table 5.3 shows the results of the estimated gravity model from the basic model to extended model. Equation (1) shows the GDP and distances, while equations (2), (3), and (4) represent the augmentation with other variables including the digitalization indexes.

Based on the basic estimation (1), the log of GDP of the country of origin and the log of GDP of the country of destination are positively significant, while the log of the distance between countries is negatively significant. When the model is extended with the log of the population of the country of origin and log of the population of the country of destination in (2), the population of the country of origin is positively significant, and the population of the country of destination is negatively significant. When further supplemented by the areas of the countries, the log of the area of the country of destination is also negatively significant. However, the literature provides evidence that some other significant variables can have an influence on the trade flow between the countries in Asia. Hence, the model was further elaborated with the binary variables to incorporate barriers to trade integration. Among those variables, the binary variable for common religion was significantly positive in model (4). This implies that, at a robust estimation level, these factors are highly influenced by the import flow of the Asian economies. Throughout the four models, the GDP values of the original and destination countries are positively significant, whereas the distance between the countries is negatively significant.

As Table 5.3 shows, the coefficients on GDP of origin and GDP of destination are significant and positively signed, as are most of the population coefficients. This implies that the rich, highly populated countries tend to trade more in Asia and contribute to the trade integration. Further, it can be explained that trade integration will be successful in those countries that contribute to trade integration in the Asian region. However, in order to identify the impacts of trade integration, country-specific coefficients need to be calculated. As expected in the model, the coefficients on the distance variable "distance between countries" were all negative and significant. This also implied

Table 5.3: Results of the Gravity Model for Asian Economies

Variables: Log (Import)	Coefficients (Std. Err.) (1)	Coefficients (Std. Err.) (2)	Coefficients (Std. Err.) (3)	Coefficient (Std. Err.) (4)
Log of GDP of country of origin	0.51*** (0.03)	0.75*** (0.01)	0.88*** (0.01)	0.61*** (0.04)
Log of GDP of country of destination	0.74*** (0.01)	0.43*** (0.02)	0.45*** (0.02)	0.91*** (0.00)
Log of distance between countries	−0.76*** (0.03)	−0.84*** (0.01)	−0.68*** (0.01)	−0.53*** (0.12)
Log of mobile telephone subscriptions per 100 people	0.61*** (0.16)	0.32*** (1.40)	0.25*** (0.91)	0.21*** (0.06)
Log of mobile-broadband subscriptions per 100 people	0.28*** (0.14)	0.36*** (0.30)	0.20*** (0.01)	0.53*** (0.04)
Log of fixed-broadband internet subscriptions per 100 people	0.22*** (0.10)	0.31*** (0.30)	0.26*** (0.04)	0.26*** (0.06)
Log of fixed telephone lines per 100 people	0.24*** (1.40)	0.61*** (0.30)	0.22*** (0.08)	0.19*** (0.06)
Log of internet users' % of adult population	0.23** (1.13)	0.62** (0.31)	0.14** (0.02)	0.52*** (0.04)
Log of population of country of origin	–	0.17*** (0.02)	0.19*** (0.03)	0.12*** (0.06)
Log of population of country of destination	–	−0.02** (0.03)	−0.93*** (0.03)	−0.44*** (0.00)
Log of area of country of origin	–	–	0.08 (0.01)	0.09 (0.03)
Log of area of country of destination	–	–	−0.33*** (0.02)	−0.54*** (0.04)
Log of exchange rate of country of origin	–	–	−0.46*** (0.06)	−0.32*** (0.05)
Log of exchange rate of country of destination	–	–	0.47*** (0.01)	0.79*** (0.01)
Conflict of the sibling countries	–	–	–	0.44 (0.15)
Common religion	–	–	–	0.98*** (0.33)
Common language of pretrans	–	–	–	0.84*** (0.02)
Common language of posttrans	–	–	–	0.53*** (0.09)
Constant	−8.21*** (0.723)	−7.77*** (0.981)	−7.96*** (0.286)	−12.75*** (0.653)
No. of observations	12,368	12,024	12,852	12,342
R-squared	0.62	0.69	0.72	0.76
F-value	832.40	301.23	201.09	143.66
p-value	0.0000	0.0000	0.0000	0.0000

GDP = gross domestic product.

Note: *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

Source: Author's estimations.

that transport costs, a proxy for the geographic distance between the two countries, have a significant influence in determining the volume of trade between countries. This is where digitalization can have a significant influence in minimizing the transaction costs of the trade inflow.

The coefficient on the area of the destination was negatively signed and was significant for the country of destination. The literature suggests that this is because large countries have more natural resources and tend to trade less with other countries. Therefore, it also affects the trade integration of the countries in Asia. The inclusion of the exchange rate shows that an increase in the exchange rate of origin or destination implies a depreciation of the real effective exchange rate. As expected, for the coefficients associated with the importing partner, the exchange rate is negatively significant, whereas the exchange rate of the destination is positively significant. The binary variable for common language pre- and post-transition was also significant in the trade integration of Asia. This implies that a common language and therefore cultural similarities have influenced the trade contracts between countries. This could be due to the use of technologies in the trading process and the use of English as a common language in those countries for international trading.

DigitalizationIndex is significant in all four models. This implies that digitalization has a significant influence on the trade flow of the countries. Recently, digitalization has had an impact everywhere in the countries with the impact of mobile telephones, broadband, the internet, and fixed telephones to improve the digitalization process. Hence, trade has been facilitated by digitalization, especially in e-commerce and e-transactions.

In summary, the coefficient on GDP in the origin country and GDP in the destination country, population, and area of the original country and destination country is positive and significantly predicts the import growth. However, the distance between the countries has a negatively significant estimation in the model. Therefore, for these Asian economies, these macroeconomic variables have contributed to the trade integration. All the estimations suggest that trade integration has been significantly affected by the respective GDP, population, and area of the origin and destination countries. Therefore, the study suggests that the consideration of the trade integration needs to be deliberated on the impacts of trade flows. Even though the above econometric approach provides evidence on the significant factors that determine the trade integration, the Bayesian approach is required for more precise results of the estimates to give results of robust coefficients to understand the impacts and significance of different variables in the gravity model.

The results corresponding to the Bayesian approach of the gravity model for total import are depicted in Table 5.4. The estimates result in robust parameters for determining the impact factor for the importation of the trading countries, in that the elasticity of total imports with respect to distance and population of the destination and the exchange rate of the origin is negative, while it is positive for the proxies of economic size, areas, and exchange rates of the destination. The model is tested against its consistency through model testing as shown in Table 5.5.

Table 5.4: Results of the Bayesian Gravity Model

Variables: Log Import (Log of Trade Inflow)	Mean (Std. Err.)	MCSE***	Median
Log of GDP of country of origin	0.81 (0.00)	0.000	0.622
Log of GDP of country of destination	0.52 (0.07)	0.000	0.734
Log of distance between countries	−0.68 (0.01)	0.001	−0.754
Log of mobile telephone subscriptions per 100 people	0.29 (0.02)	0.003	0.493
Log of mobile-broadband subscriptions per 100 people	0.63 (0.00)	0.001	0.297
Log of fixed-broadband internet subscriptions per 100 people	0.82 (0.02)	0.002	0.429
Log of fixed telephone lines per 100 people	0.64 (0.00)	0.000	0.123
Log of internet users' % of adult population	0.13 (0.02)	0.002	0.425
Log of population of country of origin	0.21 (0.01)	0.001	0.812
Log of population of country of destination	−0.08 (0.02)	0.000	−0.097
Log of area of country of origin	0.03 (0.00)	0.001	0.010
Log of area of country of destination	0.05 (0.01)	0.001	0.212
Log of exchange rate of country of origin	−0.07 (0.01)	0.002	−0.048
Log of exchange rate of country of destination	0.22 (0.12)	0.001	0.094
Constant	−8.04 (0.01)	0.002	−8.217
Number of observations	12,764	12,764	12,764
Random-walk Metropolis-Hastings sampling burn-in	2,800	2,800	2,800
MCMC sample size	12,000	12,000	12,000
Acceptance rate	0.144	0.144	0.144
Efficiency: min	0.002		0.002
Efficiency: avg	0.004		0.004
Efficiency: max	0.011		0.011
Log marginal likelihood	−22,442.01	−22,442.01	−22,442.01

GDP = gross domestic product, MCMC = Markov Chain Monte Carlo.

***Monte-Carlo Standard Error (MCSE).

Source: Author's estimations.

Table 5.5: Bayesian Model Tests

	Log (ML)	P(M)	P(M|y)
Active	−1.75e+05	0.8600	0.6348

Note: Marginal likelihood (ML) is computed using Laplace-Metropolis approximation.
Source: Author's estimations.

5.4.2 Poisson Pseudo-Maximum Likelihood Estimator

This subsection reports on the robustness checks that were conducted for the gravity model analysis. First, the Poisson pseudo-maximum likelihood estimator was assessed for the full sample. Table 5.6 presents the results of the estimated gravity model. It can be seen from the estimator that the quantitative evidence obtained from the Bayesian gravity model for the full sample still holds when accounting for the comparability of the Poisson estimator.

Table 5.6: Results of the Poisson Estimates of a Fixed-Effects Gravity Model

Variables: Log of Import	Eq 1	Eq 2
Log of GDP of country of origin	0.31*** (0.02)	0.11** (0.03)
Log of GDP of country of destination	0.54*** (0.03)	0.18*** (0.01)
Log of distance between countries	−0.82** (0.02)	−0.03*** (0.00)
Log of mobile telephone subscriptions per 100 people	–	0.07*** (0.00)
Log of mobile-broadband subscriptions per 100 people	–	0.06*** (0.01)
Log of mixed-broadband internet subscriptions per 100 people	–	0.14*** (0.01)
Log of fixed telephone lines per 100 people	–	2.03** (0.02)
Log of internet users' % of adult population	–	0.11** (0.00)
Log of population of country of origin	0.11** (0.00)	−0.18*** (0.01)

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Table 5.6 *continued*

Variables: Log of Import	Eq 1	Eq 2
Log of population of country of destination	–0.18*** (0.01)	–0.03*** (0.05)
Log of area of country of origin	0.03*** (0.00)	0.07*** (0.02)
Log of area of country of destination	–0.07*** (0.00)	–0.06*** (0.01)
Log of exchange rate of country of origin	0.06*** (0.01)	0.14*** (0.01)
Log of exchange rate of country of destination	0.14*** (0.01)	0.03** (0.12)
Constant	–7.03** (0.01)	–7.03** (0.02)
Number of observations	6,298	6,184
R-squared	0.44	0.54
F-value	176.01	124.90
p-value	0.0000	0.0000

Note: *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.
Source: Author's estimations.

A robustness check of the gravity model was conducted with estimation of an alternative gravity model using the Poisson pseudo-maximum likelihood estimator. The results revealed that the digitalization indicators, such as mobile telephone subscriptions per 100 people, mobile-broadband subscriptions per 100 people, fixed-broadband internet subscriptions per 100 people; fixed telephone lines per 100 people, and internet users as a percentage of the adult population, are significant at the 5% level.

Similar results can be found in the Poisson pseudo-maximum likelihood estimator in estimating the gravity model with respect to the Bayesian gravity model. The effects of the trade inflow and GDP of the country of origin and destination are positive, while the distance between countries is negative.

5.5 Conclusion

The Bayesian gravity analysis was conducted to estimate the degree of impacts of determinants on international bilateral trade providing pragmatic evidence for trade integration in Asian economies. Further, the gravity model aimed at identifying the regional trade integration with a robustness scenario for the aptness of the trade integration in the region. The Bayesian gravity model reveals that the estimated coefficients on GDP in the country of origin and GDP in the country of destination, population, and area of the country of origin are positively significant predictors of the import growth. The distance between the countries has a negatively significant estimation, showing barriers in trade. The model predicts the trade integration, especially toward the trade inflow process in Asia with the rest of the world. The Bayesian approach of the gravity model gives robust estimates for determining the impact factor for the importation of the trading countries, including the elasticities of total imports with respect to distance and area of destination, and the exchange rate of origin are negative, while the proxies of economic size and areas are negative. The exchange rate of the destination is positive. The estimated parameters are directly the elasticities, in which increases in GDP are consistent with higher import volumes. The digitalization of the regions has a tremendous influence on the trade as depicted in the results, which indicate that digitalization indicators are significant in all equations.

The trade inflow in the model analyzes the "trade creation" and "trade diversion" effects of RTAs. In simulating the scenarios for international trade integration, the explanatory indicators quantify the trade potential between two partners. The gravity model is modified for international trade integration according to changes in key determinants to quantify the trade potential between two countries and measure the trade costs instead of trade inflows and to express these costs as a function estimating the barriers for trade integration with the assistance of digitalization. Finally, trade integration can be facilitated across Asia using the evidence and simulated scenarios for the estimation of the impacts of the trade inflows in Asia. Therefore, combining all the results of the Bayesian gravity model, a significant piece of evidence of this study is that trade integration can be promoted with the increase of particular significant variables at the country level, while stimulating those toward innovative approaches to trade facilitation in the digitalization process plays a significant role in the policy making in these economies. Therefore, the research evidence suggests that policy makers should design appropriate trade openness policies with the use of pragmatic findings for Asian countries.

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6

Impact of Information Technology and E-Commerce on Indonesia's Trade with ASEAN Countries

Yulya Aryani, Wina Andari, and Suhindarto

6.1 Introduction

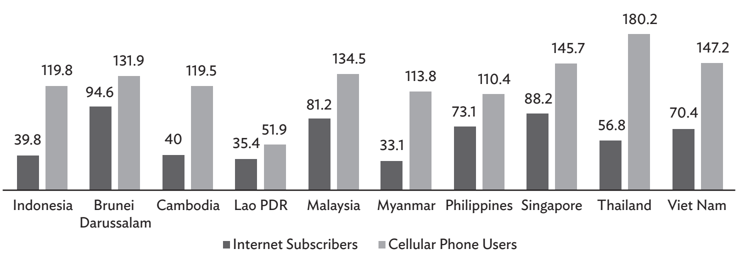
Massive technological development trends are leading to a fourth industrial revolution that emphasizes the use of information and communication technology (ICT) as a basis in various fields including economics. ICT is fully utilized not only in the production process but also throughout the industrial chain, and more than that is giving birth to new business models. At the macro level, technological development encourages economic development and contributes to the economic growth of a country (Arsyad 1999; Cette, Lopez, and Noual 2005; Choi and Yi 2009) by contributing to productivity and efficiency and competition in trade (Choi and Yi 2009).

The Association of Southeast Asian Nations (ASEAN) is one of the regions with great potential as a world economic power. This is because ASEAN has a large population that amounts to 8.5% of the world population and was able to contribute 3.5% of world gross domestic product (GDP) in 2018. In terms of trade, goods trade in ASEAN grew 9.4% and service trade grew 10.7% in 2018. ASEAN's main external trading partners are the People's Republic of China (PRC) (17.12%), the European Union (10.20%), and the United States (9.31%). Intra-ASEAN trade is the largest share of ASEAN trade, reaching 23.03%.

In terms of exports, in 2018 the proportion of exports from ASEAN countries to intra-ASEAN countries reached 24% or equivalent to $346.46 billion, while the proportion of exports to extra-ASEAN countries reached 76%. This shows that the volume of ASEAN's exports to intra-ASEAN countries is quite large. Out of the total value, Indonesia's total exports to intra-ASEAN countries alone amounted to $41.19 billion or 12% of the total intra-ASEAN exports.

Figure 6.1 shows that ASEAN countries have been connected online and enjoyed communication services through smartphones. Bankole, Osei-Bryson, and Brown (2013) and Chu and Guo (2019) explain that progress in using ICT plays an important role in facilitating trade. With a population of more than 649.1 million people and an internet penetration rate of 53.4 per 100 people in 2018, this also makes ASEAN the third-largest group of internet users in Asia, after the PRC and India (Sen, Attavar, and Jaiswal 2016). Various studies state that internet penetration drives a country's international trade, which then drives economic growth.

Figure 6.1: Level of ICT Use in ASEAN Countries (per 100 Persons)



ASEAN = Association of Southeast Asian Nations, ICT = information and communication technology, Lao PDR = Lao People's Democratic Republic.

Source: ASEAN Secretariat (2019).

Improved ICT infrastructure along with demographic bonuses that are technology literate are the main drivers of ASEAN economic growth. Studies conducted by Xing (2017), Chu and Guo (2019), and Ozcan (2017) show that the use of ICT in trade offers several benefits, including (i) integration of markets and industries with transactions, and distribution of goods and services with no time and geographical limits; (ii) efficiency of trade costs; (iii) opening and expanding of market access; and (iv) acceleration of business activities in the intra-ASEAN and global markets. Furthermore, the ICT revolution with digitalization has led to the creation of e-commerce. E-commerce continues to experience rapid growth in the world of trade, because it has a significant influence that can be seen from the quality of transactions through this facility, whether done by business to business (B2B) or business to consumer (B2C) or other forms of utilization. Google, Temasek, and Bain & Company (2019) state that the internet economy in ASEAN will reach $300 billion in 2025 with a compound annual growth rate (CAGR) of 33%. In the 2016 *Global Information Technology Report* released by the World Economic Forum, B2C trade in ASEAN was reported to have experienced rapid development with CAGRs from five ASEAN countries (Singapore, Malaysia, Thailand, Indonesia, and Viet Nam) projected to grow by 37% from $7 billion in 2013 to $34.5 billion in 2018.

In order to optimize market potential, in the ASEAN ICT Masterplan 2020 (ASEAN 2015) ASEAN member states agreed that the ASEAN economy is driven through involvement in the digital economy and e-commerce. For this reason, ASEAN countries have carried out several leading ICT development programs, such as enhancing digital connectivity aimed at minimizing obstacles and increasing public access to e-commerce. Furthermore, in 2018, ASEAN countries agreed to form an ASEAN Coordinating Committee on Electronic Commerce, which aims to bridge the needs of cross-border e-commerce trade in promoting economic growth in ASEAN.

In the midst of the intense application of ICT in stimulating trade, the digital economy contributes significantly to Indonesia's economic growth. This is supported by research facts regarding the positive impact of ICT on development and economic growth, e.g., an internet penetration rate of 10% causes an increase of 1.3% of GDP, and an internet usage rate of 21.5% equals an increase of 10% of GDP per capita (Andres et al. 2010; Choi and Yi 2009). At the ASEAN level, Indonesia is the largest e-commerce market. The study of Google, Temasek, and Bain & Company (2019) shows that Indonesia's digital economy reaches $40 billion. This figure means that the digital economy transactions of Indonesia are ranked first for the Southeast Asian region with a CAGR of 32%. The growing demographic and telecommunications infrastructure bonus with increasing internet penetration (reaching 68.4% in 2018) causes the contribution of this sector to the Indonesian economy to continue to increase and it is projected to reach $133 billion in 2025.

Studies on the impact of ICT and the development of e-commerce have been widely carried out. Several studies have focused on exploring the impact of ICT on trade in the markets of ASEAN partner countries and the use of e-commerce in driving trade activities, but there has been no research illustrating the impact of ICT and e-commerce utilization from optimizing its own market, namely intra-ASEAN. For this reason, further research is needed related to trade interactions between Indonesia and ASEAN countries to gain a comprehensive understanding of the impact of the development of ICT and the use of e-commerce on increasing Indonesia's trade in ASEAN countries.

6.2 Literature Review

6.2.1 Information and Communication Technology and Its Impact on International Trade

In the recent massive digitalization and globalization era, the use of ICT in every aspect of human activity has been very important, especially in international trade. There are several studies that analyze the impact of ICT on regional trade flows and have become references in this study. A recent one from Chu and Guo (2019) explains that ICT has a positive and significant impact on international trade between the PRC and ASEAN countries. This study also concludes that ICT is the key determinant of international trade between the PRC and ASEAN countries. In terms of exports from ASEAN countries to the PRC, the internet has a bigger impact than telephones or cellular phones. On the other hand, the internet and cellular phones have a positive impact on the imports and bilateral trade of ASEAN countries from the PRC.

Xing's (2017) study on Organisation for Economic Co-operation and Development (OECD) countries explains that the application of ICT has a positive and significant impact because it improves two-way communication between trading partner countries. The study also explains that improvements in terms of faster internet access and server security will increase trade. Moreover, ICT-based technology will encourage people and companies to find the best service providers or producers regardless of distance.

In particular commodity cases such as international trade of fruit and vegetables by Asia-Pacific Economic Cooperation (APEC) economies, Chung, Fleming, and Fleming (2013) explain that landline telephones (traditional ICT devices) in the export value chain sector have a positive impact on the trade value of fruits and vegetables between trading partner countries, while the impact on imports is not significant. Therefore, we can infer that the positive impact of ICT on the trade value of fruits and vegetables is only found in exports, and not in imports.

Bianchi and Mathews (2015), in a study conducted in developing countries, show that the use of ICT, in this case internet marketing capabilities, has a positive effect on the availability of export information, which in turn has an impact on the development of business network relationships and the growth of export markets. Furthermore, a study conducted by Demirkhan et al. (2009) states that the use of ICT can affect trade costs and that with the use of ICT the flow of trade will decrease with distance. This is based on the notion that ICT can positively affect trade (Venables 2001) through the following:

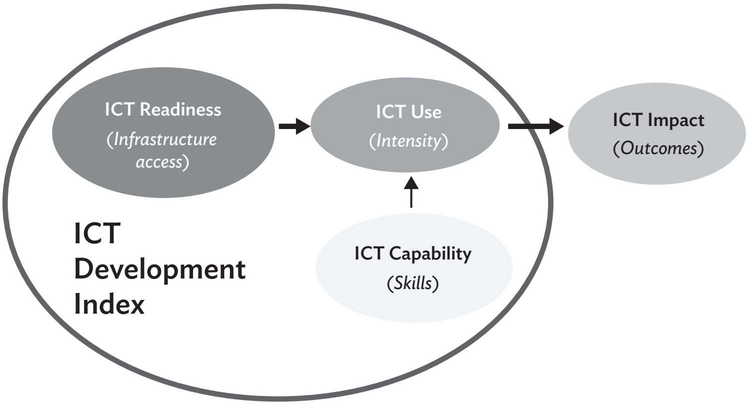
(i) *Search cost*. ICT-supported intermediation between buyers and sellers creates an e-marketplace that lowers buyer costs of acquiring information about seller prices and produce offerings. This reduces buyer search cost inefficiency.
(ii) *Management and control cost*. Monitoring employees and trading partners ensures transactions can be performed electronically by the principal, thereby reducing cost.
(iii) *Shipping cost*. ICT reduces coordination cost, which reduces shipping cost. This reflects ICT-led reductions in supply chain management overall.
(iv) *Time cost*. ICT supports communication at lower cost; the marginal cost of communicating at any greater distance is essentially zero.

6.2.2 ICT Development Index and Its Impact on Trade

The ICT Development Index (IDI) is a composite index that combines 11 indicators into one index, which becomes a benchmark measure. This index is used to monitor and compare developments in ICT between countries and over time (ITU 2021). We can identify the three-stage model, which shows the ICT development process and a country's evolution toward becoming an information society as illustrated in Figure 6.2:

(i) Stage 1: ICT readiness
reflecting the level of networked infrastructure and access to ICTs
(ii) Stage 2: ICT intensity
reflecting the level of use of ICTs in the society
(iii) Stage 3: ICT impact
reflecting the results/outcomes of more efficient and effective ICT use

Figure 6.2: Three Stages in the Evolution Toward an Information Society



ICT = information and communication technology.

Source: International Telecommunication Union (2021).

Based on the conceptual framework shown in Figure 6.2, the IDI is divided into three subindexes and 11 indicators.

(i) *Access subindex* (captures ICT readiness), consisting of indicators such as: fixed-telephone subscriptions, mobile/cellular telephone subscriptions, international internet bandwidth per internet user, households with a computer, and households with internet access.

(ii) *Use subindex* (captures ICT intensity), including individuals using the internet, fixed-broadband subscriptions, and mobile-broadband subscriptions.

(iii) *Skills subindex* (captures capabilities or skills), such as mean years of schooling, gross secondary enrollment, and gross tertiary enrollment.

Several studies used the IDI as an indicator to determine the impact of ICT on trade. The study of Ozcan (2017), who saw the impact of ICT on international trade in Turkey, also found that the IDI has a significant and positive impact on the bilateral export and import volume of Turkey. The positive impact of ICT is the result of the decreasing cost related to trade, such as fixed-market entry cost, and communication and information cost. The increasingly connected ICT between two countries will also increase the bilateral trade between them. Overall, ICT has a positive and significant impact on Turkey's export and import volume, but the impact is bigger on import than export. Furthermore, for export, access and high-level ICT skills are crucial to increasing export volume.

Table 6.1: Indicators, Reference Values, and Weight in the ICT Development Index

ICT Access (40%)	Reference Value	%
Fixed-telephone subscriptions per 100 inhabitants	60	20
Mobile/cellular telephone subscriptions per 100 inhabitants	120	20
International internet bandwidth (bit/s) per internet user	976'696*	20
Percentage of households with a computer	100	20
Percentage of households with internet access	100	20
ICT Use (40%)	**Reference Value**	**%**
Percentage of individuals using the internet	100	33
Fixed-broadband subscriptions per 100 inhabitants	60	33
Active mobile-broadband subscriptions per 100 inhabitants	100	33
ICT Skill (20%)	**Reference Value**	**%**
Mean years of schooling	15	33
Secondary gross enrollment ratio	100	33
Tertiary gross enrollment ratio	100	33

ICT = information and communication technology.

Note: *This corresponds to a log value of 5.99, which is used in the normalization step.

Source: International Telecommunication Union (2021).

The research by Wardani, Azizurrohman, and Tanthowy (2019) on the case of the bilateral trade between Indonesia and ASEAN countries shows that ICT development has positive and significant impacts on Indonesia's volume of exports toward ASEAN countries. Moreover, other variables, such as the real GDP of Indonesia, the real GDP of partner countries, and population, have a positive and significant effect on Indonesia's export. Meanwhile, distance and real exchange rates have a negative and significant effect on Indonesia's export.

Another study by Wardani, Nahar, and Hairunnas (2020) shows that subindexes of the IDI such as mobile/cellular telephone subscriptions have a positive and significant impact on Indonesia's service export to ASEAN countries. The other variables that have a significant impact on Indonesia's export in terms of service are GDP and distance. GDP reporters, GDP partners, and common language have a positive and significant effect on Indonesia's service export. Meanwhile, distance has a negative and significant effect on Indonesia's service export.

6.2.3 The Impact of E-Commerce on International Trade

The study conducted by Xing (2017) confirms the impact of ICT adoption and e-commerce on bilateral trade flows. This research used a panel data approach (gravity model) with a cross-section consisting of 21 least developing or least developed countries and 30 OECD countries. Specifically, this study used B2B and B2C indexes (data taken from the World Economic Forum report), which are part of the Network Readiness Index. The index consists of 54 indicators and is regulated by 10 pillars. The B2B index measures the extent of ICT adoption for B2B transactions, while B2C shows the extent to which businesses use the internet to sell their goods and services to consumers. This index is below the business use subindex (7th pillar) and is measured on a scale of 1 to 7 (with 7 being the best result). The results show significant linkages to countries that are increasing their trade through e-commerce, use of the internet, and export of goods to other countries. The study also found that there is a great potential of e-commerce for developing and least developing countries. Moreover, B2B and B2C e-commerce has a great role as a potential booster of trade, so the government must continue to carry out efficient e-commerce import and export procedures (including handling fast-track intermediary goods in e-commerce transactions).

Furthermore, Yushkova (2014) used the Business Internet Index to estimate the influence of the internet on total goods exports in 2011. The study used data from 40 countries (OECD countries plus Brazil, the PRC, India, Indonesia, the Russian Federation, and South Africa). The results show a significant positive relationship between internet use and export and import activities. Then, Ueasangkomsate (2015), in a study of the adoption of e-commerce for export markets of small and medium-sized enterprises (SMEs) in Thailand, shows that there is a relationship between SME exporters and e-commerce adoption, which is significantly dependent. Terzi (2011), in her study, tells us that international trade volume will increase via e-commerce, but the gains that are caused by e-commerce will likely be concentrated among developed countries in the short run, although developing countries will gain more benefit in the long run. The countries open to imports from high-income economies will benefit from knowledge spillovers.

In line with the above research, this study will further examine the nexus of e-commerce (i.e., B2B and B2C) adoption in Indonesian trade flows with trading partner countries in ASEAN. The following sections discuss data and variable definitions, method, and model specifications.

6.3 Data, Model, and Estimation Methodology

6.3.1 Data and Variable Definitions

The data set used in this study comprises panel data collected from a variety of sources (see Table 6.2). The cross-sectional data come from nine ASEAN member states that are trade partners of Indonesia, namely Brunei Darussalam, Cambodia, the Lao People's Democratic Republic, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Viet Nam. The variables used include factors that affect Indonesia's exports to ASEAN member states, which consist of macroeconomic variables and

Table 6.2: Variable Definition and Source

Variable	Definition	Source
$Export_{ijt}$	Total exports of goods from country *i* to country *j* for year *t*	World Bank (UN Comtrade)
$GGDP_{it}$	GDP growth in country *i* for year *t*	World Bank
$GGDP_{jt}$	GDP growth in country *j* for year *t*	World Bank
$Distance_{ijt}$	Economic distance between country *i* and country *j* for year *t*	Centre d'Études Prospectives et d'Informations Internationales (CEPII)
$MarketSize_{ijt}$	Relative market size of country *i* in country *j* for year *t*	World Bank (UN Comtrade)
IDI_{it}	Index value of ICT development in country *i* for year *t*	International Telecommunication Union (ITU) Report 2010–2013 and Report 2015–2017
IDI_{jt}	Index value of ICT development in country *j* for year *t*	ITU, Report 2010–2013 and Report 2015–2017
$B2B_{it}$	Index value of internet usage in business-to-business transactions in country *i* for year *t*	INSEAD, The Global Information Technology Report 2012–2015, World Economic Forum (WEF)
$B2B_{jt}$	Index value of internet usage in business-to-business transactions in country *j* for year *t*	WEF, Report 2012–2015

ICT = information and communication technology, UN Comtrade = United Nations International Trade Statistics Database.

Source: Authors' compilation.

ICT variables. There are data limitations particularly on the ICT and e-commerce variables, therefore this study limits the research period to the years 2010–2018.

6.3.2 Method and Model Specification

The analysis method used is a quantitative and qualitative analysis of static panel data with a gravity model approach using the fixed-effect model. The gravity model is used to explain bilateral trade flows by dividing the size of the economy between two countries represented by GDP and the distance between the trade centers of the two countries (Bergstrand and Egger 2011). According to Burger, van Oort, and Linders (2009), the gravity model equation is as follows:

$$trade_{ij} = A \frac{(GDP_i)^{b1}(GDP_j)^{b2}}{(distance_{ij})^{b3}}$$

where $trade_{ij}$ shows the trade value between countries i and j, GDP_i shows the national income of country i, GDP_j shows the national income of country j, $distance_i$ shows the economic distance between countries i and j, and A shows a constant. The formula shows that the trade value is positively influenced by the national income of the origin country and the national income of the destination country, and negatively influenced by the economic distance between the origin country and the destination country.

Furthermore, the basic equation for the gravity model is developed by including variables that have a potential impact on trade value. Therefore, to analyze the impact of ICT and e-commerce on Indonesia's trade with ASEAN member states, several variables are used based on previous theory and studies. Xing (2017) used ICT-related infrastructure variables such as broadband subscriptions and number of internet users, and e-commerce indices such as B2B and B2C indexes to analyze the impact of ICT and e-commerce on bilateral trade flows. Meanwhile, Ozcan (2017) used ICT indices such as the IDI to analyze the relationship between ICT and international trade.

This study divides the variables into two groups, namely macroeconomic variables and ICT variables. The difference between this study and previous studies is the research period from 2010 to 2018, and it specifically discusses Indonesia's trade interactions with ASEAN member states. To avoid biased models, two models are used in this study, with model (1) aiming to analyze the impact of ICT and model (2) aiming to analyze the effect of e-commerce on ASEAN member states among Indonesia's trading partners. The model used in this study is formulated as follows:

$$LNExport_{ijt} = \beta_0 + \beta_1 GGDP_{it} + \beta_2 GGDP_{jt} + \beta_3 LNDistance_{ijt} + \beta_4 MarketSize_{ijt} + \beta_5 IDI_{it} + \beta_6 IDI_{jt} + \varepsilon_{it} \quad (1)$$

$$LNExport_{ijt} = \beta_0 + \beta_1 GGDP_{it} + \beta_2 GGDP_{jt} + \beta_3 LNDistance_{ijt} + \beta_4 MarketSize_{ijt} + \beta_5 B2B_{it} + \beta_6 B2B_{jt} + \varepsilon_{it} \quad (2)$$

where:

$LNExport_{ijt}$	is the natural log of total exports of goods from Indonesia to ASEAN partner countries in current United States dollars;
$GGDP_{it}$	is the GDP growth of Indonesia;
$GGDP_{jt}$	is the GDP growth of ASEAN partner countries;
$LNDistance_{ijt}$	is the natural log of economic distance between Indonesia and ASEAN partner countries;
$MarketSize_{ij}$	is the market size of Indonesia in ASEAN partner countries;
IDI_{it}	is the level of ICT development in Indonesia;
IDI_{jt}	is the level of ICT development in ASEAN partner countries;
$B2B_{it}$	is the level of internet usage in business-to-business transactions in Indonesia;
$B2B_{jt}$	is the level of internet usage in business-to-business transactions in ASEAN partner countries; and
ε_{it}	is the disturbance term.

Based on the background and literature review, the independent variables used in this study are expected to have an impact on trade value. The first macroeconomic variable, $GGDP_{it}$, shows the market strength of Indonesia as an exporter country as it is expected to have a positive impact on the export value of Indonesia. $GGDP_{jt}$ shows the market strength of ASEAN member states as importer countries as it is expected to have a positive impact on the export value of Indonesia. $LNDistance_{ijt}$ describes the time and cost of international trade, which is expected to have a negative impact on the export value of Indonesia. $MarketSize_{ijt}$ describes the market size of Indonesia in ASEAN member states, which is expected to have a positive impact on the export value of Indonesia.

The ICT variable, which is the level of ICT development both in Indonesia (IDI_{it}) and ASEAN partner countries (IDI_{jt}), is expected to have a positive impact on the export value of Indonesia. The e-commerce

variable, namely the use of the internet in B2B transactions both in Indonesia ($B2B_{it}$) and ASEAN partner countries ($B2B_{jt}$), is expected to have a positive impact on the export value of Indonesia.
Furthermore, the formulated model needs to go through several stages: the selection of estimation models, criteria test, and analysis of estimation results. More complete estimation results are presented in the next section.

6.4 Results and Discussion

6.4.1 Preliminary Data Analysis

The general description of the descriptive statistics of the variables used in this study is divided into two groups: first, variables that describe the development and level of ICT use as shown in Table 6.3; second, variables that describe the performance of macroeconomic indicators as shown in Table 6.4.

The IDI is an indicator that we use to describe the level of ICT development between countries. Table 6.3 shows that the IDI of ASEAN countries is quite good (scale 0–10). The average score for the IDI for Indonesia's trading partner countries in ASEAN is 4.66, with the highest score being 7.90 for Singapore. During the research period, Singapore consistently recorded an IDI score above 7, while Myanmar consistently recorded the lowest IDI score.

Furthermore, Indonesia itself has an average IDI score of 3.86, which is lower than the average of its trading partner countries in ASEAN. In 2015, Indonesia recorded the highest IDI score with a value of 3.94. However, in 2012 the value of Indonesia's IDI was only 3.43, which is the lowest score for Indonesia during this research period. Thus, between the highest and lowest average values of Indonesia's IDI, the values are not too different. This can be a signal that ICT development in Indonesia is still not very significant.

There are interesting things that emerge from the B2B variable. This indicator describes the level of ICT use in the business or economic activities of a company (e-commerce) on an index scale between 1 and 7. During that period, the level of ICT use in business activities (e-commerce) in ASEAN countries was almost the same. This is indicated by the average value of the level of ICT use for business activities in Indonesia ($B2B_i$), which is not very different from the ASEAN region ($B2B_j$). This indicates that although the IDI of each country in ASEAN has significant differences, in general the public or companies in these ASEAN countries have used ICT to help their economic activities (e-commerce) properly.

Table 6.3: Descriptive Statistics of ICT Variables (Indexes)

	IDI_i	IDI_j	$B2B_i$	$B2B_j$
Mean	3.860000	4.658095	4.876190	4.990476
Median	3.860000	4.760000	4.900000	5.000000
Maximum	3.940000	7.900000	5.100000	6.000000
Minimum	3.430000	1.950000	4.600000	3.300000
Std. Dev.	0.110091	1.844371	0.216575	0.724503
Skewness	−2.902903	0.291864	−0.291064	−0.850650
Kurtosis	12.33792	2.236821	1.451022	3.315098
Jarque-Bera	105.7911	0.807783	2.395931	2.619496
Probability	0.000000	0.667716	0.301808	0.269888
Sum	81.06000	97.82000	102.4000	104.8000
Sum Sq. Dev.	0.242400	68.03412	0.938095	10.49810
Observations	21	21	21	21

ICT = information and communication technology.
Source: Eviews Output.

The next section is the group of macroeconomic variables that are the control variables in this study. $Export_{ij}$ is an indicator that describes Indonesia's total exports (merchandise trade) to trading partner countries in ASEAN. During 2010–2018, Indonesia's export performance continued to increase with an average export rate of $4.27 billion. This is also in line with Indonesia's market share in ASEAN partner countries ($MarketSize_{ij}$), which also continues to increase. In 2017, Indonesia's market share even reached 6.73% (the Philippines was a trading partner country), which is quite high compared to several other trading partner countries in ASEAN.

The data in Table 6.4 also show that on average, Indonesia's economic growth rate ($GGDP_i$) is slightly higher than the GDP growth of ASEAN partner countries ($GGDP_j$). In 2010, Singapore was one of Indonesia's trading partners in ASEAN and achieved the highest economic growth rate of 14.53%. Lastly, the indicator that describes the economic distance between Indonesia and trading partner countries in ASEAN, $Distance_{ij}$, shows an average value of 213.71 kilometers. Meanwhile, Indonesia's economic distance to the closest trading partners in ASEAN is 72.55 kilometers (to Singapore) and the farthest distance is 396.21 kilometers (to Viet Nam).

Table 6.4: Descriptive Statistics of Macroeconomic Variables

	Export$_{ij}$ ($ million)	*GGDP$_i$* (%)	*GGDP$_j$* (%)	*Distance$_{ij}$* (km)	*MarketSize$_{ij}$* (%)
Mean	4,269.805	5.460000	5.457778	207.7243	3.403333
Median	2,451.200	5.170000	6.250000	215.7300	3.600000
Maximum	18,443.89	6.220000	14.53000	370.2300	6.730000
Minimum	4.210000	4.880000	−2.510000	72.55000	0.080000
Std. Dev.	4,919.618	0.517076	2.757447	78.90537	1.698373
Skewness	1.167569	0.436944	−0.720354	0.041910	−0.270269
Kurtosis	3.473790	1.453144	5.000191	2.035552	2.339872
Jarque-Bera	19.16103	10.65300	20.50785	3.163000	2.456829
Probability	0.000069	0.004861	0.000035	0.205666	0.292756
Sum	345,854.2	442.2600	442.0800	16,825.67	275.6700
Sum Sq. Dev.	1.94E+09	21.38940	608.2812	498,084.6	230.7576
Observations	81	81	81	81	81

km = kilometer.

Source: Eviews Output.

6.4.2 ICT and E-Commerce Impact on Indonesia's Trade with ASEAN

The next section is an analysis of how the influence of ICT and the use of ICT for business activities (e-commerce) impact the performance of Indonesian trade ($LNExport_{ij}$) with trading partners in ASEAN. Table 6.5 shows the estimation results used with the selected approach. This model approach is based on the results of selecting the best model through the Chow test and Hausman test.

Table 6.5: Chow Test and Hausman Test

	Chi-Square Probability		
	Chow Test	Hausman Test	Model Approach
Model 1	0.0000	1.0000	*Random-Effect Model (REM)*
Model 2	0.0000	0.0469	*Fixed-Effect Model (FEM)*

Source: Eviews Output.

In addition, in the selected estimation results, the classical assumption test has been carried out in order to obtain a regression model that is free from problems such as multicollinearity (the variable value of the inflation factor variance < 10; see Appendix Table A6.1), normality (Jarque-Bera probability value > 0.05), and autocorrelation (DW values 1.050736 and 2.706250), and heteroscedasticity (sum square residual unweighted > sum square residual weighted), which have been overcome by weighting the cross-section weight and period weight (Prasanti, Wuryandari, and Rusgiyono 2015; Sutikno, Faruk, and Dwipurwani 2017).

Based on the estimation results shown in Table 6.6, the results show that the ICT variable, the use of ICT for business activities (e-commerce), and the macroeconomic variables have a significant effect on Indonesia's trade performance with trading partner countries in ASEAN. The influence of ICT can be shown by the significance of the IDI_i and $B2B_i$ variables, while the effect of macroeconomic indicators is shown by the significance of *GGDP*, $LNDistance_{ij}$, and $MarketSize_{ij}$.

Table 6.6: Estimation Results

Independent Variable	Dependent Variable: *LNExportij* [1]	[2]
$GGDP_i$	0.371384** (2.156878)	0.134126* (1.899804)
$GGDP_j$	0.006028 (0.355371)	0.077533*** (6.177529)
$LNDistance_{ij}$	1.062185** (2.666720)	0.474788*** (4.269426)
$MarketSize_{ij}$	0.250827*** (2.771705)	0.546811*** (13.27166)
IDI_i	0.533355* (1.948705)	
IDI_j	0.063989 (0.742054)	
$B2B_i$		0.386182*** (3.520757)
$B2B_j$		0.048204
Constant	−3.832662	−0.402092
Adj-R2	0.174459	0.999690
F-Stat	3.113262	6448.519
Cross-section/N	61	29

Notes: The value in ( ) is the t-stat; ***, **, and * significant at 1%, 5%, and 10%, respectively.
Source: Eviews Output.

The estimation results confirm that the IDI variable (IDI_i) has a significant positive relationship in increasing Indonesia's trade with trading partner countries in the ASEAN region. This finding is in line with the initial hypothesis that there is a positive relationship between IDI_i and $LNExport_{ij}$. These results are also in line with research conducted by Chu and Guo (2019), Xing (2017), and Ozcan (2017). This positive relationship is also in line when we look at data from the Indonesian Internet Service Providers Association, which show that the number of internet users in the country continues to increase. The increase in the number of internet users is also followed by the characteristics of the behavior of Indonesian internet users who actively utilize ICT (internet) as a medium for communication and business activities (trade). For example, in 2017, with the number of internet users in Indonesia reaching 143.26 million people (58.08% of the population), based on the type of ICT services used, 32.19% used ICT (internet) for purchasing activities and 8.12% for selling goods. Furthermore, the use of ICT (internet) in the economic sector is also dominated by price-seeking activities (45.14%), online buying activities (32.19%), and online selling activities (16.83%). This proportion of the behavioral characteristics of internet users in Indonesia was stable during the period in which this research was conducted. In addition, the positive relationship between IDI_i and $LNExport_{ij}$ is indirectly the impact of the ICT infrastructure development carried out by the government, including the development of the Palapa Ring telecommunication network.

Then, to further confirm what the impact of ICT is, we also use an indicator of the use of ICT for business activities (e-commerce), namely the B2B index. Table 6.6 shows that the use of ICT for business activities (e-commerce) carried out by Indonesia ($B2B_i$) has a significant positive effect on increasing the value of Indonesian exports ($LNExport_{ij}$) to trading partner countries in ASEAN. The results of this study are in line with research conducted by Xing (2017). Studies conducted by Xing (2017) and Chu and Guo (2019) state that through e-commerce activities, business actors, both individuals and the general public, no longer have time and distance constraints in carrying out trading activities. Trading activities, including transaction activities, can also be carried out online. In addition, business actors and individuals in general also have the opportunity to attract more consumers. This finding can be confirmed from the e-commerce business landscape in Indonesia. The study of Google and Temasek (2018) states that the gross merchandise value (GMV) of the e-commerce industry in Southeast Asia reached $23.2 billion or the equivalent of Rp336.4 trillion, with the GMV of e-commerce in Indonesia reaching $12.2 billion. The GMV of Indonesian e-commerce in 2018 was higher than that of Malaysia

($2 billion), the Philippines ($1.5 billion), Singapore ($1.8 billion), Thailand ($3 billion), and Viet Nam ($2.8 billion). This value is predicted to continue to increase.

In another context, macroeconomic variables ($GGDP_i$, $LNDistance_{ij}$, and $MarketSize_{ij}$) have a significant positive effect on Indonesia's trade with intra-ASEAN partners. Indonesia's economic growth ($GGDP_i$) shows a significant positive relationship with the value of Indonesian trade in the intra-ASEAN market. These results are in line with studies conducted by Arsyad (1999); Cette, Lopez, and Noual (2005); and Choi and Yi (2009). Mankiw (2007) explains that GDP is used as an indicator in determining the direction of development and the level of income of a country. In addition, GDP also describes the size of a country's economy and shows the potential capabilities of that country. From the Indonesian perspective as an exporting country, increased economic growth will lead to increased production, thereby increasing the supply of goods and services, which in turn will encourage increased exports.

Furthermore, the economic distance variable is a proxy for transportation costs. The estimation results show a positive relationship between economic distance ($LNDistance_{ij}$) and Indonesia's trade with partner countries in ASEAN ($LNExport_{ij}$). These results are not in line with studies conducted by Wardani, Azizurrhoman, and Tanthowy (2019) and Demirkhan et al. (2009). This positive relationship can be explained by the fact that the distance variable in the gravity regression is a proxy for several determinants of international trade and also combines some of the effects of improvements in communication and technology. In addition, the data plots for exports and economic distance show a unidirectional relationship. For example, Indonesia's exports to Viet Nam, which was the farthest country for export during the study period, continued to increase. This indicates that the focus of Indonesia's exports is to target the main market for the commodity to be exported and not only the proximity of the export destination countries. As a compensation for geographical distance, producers will increase export volume so that transportation costs become more efficient. Therefore, the farther the distance between Indonesia's main trading partners, the greater the exports carried out by Indonesia.

The market share variable ($MarketSize_{ij}$) shows a significant positive relationship with Indonesia's exports to trading partner countries in ASEAN. A large and increasing market share will have an impact on increasing demand for goods and services. This will then be followed by an increase in export activity so that in the end it will have an impact on Indonesia's economic growth. The results of this study are in line with the study conducted by Xing (2017).

6.4.3 Government Policies for Accelerating the Wave of the Digital Economy in Indonesia

In order to optimize the growth of the digital economy (including e-commerce) in Indonesia, which is projected to have a substantial impact on the Indonesian economy, the government will focus on developing digital infrastructure. One aim is the completion of the National Strategic Project, the Palapa Ring. The Palapa Ring is a telecommunication infrastructure project in the form of fiber-optic development that will reach 34 provinces and 440 cities/regencies throughout Indonesia. This project consists of three development packages: the West Package (2,275 kilometers), the Central Package (2,995 kilometers), and the East Package (6,878 kilometers). The development of the Palapa Ring is aimed at maximizing internet connectivity in all regions in Indonesia so that it can encourage electronic-based economic activities that reach all communities.

In addition, in order to build a more efficient trading system and ecosystem, Indonesia also compiled Presidential Regulation No. 74 of 2017 concerning the Electronic-Based National Trade System. This presidential decree served as strategic direction and guidance in accelerating the implementation of the e-commerce road map in the 2017–2019 period. This road map contains an action plan with seven pillars that are components of the e-commerce ecosystem: funding, taxation, consumer protection, education and human resources, communication infrastructure, logistics, and cybersecurity.

During the period when this research was carried out, there were at least two main outputs that supported the development of the electronic commerce ecosystem (e-commerce), Government Regulation No. 80 of 2019 concerning Trade Through Electronic Systems (PP PMSE) and Government Regulation No. 71 of 2019 concerning System Implementation and Electronic Transactions (PP PSTE). PP PMSE regulates business opportunities for all parties, legal certainty and protection, as well as the prioritization and protection of national interests. Meanwhile, PP PSTE regulates the operation of electronic systems and transactions, which include, among others, the management, processing, and/or storage of electronic systems and electronic data in and/or outside the territory of Indonesia, as well as the principles of protection of personal data.

The government's efforts to maximize the potential of the digital economy in Indonesia also come from the external side through various collaborations in the e-commerce field. In one of them, in November 2019, Indonesia stated that it had joined the Joint Statement Initiative on e-commerce. It is hoped that Indonesia's participation will become a counterweight and bridge between developed and developing countries. In addition, the government has begun to include issues related to e-commerce in the negotiation of free trade agreements in both bilateral and regional negotiations.

Going forward, Indonesia's government will focus on implementing government regulations related to the use of ICT in trade. In addition, the government will encourage the completion of integrated e-commerce data collection, which will be used as a reference for evaluation and policy formulation, as well as a monitoring and guidance tool. Cooperation in the field of e-commerce and the use of digital infrastructure (Palapa Ring) will continue to be enhanced to encourage the development of domestic electronic commerce. Furthermore, in capturing and optimizing digital opportunities in economic activity, the government will formulate a national digital economic strategy (not only covering e-commerce). These various efforts can be a catalyst for national economic growth.

6.5 Conclusion and Policy Implications

Based on the results of the research that has been carried out, this study confirms that the ICT indicated by the ICT Development Index (IDI_i) indicator and the use of ICT for business activities (e-commerce) shown by the $B2B_i$ variable have a positive influence on Indonesia's trade (export) activities with Indonesia's trading partner countries in ASEAN. In addition, the macroeconomic indicators described by the GDP growth of Indonesia ($GGDP_i$), the economic distance ($LNDistance_{ij}$), and the market size of Indonesia in ASEAN partner countries ($MarketSize_{ij}$) also have a significant positive effect on increasing Indonesia's exports to trading partner countries in ASEAN.

In order to optimize the use of ICT, the government needs to continue to encourage economic activity through the use of ICT (e-commerce and/or the digital economy). Furthermore, digital infrastructure development also needs to be continuously improved so that the IDI continues to improve. In addition, ICT development must also be followed by innovation in its use, so that in addition to encouraging connectivity, the use of ICT can be more inclusive. Business actors who use ICT in business activities (e-commerce) also need to be given incentives. This is aimed at motivating business actors to increase the use of ICT in trading activities, so that Indonesia's trade activities with partner countries in ASEAN can be more effective and efficient. Then, from the use of ICT, in the end Indonesia's exports to ASEAN can increase.

In the future, with the existence of government regulations related to e-commerce, it is expected that the implementation of these regulations can run well. This can happen through increasing the role and coordination of each stakeholder. Then, business actors are expected to be able to optimize economic and digital economic opportunities through the use of existing digital infrastructure facilities. In the end, the increase of the IDI and the use of ICT in business activities will encourage the development of the digital economy and create more inclusive economic activities, so that the use of ICT can be a catalyst for national economic growth.

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Appendix A6

Table A6.1: Variance Inflation Factor

Independent Variable	Dependent Variable: $LNExport_{ij}$ [1]	[2]
$GGDP_i$	8.896876	7.730544
$GGDP_j$	1.295156	2.039052
$LNDistance_{ij}$	2.358691	2.276406
$MarketSize_{ij}$	1.132277	1.178516
IDI_i	8.523769	
IDI_j	2.253196	
$B2B_i$		6.869972
$B2B_j$		1.911534

Source: Authors' compilation.

PART II

Firms, Technology Spillovers, and the Labor Market

7

Three Challenges to Manufacturing Digitalization and How to Overcome Them: Lessons from Small and Medium-Sized Enterprises in the People's Republic of China

Yasheng Huang and Meicen Sun[1]

7.1 Introduction

The current size of the digital economy of the People's Republic of China (PRC) is second only to that of the United States (US) (Meltzer 2020). This has understandably triggered much discussion on the PRC and the US as being the two so-called "AI [artificial intelligence] superpowers" of the world.[2] Along these veins, prevailing commentaries on the PRC's AI strategy and the digital economy tend to cast the country as one monolithic player without much attention to the variation across different domains within the country's digital economy.

To enhance our understanding of the complexity of the PRC's digital economy, we offer here an analysis of the current state of digitalization among the country's manufacturing small and medium-sized enterprises (SMEs), bottlenecks to further digitalization, and potential pathways to

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2 Notable examples include the well-known thesis put forward by Lee (2021) in his book and commentary by Thompson and Bremmer (2018).

greater automation. Our fieldwork in Guangdong Province that yielded dozens of in-depth interviews reveals that manufacturing SMEs, which remain a backbone of the PRC economy, have inadequately benefited from AI and other frontier, productivity-enhancing digital technologies when compared to their larger counterparts. Importantly, these firms are held back from digitalization by their continued reliance on analog-era assets that at once curb productivity and further entrench the firms into older modes of production, with limited cross-sector spillovers despite vertical cross-product spillovers.

Synthesizing the rich empirical findings from our fieldwork, we characterize the challenge in automation faced by the vast number of manufacturing SMEs in the PRC as one comprised of a negative feedback loop of high policy transaction cost, a lack of economies of scale, and a trust deficit between SMEs and intermediaries.

We follow this up with a number of policy recommendations that may help the SMEs escape this analog asset trap. These involve a combination of:

(1) lowering transaction cost for AI subsidies,
(2) prioritizing data-collection equipment in government support, including subsidies, and
(3) strengthening the requisite legal framework needed for contract enforcement throughout the SME supply chain.

Given the highly interlocked nature of the economic, social, and cultural institutions in the PRC SME ecosystem, we emphasize that the three policy elements need to work in close tandem that must be achieved through careful, dynamic reevaluation and readjustment.

7.2 The Economics of Artificial Intelligence: Divergent Paths for Different Sectors

While the rapid development of big data-fueled AI technologies is a feature of the economy in the PRC, the nature of AI as a data-driven technology determines that not every sector can take advantage of this effectively. More specifically, sectors that employ data as a direct input factor of production, such as facial recognition technology and vast sectors involved in smart city development, can leverage AI policies much more readily than sectors that employ data only for efficiency gains and user-specific applications, such as manufacturing. The role of the government is critical in this regard and has been proven to be successful in jump-starting sectoral developments historically, including solar, high-speed rail, and more recently big-data applications. Digitalizing SME development requires a similar push from the government.

As a team of economists have found, the government has been able to exert a demand pull on facial recognition AI firms in the PRC. Importantly, these firms have seen a significant increase in AI software development thanks most of all to the swaths of user data acquired via government contracting that serve as the key input to algorithmic training. Moreover, the data advantage incurs a positive spillover that leads to an overall increase in AI software development for these firms and not just that for government use (Beraja, Yang, and Yuchtman 2021). Because of the centrality of data as a factor of input for these sectors, a firm's incentive to produce more and innovate faster binds them even closer to the government for data-rich contracts, which in turn enable the government to leverage data more effectively in its governance model. What this case crucially illustrates is that the positive spillover effect from government contracts on AI firms in the PRC essentially combines a "demand pull" with a "supply push." Here, government contracts create at once the demand for AI firms to develop more, better technology and the supply of exclusive user data that these firms could and often did use for commercial ends. Data as a non-rivalry input factor in this instance are a critical link in this positive compounding effect.

The data-intensive nature of facial recognition technology shows how government acquisitions of data can be more efficient than by individual firms as such acquisitions often incur a large up-front fixed cost. Sensor-embedded infrastructure and smart cities provide two additional illustrations, both of which notably span economically heterogenous regions. While economically advanced cities like Wuxi showcase multiple domains of sensor-embedded infrastructure and smart city development, much less developed regions in the PRC have likewise seen considerable progress in these areas.

Two areas of application in Wuxi as a national sensor innovation network demonstration city are of particular relevance for showing the centrality of data: energy governance and public security (Xinhua 2013). For example, a university in Wuxi adopted a smart energy monitoring system for granulated energy use by location anywhere from offices to dining halls and bathrooms. A wall-sized digital screen at the energy monitoring center on campus displays electricity consumption by university department that has been gathered by close to "ten thousand" sensors across campus. In one instance, rampant use of heating rods by students in their dormitories has been a persistent challenge. The system allows the university to know exactly in which dorm room such use is taking place and thus regulate energy consumption more effectively through timely detection and follow-up actions. Similarly, when someone forgets to turn off their computer at the end of the day, the stream of electricity overnight is instantly recorded and fed into the system, which results in a warning to the person the very next morning. Elsewhere in Wuxi, the adoption of this system was reportedly associated with a fall in energy use by almost 15% (Xinhua 2013). The scope, granularity, and richness of data supplied by the numerous sensors that line up the system were key to its success.

In the domain of road safety, traditional security cameras mounted at intersections are low in image quality and bulky in size. This makes it hard to catch offenders and easy to circumvent. One particular ARM+DSP-based (digital signal processing) vehicle monitoring system uses high-definition industrial cameras of up to 5 million pixels which enables automatic reading of license plates and facial recognition of drivers and passengers. In addition, the cameras are connected to a cigarette pack-sized smart image analyzer that comes with 8 gigabytes of storage, which allows for real-time data analysis, caching, and transmission. By the local police's estimation, the approximately 1,000 smart cameras deployed around Wuxi have replaced about 3,000 police officers while increasing the efficiency and effectiveness of law enforcement. A simple text search of "red down coat" in the system returns 23 images, and "red motorbike" returns 920 images, with the earliest dated March 2011. In August 2013, a sedan crashed into a guardrail and the driver fled the scene. A man turned himself in, but the cameras promptly called his bluff. The moment the crash occurred, it triggered an instant response in the system that started capturing images of "suspicious vehicles," which included footage of the entire crash as well as the subsequent fleeing of the driver—who was clearly shown as a woman (Xinhua 2013). Again, the simultaneity, precision, and volume of data provided the backbone of the system's functioning.

Shanghai's Smart Sensors Industrial Park provides another example of relative success in government policy push. With as many as 39 policy directives introduced and 32 key projects signed, government support covers all areas ranging from financing, cost reduction, research and development, scaling, and talent acquisition, to cooperation and exchange. For instance, through financial institutions, sensor manufacturers in the park enjoy perks such as financial guarantee discounts, listing subsidies, and loan discounts. In addition, they gain priority access to real estate and transitional factory buildings as well as subsidies when purchasing land and buildings. Firms also enjoy one-time rewards for collaborating with universities and research institutions, and financial support for acquiring intellectual property rights, among numerous other benefits (China News 2019).

With regard to smart city development in the PRC, key ministries conduct national-level planning: 1) National Development and Reform Commission, 2) Ministry of Housing and Urban-Rural Development,

3) Standardization Administration of the PRC, and 4) Ministry of Industry and Information Technology. Local governments are then expected to follow guidelines from these national authorities while making adjustments when necessary in the actual development process (ICA 2018). Importantly, these directives reveal a pattern where repeated follow-ups were often issued to ensure the desired outcome given that smart city development requires many years of planning, implementation, and execution. A consistent and dynamic policy review process is crucial for sectors that intersect with emerging technologies such as AI. We will reiterate this point in our analysis and recommendation with regard to the manufacturing SMEs.

What the foregoing demonstrates is that access to data, rather than capital, as the key input factor has contributed to what is largely a sectoral rather than regional pattern in the development of AI-related domains. In these cases, access to data has largely compensated for a lack of access to capital. Government policy has provided just the right synergistic push that the firms in these sectors need. In contrast to the sectors thriving under the PRC's current AI policy, those in which data are employed only indirectly for improving production efficiency cannot compensate for a lack of access to capital. One notable example is the labor-intensive, higher-tiered producers in the country's massive manufacturing supply chain. In our field trip to Guangdong Province, which we will analyze in the next section, we observed a relatively low level of digitalization among the manufacturing SMEs. As the result of a series of interlinked economic, social, and cultural institutions, opportunities for digitalization would get routinely passed up for continued reliance on existing analog assets. Whatever data that failed to be harvested for the purpose of digitalization continued to be substituted with manual labor. The type of policy that has amply benefited the AI-related sectors must therefore be tailored to better suit the need of the manufacturing SMEs that employ data in their production process in a decidedly different way.

7.3 A "Local Maxima" Trap for Manufacturing SMEs—and a Potential Way Out

In 2019, we conducted a weeklong in-depth field study of over a dozen manufacturing SMEs, as well as interviews with local government and nongovernment organization representatives in Shunde. As representative as we think the Shunde story is of manufacturing SMEs in the PRC, we caution our readers against over-extrapolating from what after all is one single, albeit rich, case study.

Located in the Pearl River Delta in the highly developed region of Guangdong, Shunde has long been one of the PRC's export and manufacturing hubs. Despite the seemingly ripe conditions for automation, digitalization for the purpose of AI application among the manufacturing SMEs we studied was comparatively scant. To be sure, we did observe automation—preprogrammed to perform one specific task—but we did not observe AI application in the sense of smart decisions in the production process that were made with data generated on-site.

The demand-side preferences are straightforward, and in our interviews we have heard strong voices from firms to adopt digital technology. The labor costs are rising rapidly due to the PRC's demographic shift, compounded by the changing work ethics of the working-age urban population. Both access to finance and scale economies of digital technology create obstacles to individual SMEs to invest heavily in digital technology. So do the positive spillover effects of data collection, first-mover disadvantage, and the high costs of integrating data collection in production processes. A strong government push to overcome the simultaneity problem, in the style modelled by Rosenstein-Rodan (1943), is called for.[3]

We attribute the currently low level of digitalization among the manufacturing SMEs in the space below to a confluence of three interlocked factors at play. First, while there have been policy initiatives aimed specifically at fostering digitalization and automation among manufacturing firms, the high transaction cost for the SMEs means that they are not able to benefit as much from government support as their bigger, better-financed counterparts. Second, while existing infrastructure of analog assets provide the firms with a low-cost means of production in the shorter term, it entrenches these firms in the same low-efficient mode of production by depriving them of the opportunities for gathering data needed for digitalization. Third, specific business models, notably the original equipment manufacturer (OEM) model, exacerbates the challenges in contract enforcement faced by SMEs when dealing with intermediaries. This further limits their capacity in making the requisite investment for digitalization. Together, these factors have led to a trap in which a vast number of PRC manufacturing SMEs are locked in with low-tech products, labor-intensive processes, low-profit-margin business models, and, ultimately, limited degrees of automation. This is a cycle that would deter attempts by individual firms to break free, which we scrutinize with primary evidence from our fieldwork in the space below. Concluding our analysis, however, in the

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3 See an extension of the model in Murphy, Shleifer, and Vishny (1989).

final sections we offer a number of policy recommendations directed at each of these challenges. When carefully implemented, these measures will build an effective way toward digitalization and automation for the firms in question.

7.3.1 Policy Transaction Cost on SMEs

We begin with the previously outlined distinction between firms in AI-related sectors such as facial recognition technology development firms and manufacturing firms. For the former, data are a principal factor of production for key products that typically involve algorithms. Government contracting therefore provided both the demand pull and the supply push. Access to large quantities of data through these contracts helped overcome the critical bottleneck in production—and in innovation—for these firms. For manufacturing firms, meanwhile, data are typically only used to improve the efficiency of production of real goods. Access to capital, rather than to data, continues to matter more. Given the relative capital-scarcity of SMEs, they remain especially sensitive to transaction cost while trying to take advantage of government subsidies and other types of benefits. Insofar as these firms are not able to either acquire better, faster access to capital or improve the cost-effectiveness of existing production, policy initiatives aimed at greater digitalization and automation may fall flat.

Existing research on this topic has provided similar insights. A 2018 study on automation in Dongguan, another leading city in the PRC's export industry that neighbors Shunde in Guangdong Province, notes that a firm's decision to automate depends primarily on profitability, with government subsidies playing a minor role (Sharif and Huang 2018). Other government policies have driven SMEs to automate much less directly but much more decisively in the firms' effort to cut cost. These include, among others, policies on minimum wage, as well as those on welfare benefits and insurance (Sharif and Huang 2018). On balance, it was the sea change in relative returns to labor brought about by labor policies that incentivized the SMEs to automate out of the constant need to cut (immediate-term) costs and widen (immediate-term) profit margins.

Echoing these findings, our field research likewise shows that for the SMEs in Guangdong, supply-side policy incentives explicitly intended for AI adoption have had a somewhat limited impact. Policies not directly aimed at AI adoption have ended up influencing firm decisions more strongly in practice, precisely because of their greater impact on the firms' near-term profitability and cost-effectiveness. Enhanced labor protection mandated by the government was cited repeatedly by firms as their motivation to automate—a line of thinking that evokes the current debate on minimum wage around the US.

As with Dongguan, labor policies on the provincial- and national-levels have played a decisive role in the firms' decision to automate in Shunde. An industrial mold-producing firm refers to the 2012 Labor Law as a major impetus to massive layoffs by labor-intensive firms, which also led to its own effort in downsizing from 150 to 120 in combination with more use of automation such as robotic arms. A home appliance-producing firm points out not just the law itself, but that greater familiarity with the law, especially among the young, has made cheap hiring more challenging than before. As a result, the average monthly salary for a typical worker has increased tenfold from about $100 to about $1,000 over the years. Another firm that manufactures foodstuff, which has seen a 200% rise in labor cost over 10 years, summarizes that both the shrinking labor base and the increase in cost of labor relative to capital have made it more expensive to hire.

It should be noted that the rise in labor cost reflects more fundamental shifts in demography and ideology that have been happening across the country and around the world. Multiple firms allude to the disappearing "demographic dividend" that used to fuel the PRC's labor-intensive industries. The overall rise in living standards in the PRC has on the whole increased the bargaining power of labor who care increasingly about quality of life. The disintegration of multigenerational large family units in Chinese society has given rise to an increasingly individualistic social fabric. When it comes to the labor market, as one firm observes, there has been a marked change in the workers' motivation when compared to a generation ago. Workers now make money not because they have a family to raise but because they want to enjoy a better life for themselves. Even spotty Wi-Fi connection in the dormitory has become a common reason for quitting one's job.

Along the same line, a nongovernment organization in the furniture industry we interviewed further notes that non-material factors such as "status" work against manufacturing jobs. For example, a college graduate would be willing to take a white-collar job for as low as $300 per month, while SMEs scramble to fill workshop positions even for twice the pay. Not only have wages surged, but even higher wages alone are proving insufficient for retaining the younger workforce. Conversations with representatives from one municipal government reinforce this observation: For younger workers who value freedom and flexibility, manufacturing jobs that entail long hours in a confined environment become all the less appealing for the same pay than, for instance, delivery gigs.

Similar to the situation in Dongguan, government incentives specifically aimed at promoting automation were not nearly as effective as those in the case of sensors and smart cities. Here enters the important role that transaction cost plays in a firm's decision to take government support for digitalization or continue with their existing mode of production. In our interviews, we observed that while acknowledging various forms of government subsidy for automation, firms show limited enthusiasm in taking advantage of such. One firm that specializes in industrial pipes is aware of government subsidies for automation on the county, municipal, and provincial levels, yet it only plans on applying for small subsidies as a next step. A textile-producing firm says that it has accepted very little government subsidy apart from industry tax breaks. Importantly, a persistent lack of policy attention to not just the content but the implementation of these incentives makes it difficult and costly for firms to benefit from them. Expressing reservation in taking the 30% subsidy for automation as part of the "Made in China 2025" policy push, a lighting equipment-manufacturing firm explains that just the process of invoicing would add another 10%–15% to the cost in automation, not to mention the additional reviewing cost after adoption. This means that, in practice, the net positive from government subsidies is not always enough to offset what is often a sizable short-term investment for the SMEs, which the firms do not feel optimistic about balancing out down the road.

Access to capital on the part of SMEs has been a chronic problem in the PRC—and in other developing economies. Financial sector reforms are vital to the robust development of SMEs. One key bottleneck in the ability of financial institutions to provide capital to SMEs is the lack of quality information. This makes for an additional rationale to digitalize the operations of SMEs: to collect and collate data for the purpose of improving not just managerial decision-making but also external decision-making on the part of capital suppliers.

Similar to the access to finance, access to quality hardware is the other essential step toward digitalization that many SMEs have failed to take. Outdated machinery and equipment further impede the transition to automation. One firm had in the past actively explored further digitalization of its production line with the help from the likes of ZTE, Mitsubishi, and Siemens. However, a shortage in the requisite hardware from communications system to connectors for machines stood in the way. Even if data get collected with lower-grade hardware, they are often of lower quality than is needed for meaningful digitalization to happen.

7.3.2 The OEM Business Model and the Economics of Analog Assets

In our fieldwork on the SMEs, we also discovered the *economics* that sustains the firms in their existing mode of production, which involves little to no data collection and utilization. This boils down to the OEM business model common to the Shunde SMEs and the small order size that this model typically entails. This essentially locks the firms into a continued use of existing analog assets instead of investing in digital assets that would enable automation.

For manufacturing firms, clients play a central role in technology adoption. Throughout Guangdong, OEM remains a prevalent business model for manufacturing SMEs. Most smaller firms specializing in industries spanning from machinery to electronics begin their business by making parts and products for multinational corporations (MNCs) such as Philips, Ford, and Tesla. In the course, some have found a way to establish their own brand name. The aforementioned Dongguan study illustrates the push to automate from external customers through the case of a certain factory which was “forced to automate” due to customers’ demand for rolls instead of single slices that could only be made through automated production lines. This pressure is amplified by the “hypercompetition” among numerous SMEs in the region vying for a limited number of major clients where any single firm has little bargaining power but to adopt and evolve (Sharif and Huang 2018).

However, what this shows is less of the importance of the OEM model than that of client orders more generally. Across the firms we studied, “orders” from clients are the most cited motivation for any major business decision, including those concerning automation and AI-enabled technologies. While the rise in labor cost and government subsidy for automation have each played a role, from the business perspective neither has been nearly as decisive as the volume and stability of orders. When orders are sufficiently large and stable, return on investment to further automation takes care of itself, even in the absence of government subsidies. On the contrary, when orders are limited or fluctuate too much, government subsidy is unlikely to motivate a firm into investing in technologies that cannot be justified by business rationale.

Multiple firms emphasize that the rise in labor cost in and of itself would not necessarily lead to automation because downsizing, offshoring, and outsourcing would all make for easier solutions. Invariably, firms point to the volume of orders as the primary driver for the decision to adopt automation. A bedding-manufacturing firm observes that even those producing for IKEA have only managed to achieve semi-automation in their production lines with such large volumes of orders. This is echoed by another firm, which stresses that only a sufficiently large and stable volume of orders would warrant further investment in automation. If not, manual labor would be more cost-efficient. In their words, a blind rush into AI in these instances would be akin to "driving a BMW just to use the bathroom."

When explaining its rationale with regard to the use of automation and robotics, a medium-sized furniture-manufacturing firm under its own brand says that cost, not technological limitation, is what drives the decision. For instance, the decision to use either the imported automated machinery with CNC that costs tens of thousand dollars but with a precision of 0.1 millimeters or the domestically manufactured version with a precision of just 1 millimeter depends entirely on the orders. Manual fine-tuning for the former itself takes hours, which requires that the orders must be large enough to more than offset both the capital and labor costs.

In fact, the factory of the aforementioned lighting-manufacturing firm, which started as an OEM manufacturer for large MNCs, was first built so that the latter could inspect the production process. At one point, it had the option of automating most of its production line, which its neighboring firm had been doing. What led to its own decision to keep its two mostly manual production lines as they were, eventually, was again the relatively small volume of orders. Given this, automated assembly lines would not serve their purpose while still requiring regular maintenance that costs money. By comparison, manual work can be assigned as needed much more flexibly without the fixed cost. However, as the manager speculates, should the volume of orders reach the order of million per day, automated assembly lines would then be "imperative," and any maintenance and operational costs would then be more than recovered.

As these examples demonstrate, while a large number of orders would push the SMEs into automation, the opposite would precisely inhibit their ability to do so. To be sure, limits to automation occur via different mechanisms for OEM and for non-OEM SMEs in Shunde—and possibly in general. For the former, *a lack of credibility* puts a de facto cap on the volume of orders that an SME would realistically receive, oftentimes as a matter of their own hedging strategy. For the latter, a high level of *customization* in their products makes it exponentially harder to take advantage of the scale effect of automation than with standardized products. We expound on both below.

7.3.3 Credibility Deficit, Customization, and the Negative Feedback Loop

Whereas the OEM model has pushed the SMEs in Dongguan to automate, it has at once pushed those in Shunde to automate while also limiting the extent to which they do so. The different types of predominant OEM products in Dongguan (electronics) and in Shunde (machinery) have led the firms to adopt different business strategies for profit maximization and risk reduction. Due to the nature of their products, the SMEs in Shunde are faced with a greater need to diversify and less room to scale, thus limiting the return on investment on higher degrees of automation. Moreover, the non-OEM manufacturers in Shunde face the additional demand for product customization more than their electronics-manufacturing counterparts. This further reduces the return on investment on automation for these firms.

While a large number of orders from clients is usually good news for an OEM manufacturer, one firm we interviewed discloses a seemingly counterintuitive strategy that it has consistently employed. Even though a multitude of orders would complicate the use of automation due to the greater variety of products, our interviewee firm still maintains that orders from any one client not exceed 30% of the total. So important this is to the firm, in fact, that in an effort to maintain this limit it had to once expand its total operational capacity by 400% just so that the share by one particular client, which had dramatically increased its orders from the firm, would stay under 30%.

Why the stubborn rule? In a somewhat bleak tone, the firm attributes this to what they see as the persistently low level of credibility among OEM industries across the PRC. According to our interviewees, overdue payments by clients to OEM manufacturers remain common, which forces the latter to spread their eggs across more than one basket wherever possible. Even though the MNC clients are themselves credible, the SMEs only deal with them through intermediaries that are "not always to be trusted."

The need for intermediaries between OEM SMEs and MNCs is, as the interviewee firm also acknowledges, due to the still uneven production capacities across SMEs in the PRC that warrant intermediaries to act as quality controllers and guarantors. Moreover, many smaller OEM firms borrow heavily in the early stage, which pushes them to cut cost and diversify capital. One major way to do so is to invest only in assets that can be repurposed for a variety of products so as to cater to as many different clients. The combination of these factors together limits the freedom of these SMEs to explore and invest in automation and other AI-enabled technologies at will.

On the other hand, non-OEM firms face a different yet nonetheless persistent set of challenges with regard to automation. The experience of the aforementioned bedding-manufacturing firm serves as a vivid illustration where Chinese consumer tastes have created a set of market conditions that hinder automation. Unlike in Western countries where beddings are considered disposable goods that get replaced frequently, in the PRC beddings are typically durable goods. This in turn means that the desire for bedding customization is stronger in the PRC market as they are used for a longer period of time. Compared to their Western counterparts, Chinese consumers have much more individualized preferences for beddings, such as the printing of personal photos and signatures on bedsheets, which can hardly be fulfilled by one uniform production line without intensive manual labor.

Similarly, one firm affirms that because of a high degree of customization involved in its products, it has only managed to adopt lower levels of automation without any meaningful use of robotics. Currently, automated processes are only employed in packaging. Even so, manual work is still needed in selecting products, unlike the fully automated similar workflows in Europe. A tile-producing firm likewise observes that Chinese consumers are often more discriminate about product colors than their foreign counterparts.

The potential for automation also varies greatly for different types of product, such as fixed furniture versus movable furniture due to the vastly different levels of standardization involved. For the former where dimensions are often fixed and uniform, some AI-enabled technologies are already in use. Rapid production is achieved, for instance, when sheets are produced through an automated process with materials measured using AI-enabled precision technologies. Even in this case, each household typically has its own specific requirements that limit the applicability of the IKEA model where full-on automation can be leveraged for mass production. By contrast, the production process for movable furniture is extremely unlikely to be fully automated, not only because of the higher degree of customization but also because of the softer materials involved.

Interestingly, the issue of trust as a social institution again gets in the way of automation, but this time on the workshop floor. As managers of one firm tell us, a lack of trust among workers makes it difficult to implement the "flow shop" production schedule where each worker is responsible for only one sequence in the production process. Instead, each worker would rather take on complete tasks from beginning to finish in a "job shop" schedule that effectively limits the possibility of automation on a larger scale.

Taken together, as another firm observes, limits to standardization along with the limit in business volume have become the ultimate impediments to further automation among the SMEs. The tile-producing firm provides an excellent case in point. To begin, domestically manufactured production equipment often lacks the degree of precision required for full automation. For instance, internal pressures and temperatures for furnaces must be measured to an especially high degree of precision in order to ensure the smooth running of an automated process. To rectify the lack thereof, however, SME managers typically turn to ad hoc manual adjustment by hiring a contractor for a few hundred dollars in an effort to minimize short-term cost. In so doing, they miss the opportunity to invest in high-caliber equipment that is necessary for the realization of automated production. Without such equipment, production data are never systematically collected, in the absence of which optimization in turn cannot take place. Commenting on this negative feedback loop, managers of one firm note that the lack of willingness to invest in capital-intensive assets that are necessary for the development of smart manufacturing is a broad phenomenon that exists across the country. Even as we speak, this negative feedback loop continues to lock tens of thousands of Chinese firms into the local maximum that profits off analog assets at the expense of the long digitalization game.

7.4 A Pathway Forward: Three Policy Recommendations and a Systemic Approach

In a complex economy, it is not just one thing but a set of complementary, interdependent, and mutually-reinforcing institutions that explain a difference in outcomes.[4] Once a distinct policy imperative sets the engine into motion, it is the collection of political, economic, and social institutions working in tandem that then sustain and expand the effect—a good one or a bad one—over time.

This is exactly what we have witnessed in our study of the manufacturing SMEs in the PRC. On the one hand, the nature of their production as being focused on real goods means that they are not in a position to leverage government AI policy benefits as readily as their data-intensive counterparts who enjoy the combined benefit of a

4 See, for instance, Hall and Soskice (2001).

"demand pull" from government contracts as well as a "supply push" of exclusive user data acquired from these contracts. In sharp contrast to the rapidly rising facial recognition sector, swaths of manufacturing SMEs have faced challenges in reaping the benefit of big data despite manufacturing's persistently vast share of the country's economy in terms of gross domestic product. Immense quantities of data are being generated by the second on millions of conveyer belts in numerous workshops, but they are left unharvested and passed up for potential opportunities digitalization and automation that are within reach.

On the other hand, it is the interaction of 1) a high transaction cost in taking government support, 2) the prioritization of short-term profitability that favors using analog assets, and 3) the still prevalent trust deficit in the SME supply chain that has held these firms back from realizing their full potential in digitalization and automation. All of these challenges, however, may be addressed through deliberate policy measures. Policy formulation should especially take note of the evolving demographic trends, the highly varied business models within the SME sector, and the cultural institutions that have formed over time. These factors, as our fieldwork demonstrates, may require modification upon the existing government support policies that are tailored for big firms. We propose here a few such policy measures in response to the three specific challenges.

First, policies aimed at digitalization and automation for these SMEs must thoroughly appraise the transaction cost entailed for the firms in accepting government support. Notably, when compared to the more streamlined processes for large firms, the high degree of heterogeneity among these SMEs, such as the multitude of business models, makes it imperative to evaluate the transaction cost entailed for each type of firm and avoid designing a one-size-fits-all policy formula. Additionally, feedback from the SMEs we interviewed suggests that interagency coordination is crucial in lowering transaction cost given that the various processes— from invoicing to reviewing—often involve a variety of government agencies and offices. While these will require efforts in due diligence early in the policy design process, they will be necessary for ensuring that the policies will be appealing enough for the target beneficiaries to take advantage of them at all.

Second, to the extent that the OEM business model will continue to prevail for the foreseeable future, government financing should target areas that are the most foundational to future digitalization and automation. When it comes to government-assisted financing of the SMEs for automation, the focus should be on updating outdated, analog-era assets that do not have data-collection capabilities. As much as we registered widespread desire among SME managers to digitalize their production line, their short-term-oriented business models make it unprofitable to invest in the often costly equipment that is necessary for digitalization to happen. This is exactly where a "big push" role of the government can be most productive. A part of that role can target modernization of existing asset base, but it can also target retrofitting existing assets to the digital age. Moreover, given the continually rising labor cost, it may soon cease to be viable for firms to rely on ad hoc manual adjustment in making up for the deficiency in analog assets. Financing basic digital assets, therefore, will pay increasing dividends in the context of the current demographic trend.

Third, a serious effort should be made in strengthening the legal and normative framework for contract enforcement in the manufacturing SME supply chain. This should simultaneously proceed on two fronts. First, there must be more robust legal enforcement mechanisms for contracts between OEM firms and their intermediaries. As our fieldwork indicates, a low level of credibility among intermediaries has resulted directly in an unwillingness for these firms to invest in costly assets including digital assets. A compulsive need to not rely on a single client forces these firms to make small batches of different products, which disincentivizes them to invest in digital assets for scaling up production. Coordination with the relevant legal authorities may be necessary for this process. Second, intra-firm contracting on the workshop floor should be strengthened. This can be done through a combination of legal and normative sanctions, with the goal of promoting greater trust among workers so as to facilitate a move toward a flow shop and away from a job shop schedule, which is more compatible with digitalized production lines.

Lastly, taken together, successful policy initiatives including many in the smart city domain have demonstrated that effective policy implementation requires meticulous and consistent review and adjustment. With regard to our case, it is especially important for those executing the policy measures to remain keenly aware of the fast-changing technological landscape, including ongoing developments in AI algorithms that may likely reduce the relative importance of data, putting in jeopardy a strategy that relies lopsidedly on data accumulation. This development may augur well for digitalization of the SME sector since the importance of scale economies may very well decline as the result of technological evolution.

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8

Information Technology and the New Capitalism

James Bessen[1]

8.1 Introduction

As the dot-com boom accelerated 2 decades ago, there was much talk in the business world of a "new economy." *Fast Company*, one of the magazines created to herald this change, declared that this "democratic capitalist" movement was about "the expansion of individual opportunity, the disruptive energy of ceaseless innovation, and the transformative power of information technology and communications." Individuals could access inexpensive new computer and networking technology, learn valuable skills, innovate, create new companies based on their innovations, grow these companies rapidly, outsource other tasks to global partners thanks to the internet, and ultimately disrupt entrenched old economy companies.

In this view, new information technology was fundamentally changing the nature of the capitalist economy. But in hindsight, the new economy vision failed. While several aspects of the new economy did play out for a time, few seem to hold true today. One might suppose that the new information technologies failed to fundamentally change the nature of the economy. This chapter argues, to the contrary, that information technology is indeed transforming capitalism—just not in the way envisioned by the new economy proponents. It is changing the nature of markets, innovation, and firm organization, exacerbating economic inequality and undermining government regulation.

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1 This article draws on the author's forthcoming book *The New Goliaths: How Corporations Use Software to Dominate Industries, Kill Innovation, and Undermine Regulation*, to be published by Yale University Press (Bessen 2022).

8.2 The Rise of the New Economy

The developments that fostered the new economy vision were real but short-lived. The emergence of the personal computer and the sharp fall in computing prices spurred the adoption of new digital technologies across many industries. And in many, these technologies allowed small companies to compete on a level playing field—or even to displace less-nimble established large firms. In 1995, *Inc*. magazine enthused:

> Can information technology (IT) make a David seem like a Goliath? According to the CEOs and company presidents we spoke with, the answer is an unqualified yes. In today's world of networked databases, E-mail, CD-ROM subscriptions, and teleconferencing, success is determined less by size than by technological muscle. Even companies of 15 or 20 can gather market data in all parts of the world, establish long-distance strategic partnerships, advertise anywhere via the World Wide Web, or hold international sales meetings – and their employees never have to leave the office.
>
> Competing with big business is easier than ever now that IT is so affordable. Ten years ago, purchasing a high-powered computer system could set a small company back half a year's revenues. (Schafer 1995)

With the relatively inexpensive personal computer, small companies could get software packages for a few hundred dollars each to do their payroll, their accounting, and their tax preparation. Such programs were formerly available only on the expensive mainframe or minicomputers that larger companies owned. Other programs could do word processing that had been available on dedicated minicomputers. As the prices of personal computing continued to fall, all of these programs became affordable to the smallest companies. These companies really could compete with comparable capabilities to large firms in many areas.

Soon many personal computer applications went beyond their mainframe or minicomputer ancestors. They became interactive; they added graphical user interfaces, making it easier for people to learn the systems; and they added new and important features. While it had been possible to compute a spreadsheet in batch mode on a mainframe computer since 1969, with the introduction of VisiCalc in 1979, spreadsheets could be entered interactively on a personal computer, providing much greater ease of use, real-time adaptability, and other powerful tools for customizing spreadsheets to a wide variety of uses.

Many companies were able to harness these new programs to develop innovative business models that disrupted a wide range of industries. All sorts of businesses were able to create custom applications for their specific needs using inexpensive off-the-shelf spreadsheet programs and desktop computers. All sorts of businesses, large and small, were able to use the new tools in innovative ways. The exuberance of the *Inc*. writer about the opportunities for small firms was real and widely experienced.

One industry upended by these changes was publishing. For decades, the newspaper industry had been consolidating. Papers bought up their rivals, and newspaper chains bought up the papers. Increasingly, towns were served by only one newspaper. Rivals would not enter these markets because it was so expensive to set up the production and distribution capabilities. The number of weekly newspapers in the United States (US) had been falling for decades, from 11,516 in 1939 to 6,798 in 1984. A. J. Liebling, writing in *The New Yorker* on the paucity of competing views in the press, famously quipped that “Freedom of the press is guaranteed only to those who own one”(Liebling 1960).

However, desktop publishing suddenly allowed more people to own the press. I wrote the first WYSIWYG (what you see is what you get) desktop publishing program, and my company sold it to all sorts of newly created newspapers, magazines, and catalogs. Beginning in 1984, the decline in the number of publications reversed. Over the next 5 years, the net number of weeklies grew by over 824. The number of monthly periodicals grew by 349. Even the number of daily newspapers increased from 1,646 in 1987 to 1,788 in 1990. Decades of industry consolidation dominated by large newspaper and magazine chains gave way to a renaissance of new publications.

Retail was another industry rejuvenated by new computer technology, in particular the barcode scanner combined with personal computers. Since the early 20th century, chain stores in the US came to dominate many retail segments because they could realize efficiencies of scale in distribution and warehousing. The barcode scanner tied to inexpensive personal computers running inventory management software gave an advantage to smaller retailers. The scanner was introduced to supermarkets in the 1970s and midsized retail chains—not the big national chains—led in its adoption. These systems allowed medium-sized or small retailers to speed checkout times and also to reduce the time employees spent doing inventory. This reduced costs, allowing the stores to offer lower prices. More important, it allowed firms to merchandise more effectively. Because they could track which items were selling and which were not, retailers with these new systems could quickly adjust the products on their shelves to meet rapidly changing demand. Moreover, they could customize their offerings across stores in different neighborhoods. The competing chain store outlets, however, tended to offer the same product mix across geographic areas, and they tended to respond only slowly to changing demand. By offering lower prices and by selling those products that were most in demand, the barcode information often allowed medium-sized and smaller retailers to gain a competitive advantage over the large chain stores. They were more nimble and responsive to local needs.

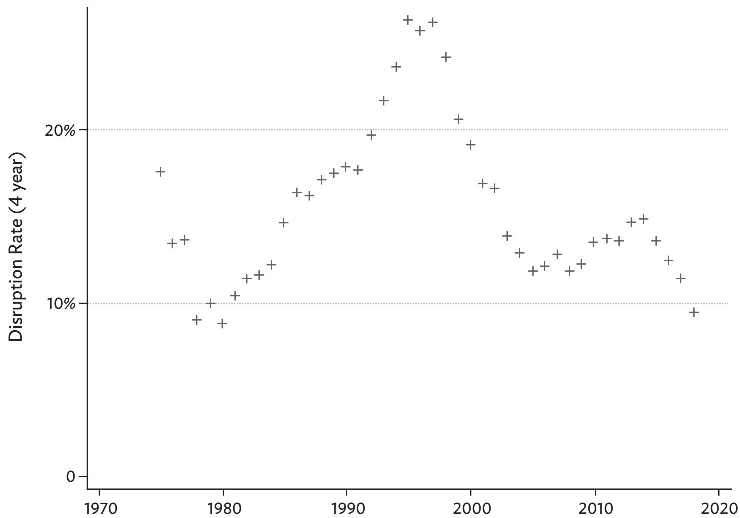
The advantages new technology brought to small and medium-sized publishers and retailers really did change the nature of industry structure and competition. Of course, the trend affected many more industries. We can get a sense of this change by looking at the rate at which dominant firms were displaced, or the rate at which industry leaders are "disrupted." Figure 8.1 shows the probability that a firm that was in the top four in its industry by sales 4 years earlier is ranked below the top four—the "disruption rate." During the 1980s and 1990s, this rate more than doubled. The era of the personal computer was very much an era where smaller firms overtook their larger rivals. For a time, the new economy was real.

8.3 Goliath Strikes Back

Figure 8.1 also shows that the rate of disruption, rising since 1980, sharply reversed trend in the late 1990s. Something changed. In publishing, it was the internet. All sorts of publishers' business models were undercut by the internet, especially those relying on advertising. The numbers of new publications declined, and more publications started going out of business. The most successful local publishers became national publishers with effective online businesses. In publishing, the entire industry was affected by new technology.

But in retail and in many other industries, the story was different. In these industries, new information technology played a central role in reversing the new economy in another way. In retail, for example, a few savvy companies were able to harness the technology based on barcode scanners to build powerful new business models that allowed them to become dominant and to remain dominant. In 1982, Walmart's sales accounted for only 3% of the general merchandise retail category in the US. Walmart grew rapidly, however, displacing Sears as the largest retailer in 1990 and capturing a market share over 50% by 2012. They achieved this dominance with a unique combination of technology and organization. Walmart was an early adopter of barcode scanners, but soon used those scanners to build an entirely new sort of system. By the late 1980s, they had the technology in all of their distribution centers. These scanners generated a fire hose of information—every purchase

Figure 8.1: Share of Firms Ranked below the Top Four by Sales (Six-Digit NAICS Industry) That Were Ranked in the Top Four 4 Years Ago



NAICS = North American Industry Classification System.

Source: Compustat.

of every item at every checkout lane in every store. Rather than direct that information to headquarters for centralized decision-making as in the chain store model, Walmart turned the flow around to support decentralized decision-making by individual store managers and even by suppliers. By the late 1970s, all distribution centers were linked by a computer network (Basker 2015). In 1987, Walmart completed its own $24 million satellite network to facilitate communications between stores and headquarters. This was the largest private satellite communication system in the US at the time.[2] In 1990, Walmart introduced Retail Link—software connecting its stores, distribution centers, and suppliers and providing detailed inventory data "to bring our suppliers closer to our individual stores" (Basker 2007 quoting Wal-Mart Stores, Inc. 1991, p. 3). Suppliers and individual stores are in close contact so that suppliers can track sales at individual stores and generate orders to

2 Walmart History. http://www.wal-martchina.com/english/walmart/history.htm

restock shelves quickly. In some cases, computers generate the new orders using automated purchasing technology. And Walmart uses its superior data on purchasing to streamline the shipments from suppliers to warehouses to stores. They are not only able to stock the shelves at lower cost, but each store also receives shipments more frequently so they are able to respond faster to changes in demand.

This technology and decentralization bring other critical advantages. Walmart stores dramatically increased the selection of products offered, facilitating one-stop shopping. With greater variety, Walmart is more likely to have the goods the consumer wants, and one-stop shopping makes it easier to purchase a range of different products and services. This proved to be an important attraction for consumers. In addition, it means that Walmart can respond rapidly to changes in demand, and merchandise can be tailored to the needs of each store's local market.

In effect, Walmart has combined the market responsiveness of smaller retailers with the efficiencies of chain stores. Walmart is able to deliver a large selection and rapid response to changing demand along with lower prices. This proved to be a formidable competitive advantage. Walmart grew to overpower the dominant firms in retailing such as Sears and Kmart, which are now in bankruptcy. While Walmart faces threats from e-commerce, it is not likely to be disrupted in brick-and-mortar retail anytime soon. The rate of disruption in retail has dropped sharply.

Notably, Walmart's business model is enabled by custom software. Essentially, this software allows Walmart to manage complexity efficiently. Because Walmart can manage the complex ordering and distribution of a large number of rapidly changing products, they can benefit from efficiencies of scale while responding to local market needs.

In many other industries, software has played a similar role. Since the late 19th century, leading firms in many industries were able to achieve substantial economies of scale through standardization. For example, in manufacturing, mass production required a significant degree of standardization. Henry Ford famously declared that customers could have "any color so long as it is black." He was intensely focused on driving down costs to make automobiles affordable, and allowing for multiple colors would have added equipment, labor, and a degree of complexity to the marketing and manufacturing process, increasing costs. While General Motors countered by introducing cars with multiple colors and stylish bodies that changed each model year, these changes were largely cosmetic and auto production at the company was still highly standardized.

The automobile has become much more complex in recent years, mainly because software has enabled an explosion of features. Even 30 years ago, cars had 10,000 components. Today, they have 30,000—and these are controlled by software. Today's automobiles contain 50, 100, or more computers, all networked together. An average model contains over 100 million lines of software code. By comparison, the Space Shuttle has only 400,000 lines of code; Google Chrome and a Boeing 787 each have a bit over 6 million lines of code. This software enables all sorts of new features that improve drivability, provide new safety measures, and improve passenger comfort. All of these features allow a car to be tailored to individual needs. In this way, auto manufacturers overcome the trade-off between efficiencies of scale and heterogeneity of individual demand.

Auto manufacturers thus compete on features. The winners are those firms that can effectively integrate large numbers of features into a model and manufacture it efficiently—but this drives up design costs. Because of the complexity, the cost of designing a new model using major existing components (engine, platform, etc.) begins at around $1 billion and can take 5 years. Designing a new car from scratch costs as much as $5 billion or $6 billion. The cost of software code alone can reach $1 billion. Only the largest firms can afford to play this game. Increasingly, small car manufacturers are merging in order to economize on the high costs of developing new products and speed them to market. The dominance of the top firms is now more secure; they are less likely to be disrupted.

In effect, these large software investments allow firms to compete on their ability to manage complexity that offers more features or greater tailoring to individual or local needs. Other manufacturing industries have also seen consolidation resulting from rising complexity of product design and development, which is now largely done in software. It now costs between $25 billion and $30 billion to develop a major new jumbo jet. Only Boeing and Airbus have survived in this market, and they are not about to be disrupted.

Industries in service sectors also leverage complexity for competitive advantage. Using large amounts of data and sophisticated software systems, Google and Facebook provide advertisers an unprecedented level of targeting, allowing them to target ads to very narrowly defined groups, increasing the effectiveness of advertising. These systems, too, are highly complex. Google, for instance, has been tweaking its search algorithms for 2 decades conducting over 10,000 experiments per year in recent years to refine their search efficacy. Financial institutions compete on complexity both by tailoring their products and their marketing. For example, four large banks dominate the credit card industry in the US by marketing tailored credit offerings to highly select groups of prospective customers, thus managing risk while maximizing market reach. These systems also are built using large amounts of data endlessly tweaked to optimize performance.

Across industrial sectors, leading firms, driven by similar opportunities, have made large investments in proprietary software. In aggregate, these comprise a huge shift in investment. Private investment in proprietary software—software that firms develop on their own or by contracting others—grew to $234 billion in 2019.[3] That is about as much as firms' net investment in equipment. Moreover, this investment is dominated by the largest firms, and it is occurring in every major sector of the economy. It is hard to think of another technology that brought such a large shift in investment across all major sectors of the economy in such a short time. Furthermore, concentrated among the largest firms, it appears linked to a change in the nature of competition.

8.4 Does Technology Change the Economy?

Thus, the new economy represented at best a short episode in economic history. Did this phenomenon—or what has come after it—ever represent a fundamental change in the way the economy works? For the leading economists of the time, the answer was clear: there is no "new economy." Martin Feldstein, who had been chair of the Council of Economic Advisers under Ronald Reagan, asserted:

> Have the relationships that govern economic processes in the United States--the relationships between growth, unemployment, inflation, and budgets--changed in a fundamental way? And my answer to that question is no. The astonishingly good performance represents a change in productivity, but not a fundamental change in the relationships among the major macroeconomic variables. (Feldstein 2000)

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3 United States Department of Commerce, Bureau of Economic Analysis "National Income and Product Accounts" Table 9.4U. Software investment and prices, 31 July 2020 revision. This figure excludes purchases of prepackaged software, and it excludes investments in own-developed software in products sold; that is, this is software for firms' internal use.

Alan Greenspan, chair of the Federal Reserve, agreed:

> Our economy, of course, is changing everyday, and in that sense it is always "new." The deeper question is whether there has been a profound and fundamental alteration in the way our economy works that creates discontinuity from the past and promises a significantly higher path of growth than we have experienced in recent decades...Hence, as the first cut at the question "Is there a new economy?" the answer in a more profound sense is no.
>
> ... The American economy, like all advanced capitalist economies, is continually in the process of what Joseph Schumpeter, a number of decades ago, called "creative destruction." Capital equipment, production processes, financial and labor market infrastructure, and the whole panoply of private institutions that make up a market economy are always in a state of flux--in almost all cases evolving into more efficient regimes.
>
> ... But what was always true in the past, and will remain so in the future, is that the output of a free market economy and the notion of wealth creation will reflect the value preferences of people. (Greenspan 1998)

In the view of Feldstein and Greenspan, technology had a limited role to play. New technology might increase the rate of productivity growth, it might increase the rate of creative destruction, but it did not fundamentally change the way the economy worked.

One might ask whether technology *ever* changes economic fundamentals. Economic history provides at least one clear example where technology did change the economy. Beginning during the late 19th century in the US, new technologies allowed firms to realize major economies of scale in many industries such as steelmaking, oil refining, chemical and sugar processing, and mass production manufacturing. Because technology enabled dramatically higher throughput, the entire process of production had to be actively managed rather than relying on markets to coordinate activity (Chandler 1990, 1993; Beniger 1986). The steel mills, for instance, needed to secure regular inputs of iron ore and coke of the right quality and chemical composition; they needed to manage the production of rails and fabricated steel. This required sales and marketing. Business organizations split internally into multi-unit enterprises where professional managers handled the details of these different aspects. The occupation of middle manager was created to staff these hierarchies. In some cases, the firms vertically integrated. For example, Andrew Carnegie bought up iron ore and coke firms to secure a reliable supply of the right quality. More generally, economies of scale also changed industry structure, replacing large numbers of small enterprises with a small number of dominant ones in industry after industry. Innovation also shifted away from the market. Earlier, independent inventors typically worked on their own and sold their patents on the market to producers. With the rise of the new market structures, independent inventors were largely replaced by corporate research and development (R&D) labs.

Effectively, large segments of the economy were removed from direct market coordination and placed under corporate central planning in order to realize efficiencies of large-scale production. In this way, technology did change the economy. The impact went beyond just the extent of the economy covered by the market. It changed the nature of firm organization, it created managerial occupations, it led to more concentrated industries, and it changed the role of corporations in society. As the new large enterprises, called trusts, gained economic power, they also began abusing their power. Populist and progressive movements grew in reaction, giving rise to new laws covering antitrust, food and drug safety, child labor, unionization, and more. This reaction begat the new regulatory state. The government, particularly the federal government, came to balance the power of the new giant corporations.

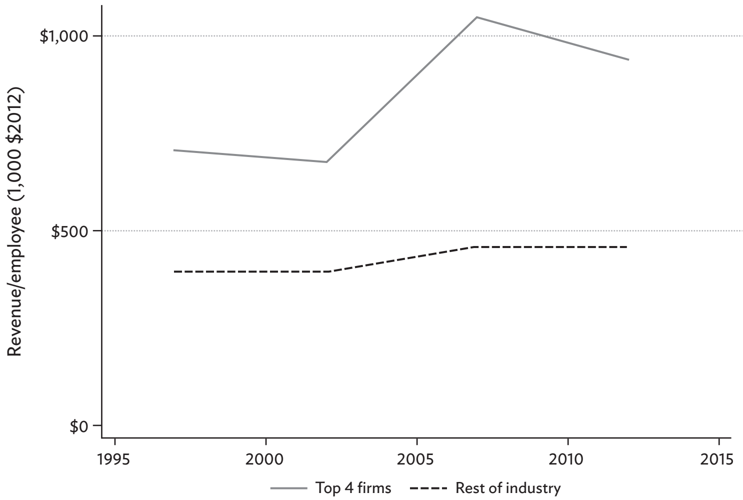
8.5 Evidence

Is information technology playing a similarly transformative role today? Clearly, this technology is not merely accelerating creative destruction anymore. From Figure 8.1, creative destruction has gone into steep decline. In a sense, the new technology is expanding the extent of nonmarket coordination. The dramatic increase in Walmart's product selection, manufacturers' product features, financial institutions' credit offerings, etc. all signify a greater extent of nonmarket coordination. There is accumulating evidence that this technology has fundamentally changed economic processes in ways that affect the dominance of large firms, the spread of new technology through the economy, income inequality, and the relative power of corporations and government.

8.5.1 The Dominance of Large Firms

It is now well-established that the dramatic decline in the disruption of dominant firms seen in Figure 8.1 has been accompanied by an increase in industry concentration and in markups.[4] In retail, banking, and other examples, the rising dominance of top firms appears to be tied to new

Figure 8.2: Productivity Gap (revenue per employee, comparing top four firms in industry to remainder)



Source: Economic censuses, nonmanufacturing data.

4 To some extent, the rise in industry concentration and markups predates the decline in disruption rates. On markups, see De Loecker, Eeckhout, and Unger (2020); Barkai (2020); Robert (2018). These estimates are contested by some (see Basu 2019; Syverson 2019; Berry, Gaynor, and Scott Morton 2019). On concentration, see Bajgar et al. (2019); Grullon, Larkin, and Michaely (2019); Autor et al. (2020); Gutierrez and Philippon (2017); Philippon (2019a, 2019b); Bessen (2020). While industry concentration has been rising at the national level, it has been falling when measured at the local level (see Rinz 2018; Rossi-Hansberg, Sarte, and Trachter 2018).

proprietary software systems and associated business models. A variety of evidence suggests that this relationship is more general.

First, the decline in disruption rates occurred just as large firm investment shifted sharply into proprietary software. While large firms also increased their investments in other intangibles such advertising and R&D, the shift into proprietary software was much larger. By my estimates, the stock of own-developed software held by the top four firms in each industry increased eightfold, while these other intangibles merely doubled.

Of course, many other things changed around the year 2000 that might play a role. For example, the dot-com boom collapsed and some new industries with network effects emerged. However, many more industries were affected by declining disruption than were affected by the dot-com entrants or by network effects. Some economists have sought to explain the trends by looking at the decline in real interest rates or in the aging of the workforce (Liu, Mian, and Sufi 2019; Hopenhayn, Neira, and Singhania 2018). However, both of these trends began during the early 1980s, much earlier than the decline in disruption. Indeed, for 2 decades disruption rates increased as real interest rates declined and labor force growth slowed.

Better evidence comes from econometric studies. In cross-country studies, researchers at the Organisation for Economic Co-operation and Development (OECD) find that the increase in markups is occurring mainly in digitally intensive sectors (Calligaris, Criscuolo, and Marcolin 2018). Firm-level research finds that investments by top firms in proprietary software is associated with a lower risk of getting disrupted (Bessen et al. 2020). Moreover, these investments slow the growth of smaller firms in the same industry, making it less likely that they will "leapfrog" industry leaders. In effect, investments in proprietary software by dominant firms is associated with suppression of disruption.

Furthermore, these effects appear to be causal. Instrumental variable analysis at the industry level finds that investments in proprietary software account for both the increase in industry concentration in the US since 1998 and the decline in disruption rates (Bessen 2020; Bessen et al. 2020). The magnitude of these effects is large enough to account for most of the changes since the late 1990s. Thus, a variety of evidence connects the investments in information technology to substantial changes in the dominance of large firms within industries.

Some people, however, point to weakened antitrust enforcement in the US as the cause of increasing industry concentration and markups (Grullon, Larkin, and Michaely 2019; Khan 2016). According to this view, during the 1980s, under the influence of Robert Bork and other laissez-faire scholars of the Chicago School, antitrust authorities at the Department of Justice and the Federal Trade Commission changed the standards they used to judge mergers and acquisitions. As a result, large firms could more easily buy out their rivals, and thereby preserve or increase a dominant market position.

There is, indeed, evidence that antitrust enforcement has weakened in the US, although this does not appear to provide a convincing explanation for the decline in industrial disruption for several reasons. First, as with the explanations based on interest rates and demographics above, the timing is off. Antitrust policy changed in the 1980s, but for 2 decades industrial disruption *increased* sharply before reversing. Second, industry concentration and markups have increased also in OECD countries that were not affected by the US-specific changes in antitrust policy (Bajgar et al. 2019; Calligaris, Criscuolo, and Marcolin 2018). Finally, firm-level analysis does not find a significant association between acquisition rates of top firms and their risk of being disrupted (Bessen et al. 2020). Moreover, the rate at which top firms have been acquiring companies has declined since the late 1990s. It is hard to see how acquisitions can explain an increase in industry concentration if the rate of acquisitions has gone down. While there may be solid reasons to reinvigorate US antitrust policy, weak enforcement does not appear to be a prime factor explaining the sharp decline in industrial disruption over the past 2 decades; proprietary software does.

8.5.2 Slow Diffusion and the Productivity Gap

A large literature finds that information technology improves firm productivity,[5] though some firms seem to benefit more than others (Bloom, Sadun, and Van Reenen 2012). Bessen (2020) finds that while information technology intensity is associated with higher productivity for all firms, the largest four firms in each industry benefit substantially more. This explains why information technology helps top firms increase their market shares, raising industry concentration. It also helps explain why dominant firms invest more in software.

There is another implication: a growing gap between the productivity of the top firms and the rest. Researchers at the OECD first identified a growing gap between "the best and the rest" (Andrews, Criscuolo, and Gal 2016). Figure 8.2 shows the gap between the labor productivity of the top four firms in each industry and the rest. While most firms have

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5 See a review in Syversson (2011, section 3.3).

seen stagnant productivity growth over the last 2 decades, the dominant firms have continued with robust growth.

This growing gap represents a fundamental change in the nature of innovation. Innovating firms gain a boost in productivity, but typically innovations are "diffused" so that other firms can benefit from them. This happens a number of different ways: Innovations may be licensed. They may be independently developed, possibly "inventing around" patents. Or alternative technologies may be developed. The rapid diffusion of innovations has been central to US economic growth over the past 2 centuries. What is clear from the data is that this diffusion process has slowed down over the last 2 decades. It is beyond the scope of this chapter to elaborate why the slowdown has occurred. Part of the reason is that much of the new technology is used to differentiate products on quality and in such markets, firms have insufficient incentives to license relative to the socially optimum level of licensing. Part of it is that the new information technologies have large scale and complexity that cannot be easily replicated by rival firms. As a result, there are growing gaps in access to the new technology.

The barriers to diffusion have several direct implications for aggregate productivity growth. First, it means diminished growth in average productivity. Productivity growth has not slowed at the largest firms who have the technology; it has slowed at the many firms that lack access. Because of this, the average or aggregate rate of productivity growth has slowed. The problem is not that there is less innovation, but that the innovations are not adequately spread through the economy.

Second, researchers using microdata have found that a key driver of productivity growth is reallocation—more productive firms grow faster while less productive firms shrink or exit (Decker et al. 2017; 2016a; 2016b; 2020). However, investments by dominant firms in proprietary software slow the growth of smaller rivals. In particular, productive small firms do not grow as fast, diminishing reallocation and thus slowing productivity growth (Bessen et al. 2020).

Finally, most productivity growth comes not from single innovations but from a long stream of subsequent innovations that improve the initial technology (Bessen 2015). To the extent that access is limited to these new information technologies, improvement may also be diminished in the long run. Thus, rather than accelerating productivity growth, as Martin Feldstein saw happening in the 1990s, information technology appears to be a significant culprit in the more recent productivity slowdown.

8.5.3 Limited Access and Wage Inequality

Many economists have attributed the growth in income inequality since 1980 to the ubiquitous use of low-cost computers. A large literature promotes the skill-biased technical change hypothesis.[6] Computers complement the labor of high-skilled workers, raising relative demand for these workers and the wages they are paid.

Recent research has raised a puzzle for this line of thinking. Thanks to the availability of large-scale administrative data that link employers and employees over time, researchers have found that most of the rise in wage inequality since 1980 has occurred *between* firms rather than from growing differences between individuals within firms (Card, Heining, and Kline 2013; Song et al. 2019; Lachowska et al. 2020). In particular, the main source of rising between-firm inequality is sorting of skills across firms—that is, some firms pay higher wages for comparable jobs and these firms also tend to hire more highly skilled workers. These findings pose a problem for the skill-biased technical change story: if low-cost computers are everywhere, why are the wages at all employers not affected equally?

However, the large proprietary systems that dominant firms use today are hardly ubiquitous, in contrast to general purpose personal computers. Only workers at select firms have access to this technology, and these firms pay more and demand more highly skilled workers. My research (with coauthors) studying help-wanted ads finds that firms with large investments in developing their own software offer to pay 15%–20% more for comparable jobs, and these firms also hire more highly skilled workers (Bessen, Denk, and Meng 2021). The combined effect is that the most information technology-intensive firms—the top quartile ranked by the share of information technology workers employed—offer jobs that pay 36% more than firms in the bottom quartile. Information technology intensity accounts for the majority of worker sorting by skills to high-paying firms. These huge differences apparently reflect difference in the marginal productivity of workers using these new technologies; they appear to strongly complement skill. Hence, proprietary software is significantly related to the rising between-firm differences that have been driving inequality.

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6 For a review of the literature see Acemoglu (2002).

8.5.4 Complexity and Regulatory Failure

During the late 19th and early 20th centuries, a new generation of large firms began exerting unprecedented power over society in the US. Thanks to economies of scale and financial combination, these firms removed a large swath of economic activity from the market and put it under their direct corporate control. They exerted unprecedented economic power. Unfortunately, these firms too often abused that power, charging monopoly prices, selling unsafe or unhealthy products, abusing adult and child labor, and more. In response, political pressure grew for the government to curtail these abuses. First, the farmers and the populist movement pushed for regulation of railroads and for the first antitrust laws. Later, the progressive movement successfully pushed an agenda to extend federal government regulation over large areas of society including unions, child labor laws, drug and food safety, and other consumer protections.

Today there has been another expansion of economic activity under private control. The effect has been to remove a range of activity from regulatory oversight. In particular, as the software systems used to run this economic activity have become more complex, it has become harder for regulators to gain access to the code and data needed monitor activity. This limitation is seen in many notable regulatory failures of recent years:

- Volkswagen and many other auto manufacturers modified the software controlling diesel engines to deceive emissions testing procedures. Regulators could not access this code, and the automobiles evaded emissions regulations for many years on millions of cars.
- In the subprime debt collapse, rating agency software was gamed by financial institutions, and financial institution risk models (software) obscured the real risks from regulators.
- In the Boeing 737 MAX, engineers inserted a software code patch to enable the planes to pass a particular test needed for Federal Aviation Administration certification. However, they hid the code and did not document it. Regulators were unable to know that the patch itself could fail, leading to catastrophic outcomes.

When firms compete by using software to manage ever more complex products and services, that software can undermine regulation in several ways. It allows firms to obfuscate monitoring. It makes regulators more reliant on industry experts and more prone to regulatory “capture.” It places an information burden on regulators, firms, and consumers—

firms have burdensome compliance costs, and consumers are presented with incomprehensible information disclosures, making it practically impossible for them to make informed choices. While these things do not necessarily alter the way economic processes work, they do tilt the balance of power between governments and large corporations in favor of the corporations.

8.6 The New Capitalism

This evidence strongly suggests that technology has changed economic processes in many industries. Martin Feldstein relegated technology to the role of increasing productivity. Evidence suggests that, although technology improves productivity at some firms, it is implicated in the slowdown of aggregate productivity growth. Alan Greenspan relegated technology to the role of increasing creative destruction, but the evidence suggests that information technology is suppressing the rate of creative destruction. Firms using proprietary software systems have become more persistently dominant in their industries, they have slowed the diffusion of technology through the economy, they have increased income inequality, and they have undermined government regulation. These are characteristics of a different form of economic competition, of a new capitalism. But how do we explain it?

In the past, technology has also changed the nature of competition. Beginning in the late 19th century, firms taking advantage of scale economies ushered in an era of oligopolistic competition in many industries. These firms dominated markets, productivity grew, and wages at large firms grew as well. The nature of innovation changed: independent inventors were replaced by corporate R&D labs. These firms grew powerful, and too often they abused their power.

Nevertheless, scale economies do not explain what has occurred recently in many industries. Indeed, the scale requirements of dominant information technology systems are not so large. In 2018, the largest spenders invested between $5 billion and $15 billion on information technology. This is small compared to the capital expenditures of the big energy companies and in the same range as capital expenditures by General Electric, Toyota, and Intel (Nash 2019).[7] So, economies of scale are nothing new. Although scale economies may be new to certain industries, the recent decline in disruption has occurred across the board, including in many industries that were already capital intensive. Nor do scale economies explain the apparent slowdown in the diffusion

7 The capital expenditure data are from Compustat.

of new technology. At best, scale economies do not provide a complete account of the change I outlined above.

To understand how information technology affects the nature of competition, it is helpful to look at what the technology actually does. Scale economies allow firms to compete more effectively on price: larger size brings lower costs, up to the point of minimum efficient size, allowing dominant firms to underprice smaller rivals. Today's dominant firms use large proprietary software systems to compete by offering more features or greater tailoring to individual or local needs. That is, they compete on *quality*; the technology allows them an unprecedented degree of product differentiation.

It is well known that product differentiation "softens" competition. Because firms can invest in varying amounts of software development that generate differing levels of quality, these investments give rise to a different kind of industry structure, what John Sutton calls a "natural oligopoly" (Shaked and Sutton 1982, 1983, 1987; Sutton 1991, 2001). This different kind of competition can explain many of the observed patterns related to proprietary software systems.

First, in a natural oligopoly, industry concentration persists even in rapidly growing markets. With economies of scale, as the size of the market grows, the dominance of leading firms tends to diminish; markets that are much larger than the minimum efficient plant scale tend to be less concentrated. Also, in a natural oligopoly, as the market grows, dominant firms increase their investments in technology, maintaining their dominant shares. This pattern is seen in rapidly growing markets such as e-commerce and also across geographic markets of differing size such as supermarkets (Ellickson 2006, 2007).

Second, in a natural oligopoly, follower firms face reduced returns to quality improvements. When a follower firm improves its quality, either by innovation or by further investment, it also *decreases* the degree of differentiation from higher quality firms. Less differentiation means greater price competition and lower prices, reducing the returns. Dominant firms face no such pricing pressure because their quality improvements increase the differentiation from their smaller rivals. This asymmetry can explain why smaller rivals are less likely to leapfrog the top firms and why smaller firms grow more slowly in response to innovations.

Third, in a natural oligopoly, dominant firms have reduced incentives to license their technology and they have increased incentives to keep it secret. Licensing is advantageous when the joint profits of the industry are greater with licensing. When technology is used to differentiate firms, arm's-length licensing reduces product differentiation. This, in turn, reduces industry profits. As a result, dominant firms will not license and will take steps to prevent the diffusion of the technology. With less diffusion, there is less access, growing gaps in the productivity of firms, reduced aggregate productivity growth, and growing differences in what firms pay and whom they hire.

At a more abstract level, information technology is altering the nature of the economy because it resolves a basic information paradox of the modern economy. Because information is so important to the nature of markets and economic institutions, the technology of information affects key aspects of how the economy works. The importance of information to the workings of the economy has been one of the signal achievements of economics in recent decades, and this realization began with the critique of socialist economic planning by Mises and Hayek (Mises 1920; Hayek 1945). They argued that prices were needed for an effective economic order. Central planners lacked the knowledge of local economic conditions, of rapidly changing conditions, and knowledge that economic agents might not willingly reveal.

Of course, capitalism has not entirely avoided central planning. Particularly with the introduction of technologies exhibiting strong economies of scale during the latter half of the 19th century, large business enterprises emerged and they engaged in varying degrees of centralized planning, using internal coordination instead of coordination through prices and markets. In many cases, these businesses standardized products and services to reduce the informational burden, to reduce the costs of discovering consumer demand or the costs of communicating quality to consumers, and to reduce the costs of meeting those disparate needs. While mass production did not necessarily mean "any color so long as it is black," it did imply restricted variety and with that, a limitation on the ability to meet local needs or to respond to changing demand.

As we have seen, the new information technology systems have been able to push back on those limitations. By enhancing the nature of centralized planning within firms, these technologies allow firms to respond to local and rapidly changing needs without forgoing the advantages of large-scale production. The result is, however, a different kind of competition, a different kind of capitalism.

The implication is that we can no longer think about problems such as productivity growth or income inequality in terms of models based on atomistic competition. Firms matter, technology matters, and industrial structure matters. Major changes in technology do change economic fundamentals. There is a new capitalism, and we must understand it in order to make sense of the economy. Much research remains to be done.

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9

Technology Spillovers, Asset Redeployability, and Corporate Financial Policies

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9.1 Introduction

Innovation is perhaps the single most important driver of productivity and hence growth. However, firms do not innovate in isolation but rather within an ecosystem populated by technological peer firms (e.g., Lyandres and Palazzo 2016). Many classic studies demonstrate the importance to a given firm of the technologies of its peer firms, including Arrow (1962), Jaffe (1986), Romer (1990), and Grossman and Helpman (1991). More recently, Bloom, Schankerman, and Van Reenen (2013) ("BSV" hereafter) found that a given firm's innovation, productivity, and value all increase as a result of technology spillovers from other firms.

A number of recent studies provide evidence suggesting that technology spillovers affect corporate investment, as well as the assets, both intangible and tangible, that they generate (e.g., Bena and Li 2014; Akcigit, Celik, and Greenwood 2016). Technologies can spill over across firms voluntarily, such as when firms choose to merge, or they can do so involuntarily, for instance, when knowledge is transferred through patents, research papers, conferences, social networks, and employees changing firms.[1] Overall, as technologies spill over from one firm to another, they stimulate investment and generate assets for technologically related firms.

Taking as given the previously documented impact of technology spillovers on corporate assets, we study how firms choose the mix

[1] We discuss lasers and microprocessors, two popular illustrations of technology spillovers, in Appendix A9.1.

of debt and equity that they use in their financing. We hypothesize that technology spillovers to a firm increase the redeployability of its assets, and this ultimately leads the firm to increase its leverage. Our reasoning is as follows: In the standard capital structure framework, a key determinant of corporate leverage is the redeployability of the firm's assets, i.e., their value in alternative use (Williamson 1988; Shleifer and Vishny 1992).[2] Indeed, for innovative firms in particular, low asset redeployability may be one of the most important reasons for which leverage is low. This is because innovative firms tend to have many assets that are firm specific (before considering technology spillovers) and few that are tangible. The specificity and intangibility of assets gives rise to a variety of frictions that leave potential lenders less willing to extend credit against the security of such assets (Hall 1992a). This is because these frictions increase losses to lenders in the event of bankruptcy.

Within the same standard framework, forces that increase asset redeployability reduce expected losses to lenders and thereby increase lending to firms. Activity in the same product market space as the firm is perhaps the most widely known of such forces for greater asset redeployability (e.g., Shleifer and Vishny 1992). Other firms in the same product market as a given firm may be willing to buy the firm's assets to bulk up on their own similar assets, to round out their own dissimilar assets, as a scale or scope deterrent to their competitors, or to otherwise expand their investment opportunities and output capabilities.

The foregoing logic and illustration also apply to activity in the technology space: firms with similar technologies may be willing to buy assets from each other. To the extent that the assets of a given firm incorporate technologies from other firms, i.e., technologies actually spill over across firms, the assets of the firm in question are of some use to the other firms, and these assets create value for those firms.[3] Therefore, other firms may be more willing to buy the firm's assets, which makes these assets more redeployable.[4] Thus, activity in the same technology space is another force for greater asset redeployability. It is worth stressing that the firm's assets generated by technology spillovers

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2 Also see additional seminal papers in this area by Harris and Raviv (1990), Aghion and Bolton (1992), Hart and Moore (1994), and Bolton and Scharfstein (1996).

3 These other firms are not only those that were the initial source of technology spillovers to a given firm. For example, peer firm B may be the initial source of spillovers to firm A, but the resulting assets of firm A that incorporate technologies from firm B may in fact be useful to another peer firm C.

4 As we discuss in section 9.4.2, there is evidence in recent studies that is consistent with spillovers in technology space improving asset redeployability and facilitating borrowing.

may be either intangible or tangible.[5] Similarly, what may change is not necessarily how much the firm invests but possibly only the extent to which its investment is stimulated by the technologies of other firms.[6]

Overall, within the standard framework, technology spillovers decrease the specificity of the firm's assets and increase their usefulness and value to other firms. Therefore, technology spillovers increase the redeployability of the firm's assets, both tangible and intangible, which leads to smaller losses to the firm's creditors in the event of bankruptcy. The firm's debt capacity rises, its borrowing costs fall, the firm borrows more, and in so doing it increases its leverage.

To test these predictions, we would ideally like to examine the details of the financing decisions corresponding to all assets resulting from technology spillovers that actually happened. However, no such data exist, not least because spillovers generate a wide variety of assets, many of which cannot be measured, but also because *actual* spillovers are almost impossible to measure. Nevertheless, we can take advantage of recent developments in the literature to measure *potential* technology spillovers.

Specifically, we study the effect of technology spillovers on corporate financial policies using a sample of 694 innovative publicly traded firms during the period 1981–2001. Following BSV, we capture potential technology spillovers to a firm (referred to hereafter without the "potential" qualifier) by taking into account both the extent of its technological similarity to other firms and the stock of knowledge of other firms. Our measure of technology spillovers to a firm is calculated as the sum of the weighted research and development (R&D) stocks of other firms, where the weights are the technological proximities of two firms. The technological proximity of two firms is measured as the distance between the technology activities of the firms in the same technology space or similar technology spaces. Technology activities and spaces are captured by patents and patent classes, respectively. Since the literature shows that our measure of technology spillovers results in higher corporate innovation, productivity, and value (BSV),

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5 Such intangible assets can be patents, formulas, designs, business methods, trade secrets, etc. Tangible assets can be laboratory equipment, research facilities, communications hardware, machinery, factories, etc.

6 Technology spillovers can affect the properties and value of the firm's assets without necessarily affecting how much it invests in R&D or property, plant, and equipment. The firm's R&D spending could even fall as a result of technology spillovers if it is a substitute for the R&D of its technological peer firms. Of course, if the two are complements, then the firm's R&D spending will rise. As an empirical matter, BSV find that, for the average firm, the R&D of the firm's technological peer firms has no effect on its own R&D. The foregoing argument also applies to capital expenditures.

it is reasonable to take as given that our measure captures actual technology spillovers. Moreover, our measure enables us to examine the direct effect of spillovers using a reduced-form approach.

Our identification of technology spillovers to a given firm relies on the projected R&D of *other* firms based on *their* R&D tax credits, as in BSV. We identify the effect of technology spillovers on financial policies using exogenous variation in federal and state R&D tax credits. For each firm-year, we project R&D stock on R&D tax credits, we calculate technology spillovers using the projected R&D stock, and we use this projected measure in our main regressions.

In addition, in our main regressions, we always account for product market spillovers to ensure that we separate the negative effect of the knowledge stock of product market competitors from the positive effect of the knowledge stock of technological peer firms. We also control for the variation attributable to the firm's *own* R&D stock and its *own* R&D tax credits. Additionally, both technology spillovers and financial policies may be persistent over time within firms, and they may vary together within a given industry at a given point in time. Accordingly, we include firm fixed effects as well as industry-year fixed effects in our regressions. We therefore identify entirely off the time-series variation in technology spillovers within firms, after eliminating the variation common to firms within a given industry in a given year.

Turning to our results, we find that technology spillovers have a significant effect on financial policies. Leverage increases by 6 percentage points (or by about 0.4 standard deviations) in response to a 1-standard-deviation increase in technology spillovers. Firms issue more debt and less equity. In contrast to the well-known negative relationship between leverage and a firm's own R&D, which we also find, the R&D of its technological peer firms increases its own leverage. This is the case even though we control for the firm's own R&D. We also find a stronger effect of technology spillovers on leverage for firms with a higher credit rating. This is consistent with the notion that firms with greater access to the debt market can better exploit the collateralizability of their assets to use relatively cheap debt financing instead of equity.

We then consider the asset redeployability channel through which technology spillovers can affect financial policies. To this end, we examine two direct consequences of technology spillovers increasing the productivity and value of the firm's assets in alternative use: greater collateralization of and market liquidity for the firm's assets. These are consequences of greater asset redeployability because the more productive and valuable the firm's assets are to its technological peer firms, the more likely these assets are to be traded among firms and at a higher price. Potential lenders, in turn, should be more willing to accept these assets as collateral because, in the event of bankruptcy, the firm's creditors should be able to increase their recovery rate by selling these assets.[7] Therefore, we should observe more asset collateralization and greater asset liquidity resulting from technology spillovers.

The results of our tests confirm our predictions. We find that technology spillovers significantly increase the firm's borrowing that is collateralized by all of its assets in general as well as a specific subset of its technology assets, namely patents. We also find a significant increase in the sale of patents as well as entire firms, suggesting an increase in the liquidity of both specific and general technology assets.

Greater asset redeployability also implies lower borrowing costs. We therefore also examine the effect of technology spillovers on bond and loan spreads. We find that for a 1-standard-deviation increase in technology spillovers, spreads on bonds and bank loans decrease, respectively, by roughly 6 and 9 basis points (or about 7%–8% of a standard deviation). These results persist for several years, indicating a long-term impact of technology spillovers on the cost of debt.

We also consider alternative interpretations of our results. We demonstrate that our collective results cannot be explained by an increase in future profitability, partly by showing empirically that the effect of technology spillovers on leverage is unaffected by whether we control for realized or expected future profitability. We also demonstrate that our results are inconsistent with theories of capital structure where the use of debt is motivated by managerial agency problems, information asymmetry, or cash flow risk.

Our study provides the first empirical evidence that technology spillovers have a significant impact on capital structure. The literature documents that technology spillovers have large private and social benefits (e.g., Jaffe 1986 and BSV). We document the financing mix chosen by firms for the assets that result from technology spillovers. In so doing, we complement the young but growing literature on the effect of technology spillovers on the real activities of firms. For example, Akcigit and Kerr (2018) study corporate innovation strategies; Akcigit, Celik, and Greenwood (2016) technology transfers; Rosenkopf and Almeida (2003) human capital investment; Maksimovic and Phillips (2001) tangible asset sales; Li, Qiu, and Wang (2019) strategic alliances; and Phillips and Zhdanov (2013) and Bena and Li (2014) mergers and acquisitions.

Our study also improves our understanding of financial decision-making in innovative firms in particular. The financing of technology

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7 Indeed, redeployability of assets is often conceptualized and implemented in the literature as salability (e.g., Benmelech 2009) or liquidity (e.g., Gavazza 2011).

assets presents unique challenges (Hall 1992a; Himmelberg and Petersen 1994). However, the existing literature does not distinguish between assets generated by technological peer firms rather than the firm itself (e.g., Kortum and Lerner 2000; Thakor and Lo 2019). Our study does draw this distinction.

Finally, we contribute to the emerging literature on peer effects and corporate policies (e.g., Foucault and Frésard 2014). A few prior studies focus on financial policies as the outcome of interest, examining peer effects among customers and suppliers (Kale and Shahrur 2007) and product market competitors (MacKay and Phillips 2005; Leary and Roberts 2014). Instead, we study firms that are mutual technological peers.

9.2 Methodology and Identification

9.2.1 Measuring Technology Spillovers

We begin by explaining the construction of the Jaffe (1986) measure of technology spillovers.[8] This measure restricts technology spillovers to the same technology space. First, the Jaffe measure of the technological proximity of two firms is constructed as follows. Each of the patents of a given firm is allocated by the United States Patent and Trademark Office (USPTO) to one technology class or more out of 426 possible classes. A firm's technology activity is then characterized by a vector $T_i = (T_{i1}, T_{i2}, ..., T_{i426})$, where $T_{i\tau}$ is the average share of the patents of firm i in technology class τ over the period 1970–1999.[9] The Jaffe proximity of firm i and firm j is then defined as the uncentered correlation between the two firms' technology activities:

$$TECH_{ij}^{Jaffe} = T_i T_j' \ / \ (T_i T_i')^{1/2} \left(T_j T_j'\right)^{1/2}$$

8 The methodology and identification, as well as the data and sample of the present study, are closely related to those of BSV. The present study also has an empirical framework in common with Nguyen and Kecskés (2020), but it focuses on different corporate consequences of technology spillovers, and it is written to be fully self-contained.

9 In calculating the proximity measure, one can either use all available data or only the data within a rolling window. The former approach benefits from greater precision, while the latter approach benefits from greater timeliness. Both approaches yield similar proximity measures. The data on patents allocated to 426 technology classes are understandably sparse for most firms in any given year, so it is common in the literature to use all available data. We follow this approach as well.

The Jaffe proximity measure ranges from 0 to 1. The higher the measure, the closer the technologies of the two firms.

Second, the R&D stocks of all other firms are calculated. The formula used to calculate a firm's R&D stock is $G_t = R_t + (1–\delta)G_{t-1}$, where R_t is the firm's R&D expenditures in year t and δ is the depreciation rate. Following BSV and much of the literature, we set δ = 0.15. Similarly, for the first year in which observe a firm, we set $G_0 = R_0/(\delta–g)$, where g = 0.05. This capitalizes the first R&D expenditure, which is then depreciated every year thereafter at the rate of δ.

Finally, the Jaffe measure of technology spillovers to firm i in year t equals the sum of technology spillovers from all other firms j to firm i in year t:

$$TECHSPILL_{it}^{Jaffe} = \sum_{j \neq i} TECH_{ij}^{Jaffe} G_{jt}.$$

Next, we explain the construction of the Mahalanobis measure of technology spillovers from BSV, which generalizes the Jaffe measure to allow technology spillovers across different technology spaces. The measure of the technological proximity of two firms now takes as an input a measure of the proximity of technology spaces. The literature captures the proximity of technology classes using the observed colocation of the technology classes within firms. The rationale is that technology classes that tend to colocate within firms are the result of related technologies, thus they reflect technology spillovers across technology classes.

To calculate the proximity of technology classes, the allocation of a technology class is determined by the vector $\Omega_\tau = (T_{1\tau}, T_{2\tau}, ..., T_{N\tau})$, where N is the number of firms and $T_{i\tau}$ is the average share of patents of firm i in technology class τ over the period 1970–1999. The proximity of the two technology classes, τ and ζ, is the uncentered correlation (as for the Jaffe proximity measure) of the allocation vectors Ω_τ and Ω_ζ:

$$\Omega_{\tau\zeta} = \Omega_\tau \Omega'_\zeta / (\Omega_\tau \Omega'_\tau)^{1/2} \left(\Omega_\zeta \Omega'_\zeta\right)^{1/2}.$$

A 426×426 matrix Ω is then constructed such that its (τ, ζ)th element equals $\Omega_{\tau\zeta}$. This matrix captures the proximity of technology classes.

The measure of the technological proximity of firm i and firm j is a function of the technology activities of the two firms (as captured by the vectors T_i and T_j in the Jaffe measure) and the proximity of technology classes. It is defined as follows:

$$TECH_{ij}^{Mahal} = \left(T_i/(T_iT_i')^{1/2}\right)\Omega\left(T_j'/\left(T_jT_j'\right)^{1/2}\right).$$

This measure of the technological proximity of two firms weights the overlap in technology activities between the two firms by the proximity of their technology classes. (It is worth noting the special case of $\Omega = I$, which implies that $\Omega_{\tau\zeta} = 0$ for all $\tau \neq \zeta$; that is, technology spillovers can only occur within the same technology class. In this case, the Mahalanobis technological proximity measure is identical to the Jaffe technological proximity measure.) This completes the Mahalanobis measure of the technological proximity of two firms.

The R&D stocks of all other firms are then calculated exactly as for the Jaffe measure of technology spillovers. Finally, the Mahalanobis measure of technology spillovers to firm *i* in year *t* is the sum of technology spillovers from all other firms *j* to firm *i* in year *t*:

$$TECHSPILL_{it}^{Mahal} = \sum_{j \neq i} TECH_{ij}^{Mahal} G_{jt}.$$

9.2.2 Measuring Product Market Spillovers

The effect of technology spillovers on a firm can be contaminated by the effect of product market spillovers because other firms that adopt similar technologies may also produce competing products. Therefore, the R&D activities of other firms have two separate and opposing spillover effects on the firm itself: technology spillovers, which positively affect its productivity, and product market spillovers, which negatively affect its market share. To isolate the effect of technology spillovers, we control for product market spillovers.

The product market spillover measures that we use are motivated by the insight that a firm's market shares in its various product markets are negatively affected by the R&D activities of other firms with which it competes. As with technology spillovers, the extent of product market spillovers from firm *j* to firm *i* depends on the product market proximity of firm *i* and firm *j* as well as the R&D stock of firm *j*. Aggregating across all other firms, product market spillovers to firm *i* equal the sum of product market spillovers from all other firms *j* to firm *i*.

Both the Jaffe and Mahalanobis measures of product market spillovers are calculated analogously to the corresponding technology spillover measures. To briefly describe the construction of the Jaffe measure, the sales of a given firm are allocated to one or more industry segments using data from Compustat. The firms in the sample cover 597 industries. A firm's product market activity is characterized by a vector $S_i = (S_{i1}, S_{i2}, \ldots, S_{i597})$, where S_{ik} is the average share of the sales of firm *i* in industry *k* over the period 1993–2001 (shortened because of limitations on industry data). The Jaffe distance, the R&D stocks of all other firms, and the product market spillover measure are all calculated as before.

9.2.3 Identification Strategy

We use variations in federal and state R&D tax credits to identify the causal effects of technology spillovers on financial policies. There is a large body of accumulated evidence on the suitability of R&D tax credits for identification in our setting, which can be summarized as follows: changes in R&D tax credits do affect corporate policies, they are plausibly exogenous to corporate policies, and they vary across firms. We now describe the evidence in greater detail. First, a substantial literature shows that R&D tax credits stimulate large increases in R&D spending, both in the United States (US) and internationally (Hall 1992b; Berger 1993; Hines 1993; Bloom, Griffith, and Van Reenen 2002). Their relevance to corporate investment is therefore well established.

Second, the exogeneity of these tax policies to corporate policies is also demonstrated in the literature. For example, BSV provide compelling evidence that changes in economic or political conditions cannot explain changes in R&D tax policies. Other studies perform similar analyses and come to the same conclusion (Cummins, Hassett, and Hubbard 1994; Chirinko and Wilson 2017; Moretti and Wilson 2017; Hombert and Matray 2018; Babina and Howell 2019). Indeed, since R&D tax credits have a relatively modest impact on government finances, it is unlikely that changes in these tax policies are caused by widely anticipated changes in corporate policies. Rather, R&D tax credits have gradually increased across states and over time. Nevertheless, there is substantial variation in R&D tax credits across states and over time, even those determined at the federal level.

Finally, R&D tax credits vary greatly across firms. This heterogeneity arises at the federal level because effective federal tax credits are determined by the difference between the actual R&D expenditures of a firm and a base amount that varies across firms and time according to the applicable federal tax rules. Moreover, the amount that a firm can claim depends on the extent to which the credits exceed the firm's profits, and the amount also depends on other factors such as deduction rules, the corporate tax rate, and so forth. At the state level, heterogeneity in tax credits arises because state tax credits are determined by the location of the firm's R&D hubs. Since firms can have R&D hubs in different states, their state R&D tax credits also vary across states.

We refer to spillover measures constructed in section 9.2.1 as "raw" to distinguish them from "orthogonalized" spillover measures. These orthogonalized measures are constructed below in a manner that removes the variation in R&D investment that is endogenous to corporate policies and retains the variation that is exogenous. A detailed description is provided by BSV, but to summarize here, federal and state R&D tax credits are calculated at the firm-year level using the Hall-Jorgenson (1967) user cost of capital approach. For firms that operate in more than one state in a given year, tax credits are aggregated to the firm-year level as the sum of the weighted state-level tax credits for the firm-year in question, where the weights are the average shares of the firm's inventors located in a given state.

Then, using a firm-year panel, R&D expenditures are regressed on federal tax credits, state tax credits, and firm and year fixed effects. The results are as in column 3 of Table A.I in Appendix B of BSV. This regression is then used to calculate predicted R&D expenditures. The remaining calculations are the same as in section 9.2.1. Predicted R&D expenditures are used to calculate the exogenous R&D stock for each firm-year. Finally, the orthogonalized spillover measures are calculated like the raw spillover measures but using the exogenous R&D stocks of other firms instead of their raw R&D stocks. BSV provide additional details, in section B.3 of Appendix B, as do Wilson (2009) and Falato and Sim (2014). It is worth stressing that our identification of technology spillovers to a given firm relies on the projected R&D of *other* firms based on *their* R&D tax credits and not on the firm's own R&D tax credits.

9.2.4 Main Regression Specifications

Our regression specifications take the following general form:

$$Outcome_{i,j,t+1} = \alpha \cdot \text{Tech\_Spill}_{i,t} + \beta \cdot \text{X}_{i,t} + \gamma_i + \gamma_{j,t} + \varepsilon \qquad (1)$$

where i indexes firms, j industries, and t years. $X_{i,t}$ is a vector of firm-level control variables, γ_i is a firm fixed effect, and $\delta_{j,t}$ is an industry-year fixed effect. Throughout our empirical analysis, we use four regression specifications for all our outcomes of interest. In the first two specifications, we capture spillovers with the raw and orthogonalized Jaffe spillover measures for both technology and product market spaces. In the last two specifications, we capture spillovers with the raw and orthogonalized Mahalanobis measures. We use both the Jaffe and Mahalanobis measures because each has various advantages. The Jaffe measure has been extensively used in the literature since it was popularized by Jaffe (1986), but it restricts technology spillovers to the same technology space. The Mahalanobis measure is a more recent contribution to the literature (BSV), but it allows technology spillovers across technology spaces rather than only within the same space.

Our regression specifications have several common features. We always include technology spillovers, and we always control for product market spillovers and the firm's own R&D.[10] In specifications using orthogonalized spillover measures, we also control for the firm's own federal and state tax credits. Among other control variables, we include firm age to capture possible life cycle effects associated with technology and product market spillovers. All variables are defined in Appendix Table A9.1.

Additionally, in all firm-year regressions, we always include firm fixed effects and industry-year fixed effects. We thus identify entirely off the time-series variation of technology spillovers within firms across time, and within a given industry in a given year across firms. In all firm-deal regressions (e.g., for the cost of debt), we control for industry and year fixed effects because at the firm-deal level many firms appear only once.

Finally, we cluster standard errors by industry-year. We generally multiply the dependent variables by 100 for expositional simplicity. We standardize the independent variables so that each coefficient estimate captures the effect on the dependent variable of a 1-standard-deviation change in the corresponding independent variable.

9.3 Sample and Data

9.3.1 Sample Construction and Data Sources

We begin constructing our sample with all publicly traded US firms in the Center for Research in Security Prices (CRSP) and Compustat database. We keep US operating firms defined as firms with CRSP share codes of 10 or 11. We drop firms that are financials or utilities. We then keep firms for which we have data on technology and product market spillovers. As a result, our sample is restricted to firms that had been issued at least one patent since 1963. Even so, our sample firms account for much of the R&D expenditures in the US: 62% in 1995, for example (BSV). Our

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10 BSV find that technology spillovers do not reliably affect the firm's own R&D spending, but they do increase its innovation output. Nevertheless, we control for the firm's own R&D to ensure that we only capture the direct effect of technology spillovers on the firm's leverage and not any indirect effect they may have through the firm's R&D.

final sample comprises 12,118 firm-year observations corresponding to 694 unique firms between 1981 and 2001.[11]

We obtain data on raw and orthogonalized technology and product market spillover measures from Nick Bloom (see BSV). We obtain patent data from the USPTO patent assignment database and from Noah Stoffman (see Kogan et al. 2017). Our stock trading data are from CRSP, and our accounting data are from Compustat. We obtain data on mergers and acquisitions from Securities Data Company (SDC). We also obtain bond issues data from SDC and bank loans data from Dealscan (the latter data start in 1987). We winsorize all continuous variables at the 1st and 99th percentiles.

9.3.2 Descriptive Statistics

In Table 9.1, we present descriptive statistics for our sample. We start with technology spillovers. Since they are typically large in dollar value and right skewed, we use them in logarithmic form throughout the chapter. However, we interpret them here in level form (not tabulated), which is more natural than interpreting them in logarithmic form. For the raw Jaffe measure, the value of technology spillovers is roughly $25 billion for the average firm (median of $20 billion), with a standard deviation of about $20 billion. These figures are close to the corresponding figures in BSV (Table II). Turning to our other three measures, the orthogonalized Jaffe measure is comparable in magnitude to the raw Jaffe measure, and the two Mahalanobis measures are roughly five times larger. The two Jaffe measures are naturally smaller than the two Mahalanobis measures since technology spillovers in the former are defined over a more restricted technology space than in the latter.

Next, we turn to general firm characteristics. Given the manner in which we construct our sample, our firms invest heavily in R&D and produce a large number of patents. Our firms have high valuations, with mean and median market-to-book of assets of 1.6 and 1.3, respectively.

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11 We end our sample in 2001 due to data limitations. First and foremost, the National Bureau of Economic Research patent database becomes sparsely populated by the mid-2000s, and it ends completely in 2006. Patents are not included based on filing dates but based instead on grant dates. The National Bureau of Economic Research patent database becomes sparse by the mid-2000s because many of the patents filed in the early 2000s were not granted by 2006. We therefore end our sample in 2001 to ensure that we have accurate patent data with which to calculate technological proximity and hence technology spillovers. Second, some of our analyses require data for up to 5 years into the future. This requirement also limits our ability to extend our sample period. Nevertheless, we do have a large sample of innovative firms spanning more than 2 decades.

Table 9.1: Descriptive Statistics

	Mean	Standard Deviation	25th Percentile	Median	75th Percentile
Technology spillover variables					
• Raw Jaffe	9.7	1.1	9.2	9.9	10.4
• Orthogonalized Jaffe	9.6	1.0	9.1	9.8	10.3
• Raw Mahalanobis	11.3	0.9	10.8	11.4	11.9
• Orthogonalized Mahalanobis	11.3	0.8	10.8	11.4	11.8
Firm characteristics variables					
• R&D (%)	44.9	68.9	0.0	19.9	59.5
• Patent stock	611	1,935	5	28	175
• Firm age (years)	24.6	18.1	11.7	20.1	31.5
• Total assets ($ millions)	2,507	6,366	90	338	1,648
• Market-to-book of assets	1.6	1.0	1.0	1.3	1.8
• Cash flow	15.0	8.7	10.3	15.2	20.1
• Asset tangibility	31.4	16.2	19.5	28.8	40.0
• Cash flow volatility	3.5	3.3	1.3	2.5	4.5
Capital structure variables					
• Leverage	21.7	15.6	9.0	20.6	31.5
• Debt issuance	5.6	9.8	0.0	1.1	7.1
• Equity issuance	1.5	4.1	0.0	0.2	0.9
Asset redeployability variables					
• Collateralized debt	3.2	7.7	0.0	0.0	2.0
• Number of patents collateralized	1.5	7.5	0.0	0.0	0.0
• Number of patents sold	2.1	10.1	0.0	0.0	0.0
• Number of mergers and acquisitions	0.2	0.5	0.0	0.0	0.0
• Value of mergers and acquisitions	1.8	8.1	0.0	0.0	0.0
Cost of debt variables					
• Bond issue spreads	107.1	93.4	55.0	83.0	130.0
• Bank loan spreads	125.5	118.9	32.5	75.0	200.0

R&D = research and development.

Notes: This table presents descriptive statistics for technology spillover variables, firm characteristics variables, and all dependent variables. The sample comprises 12,118 firm-year observations corresponding to 694 unique firms between 1981 and 2001. The firms in the sample are publicly traded United States operating firms excluding financials and utilities. All variables are defined in Appendix Table A9.1. All variables are multiplied by 100 except for the technology spillover variables, the stock of patents, firm age, total assets, the market-to-book of assets, the number of patents collateralized, the number of patents sold, and the number of mergers and acquisitions.

Source: Authors' calculation.

They are large, with mean and median total assets of $2.5 billion and $338 million, respectively. They are also mature, with a mean and median age of 25 and 20 years, respectively. Given their size and age, our firms are predictably profitable as reflected by their cash flow of 15% of total assets (both mean and median). At the same time, the above characterization of our sample firms should not be surprising because much of the innovation in the economy is carried out by mature public firms (Baumol 2002).

Overall, while our firms are larger, older, more profitable, and more innovative than the typical publicly traded firm, they are comparable in terms of their leverage. In particular, their leverage averages out to 22% of total assets (median of 21%) compared to 24% (median of 22%) in Leary and Roberts (2014). Our firms are also similar to the typical publicly traded firm in terms of their cost of debt. Their bond issue spreads are 107 and 83 basis points (bps) in the mean and median, respectively, whereas the corresponding figures for their bank loan spreads are 126 bps and 75 bps. By comparison, Valta (2012) finds mean and median spreads of 180 bps and 150 bps, respectively, in a sample that includes smaller firms and covers a somewhat later time period.

Table 9.2: Descriptive Statistics by Industry Sorted by Technology Spillovers

Industry	Obs.	Mean of Raw Jaffe Technology Spillovers	Standard Deviation of Raw Jaffe Technology Spillovers	Mean of Raw Jaffe Product Market Spillovers	Mean of R&D	Mean of Leverage
Communications (SIC=48)	61	10.50	1.09	9.42	56.8	23.7
Transportation equipment (SIC=37)	727	10.30	0.74	8.25	31.0	23.4
Chemicals and related products (SIC=28)	1,226	10.24	0.57	8.54	52.8	20.8
Electronic equipment excl. computers (SIC=36)	1,876	10.11	0.74	8.53	70.4	18.7
Construction products (SIC=32)	258	10.04	0.69	6.02	16.4	28.5
Consumer and business instruments (SIC=38)	1,086	9.98	0.69	8.15	101.4	17.1
Business services incl. technology (SIC=73)	166	9.94	0.78	7.73	74.9	16.1

continued on next page

Table 9.2 *continued*

Industry	Obs.	Mean of Raw Jaffe Technology Spillovers	Standard Deviation of Raw Jaffe Technology Spillovers	Mean of Raw Jaffe Product Market Spillovers	Mean of R&D	Mean of Leverage
Machinery and equipment incl. computers (SIC=35)	1,806	9.88	0.86	7.89	76.4	20.2
Paper and related products (SIC=26)	425	9.85	0.94	7.13	16.0	26.5
Rubber and plastic products (SIC=30)	261	9.79	1.01	7.74	25.1	18.9
Metal mining (SIC=10)	52	9.70	0.46	4.52	0.8	24.3
Primary metal industries (SIC=33)	392	9.59	0.86	6.47	9.7	22.3
Wood products excl. furniture (SIC=24)	84	9.56	0.83	4.77	0.0	31.9
Fabricated metal products (SIC=34)	735	9.42	0.97	6.74	17.4	20.7
Petroleum refining and related industries (SIC=29)	183	9.40	1.52	8.81	4.7	26.1
Textile mill products (SIC=22)	185	9.34	1.12	4.06	9.5	27.7
Oil and gas extraction (SIC=13)	196	9.29	1.28	7.48	6.4	32.5
Wholesale durable goods (SIC=50)	216	9.16	1.03	7.66	20.2	24.4
Food and related products (SIC=20)	517	9.14	0.96	5.69	4.8	21.7
Printing, publishing, and related industries (SIC=27)	280	8.97	1.16	6.69	3.7	18.7
Furniture and fixtures (SIC=25)	236	8.94	1.07	4.50	15.6	20.5
Miscellaneous manufacturing industries (SIC=39)	318	8.54	1.36	7.11	12.3	21.3
Wholesale nondurable goods (SIC=51)	69	8.34	1.53	3.91	11.8	24.7
Apparel and related products (SIC=23)	224	8.27	1.29	1.64	0.7	23.2
Leather and related products (SIC=31)	122	7.05	1.41	0.96	16.5	19.5

R&D = research and development, SIC = Standard Industrial Classification.

Notes: This table presents descriptive statistics by industry sorted by technology spillovers. The sample comprises 12,118 firm-year observations corresponding to 694 unique firms between 1981 and 2001. The firms in the sample are publicly traded United States operating firms excluding financials and utilities. Only industries with at least five unique firms are included (97% of the sample). Industries are sorted and tabulated in descending order of mean raw Jaffe technology spillovers. All variables are defined in Appendix Table A9.1. R&D and leverage are multiplied by 100.

Source: Authors' calculation.

In Table 9.2, we present descriptive statistics by industry. More precisely, we group firms by their primary industries, and then we sort industries by technology spillovers. We then compute descriptive statistics for each industry. Industries that are generally thought of as innovative cluster at the top of the table (high technology spillovers), such as communications, transportation equipment (automobiles, airplanes, etc.), and chemicals (including pharmaceuticals). Conversely, industries that are not typically considered to be innovative bunch at the bottom of the table (low technology spillovers), such as food, furniture, and clothing.

Furthermore, there is a positive correlation between technology spillovers and product market spillovers. This demonstrates the importance of controlling for product market spillovers. Finally, there is significant intra-industry variation in technology spillovers compared to their inter-industry variation. For example, a computer manufacturer (SIC = 35) (high technology spillovers) at one standard deviation below the industry mean has lower technology spillovers than the average food producer (SIC = 20) (low technology spillovers).

9.4 Results

9.4.1 Capital Structure

We begin our empirical analysis by examining the effect of technology spillovers on capital structure. Leverage is our main outcome of interest (debt-to-total assets), but we also examine debt issuance and equity issuance (both scaled by total assets). Our regression specifications follow the empirical literature on capital structure (e.g., Rajan and Zingales 1995; Lemmon, Roberts, and Zender 2008; Leary and Roberts 2014). In addition to the features common to all of our regression specifications (section 9.2.4), we control for sales, market-to-book of assets, cash flow, asset tangibility, and cash flow volatility.

Table 9.3 presents the results. Panel A shows that technology spillovers lead to an economically and statistically significant increase in leverage. In particular, as a result of a 1-standard-deviation increase in technology spillovers, the amount of debt used compared to equity increases by approximately 6 percentage points as a proportion of total assets. By way of comparison, the average firm has leverage of 22% (21% for the median firm) (Table 9.1).

Returning to our results in Table 9.3, Panel B shows that firms with greater technology spillovers increase their debt issuance, and Panel C shows that they decrease their equity issuance. In Panel B, debt issuance increases by roughly 3–4 percentage points (although one of our coefficient estimates is admittedly statistically insignificant at the 10% level, albeit only marginally). In Panel C, equity issuance decreases by about 2 percentage points These results on debt and equity issuance are consistent with our leverage results, and they suggest that technology spillovers lead firms to adjust their leverage through their securities issuance decisions.

In contrast to technology spillovers, product market spillovers do not reliably affect leverage. The firm's own R&D, however, is significantly related to leverage: a 1-standard-deviation increase in R&D is associated with a decrease in leverage of approximately 2 percentage points as a proportion of total assets. Our findings are consistent with the negative relationship between R&D and leverage documented in the literature (e.g., Titman and Wessels 1988; Frank and Goyal 2009). The relative strength of our leverage results for technology spillovers compared to the firm's own R&D is an artifact of our rigorous regression specifications, but it is also consistent with the notion that technology spillovers can have a stronger and positive effect on asset redeployability (and hence leverage) compared to a weaker and negative effect for R&D.[12]

12 Instead of using product market spillovers constructed using Standard Industrial Classification (SIC) codes and sales weights, we also use as an alternative the Hoberg-Phillips product similarity measure (Hoberg and Phillips 2010, 2016). We construct product market spillovers as before with the exception of using as weights the pairwise similarity scores between two firms before multiplying by R&D stock and aggregating across firms. Although data availability does cause the sample size to shrink, our principal inferences are unchanged.

We also examine the possibility that our results may capture asset redeployability in product market space rather than just in technology space. We use a recently developed measure constructed for this purpose from Kim and Kung (2017) and include it as a control variable in our regressions. The sample size shrinks due to data availability, but our main inferences remain the same.

Table 9.3: The Effect of Technology Spillovers on Capital Structure

Panel A: Leverage				
	Dependent Variable is Leverage (t)			
	Raw Jaffe	Orthogonalized Jaffe	Raw Mahalanobis	Orthogonalized Mahalanobis
Technology spillovers (t-1)	6.52***	5.82**	6.46***	6.97***
	(3.12)	(2.28)	(3.41)	(3.14)
Product market spillovers (t-1)	1.07	4.59**	−0.20	5.13**
	(1.17)	(2.39)	(−0.17)	(2.09)
R&D (t-1)	−2.21***	−2.19***	−2.17***	−2.19***
	(−6.33)	(−6.37)	(−6.23)	(−6.39)
Control variables?	Yes	Yes	Yes	Yes
Firm fixed effects?	Yes	Yes	Yes	Yes
Industry-year fixed effects?	Yes	Yes	Yes	Yes
Observations	11,682	11,682	11,682	11,682
Adjusted R^2	0.607	0.608	0.607	0.608
Panel B: Debt Issuance				
	Dependent variable is debt issuance (t)			
	Raw Jaffe	Orthogonalized Jaffe	Raw Mahalanobis	Orthogonalized Mahalanobis
Technology spillovers (t-1)	3.47**	3.85*	3.34**	2.77
	(2.22)	(1.86)	(2.14)	(1.56)
Product market spillovers (t-1)	0.61	1.93	−1.02	1.72
	(0.86)	(1.62)	(−1.03)	(0.94)
R&D (t-1)	−0.41*	−0.40*	−0.37	−0.37
	(−1.79)	(−1.73)	(−1.62)	(−1.61)
Control variables?	Yes	Yes	Yes	Yes
Firm fixed effects?	Yes	Yes	Yes	Yes
Industry-year fixed effects?	Yes	Yes	Yes	Yes
Observations	11,654	11,654	11,654	11,654
Adjusted R^2	0.233	0.233	0.233	0.233

continued on next page

Table 9.3 *continued*

Panel C: Equity Issuance				
	Dependent variable is equity issuance (t)			
	Raw Jaffe	Orthogonalized Jaffe	Raw Mahalanobis	Orthogonalized Mahalanobis
Technology spillovers (t-1)	–1.81***	–2.47***	–1.98***	–1.63*
	(–2.60)	(–2.70)	(–2.66)	(–1.95)
Product market spillovers (t-1)	0.23	0.65	–0.24	–0.55
	(0.90)	(1.07)	(–0.59)	(–0.65)
R&D (t-1)	0.29*	0.29*	0.30*	0.28*
	(1.92)	(1.90)	(1.96)	(1.85)
Control variables?	Yes	Yes	Yes	Yes
Firm fixed effects?	Yes	Yes	Yes	Yes
Industry-year fixed effects?	Yes	Yes	Yes	Yes
Observations	11,654	11,654	11,654	11,654
Adjusted R^2	0.186	0.186	0.186	0.186

R&D = research and development.

Notes: This table presents the results of regressions of leverage, debt issuance, and equity issuance on technology spillovers. The sample comprises 12,118 firm-year observations corresponding to 694 unique firms between 1981 and 2001. The firms in the sample are publicly traded United States operating firms excluding financials and utilities. For each dependent variable, four regressions are run, one for each measure of spillovers. In each regression, the same measure is used for technology spillovers and product market spillovers. The four spillover measures are the raw and orthogonalized Jaffe and Mahalanobis measures. The independent variables are as follows: technology and product market spillovers; R&D; federal and state tax credits, but only in specifications using orthogonalized spillover measures; the natural logarithm of firm age; the natural logarithm of sales; the market-to-book of assets; cash flow; asset tangibility; and cash flow volatility. All variables are defined in Appendix Table A9.1. The dependent variables are expressed as a percentage of total assets. The independent variables are lagged and standardized. Standard errors are clustered by industry-year. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. Only selected results are tabulated.

Source: Authors' calculation.

Table 9.4: The Effect of Technology Spillovers on Capital Structure: The Moderating Role of Debt Market Access

Panel A: Credit Rating of Long-Term Debt Only				
	Dependent Variable is Leverage (t)			
	Raw Jaffe	Orthogonalized Jaffe	Raw Mahalanobis	Orthogonalized Mahalanobis
Technology spillovers (t-1)	12.85***	11.40***	16.35***	13.51***
	(5.08)	(3.49)	(7.00)	(4.77)
Tech. spill. (t-1) Dummy variable (t-1) for credit rating is noninvestment grade	-0.14	-0.04	-0.13	-0.24
	(-0.14)	(-0.04)	(-0.12)	(-0.22)
Tech. spill. (t-1) Dummy variable (t-1) for credit rating is BBB	0.07	-0.28	-0.06	-0.23
	(0.08)	(-0.30)	(-0.06)	(-0.23)
Tech. spill. (t-1) Dummy variable (t-1) for credit rating is A	2.50**	2.77***	3.15***	3.17***
	(2.30)	(2.63)	(2.88)	(2.77)
Tech. spill. (t-1) Dummy variable (t-1) for credit rating is AA or AAA	3.15	1.99	5.16***	4.18**
	(1.61)	(1.08)	(2.84)	(2.34)
Control variables?	Yes	Yes	Yes	Yes
Firm fixed effects?	Yes	Yes	Yes	Yes
Industry-year fixed effects?	Yes	Yes	Yes	Yes
Observations	9,070	9,070	9,070	9,070
Adjusted R^2	0.676	0.676	0.676	0.677
Panel B: Credit Rating of Both Short-Term and Long-Term Debt				
	Dependent Variable is Leverage (t)			
	Raw Jaffe	Orthogonalized Jaffe	Raw Mahalanobis	Orthogonalized Mahalanobis
Technology spillovers (t-1)	12.95***	11.26***	16.38***	13.11***
	(5.19)	(3.51)	(7.15)	(4.66)
Tech. spill. (t-1) Dummy variable (t-1) for credit rating is noninvestment grade	-0.29	-0.09	-0.28	-0.26
	(-0.28)	(-0.09)	(-0.26)	(-0.24)

continued on next page

Table 9.4 *continued*

Panel B: Credit Rating of Both Short-Term and Long-Term Debt				
	Dependent Variable is Leverage (t)			
	Raw Jaffe	Orthogonalized Jaffe	Raw Mahalanobis	Orthogonalized Mahalanobis
Tech. spill. (t-1) Dummy variable (t-1) for credit rating is BBB or A-2 or A-3	-0.07 (-0.08)	-0.14 (-0.15)	-0.01 (-0.01)	0.08 (0.09)
Tech. spill. (t-1) Dummy variable (t-1) for credit rating is A or A-1	3.79*** (3.12)	3.60*** (3.00)	4.02*** (3.24)	4.01*** (3.17)
Tech. spill. (t-1) Dummy variable (t-1) for credit rating is AA or AAA or A-1+	4.52** (2.32)	3.19* (1.67)	5.30*** (2.84)	4.50** (2.45)
Control variables?	Yes	Yes	Yes	Yes
Firm fixed effects?	Yes	Yes	Yes	Yes
Industry-year fixed effects?	Yes	Yes	Yes	Yes
Observations	9,070	9,070	9,070	9,070
Adjusted R^2	0.677	0.677	0.677	0.678

Notes: This table presents the results of regressions of leverage on technology spillovers conditional upon the firm's credit rating. The regressions are the same as in Table 9.3 Panel A but every variable is interacted with each of five credit rating categories. In Panel A, the categories are based on the credit rating of long-term debt only. They are as follows: (1) no credit rating (the base category); (2) credit rating is noninvestment grade; (3) credit rating is BBB; (4) credit rating is A; and (5) credit rating is AA or AAA. In Panel B, the categories are based on the credit rating of both short-term and long-term debt. They are the same for categories (1) and (2) as in Panel A. For each of the other three categories, they are either the same as in Panel A based on long-term debt or they are as follows based on short-term debt: (3) A-2 or A-3; (4) A-1; and (5) A-1+. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. Only selected results are tabulated.

Source: Authors' calculation.

We further examine how access to the debt market moderates the impact of technology spillovers on leverage. We measure debt market access using credit ratings. We obtain data on S&P corporate credit ratings from Compustat. We sort the firms in our sample into five categories based on their credit ratings. We principally use the credit rating of long-term debt, but we also use the credit rating of short-term debt as a refinement.

Our five categories based on long-term credit ratings are as follows: no credit rating, which is the base category; noninvestment grade; BBB;

A; and AA or AAA. We also use short-term credit ratings, which are available for firms with low credit risk, to refine our measure of debt market access compared to using only long-term credit ratings. The bottom two categories are the same as before. The top three categories are either the same as before based on long-term debt or they are as follows based on short-term debt: A-2 or A-3; A-1; and A-1+.[13] We run the same regressions as in Table 9.3 Panel A, but we interact every variable with each of the five credit rating categories.

Table 9.4 presents the results. In both Panel A (long-term credit ratings only) and Panel B (both short-term and long-term credit ratings), the base category indicates that technology spillovers lead to an increase in leverage.[14] Furthermore, in both panels, as credit ratings increase, there is a stronger impact of technology spillovers on leverage. For firms rated A (long-term debt) or A-1 (short-term debt), as a result of a 1-standard-deviation increase in technology spillovers, the incremental increase in leverage is approximately 3 percentage points as a proportion of total assets. This incremental increase is, on balance, slightly stronger for firms rated AA or AAA (long-term debt) or A-1+ (short-term debt), which is the top category. Overall, the results are consistent with debt market access strengthening the impact technology spillovers on leverage.

9.4.2 Asset Redeployability

Having established that greater technology spillovers lead to higher leverage, we now consider whether asset redeployability is the channel through which this happens.[15] Assets that are more redeployable are more productive and valuable to firms that are mutual technological peers, so such assets are more likely to be traded and at a higher price among such firms. This increases recovery rates to creditors from selling the firm's assets in the event of bankruptcy, which should increase

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13 About 60% of our sample firms have no long-term credit rating and less than 10% are rated noninvestment grade. About 10% are rated BBB, and there are about twice as many A rated firms as firms that are rated AA or AAA. More than three-quarters of our sample firms have no short-term credit rating, and virtually none of them are rated less than A-3. The remaining quarter of our sample firms are A-3 or A-2 (very few are rated A-3), A-1, and A-1+ in roughly equal proportion.

14 The sample size shrinks and the economic magnitude of the effect is larger than in Table 9.3, both of which are due to the availability of data on credit ratings.

15 This channel can also be viewed through the lens of the stakeholder theory of capital structure. The firm's employees, customers, and suppliers, like its creditors, may bear significant losses in the event of the firm's bankruptcy (Titman 1984; Maksimovic and Titman 1991). Technology spillovers can decrease these losses by increasing the redeployability of these stakeholders' assets embedded in the firm.

the willingness of potential lenders to extend credit to the firm. We therefore should see that technology spillovers result in greater asset collateralization and asset liquidity.

To test these two predictions, we would ideally like to observe the assets specifically generated by technology spillovers being used as collateral for corporate borrowing and being traded among firms. Since such data do not exist, we must instead use close approximations. Our approach is supported by evidence from the literature that technology assets are increasingly important as collateral in corporate borrowing (Loumioti 2012; Mann 2018; Hochberg, Serrano, and Ziedonis 2018), and that technological similarity is associated with greater liquidity of real assets (Bena and Li 2014; Serrano and Ziedonis 2018). For both asset collateralization and asset liquidity, we consider two groups of assets. The broad group captures the entire firm, including all of the firm's technology assets. By contrast, the narrow group only captures a subset of technology assets, namely patents. However, patents are among the most valuable of technology assets, and they are often used as collateral or sold.[16]

We begin our tests with the asset collateralization prediction. We consider both the extent to which the firm's borrowing is collateralized by all of its assets in general and the extent to which the firm's patents are used as collateral for its borrowing. To capture the generalized collateralization of assets, we use collateralized debt (net of capital leases) divided by total assets, from Compustat. To capture collateralization specifically of technology assets, we use patent collateralizations from the USPTO database. Owing to the nature of the patent database, the patent collateralizations and sales that we capture involve patents issued to the firm and subsequently collateralized or sold.[17]

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16 For example, 21% of secured syndicated loans during the period 1996–2005 were collateralized by patents (Loumioti 2012). Similarly, 16% of patents issued since 1980 were eventually collateralized (Mann 2018). Among venture capital-backed start-ups in three selected innovation-intensive industries, 36% of firms founded from 1987 to 1999 received venture debt (Hochberg, Serrano, and Ziedonis 2018). Within the same group of startups but restricted to those that failed between 1988 and 2008, 83% of their patents were sold within 1 year of failure (Serrano and Ziedonis 2018).

17 While patent collateralizations and sales would appear to be rare events in absolute terms, they are in fact quite common relative to patent grants per year. For instance, the average firm collateralizes about 1.5 patents per year and sells about 2.1 patents per year (Table 9.1), which should be compared to an average of roughly 15 patent grants per year (the ratio of the firm's patent stock to its age). On an annual basis, then, the patent collateralization rate is about 10% of the patent grant rate, and the sales rate is about 15% of the grant rate. As a basis of comparison, Mann (2018) documents that 16% of patents were collateralized at some point during their lifetime (as opposed to on an annual basis).

In our regression specifications, we follow the empirical literature on capital structure and patent collateralizations (e.g., Leary and Roberts 2014; Mann 2018). In addition to the features common to all of our regression specifications (section 9.2.4), we control for sales, market-to-book of assets, cash flow, asset tangibility, cash flow volatility, and other variables as appropriate.[18] Importantly, for regressions with patent flow as an outcome, we control for patent stock to eliminate any mechanical relationship between flows and stocks (e.g., firms that have more patents also tend to collateralize or sell more patents).

Table 9.5: The Effect of Technology Spillovers on Asset Collateralization

Panel A: Collateralized Debt				
	Dependent Variable is Collateralized Debt (t)			
	Raw Jaffe	Orthogonalized Jaffe	Raw Mahalanobis	Orthogonalized Mahalanobis
Technology spillovers (t-1)	2.83***	1.76	2.57***	2.35**
	(3.32)	(1.53)	(2.79)	(2.13)
Product market spillovers (t-1)	−0.15	0.91	−0.30	0.89
	(−0.27)	(0.97)	(−0.36)	(0.62)
R&D (t-1)	−0.92***	−0.90***	−0.90***	−0.90***
	(−5.45)	(−5.41)	(−5.35)	(−5.43)
Control variables?	Yes	Yes	Yes	Yes
Firm fixed effects?	Yes	Yes	Yes	Yes
Industry-year fixed effects?	Yes	Yes	Yes	Yes
Observations	11,682	11,682	11,682	11,682
Adjusted R^2	0.436	0.436	0.436	0.436

continued on next page

18 Specifically, for regressions without leverage as the dependent variable, we control for leverage. For regressions with patent collateralizations or sales as the dependent variable, we control for the stock of patents. Finally, for regressions with mergers and acquisitions as the dependent variable, we control for stock returns and cash holdings.

Table 9.5 *continued*

Panel B: Patent Collateralizations				
	Dependent Variable is ln(Number of Patents Collateralized) (t)			
	Raw Jaffe	Orthogonalized Jaffe	Raw Mahalanobis	Orthogonalized Mahalanobis
Technology spillovers (t-1)	18.98**	27.32***	15.41*	19.66**
	(2.06)	(2.69)	(1.87)	(2.20)
Product market spillovers (t-1)	9.36**	−6.99	16.54***	0.90
	(2.27)	(−0.89)	(2.68)	(0.08)
R&D (t-1)	0.22	0.32	0.18	0.46
	(0.10)	(0.14)	(0.08)	(0.20)
Control variables?	Yes	Yes	Yes	Yes
Firm fixed effects?	Yes	Yes	Yes	Yes
Industry-year fixed effects?	Yes	Yes	Yes	Yes
Observations	11,687	11,687	11,687	11,687
Adjusted R^2	0.204	0.204	0.205	0.204

R&D = research and development.

Notes: This table presents the results of regressions of collateralized debt measures on technology spillovers. The sample comprises 12,118 firm-year observations corresponding to 694 unique firms between 1981 and 2001. The firms in the sample are publicly traded US operating firms excluding financials and utilities. For each dependent variable, four regressions are run, one for each measure of spillovers. In each regression, the same measure is used for technology spillovers and product market spillovers. The four spillover measures are the raw and orthogonalized Jaffe and Mahalanobis measures. The independent variables common to all panels are as follows: technology and product market spillovers; R&D; federal and state tax credits, but only in specifications using orthogonalized spillover measures; the natural logarithm of firm age; the market-to-book of assets; and cash flow. Additional independent variables specific to each panel are as follows: Panel A includes the natural logarithm of sales, asset tangibility, and cash flow volatility; Panel B includes the natural logarithm of total assets, leverage, asset tangibility, cash flow volatility, and the stock of patents. All variables are defined in Appendix Table A9.1. In Panel A, the dependent variables are scaled by total assets. In Panel B, the natural logarithm is taken after adding one to the dependent variables. All dependent variables are multiplied by 100. The independent variables are lagged and standardized. Standard errors are clustered by industry-year. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. Only selected results are tabulated.

Source: Authors' calculation.

Table 9.5 presents the results. Panel A shows that collateralized borrowing increases by roughly 2–3 percentage points as a proportion of total assets. This amounts to a bit under half the increase in total borrowing resulting from technology spillovers, which is approximately 6 percentage points as a proportion of total assets (Table 9.3). Indeed, the increase in borrowing (as opposed to its level) stems disproportionately from collateralized borrowing. The unconditional average collateralized borrowing of the firm is 3% of total assets (Table 9.1), which roughly doubles as a result of technology spillovers. By contrast, the firm's unconditional average uncollateralized borrowing is about 19%–20% (22% minus 2%–3%), which increases by a relatively smaller 3–4 percentage points (6 percentage points minus 2–3 percentage points).

Panel B of Table 9.5 shows that firms also use a larger number of patents to secure their borrowing. In particular, technology spillovers increase the number of patents used to collateralize debt by roughly 15%–25%. We also take the simpler approach of examining whether a firm collateralizes any patents in a given year (as captured by a dummy variable). In line with the previous results, we find that the rate of patent collateralizations increases, by 5–9 percentage points, which compares with its unconditional rate of 6%.

Overall, greater technology spillovers appear to increase the collateralization of debt. However, we wish to understand this increase better. It could be the case that the firm's assets become more redeployable, so lenders are more willing to accept them as collateral. But perhaps the firm's assets become harder to sell, so lenders require more of these assets as collateral.

We therefore proceed to testing the asset liquidity prediction. We examine the sales of patents as well as the sales of entire firms. To capture the sale of specific technology assets, we use patent sales from the USPTO database. To capture the sale of assets in general, we use data on mergers and acquisitions from SDC, specifically the number of deals as well as the value of deals as a proportion of total assets. Our sample firms must be involved in deals as either the target of an acquisition or a party to a merger (because in a merger of equals, the classification of acquirer and target is arbitrary). Our regression specifications follow the literature on asset sales (e.g., Harford 1999; Schlingemann, Stulz, and Walkling 2002; Bates 2005; Fich, Harford, and Tran 2015).

Table 9.6 presents the results. Panel A shows that the number of patents sold increases as a result of technology spillovers, very roughly, by 15%. We again take a simpler approach and examine whether a firm in a given year sells any patents (as captured by a dummy variable). The rate of patent sales is higher, by about 4 percentage points, which compares with its unconditional rate of 8% (results not tabulated). As a basis of comparison, Serrano and Ziedonis (2018) document that 83% of the patents granted to failed venture capital-backed technology startups were sold within 1 year of failure.

The next two panels of Table 9.6 show that technology spillovers also increase mergers and acquisitions activity. While the results vary

Table 9.6: The Effect of Technology Spillovers on Asset Liquidity

Panel A: Patent Sales				
	Dependent Variable is ln(Number of Patents Sold) (t)			
	Raw Jaffe	Orthogonalized Jaffe	Raw Mahalanobis	Orthogonalized Mahalanobis
Technology spillovers (t-1)	15.71*	18.74*	12.65*	15.49
	(1.81)	(1.72)	(1.67)	(1.58)
Product market spillovers (t-1)	2.46	–18.73**	5.79	–12.48
	(0.74)	(–2.35)	(0.94)	(–1.27)
R&D (t-1)	–1.98	–1.79	–1.93	–1.69
	(–1.45)	(–1.32)	(–1.40)	(–1.25)
Control variables?	Yes	Yes	Yes	Yes
Firm fixed effects?	Yes	Yes	Yes	Yes
Industry-year fixed effects?	Yes	Yes	Yes	Yes
Observations	11,687	11,687	11,687	11,687
Adjusted R^2	0.343	0.343	0.343	0.343
Panel B: Number of Mergers and Acquisitions				
	Dependent Variable is ln(Number of Mergers and Acquisitions) (t)			
	Raw Jaffe	Orthogonalized Jaffe	Raw Mahalanobis	Orthogonalized Mahalanobis
Technology spillovers (t-1)	8.53**	16.86***	7.28**	9.06**
	(2.58)	(3.58)	(2.18)	(2.21)
Product market spillovers (t-1)	2.07	–4.90	3.99	1.86
	(1.17)	(–1.27)	(1.49)	(0.39)
R&D (t-1)	–1.83***	–1.81***	–1.81***	–1.71**
	(–2.67)	(–2.60)	(–2.63)	(–2.48)
Control variables?	Yes	Yes	Yes	Yes
Firm fixed effects?	Yes	Yes	Yes	Yes
Industry-year fixed effects?	Yes	Yes	Yes	Yes
Observations	11,773	11,773	11,773	11,773
Adjusted R^2	0.206	0.206	0.206	0.205

continued on next page

Table 9.6 *continued*

Panel C: Value of Mergers and Acquisitions				
	Dependent Variable is Value of Mergers and Acquisitions (t)			
	Raw Jaffe	Orthogonalized Jaffe	Raw Mahalanobis	Orthogonalized Mahalanobis
Technology spillovers (t-1)	1.02	3.66**	2.07*	3.05**
	(0.94)	(2.48)	(1.90)	(2.43)
Product market spillovers (t-1)	0.74	0.56	0.13	1.44
	(1.26)	(0.55)	(0.15)	(0.98)
R&D (t-1)	−0.60**	−0.64**	−0.61**	−0.63**
	(−2.39)	(−2.47)	(−2.41)	(−2.41)
Control variables?	Yes	Yes	Yes	Yes
Firm fixed effects?	Yes	Yes	Yes	Yes
Industry-year fixed effects?	Yes	Yes	Yes	Yes
Observations	11,773	11,773	11,773	11,773
Adjusted R^2	0.083	0.084	0.083	0.084

R&D = research and development.

Notes: This table presents the results of regressions of asset liquidity measures on technology spillovers. The sample comprises 12,118 firm-year observations corresponding to 694 unique firms between 1981 and 2001. The firms in the sample are publicly traded US operating firms excluding financials and utilities. For each dependent variable, four regressions are run, one for each measure of spillovers. In each regression, the same measure is used for technology spillovers and product market spillovers. The four spillover measures are the raw and orthogonalized Jaffe and Mahalanobis measures. The independent variables common to all panels are as follows: technology and product market spillovers; R&D; federal and state tax credits, but only in specifications using orthogonalized spillover measures; the natural logarithm of firm age; the market-to-book of assets; and cash flow. Additional independent variables specific to each panel are as follows: Panel A includes the natural logarithm of total assets, leverage, asset tangibility, cash flow volatility, and the stock of patents; Panel B and Panel C include the natural logarithm of total assets, stock returns, leverage, and cash holdings. All variables are defined in Appendix Table A9.1. In Panel C, the dependent variables are scaled by total assets. In Panel A and Panel B, natural logarithms are taken after adding one to the dependent variables. All dependent variables are multiplied by 100. The independent variables are lagged and standardized. Standard errors are clustered by industry-year. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. Only selected results are tabulated.

Source: Authors' calculation.

in economic and statistical significance, Panel B shows that the number of mergers and acquisitions (M&As) increases by 10%, very roughly. Similarly, Panel C shows that the value of M&As also increases, by approximately 2 percentage points as a proportion of total assets, which compares with its unconditional mean of 2% of total assets. We also confirm that the rate of M&As is higher, by 10%, very roughly, compared to the unconditional rate of 12% for a given firm in a given year (results not tabulated). Overall, asset liquidity appears to increase as a result of technology spillovers.

Beyond technology spillovers, product market spillovers do not have a reliable effect on either asset collateralization or asset liquidity. By contrast, the firm's own R&D is significantly related to both collateralized borrowing and mergers and acquisitions activity, although it is not significantly related to either patent collateralizations or patent sales. Collateralized borrowing decreases by approximately 1 percentage point as a proportion of total assets. Similarly, the number of M&As decreases by about 2%, and the value of M&A decreases by roughly 0.6 percentage points as a proportion of total assets. Overall, there is some evidence consistent with the notion that the redeployability of a firm's assets is reduced by the firm's own R&D.

9.4.3 The Cost of Debt

In our final analysis, we examine the cost of debt. Borrowing costs should decrease as a result of greater technology spillovers as long as the beneficial effect of greater asset redeployability is not completely offset by the detrimental effect of higher leverage. We measure the cost of debt using bond issue spreads and bank loan spreads. In our regression specifications, we follow the empirical literature on the cost of debt.[19] In addition to the features common to all of our regression specifications (section 9.2.4), we include firm-level control variables: total assets, leverage, market-to-book of assets, cash flow, asset tangibility, and cash flow volatility. We also include deal-level control variables: the proceeds/amount of the bond/loan; the maturity of the bond/loan; the credit rating of the bond/firm; and the type of bond/loan (private versus public / term loan versus credit line).

Table 9.7 presents the results. Panel A shows that technology spillovers decrease spreads on bond issues by roughly 6 bps. Panel B shows a similar effect on bank loan spreads, which decrease by about 9 bps as a result of technology spillovers. All of the results are statistically significant. As for economic significance, bond issues and bank loans have average spreads of roughly 107 bps and 126 bps, respectively (median of 83 bps and 75 bps, respectively) (Table 9.1). Consequently, the cost of debt falls by about 5%–10% relative to its unconditional mean as a result of technology spillovers. To place these magnitudes in

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19 For bond issues, see Ortiz-Molina (2006), Francis et al. (2010), and Qi, Roth, and Wald (2010). For bank loans, see Graham, Li, and Qiu (2008), Chava, Livdan, and Purnandam (2009), and Valta (2012).

the context of prior work on peer effects, Valta (2012) finds a similar increase in the cost of debt (about 10 bps) for a comparable increase in product market competition. Chang et al. (2020) likewise find a 28 bps increase associated with a comparable magnitude decrease in bankruptcy recovery rates for product market peers. We should note that the decrease in the cost of debt that we find is consistent with the firm's assets becoming more redeployable and hence more valuable to its creditors.

Product market spillovers, in contrast to technology spillovers, have no effect on bond issue spreads. They do, however, increase the spreads on bank loans, by about 6–8 bps. Our results on bank loan spreads suggest the firm's bank lenders have an unfavorable view of product market spillovers. The firm's own R&D is also significantly related to the cost of debt. For both bond issues and bank loans, R&D is associated with an increase in spreads of roughly 10–12 bps. This suggests that the firm's own R&D is viewed unfavorably by both bondholders and bank lenders in determining the firm's borrowing costs.

We also examine whether technology spillovers affect the cost of debt not only in the short run but also in the long run. To this end, we examine bond issues and bank loans over horizons of up to 5 years. We find that debt spreads are also negative in the long run, as in the short run, but they are somewhat less economically and statistically significant as the horizon increases (results not tabulated). In summary, our results suggest that technology spillovers decrease the cost of debt. This is the case even accounting for the increase in leverage resulting from greater technology spillovers, which by itself would tend to increase the cost of debt.

Table 9.7: The Effect of Technology Spillovers on the Cost of Debt

Panel A: Bond Issues				
	Dependent Variable is Spread (t)			
	Raw Jaffe	Orthogonalized Jaffe	Raw Mahalanobis	Orthogonalized Mahalanobis
Technology spillovers (t-1)	−6.55**	−5.91**	−6.63**	−6.35**
	(−2.09)	(−2.21)	(−2.21)	(−2.10)
Product market spillovers (t-1)	−0.36	−2.79	−1.49	−2.71
	(−0.17)	(−0.95)	(−0.56)	(−0.94)
R&D (t-1)	10.26**	11.73**	10.63**	11.75**
	(2.08)	(2.43)	(2.18)	(2.44)
Control variables?	Yes	Yes	Yes	Yes

continued on next page

Table 9.7 *continued*

Panel A: Bond Issues				
	Dependent Variable is Spread (t)			
	Raw Jaffe	Orthogonalized Jaffe	Raw Mahalanobis	Orthogonalized Mahalanobis
Industry fixed effects?	Yes	Yes	Yes	Yes
Year fixed effects?	Yes	Yes	Yes	Yes
Observations	2,205	2,205	2,205	2,205
Adjusted R^2	0.557	0.558	0.558	0.558
Panel B: Bank Loans				
	Dependent Variable is Spread (t)			
	Raw Jaffe	Orthogonalized Jaffe	Raw Mahalanobis	Orthogonalized Mahalanobis
Technology spillovers (t-1)	−9.52***	−9.63***	−8.76***	−8.95***
	(−2.92)	(−3.08)	(−2.75)	(−2.85)
Product market spillovers (t-1)	6.35**	8.17***	5.49*	5.50*
	(1.98)	(2.71)	(1.77)	(1.76)
R&D (t-1)	10.57***	9.92***	10.71***	10.56***
	(2.90)	(2.77)	(2.99)	(3.00)
Control variables?	Yes	Yes	Yes	Yes
Industry fixed effects?	Yes	Yes	Yes	Yes
Year fixed effects?	Yes	Yes	Yes	Yes
Observations	2,724	2,724	2,724	2,724
Adjusted R^2	0.558	0.561	0.557	0.560

R&D = research and development.

Notes: This table presents the results of regressions of bond issue spreads and bank loan spreads on technology spillovers. The sample comprises 12,118 firm-year observations corresponding to 694 unique firms between 1981 and 2001. The firms in the sample are publicly traded US operating firms excluding financials and utilities. For each dependent variable, four regressions are run, one for each measure of spillovers. In each regression, the same measure is used for technology spillovers and product market spillovers. The four spillover measures are the raw and orthogonalized Jaffe and Mahalanobis measures. The independent variables at the firm level are as follows: technology and product market spillovers; R&D; federal and state tax credits, but only in specifications using orthogonalized spillover measures; the natural logarithm of firm age; the natural logarithm of total assets; leverage; the market-to-book of assets; cash flow; asset tangibility; and cash flow volatility. The independent variables at the firm-deal level are as follows: the natural logarithm of the proceeds of the bond issue or the amount of the bank loan; the natural logarithm of the maturity of the bond or the loan; the credit rating of the bond issue or the credit rating of the firm; a dummy variable that equals one if the credit rating is missing and zero otherwise; and a dummy variable that equals one if the bond issue is private rather than public or the bank loan is a term loan rather than a credit line. All variables are defined in Appendix Table A9.1. The dependent variables are multiplied by 100. The independent variables are lagged and standardized. Standard errors are clustered by industry-year. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. Only selected results are tabulated.

Source: Authors' calculation.

9.5 Discussion of Alternative Interpretations

We provide a substantial volume of evidence supporting asset redeployability as the channel through which technology spillovers lead to higher leverage. Nevertheless, we now examine alternative interpretations of the positive effect of technology spillovers on leverage. We show that our results as a whole cannot be explained by these alternative channels.

Under the tradeoff theory of capital structure, one possibility is that an increase in future profitability leads to an increase in leverage today. Higher cash flows translate into a higher tax shield benefit of debt, which firms may exploit by increasing leverage. While related work does show that technology spillovers lead to higher profitability in the long run (over a 5-year horizon), profitability in the short run is unchanged (Nguyen and Kecskés 2020). Since a firm needs higher cash flows to be able to make higher interest payments, the increase in the firm's debt (and hence its interest payments) should normally occur roughly around the same time as the increase in its cash flows. Since this is not supported by the extant evidence, a pure future profitability interpretation is problematic.[20] Nevertheless, in Appendix A9.2, we test the key prediction of the future profitability interpretation, which is that controlling for future profitability should subsume at least some of the effect of technology spillovers on leverage. The results, presented in Appendix Table A9.2, are also inconsistent with the future profitability interpretation.

A closely related possibility, still under the tradeoff theory, is that technology spillovers may decrease cash flow risk, which leads to lower costs of financial distress, higher debt capacity, and ultimately to higher leverage. In fact, related work suggests that cash flow risk actually increases as a result of the innovation risk that may be associated with

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20 To be precise, we do find a decrease in the cost of debt in addition to the increase in leverage. If the former effect dominates the latter, then interest payments will decrease. However, our results show that the decrease in the cost of debt (6–9 bps from Table 9.7) has a much smaller effect on interest payments than the increase in leverage (6 percentage points from Table 9.3). To illustrate the overall effect, assume that for the typical firm the cost of debt decreases by as much as 10 basis points, the spread is only 100 basis points, and the yield on a duration-matched government bond is only 3%. In this case, interest payments would decrease by at most 2.5% (= -10 bps, 400 bps). By comparison, for the typical firm with leverage of 20%, a mere 0.5 percentage point increase in leverage (i.e., a 2.5% increase) would be more than sufficient to offset the decrease in the cost of debt and increase interest payments overall. In fact, we find a much larger increase in leverage than required by the foregoing calculations.

technology spillovers (Tseng 2018). This evidence is inconsistent with a cash flow risk interpretation of the effect of technology spillovers on leverage.

Another possibility, under the managerial agency theory of capital structure, is that debt may be used as a managerial disciplinary mechanism. Higher cash flows present greater opportunities for managers to invest in projects that enrich themselves at the expense of shareholders. It is in the interests of shareholders to prevent managers from wasting the cash flows stemming from technology spillovers. Therefore, shareholders force managers to issue debt, the interest payments on which will be made using the cash flows from technology spillovers, and to pay out the issuance proceeds to shareholders. In additional empirical analyses, we find that technology spillovers do lead to higher cash holdings (in line with Qiu and Wan 2015) but not to any change in payouts to shareholders (results not tabulated). This evidence is inconsistent with the disciplinary mechanism interpretation.

A final possibility, under the pecking order theory, is that greater information asymmetry leads to higher leverage. Technology spillovers increase the complexity and uncertainty of value-relevant information about the firm, which makes the firm more difficult to value, especially for outsiders compared to insiders (Nguyen and Kecskés 2020). The resulting increase in information asymmetry can lead to higher leverage, but it requires an increase in the cost of debt and by less than the increase in the cost of equity. Since we find that borrowing costs in fact decrease (Table 9.7), a pure information asymmetry interpretation cannot explain our results.

9.6 Conclusion

This chapter is motivated by prior research showing that technology spillovers across firms increase the innovation, productivity, and value of these firms. Building on this evidence, we first argue that the growth stimulated by technology spillovers to a given firm from its technological peer firms increases the redeployability of the firm's own assets. This increase in asset redeployability leads to smaller losses to the firm's creditors in the event of bankruptcy. The firm's debt capacity thereby increases, the firm borrows more, and its leverage thus increases.

We then take advantage of recent developments in the literature to test our predictions. We implement an empirical framework that allows us to measure technology spillovers, and to identify their causal effect on a given firm based on exogenous variation in the R&D tax credits of other firms. We find that greater technology spillovers lead to higher leverage. This effect is stronger for firms with greater debt market access. Moreover, we also find more collateralized borrowing and asset transactions, and also a decrease in borrowing costs. Taken together, our results are consistent with our argument that technology spillovers increase leverage by increasing asset redeployability. Overall, our chapter demonstrates the importance of technology spillovers in explaining corporate financial policies.

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Appendix A9.1: Illustrative Examples of Spillovers

Technology spillovers to a firm are calculated as the weighted average research and development (R&D) stocks of other firms, where the weights are the technological proximities of the firm and other firms. While the R&D of other firms is a straightforward concept, the notion of technological proximities of firms stands to benefit from some examples. We illustrate relationships in technology space with reference to well-known horizontal and vertical relationships in product market space. These examples show that firms that are close in technology space are not necessarily close in product market space (horizontal or vertical).

We first compare and contrast technology relationships and horizontal product market relationships, following Bloom, Schankerman, and Van Reenen (2013). For simplicity, we use the Jaffe proximity measures in our examples. In our sample, the correlation between technological proximities and product market proximities is strong but only 0.47. IBM, for instance, is close to Apple, Intel, and Motorola in technology spaces (their proximities are 0.64, 0.76, and 0.46, respectively, on a scale of 0 to 1). However, only Apple is close to IBM in product market spaces (their proximity is 0.65), which reflects the fact that both firms produce personal computers (during our sample period). By contrast, Intel and Motorola are far from IBM in product market spaces (their proximities are both 0.01) because they produce semiconductors, whereas IBM's semiconductor production is modest. (Another illustration of the distinct relationship between technology spillovers and product market spillovers is provided by our Table 9.2.)

Second, we compare and contrast technology relationships and vertical product market relationships. For example, the Coca-Cola Company is close to both the Liqui-Box Corporation and the Tokheim Corporation in technology spaces (their proximities are 0.90 and 0.67, respectively). All three firms make some products that involve liquids and target consumers. Coca-Cola and Liqui-Box are vertically related in product market spaces because Coca-Cola makes beverage products and Liqui-Box makes packages for liquid products (e.g., bottles for drinks). However, Coca-Cola and Tokheim are not vertically related in product market spaces because Tokheim makes fuel-dispensing systems (e.g., gasoline pumps).

Finally, we offer several examples of technology spillovers. The manner in which technologies diffuse throughout the economy, across firms and over time, is instructive. The diffusion process itself shows that the assets generated by technological diffusion are more useful and therefore more valuable to technological peer firms than assets generated by technologies that are specific to a given firm.

In the first famous example, lasers were invented in 1960 by the Hughes Aircraft Company (now owned by the Raytheon Company). The original purpose of the technology was to amplify visible light, but it has since spread to a wide variety of consumer and business uses. These applications include drives, printers, barcode scanners, lighting displays, medicine and surgery, fiber-optic cables, construction, and manufacturing, in addition to military and law enforcement applications.

Microprocessors are another famous example of technology spillovers. Invented concurrently in 1971 by three firms (Garrett AiResearch, Texas Instruments, and Intel), they revolutionized the computer industry. However, the technology also spilled over into

Table A9.1: Variable Definitions

Name	Definition
Spillover variables	
• Raw Jaffe • Raw Mahalanobis	The Jaffe or Mahalanobis distances in the technology or product market spaces are computed for each pair of firms. Then the stock of R&D is computed for every firm-year. Finally, the spillover variables for a firm are computed as the natural logarithm of the sum of the R&D stock of each of the other firms weighted by the distance between the firm in question and each of the other firms.†
• Orthogonalized Jaffe • Orthogonalized Mahalanobis	Computed like the corresponding raw variables except that the R&D stock of other firms is first orthogonalized before weighting and summing. Specifically, R&D tax credits are computed for each firm-year, and the R&D stock is regressed on the R&D tax credits. The resulting predicted values are used as the orthogonalized R&D stock corresponding to each firm-year.†
Capital structure variables	
• Leverage	(DLTT+DLC)/AT*
• Debt issuance	DLTIS/AT*
• Equity issuance	SSTK/AT*
Asset redeployability variables	
• Collateralized debt	(DM-DCLO)/AT*
• Number of patents collateralized	Number of patents issued to the firm and subsequently used as collateral for borrowing. See Mann (2018).

continued on next page

Table A9.1 *continued*

Name	Definition
• Number of patents sold	Number of patents issued to the firm and subsequently sold. See Serrano (2010) and Akcigit, Celik, and Greenwood (2016).
• Number of mergers and acquisitions	Number of mergers and acquisitions involving the firm
• Value of mergers and acquisitions	Value of mergers and acquisitions involving the firm scaled by total assets
Cost of debt variables	
• Bond issue spreads	Bond issue spread related to a duration-matched government bond
• Bank loan spreads	Bank loan spread over the benchmark rate
Control variables	
• R&D	Stock of the firm's R&D accumulated up to a given firm-year adjusted for depreciation and scaled by the firm's stock of physical capital†
• Federal tax credits • State tax credits	Natural logarithm of the firm's federal and state tax credits in a given firm-year†
• Firm age	Number of years as a publicly traded firm
• Patent stock	Stock of the firm's patents accumulated up to a given firm-year
• Total assets	AT*
• Sales	SALE*
• Market-to-book of assets	(AT-(TXDITC+CEQ)+PRCC_F´CSHO)/AT*
• Cash flow	OIBDP/AT*
• Asset tangibility	PPENT/AT*
• Cash flow volatility	Standard deviation of cash flow computed using 3 years of annual data*
• Stock returns	Annualized mean daily stock returns
• Leverage	(DLTT+DLC)/AT*
• Cash holdings	CHE/AT*
• Realized future profitability	Mean OIBDP/AT during the next 5 years*
• Expected future profitability	Analysts' long-term earnings growth rate estimates

R&D = research and development.

Notes: This table presents variable definitions. Variables are computed for every firm-year except for spreads on bond issues and bank loans. In these latter cases, variables are computed for every firm deal. Industry is defined using two-digit Standard Industrial Classification (SIC) codes. * indicates that the variable is defined using Compustat data items. † indicates that the variable is computed as in Bloom, Schankerman, and Van Reenen (2013).

Source: Authors' calculation.

unrelated industries such as communications (e.g., satellites and mobile phones), household appliances (e.g., washing machines, refrigerators, and microwave ovens), automobiles, entertainment equipment (e.g., televisions and sound systems), games and toys, and household accessories (e.g., light switches and smoke alarms).

A related example is provided by open-source software. In the history of computers, it was initially ubiquitous, then challenged by licensed software in the 1970s and 1980s, and has once again become dominant. Prominent examples of open-source products include the Linux and Android operating systems, the Apache web server, and the Firefox and Chrome internet browsers. Countless technology firms use open-source output contributed by other firms (e.g., Google). Some make money by customizing the software for their clients (e.g., IBM). Others use the software to power their hardware (e.g., Samsung). Still others use the resulting technology products for their nontechnology businesses (e.g., Amazon). We refer the reader to Rosenberg (1979) for additional examples.

Appendix A9.2: The Future Profitability Interpretation of the Results

The future profitability interpretation has a key prediction that we test here. Specifically, if future profitability can explain our results, then reasonable proxies for future profitability should at a minimum partially subsume the effect of technology spillovers on leverage, and therefore our main results should become noticeably weaker or disappear.

In our empirical test of this prediction, we capture future profitability using two proxies. First, to capture realized future profitability, we use mean cash flow during the next 5 years. Second, to capture expected future profitability, we use analysts' long-term earnings growth rate estimates.

The results, which are presented in Appendix Table A9.2, are economically and statistically significant for our measures of technology spillovers. Moreover, the coefficient estimates on our technology spillover measures are comparable to those in Table 9.3. This evidence is inconsistent with the future profitability interpretation, which predicts weaker or entirely insignificant estimates on technology spillovers.[21]

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21 It is possible that measures of total factor productivity (TFP) are better at capturing the theoretical notion of future profitability than our previous two measures. As a robustness check, we obtain TFP data from Şelale Tüzel (see İmrohoroğlu and Tüzel 2014 for details), and we rerun the regressions in Appendix Table A9.2 with two modifications. In particular, we use mean TFP during the next 5 years instead of mean cash flow, and we control for lagged TFP. Our inferences remain unchanged.

Table A9.2: Replication of Baseline Capital Structure Results Controlling for Future Profitability

Panel A: Controlling for Realized Future Profitability				
	Dependent Variable is Leverage (t)			
	Raw Jaffe	Orthogonalized Jaffe	Raw Mahalanobis	Orthogonalized Mahalanobis
Technology spillovers (t-1)	6.75***	5.83**	6.60***	6.99***
	(3.27)	(2.29)	(3.51)	(3.16)
Product market spillovers (t-1)	1.04	4.55**	−0.20	5.12**
	(1.15)	(2.41)	(−0.16)	(2.11)
R&D (t-1)	−2.24***	−2.21***	−2.19***	−2.21***
	(−6.37)	(−6.38)	(−6.26)	(−6.41)
Control variables?	Yes	Yes	Yes	Yes
Firm fixed effects?	Yes	Yes	Yes	Yes
Industry-year fixed effects?	Yes	Yes	Yes	Yes
Observations	11,681	11,681	11,681	11,681
Adjusted R^2	0.607	0.608	0.607	0.608
Panel B: Controlling for Expected Future Profitability				
	Dependent Variable is Leverage (t)			
	Raw Jaffe	Orthogonalized Jaffe	Raw Mahalanobis	Orthogonalized Mahalanobis
Technology spillovers (t-1)	6.02**	10.20**	5.17**	10.17***
	(2.16)	(2.50)	(2.14)	(3.12)
Product market spillovers (t-1)	−1.36	−4.35	−1.63	0.40
	(−0.84)	(−1.24)	(−0.88)	(0.09)
R&D (t-1)	−2.59***	−2.57***	−2.55***	−2.59***
	(−5.85)	(−5.81)	(−5.79)	(−5.88)
Control variables?	Yes	Yes	Yes	Yes
Firm fixed effects?	Yes	Yes	Yes	Yes
Industry-year fixed effects?	Yes	Yes	Yes	Yes
Observations	6,968	6,968	6,968	6,968
Adjusted R^2	0.645	0.647	0.644	0.647

R&D = research and development.

Notes: This table presents the results of regressions of leverage on technology spillovers. The regressions are the same as in Table 9.3 but with slight modifications as indicated. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. Only selected results are tabulated.

Source: Authors' calculation.

10

Labor Skills, Economic Returns, and Automatability in Thailand

Theepakorn Jithitikulchai[1]

10.1 Introduction

Thailand needs to upgrade its economic engine to generate new sources of growth and create more value-added jobs (Sondergaard et al. 2016) such as science, technology, engineering, and mathematics (STEM), and other creative and analytical professions. This envisioned future requires more advanced skills among the labor force and mandates a new paradigm for Thailand's human capital development. As technology races ahead, the low-skilled and low-wage workers will be reallocated to tasks that are not susceptible to "computerization," such as tasks requiring creative and social intelligence (Frey and Osborne 2017). While automation does indeed substitute for labor skills, it also complements labor by enhancing output in a direction that leads to higher demand for labor with advanced skills (e.g., Autor 2015; Arntz, Gregory, and Zierahn 2016; Frey and Osborne 2017; World Bank 2019).

The necessary skills and competencies are extremely important for individuals to obtain productive employment that can help to secure a promising future and, for those who are poor, help them break out of the cycle of poverty (Sondergaard et al. 2016). Greater emphasis on developing a skilled workforce will also promote the deepening of macroeconomic development (Aedo et al. 2013). The intensity of national production of *nonroutine* cognitive and interpersonal skills will increase with per capita income in a monotonic way according to cross-country comparisons.

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The impact of automatability on the labor market is well established in the literature on the decline of employment in routine occupations, such as jobs that consist of tasks following a set of well-defined procedures that can be performed by sophisticated algorithms (Frey and Osborne 2013, 2017). For instance, Charles, Hurst, and Notowidigdo (2013) and Jaimovich and Siu (2012, 2020) argued that the continuing decline in manufacturing employment and the disappearance of other routine jobs in the United States (US) have caused the current low rates of employment. Another example can be found in Lekfuangfu and Nakavachara (2019) who documented that without restructuring in the labor markets, Thai workers will face a serious risk of joblessness in the near future.

The implications of the developments in artificial intelligence (AI) and machine learning for jobs and skills have dominated recent debates on the future of work. A seminal study on occupational skills by Frey and Osborne (2013, 2017) suggested that 47% of jobs in the US are at high risk of being automated. Based on the groundwork by Frey and Osborne (2013), Nedelkoska and Quintini (2018) found that close to one in two jobs in the 32 Organisation for Economic Co-operation and Development (OECD) countries are likely to be significantly affected by automation—that is, have a risk that a significant share of tasks could be automated. Specifically, about 14% of jobs in OECD countries, which is equivalent to over 66 million workers, are highly automatable. The World Bank (2016) estimated from a technological standpoint based on Frey and Osborne (2013) that two-thirds of all jobs are susceptible to automation in the developing world, but the effects can be moderated by lower wages and slower technology adoption.

Nevertheless, many manufacturers have increased the number of automatic machines to replace workers in plants and warehouses with more industrial robots. AI is disrupting the routine customer service of call centers and call center staff. Big data and machine learning suggest more accurately what to buy. Digital technologies are substituting for workers and performing tasks in both private and public sectors around the world (World Bank 2016).

Frey and Osborne (2013, 2017) examined how susceptible jobs are to computerization based on a machine learning classification to estimate the probability of computerization for 702 detailed occupations. Fundamentally, they postulated that creative jobs are non-automatable. They predicted that high-skilled jobs are relatively resistant to computerization, with a lower probability of automatability in occupations that require higher nonroutine cognitive analytical and interpersonal skills such as those requiring a bachelor's degree or higher.

Lekfuangfu and Nakavachara (2019) researched the impacts of trade and technology on labor market structures in Thailand. Extending the methodology of Frey and Osborne (2017), the occupations most vulnerable to AI replacement are clerical workers and plant or machine operators with low skills. Another major group at risk is the labor force with primary or lower education. In terms of age category, workers aged between 35 and 44 years are at the highest risk because aging makes them more difficult to reskill for the more complex labor markets. The analysis in Lekfuangfu and Nakavachara (2019) also indicated that sales workers and even farmers and fishers are at substantial risk of automatability. Technologies now allow people to access market information and trade through online platforms, so there is less demand for sales workers in physical shopping locations. Replacing agricultural and fishing workers with automatic machines or operational tools will become cheaper than labor costs.

Digital disruption already impacts employment in Thailand's financial sector as many commercial banks have shut down their branches and scaled down the number of bank tellers, investing more instead in technology to adapt to the digital economy. Autonomous driverless vehicles provide another example of how manual tasks in logistics and transportation could be widely automated very soon.

To the best of my knowledge, there is limited literature for Thailand on how skill content affects hourly earnings and, except for a recent study (Lekfuangfu and Nakavachara 2019), how future automatability will impact Thai labor market outcomes. This study fills such gaps by providing empirical evidence on the nexus of occupational skills, labor market returns, and probabilities of automatability.

This study follows a skill measurement methodology found in Autor, Levy, and Murnane (2003), Acemoglu and Autor (2011), and Aedo et al. (2013). This approach analyzes labor skills by measuring the specific tasks associated with different occupations. There are five different skill categories: nonroutine cognitive analytical, nonroutine cognitive interpersonal, routine cognitive, routine manual, and nonroutine manual physical. The embedded skill measurement relies on the information of skill content per occupation, which is generated based on the Occupational Information Network (O*NET). The O*NET details the description of task requirements.

The analysis shows that provincial gross domestic product (GDP) per capita is associated with the embedded human skill content of the aggregate economic production. This study further investigates the labor market returns to different skill categories and documents that nonroutine cognitive analytical skills significantly increase hourly earnings. Lastly, the risks of automation are examined using the occupational-based approach of Frey and Osborne (2013, 2017). The results on the probability of automatability suggest that workers with lower nonroutine cognitive analytical skills tend to face a higher risk of automatability.

10.2 Methodology

10.2.1 Measurement of Occupational Embedded Skills

This study examines the embedded human skill content of aggregate economic production in Thailand. Five different skills are defined, as proposed initially by Autor, Levy, and Murnane (2003), later updated by Acemoglu and Autor (2011), and evaluated for a cross-comparison by Aedo et al. (2013).

Autor, Levy, and Murnane (2003) and Acemoglu and Autor (2011) constructed five aggregate skill measures by selecting and extracting a subset of 16 task requirements and classifying them as *nonroutine* cognitive analytical skills, *nonroutine* cognitive interpersonal skills, *nonroutine* manual physical skills, *routine* cognitive skills, and *routine* manual skills.

A summary of skills by occupational tasks and expected impacts from computerization is provided in Table 10.1. It is important here to

Table 10.1: Five Categories of Occupational Skills

	Routine Tasks	Nonroutine Tasks
	Cognitive Tasks	
Examples	• Calculation • Repetitive customer service • Repeating the same tasks • Being exact or accurate • Doing structured rather than unstructured work	Analytical • Analyzing data/information • Thinking creatively • Interpreting information for others Interpersonal • Establishing and maintaining relationships • Guiding, directing, and motivating subordinates • Coaching/developing others
Computer impact	Substantial substitution	Strong complementarities
	Manual Tasks	
Examples	• Performing tasks involving repetitive physical motions • Working at pace determined by speed of equipment • Controlling machines and processes	• Operating vehicles, mechanized devices, or equipment • Using hands to handle, control, or feel objects, tools, or controls • Doing work requiring manual dexterity or spatial orientation
Computer impact	Substantial substitution	Limited opportunities for substitution or complementarity

Source: Based on descriptions in Autor, Levy, and Murnane (2003) and Aedo et al. (2013). Computer impacts are based on discussion by Frey and Osborne (2013) on how susceptible jobs are to computerization.

understand the role of skills in occupationally specific tasks. A task is a unit of work activity to produce outputs such as goods and services. On the other hand, a skill is a worker's endowment of capabilities to perform various tasks. A worker applies his or her own skill endowment to tasks in exchange for wages. Skills are applied to tasks to produce outputs. A given skill level can enable the performance of a variety of tasks and change the set of tasks performed in response to changes in economic conditions and technology.

The average skill intensities in the aggregate economy are primarily determined by the occupational share changes. Each occupation has a skill intensity value for each of the five skills. Therefore, each occupation is defined by a skills vector of five skill aggregates:

$$X_i = \begin{bmatrix} X_i^{Nonroutine\ cognitive\ analytical} \\ X_i^{Nonroutine\ cognitive\ interpersonal} \\ X_i^{Nonroutine\ manual\ physical} \\ X_i^{Routine\ cognitive} \\ X_i^{Routine\ manual} \end{bmatrix} \quad (1)$$

Following Aedo et al. (2013), the skills aggregates are defined below.

(1) *Nonroutine cognitive analytical skills*: This set of skills consists of thought processes required for absorption of, processing of, and decision-making about abstract information. Tasks include advanced calculation, analyzing information, forming and testing hypotheses, medical diagnosis, legal writing, or any tasks requiring critical thinking skills. Professional occupations that require such abilities include computer programmers, engineers, statisticians, economists, medical doctors, and lawyers, among many other occupations requiring skills of thinking creatively and analytically. The O*NET skills included in this category are the ability to analyze data and information (ANALYZE), to think creatively (THINK), and to interpret information for others (INTERPRET).

$$X_i^{Nonroutine\ cognitive\ analytical} = f\left(x_i^{ANALYZE}, x_i^{THINK}, x_i^{INTERPRET}\right) \quad (2)$$

(2) *Nonroutine cognitive interpersonal skills*: This set of skills characterizes personality traits that underlie human interactive behaviors such as collaborating, presenting, supervising, reliability, discipline, and teamwork. These skills are important for all team-based work environments as well as customer services. The O*NET skills included in this category are the capability to establish and maintain personal relationships (RELATIONSHIPS), to guide, direct,

and motivate subordinates (GUIDE), and to coach or develop others (COACH).

$$X_i^{Nonroutine\ cognitive\ interpersonal} = f(x_i^{RELATIONSHIPS}, x_i^{GUIDE}, x_i^{COACH}) \quad (3)$$

(3) *Nonroutine manual physical skills*: This set of skills characterizes the ability to vary and react to continuously changing circumstances—operators of a machine or heavy equipment in manufacturing or construction as well as machinery mechanics and repairers, janitorial services, or truck driving. The O*NET skills included in this category are the ability to operate vehicles, mechanized devices, or equipment (OPERATE), to spend time using hands to handle, control, or feel objects, tools, or controls (HANDLE), manual dexterity (MANUAL), and spatial orientation (SPATIAL).

$$X_i^{Nonroutine\ manual\ physical} = f(x_i^{OPERATE}, x_i^{HANDLE}, x_i^{MANUAL}, x_i^{SPATIAL}) \quad (4)$$

(4) *Routine cognitive skills*: This set of skills characterizes the ability to conduct repetitive, nonphysical tasks such as filling forms, reading and calculating bills, or call center services. Monotonous occupations that require such skills include record-keeper, cashier, clerk, and repetitive customer services (such as bank teller or telephone operator). The O*NET skills included in this category are the ability to repeat the same task (REPEAT), to be exact or accurate (ACCURATE), and to handle structured work (STRUCTURED).

$$X_i^{Routine\ cognitive} = f\left(x_i^{REPEAT}, x_i^{ACCURATE}, x_i^{STRUCTURED}\right) \quad (5)$$

(5) *Routine manual skills*: This set of skills consists of repetitive physical movements such as those displayed by labor-intensive agricultural or construction workers, some types of machine operation or assembly lines such as picking or sorting, or repetitive assembly. The O*NET skills included in this category are the ability to spend time making repetitive physical motions (REPETITIVE), adapting to a pace determined by the speed of equipment (SPEED), and controlling machines and processes (CONTROL).

$$X_i^{Routine\ manual} = f(x_i^{REPETITIVE}, x_i^{SPEED}, x_i^{CONTROL}) \quad (6)$$

A vector X is the skill information based on the O*NET database for all occupations that can be linked to the occupational structures for computing the weighted skills measures:

$$X = \begin{bmatrix} X'_1 \\ \vdots \\ X'_{i=I} \end{bmatrix} \tag{7}$$

For each skill category s of X^s, the country-level skill intensity is calculated as a weighted average of occupational-level skill intensities. The share of active workers in an occupation i is defined as

$$\theta_i = \frac{Active\ workers\ on\ occupation\ i}{Total\ active\ workers} \text{ such that } \sum_i \theta_i = 1 \tag{8}$$

The vector of all occupation shares is defined as:

$$\theta = [\theta_1 \quad \dots \quad \theta_I] \tag{9}$$

Therefore, the skill structure of the labor force is the information on the skill inputs by occupation as defined from combining all occupations and the labor force structure as a vector of average skill intensities:

$$\theta X_i = \begin{bmatrix} \sum_i \theta_i X_i^{Nonroutine\ cognitive\ analytical} \\ \sum_i \theta_i X_i^{Nonroutine\ cognitive\ interpersonal} \\ \sum_i \theta_i X_i^{Nonroutine\ manual\ physical} \\ \sum_i \theta_i X_i^{Routine\ cognitive} \\ \sum_i \theta_i X_i^{Routine\ manual} \end{bmatrix} \tag{10}$$

Since this study uses only one version of the O*NET database, the skill scores are time-invariant, an essential feature of any standard poverty measure that can be used to analyze poverty in an economy.

10.2.2 Unconditional Quantile Regression

This study follows previous literature such as Heckman, Stixrud, and Urzu (2006), Lindqvist and Vestman (2011), Hanushek et al. (2015), Deming (2017), and Lee and Wie (2017), among several others, in evaluating the labor market returns to skills. To capture the effect of systematic differences in skill content on hourly earnings, this study uses the recentered influence function (RIF) estimator (Firpo, Fortin, and Lemieux 2009; Fortin, Lemieux and Firpo 2011), with the model set having a specification similar to a Mincer equation, by focusing on the skills as the major explanatory variables.

Consider $IF(y; v)$, the influence function corresponding to an observed wage in a logarithmic form y for the distributional statistics of interest, $\nu(F_y)$. The IF captures the effect on $\nu(F)$ of an infinitesimal contamination of F at point mass y. The RIF is defined as

$$RIF(y;\nu) = \nu(F_Y) + IF(y;\nu), \tag{11}$$

so that it aggregates back to the statistics of interest, i.e., $\int RIF(y; v)\, dF(y) = \nu(F_y)$.

In the case of quantiles, the $IF(y; Q_\tau)$ is given by $(\tau - I\{Y \leq Q_\tau\})/f_Y(Q_\tau)$, where $I\{\cdot\}$ is an indicator function, $f_Y(\cdot)$ is the density of the marginal distribution of Y, and Q_τ is the population τ-quantile of the unconditional distribution of Y. Therefore, $RIF(y; Q_\tau)$ is equal to Q_τ + IF$(y; Q_\tau)$, and can be rewritten as

$$RIF(y; Q_\tau) = Q_\tau + \frac{\tau - I\{Y \leq Q_\tau\}}{f_Y(Q_\tau)}. \tag{12}$$

The idea of Firpo, Fortin, and Lemieux (2009) is to regress the RIF on the vector of covariates. In the case of quantiles, the RIF is estimated by computing the sample quantile $\hat{Q}_\tau$ and estimating the density at that particular point using kernel methods. An estimate of the RIF of each observation, $\widehat{RIF}(Y_i; Q_\tau)$), is then obtained by replacing the estimates $\hat{Q}_\tau$ and $\hat{f}(\hat{Q}_\tau)$ in the last equation of the previous paragraph.

Thus, a change in the marginal quantile is going to be explained by a change in the distribution of the covariates by means of a simple linear regression:

$$E[RIF(y; Q_\tau|X)] = X\beta \tag{13}$$

such that an estimate of the unconditional quantile regressions, $\hat{\beta}_\tau$, obtained by a simple ordinary least squares (OLS) regression is as follows:

$$\hat{\beta}_\tau = (X'X)^{-1}X'\widehat{RIF}(Y_i; Q_\tau) \tag{14}$$

The vector of covariates is composed of the skill content along with other control variables. This study uses a bootstrapped standard error estimation. The kernel function used is Epanechnikov. The vector of the skills set required for a specific occupation is thus hypothetically associated with the labor market outcomes, which in this case are hourly earnings. The hypothesis for the unconditional regression in this study is that the different skills affect the labor market returns differently. The null hypothesis is that labor skills do not affect hourly earnings. The alternative hypothesis is that labor skills do alter hourly earnings differentially across the earnings distribution.

10.2.3 Probability of Automatability

Based on the O*NET database, Frey and Osborne (2017) considered a job's automatability to be a function of the skills required to complete occupational tasks. They used a survey data set of 702 occupations, which cover employment status, income, and skills related to automatability such as finger dexterity, originality, and persuasion. They organized a workshop for AI researchers to hand-label 70 occupations as being automatable or not. Then, Frey and Osborne (2017) implemented a Gaussian process classification to estimate the probability of automatability for all occupations that relates the O*NET variables to a binary classification of whether they are automatable or not.

To estimate the occupational probability of automation in Thailand, this study applies its classification results to the four-digit occupation codes of the International Standard Classification of Occupations (ISCO-08 tool for employed workers aged 16–65. As it is expected that the skill content of jobs in the US is more intensive in terms of *nonroutine* and cognitive skills than in Thailand, the results of automatability probabilities in this study are likely lower-bound estimates. Nevertheless, this application of the automatability probabilities estimated in Frey and Osborne (2017) has been carried out for other developing countries by the Asian Development Bank (2015), Chang and Huynh (2016), Chang, Rynhart, and Huynh (2016), World Bank (2016), Ng (2017), and Hallward-Driemeier and Nayyar (2018).

From the technological perspective, the reported results from this study provide the partial equilibrium point of view that all other factors are fixed as constants (ceteris paribus). For instance, this research implicitly assumes that there is no adaptation in the labor force to upgrade themselves with advanced *nonroutine* cognitive analytical skills or there are no reallocations of the tasks between different occupations that facilitate the collaborations between machine and human.

10.3 Data

This study uses quarterly data from multiple waves of the Labour Force Survey (LFS) undertaken by the National Statistics Office of Thailand. The LFS is the primary source of data on the country's labor market and is among the most timely and important economic data series produced. It contains detailed data on individuals over a nearly 3-decade time horizon. Individual-level data include information on occupation, employment, education, demographics, and other characteristics. The surveys are representative of five geographic regions until the year 2000, and thereafter of 76 provinces within the five geographic regions separated by municipality and nonmunicipality into nine areas. This study focuses on employed workers aged 15–64 years. All estimates are weighted by the individual sample weights, which are the individual weights multiplied by the number of hours worked.

The LFS classifies occupations according to different versions of the ISCO developed by the International Labour Office. The occupations in the LFS 1985–2000 are classified according to ISCO-68, while occupations in the LFS 2001–2010 and LFS 2011–2018 are classified according to ISCO-88 and ISCO-08, respectively. This study established equivalences of the occupations across different ISCO versions based on crosswalk tables from the International Labour Organization. There are kinks in the time trends of some two-digit and four-digit occupations. Thus, this study uses ISCO-88 for the one-digit occupational categories due to its smoother occupational trends of the LFS 1985Q1–2018Q1. The regression analysis using the LFS 2011Q1–2018Q1 is based on the four-digit occupation codes from ISCO-08.

In the LFS data, there are different types of reported earnings: monthly, weekly, daily, and hourly. The number of actual worked hours is used to convert different compensation types into the hourly wage. The hourly earnings are in real 2011 terms, which are temporally and spatially adjusted. The LFS 2011Q1–2018Q1 is used to study the effects of skill attributes across the conditional wage distribution with the quantile regression model, as the LFS starts to use ISCO-08 from 2011, so this study can merge four-digit ISCO-08 codes with the skill content data from O*NET.

The analysis investigates the measured tasks performed by each occupation and their changes over time. To implement this methodology, this study matches the four-digit individual occupations with their respective skill content from the O*NET database, an online service developed for the US Department of Labor. Sixteen specific tasks are combined to create composite scores. There are 12 occupations out of a total of 434 occupations that cannot be matched with the O*NET data. All unmatched occupations are not a major occupation. For example, the unmatched occupation with the highest sample size is legislators.

As this study is not a cross-country comparison, it does not require adjustments to reflect the different meanings and job contents of labor markets in developing countries compared to the US as in Aedo et al. (2013). It is still important to emphasize that, as described in Aedo et al. (2013), the occupations that use a more nonroutine type of skills are likely to be less skill-intensive than in more advanced economies. This can cause a potential upward bias in the computations of the measured skill intensity of nonroutine cognitive analytical and interpersonal skills. Nevertheless, this is a within-country study for Thailand, so it is possible to explore the progress and inequality patterns in occupational skills by similarly using a fixed measurement as a poverty measurement analysis that applies a specific standard of poverty lines to track progress in temporal and spatial comparisons.

The data from the probability of automatability estimated by Frey and Osborne (2013, 2017) are therefore matched with the four-digit ISCO-08 occupations using a crosswalk approach. The probability data are available in the appendix of Frey and Osborne (2013), which is a list of occupations ranked by the probability of computerization.

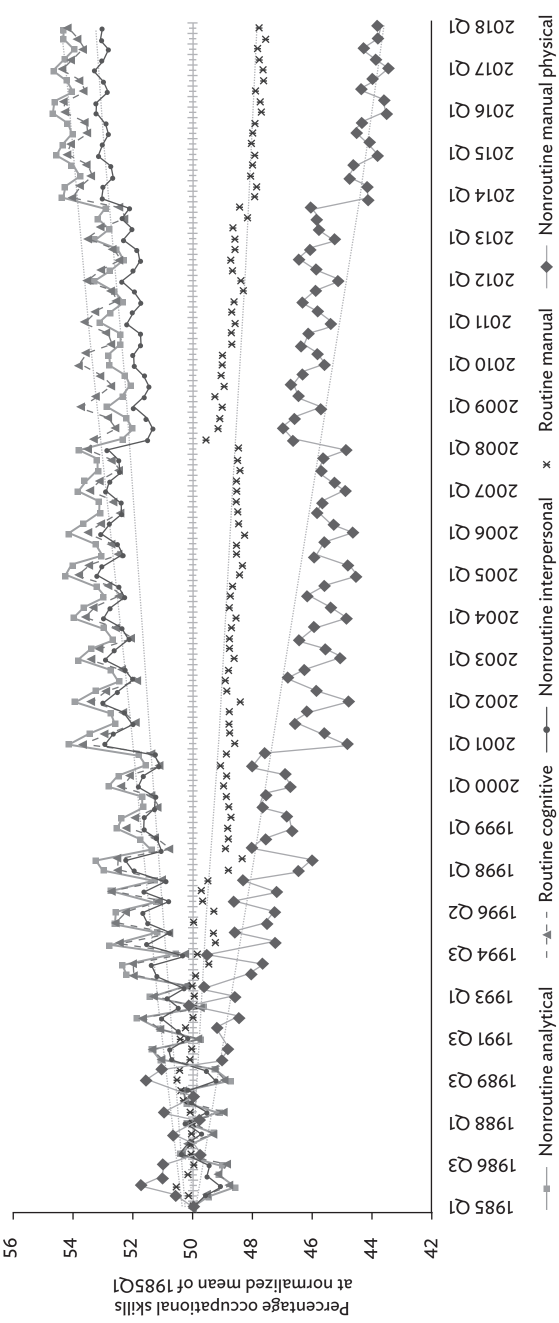
10.4 Results

10.4.1 Aggregate Trends

Figure 10.1 illustrates the extent of embedded skills changed in the occupational labor supply over the period 1985 to 2018. Through construction, each task variable has been normalized to have a mean of 50 centiles in the first quarter of 1985 as its initial point. Subsequent points depict the employment-weighted mean from each quarter. Cyclical trajectories along the megatrends reflect the seasonal agriculture production patterns by quarter, so it is not a surprise to observe narrower oscillations than 20 years ago. The trends persisted for occupational skill inputs in the economy.

The shares of the labor force employed in occupations that made intensive use of nonroutine analytical skills, nonroutine interpersonal skills, and routine cognitive skills have increased substantially during the last 3 decades. This is the right direction for future productivity development. Although the content of nonroutine occupational skills and routine cognitive skills increased faster in the 1990s of the pre-computer era than in the last 2 decades, the slower progress in the years of stagnation after 2008 is notable.

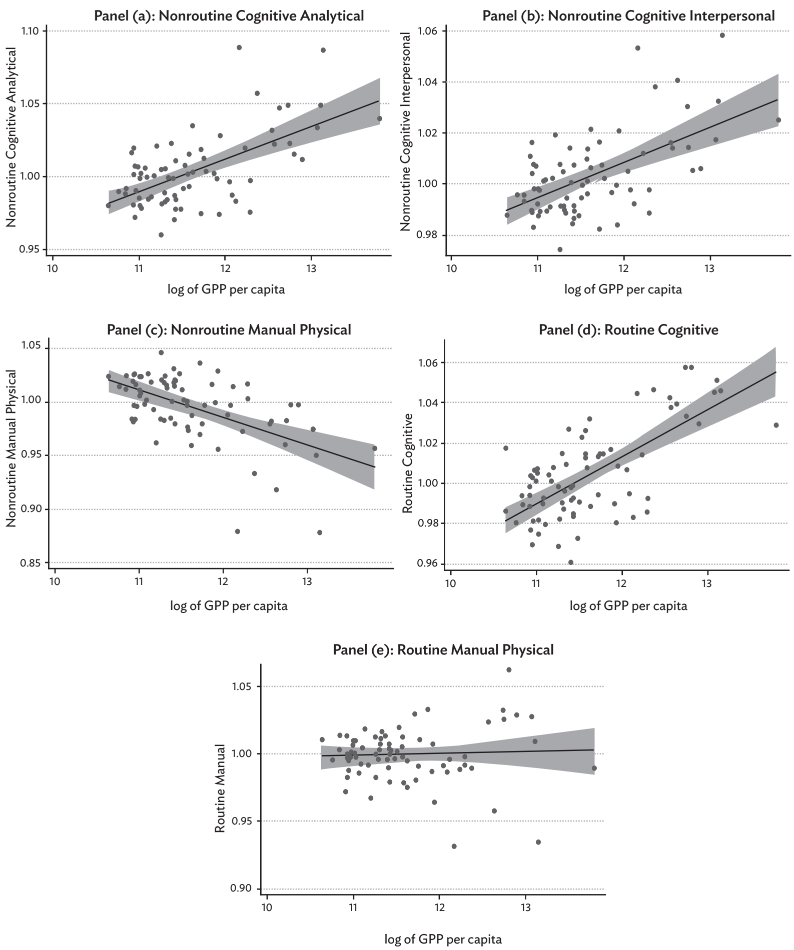
Figure 10.1: Trends in Routine and Nonroutine Skill Inputs, Q1 1985 to Q1 2018



Q = quarter.

Source: Occupational employment from the Labour Force Survey and skill content data from O*NET.

Figure 10.2: Association between Skill Intensity and Provincial Gross Domestic Product



GDP = gross domestic product.

Note: Using O*NET matched with occupations of employed workers aged 15–64 years to construct the normalized skill scores at the provincial level.

Source: Labour Force Survey (first quarter of 2018) from the National Statistical Office and provincial GDP per capita data from the Office of the National Economic and Social Development Council.

An increase in *routine* cognitive skills exhibits potential risks of the probability of computerization in low-skilled occupations. They are those from disadvantaged families who work for low incomes in jobs such as machine operators or production assemblers, labor-intensive farmers, or construction workers.

The trend patterns have remarkable shifts around the early 2000s when the economy started to take off again, after the 1997 financial crisis, and around the period of 2008 with another economic downturn. Beyond the period of these two points, the trends are quite steady after eliminating the quarterly seasonal fluctuations. The dispersions between (i) *nonroutine* analytical skills, *nonroutine* interpersonal skills, and *routine* cognitive skills and (ii) *nonroutine* and *routine* manual physical skills became slower in recent years after 2008. This observation is consistent with the stalling of structural transformation and slowdown in nonagricultural employment growth—as Thailand has struggled to move labor from low- to higher-productivity jobs.

10.4.2 Labor Market Returns to Skills

Cross-Province Analysis

Aedo et al. (2013) provided an international perspective of skill content and national gross production and demonstrated that the intensity of skills is closely associated with the level of economic development. This study applies the same approach to evaluate the occupation-based skill measurement for each province in Thailand.

Figure 10.2 illustrates the skill intensity scores and provincial GDP per capita in 2018. The plotted lines estimate the linear relationship between the skill scores and provincial GDP per capita, with the gray areas visualizing the 95% confidence interval.

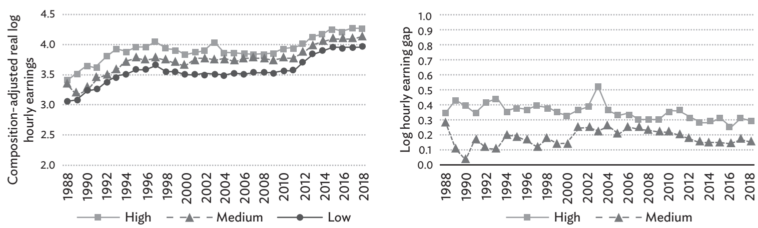
Provincial measures of skill content show that the intensity of *nonroutine* manual physical skills decline with provincial GDP per capita in a monotonic way, while we find an inverse relationship with *nonroutine* cognitive and interpersonal skills and *routine* cognitive skills. However, there is no linear relationship for *routine* manual physical skills, which are intensified for those occupations in the manufacturing and construction sectors.

Fundamentally, economic development favors *nonroutine* skills. They are provinces with an occupational structure enriched with a high intensity of *nonroutine* analytical and interpersonal skills. Their output per capita could be reflected in a higher value for more advanced skills. Using provincial GDP per worker as a measure of economic productivity provides the same conclusions for associating provincial productivity with occupational skill inputs.

Returns to Skill by Occupation

This study estimates the composition-adjusted log hourly earnings of employed workers aged 15–64 years. This composition adjustment holds constant the relative employment and socioeconomic characteristics. Specifically, this study computes the mean of log real hourly earnings in each year using the weighted average characteristics of the employment population.

Figure 10.3: Composition-Adjusted Log Hourly Earnings and Premium Gaps, 1985–2018



Note: Log hourly earnings for employed workers aged 15–64 years for each year are regressed separately by occupational skill level with covariates of a female dummy variable, years of experience, education dummy variables (primary, lower secondary, and college or higher), dummy variables for the industrial sectors, and urban and regional dummy variables. The composition-adjusted mean for log hourly earnings is the predicted mean conditional on average characteristics of all employed workers in each year to compare different skills. The sample weight is the population weight multiplied by the total hours worked. Only the third quarter is used for each Labour Force Survey year, except for the first quarter of 2018.

Source: Labour Force Surveys 1988–2018.

The key message here is that the hourly earnings gaps between high-skilled or medium-skilled occupations and low-skilled occupations are on average steady over the last 3 decades as plotted in Figure 10.3. This implies that the monetary gaps in real monetary value have been expanding. Thus, the disparities in employment income are worsening, as the same growth rates in logarithmic terms imply a higher gap in hourly earnings.

Economic Returns to Embedded Skills

This study uses unconditional quantile regression (Firpo, Fortin, and Lemieux 2009; Fortin, Lemieux, and Firpo 2011) to evaluate the impacts of *nonroutine* cognitive analytical skills, *nonroutine* cognitive interpersonal skills, *routine* cognitive skills, *routine* manual skills, and *nonroutine* manual physical skills across the distribution of log hourly earnings.

The regression model covers the education level, instead of replacing education with skills. Arguably, a higher education could be correlated with more sophisticated analytical skills. Different fields of study develop skills differently, such as STEM fields compared with a degree in business management or social sciences. This study thus preserves the education level in the regression model like other control variables. The variance inflation factor analysis reported that there was no multicollinearity in the reported regression models. The robustness checks confirm the strong associations of skills and hourly earnings. Excluding the educational variables provides the same patterns of distributional effects of five skills but including the educational variables would lower the size of impacts. This still confirms the robustness of implications from the estimated results.

Table 10.2 reports the RIF regression coefficients of five skills. It shows the marginal effects of explanatory variables on hourly earnings from both the OLS and unconditional quantile regressions. Estimation

Table 10.2: OLS and Unconditional Quantile Regression of Hourly Earnings

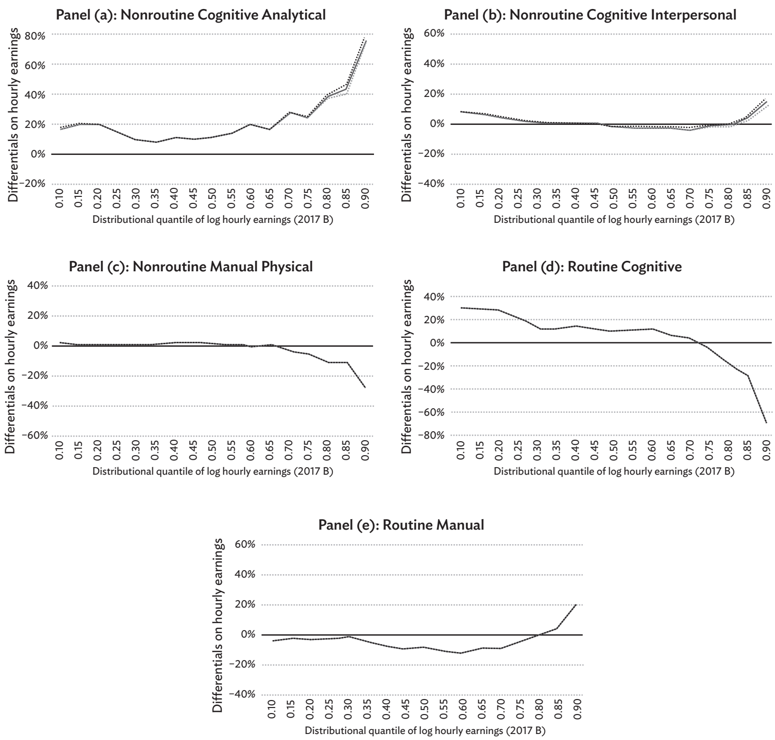
Dependent variable: log of hourly earnings	OLS	Q(.25)	Q(.50)	Q(.75)
Nonroutine cognitive analytical skills	0.236***	0.147***	0.117***	0.241***
	104.36	53.18	54.69	69.31
Nonroutine cognitive interpersonal skills	0.0446***	0.0241***	-0.0177***	-0.0131**
	18.55	9.98	-7.43	-3.27
Nonroutine manual physical skills	-0.0438***	0.000580	0.0102***	-0.0527***
	-24.97	0.25	5.48	-20.03
Routine cognitive skills	0.0426***	0.225***	0.114***	-0.0366***
	18.39	73.80	53.19	-8.89
Routine manual skills	-0.0155***	-0.0172***	-0.0821***	-0.0336***
	-9.07	-7.57	-45.75	-12.29

OLS = ordinary least squares.

Notes: t-statistics are in the second row with * $p < 0.05$, ** $p < 0.01$, and *** $p < 0.001$. The full models for the unconditional quantile regression (Firpo, Fortin, and Lemieux 2009; Fortin, Lemieux, and Firpo 2011) are reported in Appendix Table A10.1.

Source: Labour Force Surveys (first quarter of 2011–first quarter of 2018).

Figure 10.4: Impacts from Occupational Skills on Hourly Earnings



Notes: Unconditional quantile regression's estimated coefficients (solid lines) and their associated clustered and robust 95% confidence intervals (dotted lines) at every 5 percentiles are plotted. Full results with all covariates for the 0.25th, 0.50th, and 0.75th quantiles are available in Appendix Table A10.1.

Source: Labour Force Surveys (first quarter of 2011–first quarter of 2018).

results indicate the statistical significance in the skill contents. Thus, there are different impacts of skills on different levels of the hourly earnings as illustrated in Figure 10.4.

Figure 10.4 illustrates the distributional effects of occupational skills from the unconditional quantile regression as follows.

(a) *Nonroutine cognitive analytical skills*: The results show that economic returns to nonroutine cognitive analytical skills are positively and significantly correlated.

Nonroutine cognitive analytical skills provide increasing returns to skills, especially for workers with high hourly earnings such as those with hourly earnings higher than the 0.70th percentile. Specifically, the main occupations with high nonroutine cognitive analytical skills are managers, professionals, and technicians and associate professionals. The positive impacts from cognitive analytical skills on hourly earnings are highest among all five occupational embedded skills. Ceteris paribus, this implies that nonroutine cognitive analytical skills are the most important skills for determining the returns for laborers in the market economy. We can posit that this skill is the main driver of labor supply to boost economic productivity.

(b) *Nonroutine cognitive interpersonal skills*: Nonroutine cognitive interpersonal skills have only positive impacts on the tails of the hourly earnings distribution. The occupations with high scores in nonroutine cognitive interpersonal skills are managers, professionals, technicians and associate professionals, and services and sales workers. Thus, the labor market returns in these occupations are likely to have positive impacts from interpersonal skills. However, the impacts are significantly smaller than impacts from nonroutine cognitive analytical skills.

(c) *Nonroutine physical skills*: *Nonroutine* manual skills have no impact on most parts of the hourly earnings distribution except for some negative impacts on the distribution's right tail. The occupations with high scores in *nonroutine* manual skills are low-skilled occupations such as skilled agricultural, forestry, and fishery workers; craft and related trades workers; plant and machine operators, and assemblers; and elementary occupations.

(d) *Routine cognitive skills*: *Routine* cognitive skills greatly enhance the hourly earnings for the left tail of the distribution. The size of impacts reaches a 20-percentage-point increase on hourly earnings for those below the 0.30th percentile. However, *routine* cognitive skills also greatly diminished the hourly earnings at the top of the distribution, which implies that the top paid occupations with a high intensity in repetitive tasks will reduce their market returns. The occupations with high scores in *routine* cognitive skills are all occupations with medium and low skills (especially clerical support workers, plant and machine operators, and assemblers), except for skilled agricultural, forestry, and fishery workers.

(e) *Routine manual skills*: *Routine* manual skills mostly have no impacts on hourly earnings but slightly decreased the hourly earnings between the 0.30th and 0.80th percentiles. However, there are positive impacts at the top of the distribution. The occupations with high scores in *routine* manual skills are plant and machine operators, and assemblers, along with other low-skilled occupations.

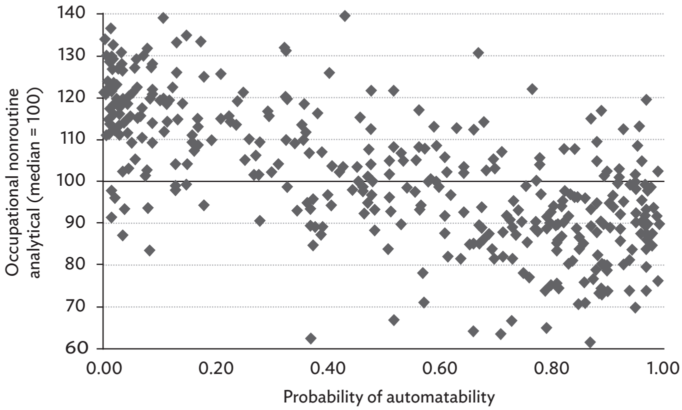
Beyond the skills discussion, there are some results from the regression of log hourly earnings as shown in Appendix Table A10.1. There is a gender gap where females have lower earnings than males, ceteris paribus. The returns to additional years of work experience are increased at a decreasing rate. Furthermore, returns from education are not a linear constant but progressed with an increasing marginal effect of higher education levels. These results for women and disadvantaged population gaps confirm previous findings in the literature (Nakavachara 2010; Bui and Permpoonwiwat 2015; Jithitikulchai 2018).

10.4.3 Occupational Risk of Automatability

Figure 10.5 shows that occupations with higher *nonroutine* cognitive analytical skills have a lower probability of automatability. The key message predicts that automation will mainly replace tasks of low-skill jobs of economically disadvantaged workers. In contrast, high-skilled occupations are less likely to be automated. We have the same findings for another figure on the reverse associations between hourly earnings and the probability of automatability, which signify higher risks for poorer populations.

Different occupation categories have specific distributions of risk of automatability as reported in Figure 10.6. The higher-skilled occupations have lower risks of automatability. Most occupations in the managerial and professional categories have the probabilistic distribution of automatability concentrated on the left tails. On the other hand, most of the low- or medium-skilled occupation categories face high automatability risks. These include clerical workers, some service and sales, agriculture, craft and trades, plant or machine operators, and elementary occupations. Many occupations in the aforementioned categories are clustered on the right tails of the distribution of the occupational probability of computerization, which indicates a high risk of automatability.

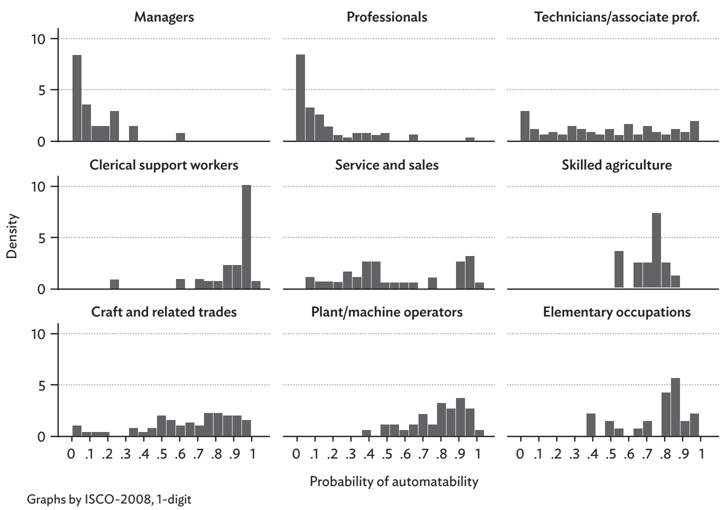
Figure 10.5: Nonroutine Cognitive Analytical Skills and Risk of Automatability



Note: Scores for nonroutine analytical skills are the mean from each occupation.

Source: Probability of automatability from Frey and Osborne (2013) and Labour Force Survey (first quarter of 2018).

Figure 10.6: Probability of Automatability by Occupation Category

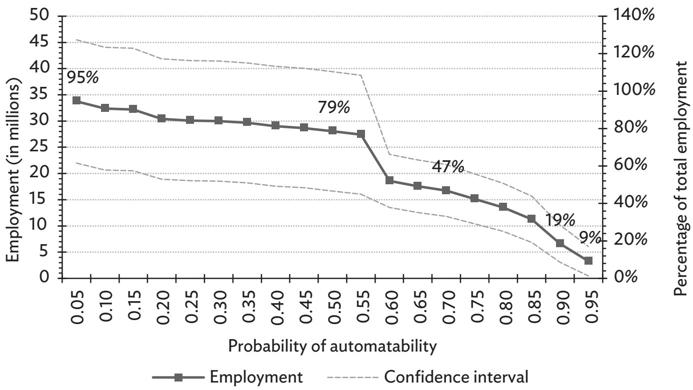


Note: Each category of the combined bar graphs shows the probability density of automatability.

Source: Probability of automatability from Frey and Osborne (2013) and Labour Force Survey (first quarter of 2018).

Figure 10.7 illustrates many jobs that are potentially automatable by different levels of risk. Each point on the curve represents both the total employment and its percentage on the same lines for both left and right vertical axes at a specific probability level that represents the risk of automatability. This figure indicates that the accumulated distribution of occupational employment over the probability of automatability such as 9% and 19% of total employment (or 3.3 million and 6.6 million jobs) has a 95% and 90% chance of automatability, respectively.

Figure 10.7: Employment Affected by Automatability



Note: The scales of the vertical axes are matched to have employment and percentage on the same line. The dotted lines represent the bootstrap 95% confidence interval of the accumulated employment.

Source: Probability of automatability from Frey and Osborne (2013) and Labour Force Survey (first quarter of 2018).

Frey and Osborne (2013, 2017) distinguished high-risk occupations with a probability of 0.7 of automatability. Figure 10.7 shows that about 47% of total employment, or about 17 million jobs, have a high risk that could be partially or fully automated relatively soon, perhaps over the next decade or two.

Appendix Table A10.2 illustrates all occupations with an employment share of more than 1%. It accounts for 20 occupations with a total of 19.5 million jobs in 2018. According to the predicted probability from Frey and Osborne (2013), there are only two occupations (shopkeepers and primary school teachers) that have less than a 50% probability of automatability. Therefore, the remaining 18 occupations account for a total of 18 million jobs with an automatable probability higher than 50%.

Furthermore, there are two other additional critical points. First, Thailand has a total of 30 occupations with a probability higher than 95%, which accounts for 3.3 million jobs in 2018. Second, field crop and vegetable growers, which accounts for 4.4 million jobs, have a probability of automatability of 57%. Therefore, we can expect large impacts on the working-age population and its dependents.

10.5 Discussion and Conclusion

This study analyzes the skill content regarding the occupational structure of the economy. The measurements of skill inputs illustrate that provincial GDP per capita increases with the *nonroutine* cognitive analytical and interpersonal skills and the *routine* cognitive skills. However, the economic value has an inverse relationship with the *routine* manual physical skills. The skill content traces the trends of skill intensities of the aggregate production and demonstrates that progress has slowed in the last decade. The regression analysis reveals that the occupational skill content could be an appropriate predictor for hourly earnings, especially for *nonroutine* cognitive analytical skills. Moreover, the risks of automation are more likely to be harmful to the low-skilled workers because their jobs are replaceable with AI and robots.

The empirical evidence from both the provincial and individual levels of the Thai economy provides the same conclusion that economic progress highly favors *nonroutine* analytical skills. This study also found that commencing in the 1990s, the labor input of *nonroutine* analytical and interpersonal skills rose, but *routine* cognitive and manual skills declined. Shifts in the labor input intensity of skills were accelerated in periods of rapid economic growth, and the progress slowed down. Lastly, this study argues that one should prepare for the impacts of automatability, and workers from disadvantaged socioeconomic backgrounds are most likely to be replaced.

Even though it is unclear when the disruptions in the labor market will occur, the analysis shows that 3 million jobs have more than a 95% probability of being automatable by robots and AI. In addition, at least one-third, or about 12 million of those employed have high risks of joblessness from technological advancements.

Given the threat of "creative disruption," we can view the probability of automatability as not only the job loss risk but also the pressure on developing the skills required to survive in the future. The results on automatability risk can be interpreted as the impacts on occupations that are vulnerable to being substituted by algorithms on big data and robots in a wide range from *routine* tasks involving rule-based activities to those with *nonroutine* cognitive tasks. The diverse impacts are found to depend on the degrees of skill content in the complementary or substitutional nature of the tasks embedded in each occupation. Therefore, industries and occupations must adjust their nature of work to survive the automatability risk.

Recent trends in technological developments appear to have directly replaced workers in certain occupations and tasks in Thailand. As discussed in Autor, Levy, and Murnane (2003), technological developments have enabled information and communication technology (ICT) to either directly allow or perform job tasks that had been performed by middle- and low-skill workers.

The forthcoming risk could be an important cause of a substantial shift in the assignment of skills to occupational tasks. The economic reform options for human capital and skills must take into account the rapid diffusion of new technologies that directly substitute capital for labor in tasks previously performed by low- and moderate-skilled workers. Routine-skilled occupations, especially routine cognitive skills that have been on the expansion trajectory over 3 decades, will be at high risk of substantial substitution by automation. This phenomenon reflects the expansion of low-skilled laborers in manufacturing and service sectors. Most likely, those with disadvantaged backgrounds and lower education are affected the most.

As discussed in Sondergaard et al. (2016), even secondary or post-secondary educated workers were pushed back into the agricultural sector with the slowdown in structural transformation. This signifies that the workers increasingly experience a tougher situation where it is harder to have a quality job. According to a recent firm-level survey, the Thailand Productivity and Investment Climate Study 2015 conducted by the Ministry of Industry and Thailand Productivity Institute, the country has an issue in that workers' skills do not match firms' expectations. Therefore, a critical policy priority is to improve the education and skills of the workforce.[2]

This study is subject to some limitations. In order to obtain harmonized occupational codes across three ISCO versions for the 3-decade labor force survey data, this study applies the one-digit classification of ISCO-88 to study the evolution of Thai labor skills. Therefore, the results can be interpreted as an approximation rather

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2 See Lekfuangfu and Nakavachara (2019) for policy recommendations for Thailand and Mason and Shetty (2019) for experience from around the world and their suggested policy directions.

than a precise estimation of the exact methods in Autor, Levy, and Murnane (2003), Acemoglu and Autor (2011), and Aedo et al. (2013).

Furthermore, the skill content from the O*NET database and the probability of automatability from Frey and Osborne (2017) are based on the US economy, which has more sophisticated technology and higher professional standards, implying different skill profiles for specific occupations. Therefore, the estimated results of automatability in this study tend to be an optimistic outlook. For example, teachers in the US are more likely to have better innovative ICT and teaching tools than those in Thailand. Furthermore, the STEM-related professions in the US probably have better access to advanced knowledge and cutting-edge equipment, which impacts their skill content and how technological capital complements their advanced skills in carrying out nonroutine and creative problem-solving and complex communication tasks. Therefore, the occupations that use less routine-type skills in more advanced economic settings such as in the US are likely to be more skill-intensive than in Thailand. On the other hand, the results on the probability of automatability could be compensated by an overestimation, as several occupations labeled as high-risk occupations still contain a substantial share of tasks that are hard to automate, which Frey and Osborne (2013) called a "computerization bottleneck."

An analytical possibility in the future is to apply the OECD's Programme for the International Assessment of Adult Competencies as in Aedo et al. (2013) or use the World Bank's STEP Skills Measurement Surveys conducted for several countries with the Thai labor occupational profile. Then, future research can analyze by weighting the measurable skill inputs with some macroeconomic development indicators such as the Global Competitiveness Index. Another, more ideal, research idea on skills and automatability is to collect primary data using online tools or conduct a national-scale labor force survey with support from government agencies to collect the country's profile.[3]

Given the aforementioned technical restrictions on measurement and interpretation, this is an important research area, which should be brought to the attention of scholars and policy makers. This study illustrates the evolution of skill inputs and presents a discussion on automatability in Thailand, which merits further work on better understanding the labor market impacts on economic productivity and providing empirical evidence to identify key issues and prioritize options in human capital and skills development planning and policy,

[3] See Moroz et al. (2019) for some lessons from Malaysia's Critical Skills Monitoring Committee and the Critical Occupations List.

along with adaptations in the private sector and labor force to mitigate and cope with the automatability risk.

It seems that Thailand is not enthusiastic enough about accelerating its economic growth concerning inclusive economic development. Thus, it is worrisome because robots and AI tend to widen the inequality gaps, and a sizable chunk of Thai labor may not be able to compete or can hardly survive in the future.

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Appendix A10

Table A10.1: OLS and Unconditional Quantile Regression of Hourly Earnings

Dependent variable: log of hourly earnings	OLS	Q(.25)	Q(.50)	Q(.75)
Nonroutine cognitive analytical skills	0.236***	0.147***	0.117***	0.241***
	104.36	53.18	54.69	69.31
Nonroutine cognitive interpersonal skills	0.0446***	0.0241***	-0.0177***	-0.0131**
	18.55	9.98	-7.43	-3.27
Nonroutine manual physical skills	-0.0438***	0.000580	0.0102***	-0.0527***
	-24.97	0.25	5.48	-20.03
Routine cognitive skills	0.0426***	0.225***	0.114***	-0.0366***
	18.39	73.80	53.19	-8.89
Routine manual skills	-0.0155***	-0.0172***	-0.0821***	-0.0336***
	-9.07	-7.57	-45.75	-12.29
Female (relative to male)	-0.119***	-0.0761***	-0.0890***	-0.119***
	-95.37	-47.04	-62.73	-56.47
Years of work experience	0.0284***	0.0170***	0.0175***	0.0301***
	159.55	66.06	83.06	93.30
Years of work experience2	-0.000385***	-0.000320***	-0.000248***	-0.000354***
	-95.61	-56.85	-56.73	-55.17
Lower secondary education (relative to no education/ primary)	0.213***	0.171***	0.157***	0.182***
	123.70	71.39	73.84	78.55
Upper secondary education (relative to no education/primary)	0.388***	0.322***	0.353***	0.400***
	223.12	114.59	119.21	105.82
College or higher (relative to no education/primary)	1.000***	0.486***	0.669***	1.402***
	397.10	153.87	148.95	121.83
Year 2012 (relative to 2011)	0.0838***	0.137***	0.0566***	0.0419***
	33.52	38.00	18.99	14.89
Year 2013 (relative to 2011)	0.188***	0.335***	0.116***	0.0886***
	76.02	80.51	42.80	26.39
Year 2014 (relative to 2011)	0.218***	0.412***	0.149***	0.0507***
	94.14	91.40	63.65	4.38

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Table A10.1 *continued*

Dependent variable: log of hourly earnings	OLS	Q(.25)	Q(.50)	Q(.75)
Year 2015 (relative to 2011)	0.265***	0.463***	0.181***	0.154***
	115.77	104.58	91.16	40.27
Year 2016 (relative to 2011)	0.269***	0.476***	0.190***	0.151***
	119.27	133.98	88.19	45.07
Year 2017 (relative to 2011)	0.272***	0.489***	0.205***	0.0866***
	121.04	142.86	91.62	23.49
Year 2018 (relative to 2011)	0.290***	0.526***	0.221***	0.0853***
	83.00	92.69	61.23	13.81
Annual quarter 2 (relative to quarter 1)	-0.0153***	0.0141***	-0.0158***	-0.0425***
	-9.51	5.81	-9.82	-21.18
Annual quarter 3 (relative to quarter 1)	0.0000835	0.0505***	-0.00306	-0.0428***
	0.05	27.44	-1.71	-17.85
Annual quarter 4 (relative to quarter 1)	0.00469**	0.0610***	0.00406*	-0.0389***
	2.85	27.85	2.31	-14.21
Urban (relative to rural)	0.0308***	0.0345***	0.00976***	0.0138***
	28.16	18.74	6.97	8.19
Constant	2.469***	1.801***	2.944***	3.330***
	240.75	113.52	271.76	207.67
Number of observations	1,427,737	1,427,737	1,427,737	1,427,737
R-squared	0.579	0.335	0.408	0.487

OLS = ordinary least squares.

Note: The t-statistics are reported in the second row with * $p < 0.05$, ** $p < 0.01$, and *** $p < 0.001$.

Source: Labour Force Surveys (first quarter of 2011–first quarter of 2018).

Table A10.2: Risk of Automatability in Occupations with More Than 1% Share of Total Employment

	Occupations (ISCO-08, 2 digits)	Occupations (ISCO-08, 4 digits)	Employment (thousands)	Share of employment (%)	Probability of automatability
1	Market-oriented skilled agricultural workers	Field crop and vegetable growers	4,388.3	12.21	0.57
2	Market-oriented skilled agricultural workers	Tree and shrub crop growers	2,857.3	7.95	0.57
3	Sales workers	Shop sales assistants	1,255.3	3.49	0.95
4	Sales workers	Shopkeepers	1,158.4	3.22	0.16
5	Subsistence farmers, fishers, hunters and gatherers	Subsistence crop farmers	961.1	2.67	0.87
6	Agricultural, forestry, and fishery laborers	Crop farm laborers	910.4	2.53	0.87
7	Drivers and mobile plant operators	Car, taxi, and van drivers	868.3	2.42	0.57
8	Sales workers	Stall and market salespersons	854.5	2.38	0.94
9	Sales workers	Food service counter attendants	780.0	2.17	0.93
10	Personal service workers	Cooks	706.8	1.97	0.73
11	Market-oriented skilled agricultural workers	Livestock and dairy producers	699.0	1.95	0.76
12	General and keyboard clerks	General office clerks	575.6	1.60	0.97
13	Laborers in mining, construction, manufacturing, and transport	Building construction laborers	565.7	1.57	0.80
14	Business and administration associate professionals	Accounting associate professionals	439.4	1.22	0.98
15	Sales workers	Street food salespersons	412.7	1.15	0.90

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Table A10.2 *continued*

	Occupations (ISCO-08, 2 digits)	Occupations (ISCO-08, 4 digits)	Employment (thousands)	Share of employment (%)	Probability of automatability
16	Metal, machinery, and related trades workers	Motor vehicle mechanics and repairers	409.7	1.14	0.65
17	Teaching professionals	Primary school teachers	403.0	1.12	0.09
18	Cleaners and helpers	Cleaners and helpers in offices, hotels, and other establishments	396.1	1.10	0.57
19	Street and related sales and service workers	Street vendors (excluding food)	395.9	1.10	0.94
20	Stationary plant and machine operators	Sewing machine operators	372.3	1.04	0.89
		Total	19,409.7	54.0	

Source: Labour Force Survey (first quarter of 2018) and probability of automatability from Frey and Osborne (2013).

11

Can the Internet Increase the Working Hours of Married Women in Micro and Small Enterprises? Evidence From Yogyakarta, Indonesia

Eny Sulistyaningrum, Budy P. Resosudarmo, Anna T. Falentina, and Danang A. Darmawan[1]

11.1 Introduction

Since the beginning of its presence, information and communication technology (ICT) has developed and improved rapidly, particularly in relation to the use of the internet. Most people now have a smartphone and easy access to the internet. Both mobile and internet communication have grown steadily since their introduction in the 1980s to the point where mobile access to the internet (e.g., smartphones) is the dominant and fastest growing form of communication. The internet has therefore become an integral part of human life. Its presence is beneficial not only for leisure purposes—such as for communicating and connecting with friends through social media like Facebook and Instagram, watching films through Netflix, and listening to music through YouTube or Spotify—but also for working and doing business. Hence, the internet

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has strongly influenced and even changed the way people live and thereby working (We Are Social and Hootsuite 2019).

Improvement of internet usage related to work has affected the labor market significantly. In addition to helping people to work more efficiently and effectively in dealing with many kinds of jobs, the internet can also help people create jobs by using online marketplaces (Tokopedia, Shopee, Amazon, etc.) and market their products by utilizing popular digital platforms (Facebook, YouTube, Instagram, etc.). Through digital or online marketplaces, people can now sell any kinds of products and services. Especially for those who prefer to stay at home rather than leaving the house for work, now they can do their work and manage their business from home while also taking care of their family.

The use of the internet for doing business offers an interesting choice, in particular for married women who usually find it difficult to allocate their time divided between work and their family. With the help of ICT, women can now work from home—i.e., doing business online, while at the same time taking care of their family. The use of the internet as a medium that may increase married women's labor force participation has been argued by Dettling (2011) who focused her observation on home high-speed internet usage. In particular, she found that home internet enabled women to combine family tasks and work.

Globally, according to an International Labour Organization (ILO) report (2018), the ease of accessing the labor market for women can be reflected by several ILO statistical indicators: female labor force participation, unemployment, employment, informal employment, and working poverty. The higher the women's labor market indicators statistically, the larger the number of working women in the market. Yet, due to the differences of countries' development levels (developed, developing, and underdeveloped), the gender gaps between female and male unemployment, labor force participation, and employment rates are significantly different. In Arabian countries, southern Asia, and northern Africa, in particular, female labor force participation is very low due to social and cultural norms and beliefs. Conversely, in developed countries, the gender gap is lower. This is because the quality of women's education and labor skills are most likely equal to those of men; the opportunity to gain access to the labor market is therefore also equal.

The gender gap between female and male participation in the global labor force remains wide. This is because the participation rates of both females and males went down at the same time. The ILO (2008) reported that the gender gap in 1997 was about 27.5%, and it slightly decreased to 26.3% in 2008. In the 2018 ILO report, the gender gap between female and male participation in the global labor force was recorded at 26.5%, which was the same as in 2008. If we look at the rates separately, the global female labor participation rates tend to decline steadily: 52.9% in 1997, 52.5% in 2008, and 48.5% in 2018. The same declining rates also apply for male participation in the global labor force: 80.4% in 1997, 78.8% in 2008, and 75% in 2018. Hence, the lower female participation rate during 1997–2008 indicates that women were less likely to be employed than men. During that period, when ICT was less developed, most household tasks were performed by women (housewives), which was the reason why fewer women, especially married women, dedicated their time for paid work. Yet today, with the world going digital and ICT being much more developed and modern, married women have more room to take an active role in supporting the household's financial burden while taking care of all domestic tasks. The presence of ICT has helped them save their time, which allows them to take part in more productive activities in addition to taking care of those domestic tasks.

In Indonesia, with its population of around 268.2 million people being ranked the fourth most-populous country in the world, there were approximately 355.5 million mobile subscriptions in January 2019. This means that for those who can afford to buy subscriptions and mobile phones, many have two mobile phones or more. In addition, it is also reported that 150 million people, or around 56% of the population, are active internet and social media users.

The development of digital technology provides an easy way for each person to do business or conduct transactions using the internet (Falentina et al. 2021). There are a lot of enterprises (start-ups) that are being developed using new technology and the internet. The recent development of start-ups has been very fast. According to the Indonesian Ministry of Communication and Informatics, based on the latest data from the start-up registration site in 2018, Indonesia has 2,079 start-ups.

Data on the share of workers' absorption per sector in Table 11.1 show that the absorption of labor in Indonesia has started to shift from the agriculture and industry sectors to the commerce and service sectors during 2012–2017 (Pratomo and Manning 2020). The highest absorption of workers, which is approximately 50%, was in the commerce, restaurant, and services sectors in 2017. This is followed by the agriculture sector and then manufacturing industry.

Nevertheless, a huge gap in the labor force participation rate between females and males also exists. According to a Badan Pusat Statistik (2018) report, in August 2017, the male labor force participation rate was approximately 83%, while the female labor force participation rate was only 52%. These labor force participation rates were higher than in the previous year by 0.18% and 0.99% for male and female labor force participation, respectively.

Table 11.1: Share of Workers' Absorption per Sector, 2012–2017

Sector	2012	2014	2017
Agriculture	26.91%	25.41%	22.01%
Manufacturing industry	15.13%	13.97%	15.83%
Construction	7.11%	7.48%	7.47%
Transportation, storage, and communication	3.28%	3.52%	3.61%
Commerce, restaurant, and services	46.69%	48.76%	50.18%
Other	0.87%	0.86%	0.91%

Source: Badan Pusat Statistik (2018).

The low rate of female labor force participation may be affected by the decreasing number of married women who participate in the labor market. They usually quit their job for a while to take care of their children, especially those below 5 years old. They will not go back to work until their children start schooling (Cameron, Suarez, and Rowell 2019). Table 11.2 shows that most female workers work part-time for fewer than 35 hours a week. Over 15% of female workers work fewer than 24 hours a week. Female workers who work fewer than 35 hours a week are still more numerous than male workers, at nearly 28%. Full-time workers who work for more than 35 hours per week are predominantly male workers, and the percentage of male workers who work for more than 45 hours a week is higher still.

Table 11.2: Percentage of Working Hours by Gender, 2017

Working Hours (per week)	Male		Female		
	Workers	Percentage	Workers	Percentage	Total
1–14	807,202	43.79%	1,036,027	56.21%	1,843,229
15–24	2,195,360	52.41%	1,993,802	47.59%	4,189,162
25–34	3,359,760	57.70%	2,463,199	42.30%	5,822,959
35–44	12,303,495	64.65%	6,727,459	35.35%	19,030,954
45+	21,819,390	74.34%	7,531,034	25.66%	29,350,424

Source: Badan Pusat Statistik (2018).

As shown in Table 11.3, the percentages of female workers in the first two age groups, 15–19 and 20–24 years, are higher than other percentages of age group of female workers. If the numbers in the age group 25–29 years age start to decrease, it may be because they are married and have children, and they prefer to reduce the number of hours of work to take care of their family at home. If they start to increase again in the age group 45–49 years, it may be because the responsibility to take care of children is already shrinking. In contrast, more than half of workers in the age group 15–64 years are male. Thus, overall, the supply of labor is still dominated by male workers in all age groups.

Table 11.3: Percentage of Age Groups of Workers by Gender, 2017

	Male		Female		
Age Group	Employee	Percentage	Employee	Percentage	Total
15 to 19	1,718,139	58.76%	1,206,079	41.24%	2,924,218
20 to 24	4,906,860	61.97%	3,010,984	38.03%	7,917,844
25 to 29	5,726,285	66.36%	2,902,992	33.64%	8,629,277
30 to 34	6,011,578	68.59%	2,752,660	31.41%	8,764,238
35 to 39	6,189,212	68.93%	2,789,197	31.07%	8,978,409
30 to 44	4,770,494	68.98%	2,144,909	31.02%	6,915,403
45 to 49	4,333,611	69.05%	1,942,299	30.95%	6,275,910
50 to 54	3,338,245	68.42%	1,540,689	31.58%	4,878,934
55 to 59	2,241,431	69.16%	999,350	30.84%	3,240,781
60 to 64	1,781,783	70.47%	746,630	29.53%	2,528,413

Source: Badan Pusat Statistik (2018).

As can be seen in Table 11.4, female workers predominate in self-employee status at more than 53%. In addition, the proportion of female workers in family worker or unpaid worker status reaches more than 80%. This information shows that female workers prefer having a flexible job rather than working with fixed office hours. Their role as mother and wife in taking care of the household makes them choose this kind of job and status, as they can make money while taking care of their children from home.

Table 11.4: Employment Status by Gender, 2017

Main Employment Status	Percentage (%)	
	Male	Female
Self-employee	46.94	53.06
Own business with temporary unpaid assistant	62.52	37.48
Own business with temporary worker/unpaid assistant	73.08	26.92
Regular employee	58.94	41.06
Casual employee	81.53	18.47
Family worker/unpaid worker	19.78	80.22

Source: Badan Pusat Statistik (2018).

The huge development of digitalization in business suggests that it can reduce unemployment in the formal sectors. People can create their own jobs and do not need to depend on jobs from government sectors. Yet, the question remains: has it encouraged married women to enter the job market in Indonesia? This research, hence, is an attempt to evaluate the impact of digitalization on labor participation among married women.

We use a case study of several micro and small enterprises in Bantul and the city of Yogyakarta, Yogyakarta Province. Bantul is the main region of our survey. As an illustration, the total number of industries established in each municipality in Yogyakarta Province in 2017 can be seen in Table 11.5. Bantul is the municipality with the highest number of workers. That is why this study observes the conditions of workers from this region, and some observations are also carried out in the city of Yogyakarta.

Table 11.5: Number of Industries and Employees in Yogyakarta Province, 2017

Regency/City	Industry Establishments	Employees
Kulon Progo	25,483	72,449
Bantul	21,402	98,695
Gunung Kidul	22,202	84,059
Sleman	18,056	62,876
Yogyakarta	4,073	24,588

Source: Badan Pusat Statistik (2018).

Furthermore, Table 11.6 shows that in Yogyakarta Province, the female labor force participation rate was more than 60% on average during 2012–2017. This means the rate was higher than the national female labor force participation rate, which was only around 50%. We will observe in this research whether internet utilization contributes to this higher female labor participation in Yogyakarta.

Table 11.6: Labor Force Participation Rate by Gender in Yogyakarta Province, 2012–2017

Year	Male	Female
2012	74.6%	60.34%
2014	77.18%	61.73%
2017	80.72%	62.69%

Source: Badan Pusat Statistik (2018).

11.2 Women's Workload and Their Well-Being

Women's decision to participate in the labor market has the consequence of increasing their workload (domestic and professional workloads). In the last few decades, the level of women's participation in paid work has been increasing along with improved access to the labor market for them. Given that women have been playing a dominant role in domestic work, the implications of increasing their time allocated to paid work are reduced total time available for domestic work and decreased leisure time. The findings of some empirical studies (Bianchi et al. 2000; Goñi-Legaz, Ollo-López, and Bayo-Moriones 2010; Sayer 2005) revealed that the time-wise upward trend in the proportion of working women is followed by increased participation of men in domestic work, thereby indicating the reallocation of the domestic workload from women (wives) to men (husbands).

These findings were confirmed by Álvarez and Miles (2006) who found that within a household, the wife's participation in paid work is positively correlated with the husband's greater contribution to domestic work. However, this workload reallocation has yet to be done in a balanced manner. This is reflected by the growing trend in men's domestic work hours, which are considerably lower than the upward trend in women's paid working time (Goñi-Legaz, Ollo-López, and Bayo-Moriones 2010). In addition, "core" domestic duties continue to be predominantly performed by women, and their average domestic work hours remain greater than those of men, although women also participate in paid work (Bianchi et al. 2000; Sayer 2005). By assuming that the required total hours of domestic work remain unchanged, the obvious implication is an increase in the total workload for women.

Other studies also found that the effects of changes in the time allocation for paid work on that for domestic work are nonsymmetrical for women and men. In general, the amount of time allocated for paid work is inversely proportional to the time allocation for domestic work, but this correlation is weaker for women (Foster and Stratton 2018; van der Lippe, Treas, and Norbutas 2018). Also, the magnitude of this correlation becomes weaker in households with low levels of educational attainment. Furthermore, if men from households with low educational attainment stop participating in paid work (become unemployed), apparently their domestic working hours decrease and are compensated for by an increase in women's domestic working time instead (Foster and Stratton 2018).

The time allocation for domestic work and paid work is also affected by other factors relating to the spouse's bargaining power, as well as the nature and type of the paid work itself. In essence, the variables that improve bargaining power will be positively associated with a reduced time allocation for domestic work. This is reflected, for example, by a research finding indicating that the time allocated for domestic work will be on a par between women and men if their income differences (Goñi-Legaz, Ollo-López, and Bayo-Moriones 2010) and differences in the ownership of personal assets (Simulja, Wulandari, and Wulansari 2014) are more subtle. In addition, flexible types of work (not limited to certain working hours) increase the opportunity for individuals to take part in domestic work (Goñi-Legaz, Ollo-López, and Bayo-Moriones 2010).

Although the factors mentioned previously play a role in the time allocation for domestic work, gender inequality in such time allocation is in fact still poorly explained by the existing data. The insensitivity of women's domestic work hours toward their paid work hours indicates the existence of sociological exogenous factors because of which women tend to be burdened with domestic work. The presence of structural identities, social norms, and attitudes toward gender roles in society plays a significant role in such domestic work inequality (Álvarez and Miles 2006). This is in line with a finding that revealed that households with more likelihood of being influenced by traditional norms, such as less educated older couples, have higher inequality in terms of the time allocation for domestic work. At the macro level, countries with more egalitarian gender norms tend to have lower inequality in terms of the total number of hours (paid work and domestic work) between women and men (Campaña, Giménez-Nadal, and Molina 2018).

Gender inequality in domestic work, which has an impact on women's high total workload, has implications for the well-being of women. This high total workload generally has an impact on women's mental health particularly relating to stress. For working married women with children, the increased workload in paid work will not only lead to stress but also reduce job satisfaction. This is because when the workload is high, the realization of workload becomes higher than the workload expectations (Boyles and Shibata 2009). Meanwhile, increased domestic workload for women has different effects on the levels of stress, with the greatest effects arising from the work related to daily housekeeping and caring for the elderly (MacDonald, Phipps, and Lethbridge 2005). Given that the highest total workload is experienced by women with low educational attainment, these women become part of the most stress-prone group (Liu, MacPhail, and Dong 2018).

The fact that inequality in the time allocation for domestic work has implications for women's well-being has proved that men's involvement in domestic work becomes essential. As well as reducing women's total workload, men's involvement in domestic work also has other positive effects. The higher men's involvement in domestic work, the greater women's satisfaction with the domestic work distribution (Foster and Stratton 2019). Men's involvement in domestic work and in caring for children also improves marital stability, regardless of whether the women work or not (Sigle-Rushton 2010). However, this increasing involvement is inadequate if there are no changes in the norms related to gender roles in society. Strict adherence to the role of women in domestic work can lead to men's involvement in domestic work being perceived as violating the norms and can adversely reduce women's satisfaction due to such social pressure (Foster and Stratton 2019).

11.3 Labor Market and the Use of Information and Communication Technology

The use of technology has led to the opening of new opportunities and development. It allows people to conduct their activities efficiently and effectively, thus saving time for doing more productive activities. For example, the use of technology and appliances—such as washing machines, gas cookers, and refrigerators—saves time for women on domestic tasks, giving them an opportunity to deal with their paid work (Omotoso and Obembe 2016). Coen-Pirani, León, and Lugauer (2010) also examine how household appliances affect married women's labor participation rate and find that such appliances are responsible for promoting 40% of the observed married women's labor force participation rates. However, Oropesa (1993) finds that female employment status affects the purchase of time-saving household appliances, especially microwaves. Nevertheless, the study of the internet and gadgets is different from other studies as those technologies can also be determinants of leisure (Dettling 2011).

Meanwhile, the use of mobile phones, computers, and the internet has been increasing rapidly. Those technologies allow fast storage and transfer of information; hence, people can communicate even across vast distances. Not only have they provided more efficient ways to communicate, but they also open up new working opportunities. Weinberg (2000) finds that the use of computers increases the demand for female labor. Dettling (2016) finds that high-speed broadband connection increases married women's labor force participation by 4.1 percentage points.

Badran (2014) estimated the impact of the use of ICT on the development of women's entrepreneurial spirit in five developing countries—Egypt, Jordan, Morocco, Algeria, and Brazil. The use of ICT and gender does not affect the profitability of small and medium-sized enterprises (SMEs). Chowdhury and Wolf (2003) found that the use of ICT actually reduced labor productivity but had a positive impact on export market expansion. In addition, the use of ICT increases labor intensity in Arabia but reduces labor intensity in Brazil.

On the other hand, Martin and Wright (2005) found that ICT can influence the development of SMEs owned by women in the United Kingdom. Badran (2010) also found an increase in women's empowerment and increased access to women's employment after using ICT. Previous research on the impact of using household appliances and technology on women's labor supply has had mixed results. Coen-Pirani, León, and Lugauer (2010), Bianchi et al. (2000), and Greenwood, Seshadri, and Yorukoglu (2005) found a positive impact of the use of household technology on female labor participation. Meanwhile, Cardia (2008), Chowdhury and Wolf (2003), and Omotoso and Obembe (2016) found that there is no significant impact. Omotoso and Obembe (2016) found that only the use of washing machines had a significant effect on female labor, while the use of a refrigerator and gas cooker had no effect.

Coen-Pirani, León, and Lugauer (2010) used microdata in the United States in the 1960s and 1970s to examine the relationship between ownership of household appliances and workforce participation among females aged 18–55 years. The results showed that the use of household appliances in the form of washing machines, refrigerators, and dryers was able to increase the participation of married women in the 1960s.

Women's labor participation is classified into three categories: employment (ratio of married women who work compared to the total workforce), full-time employment (ratio of married women who work at least 35 hours per week), and year-round employment (ratio of women who worked at least 48 weeks in the previous year). The researcher found an endogeneity of ownership of household appliances, so the study used an instrumental variable of single female household ownership of appliances at the state level. The results of the study also prove that white female labor participation increased by 10%. However, the participation of single female workers did not experience significant changes related to the technology of household appliances.

Meanwhile, the participation of married female workers who had three household appliances at the same time (washing machines, refrigerators, and dryers) increased by 17% (Coen-Pirani, León, and Lugauer 2010). The results of the study support the model developed by Becker (1965) and Gronau (1977) that describes the relationship between the purchase of household appliance technology and female labor participation, or the so-called GSY hypothesis. Becker (1965) put forward the theory of time allocation, namely the selection of labor supply depending on household production and the labor market. The theory also emphasizes that the choice of individuals to work or relax is a response to an increase in wages. Therefore, the decision of women to work is influenced by three things: relaxing, working at home (doing domestic or household work), and working in the labor market. This selection can also be influenced by socioeconomic factors, including technological innovations in household appliances (Omotoso and Obembe 2016).

The results of research by Bianchi et al. (2000) supports the GSY hypothesis that the hours to conduct household tasks will decrease for married women who work. Greenwood, Seshadri, and Yorukoglu (2005) stated that the use of household technology led to reducing the time required for married women to do household chores so that it had a positive impact on increasing female labor participation. Technology growth leads to saving time in performing household tasks, but the determination of whether women decide to work or not depends on the substitution elasticity of labor and household market utility functions (Jones, Manuelli, and McGrattan 2015).

Cavalcanti and Tavares (2008) use country-level data in the Organisation for Economic Co-operation and Development region and show the relationship between household equipment prices and female labor participation. Cardia (2008) uses country-level data to examine the relationship between the use of refrigerators and bathtubs in female labor participation in the United States between 1940 and 1950. The results of Cardia's study (2008) show that the use of household technology has no significant effect on female labor participation but helps increase their participation in the labor market in the United States. Omotoso and Obembe (2016) examined the impact of ownership of modern household technology (washing machines, gas cookers, and refrigerators) on female labor participation in developing countries. Researchers estimated parameters of interest from the interaction between dummy variables of washing machines, gas cookers, and refrigerators with ownership of generators. The results of the study found that washing machine ownership had a positive effect on female labor participation. Meanwhile, ownership of gas cookers and refrigerators had no significant effect on female labor participation.

11.4 Data

We conducted a survey of micro and small enterprises (MSEs) in Yogyakarta Province, namely in the city of Yogyakarta and the district of Bantul, in January 2018. Both regions were chosen since the number of MSEs in those regions has been higher than in other districts in Yogyakarta Province. Data and information were collected at firm level. Respondents were owners or managers of the chosen MSEs in both regions. Based on the MSE survey of September 2017, Statistics Indonesia, known as the Central Bureau of Statistics of Indonesia, provided us a random sample of 700 MSEs. We successfully interviewed 576 MSEs.

We collected information on how MSEs used the internet for their business—i.e., whether they used the internet for marketing, selling, and buying their products, and whether they utilized e-mail, websites, mobile banking, social media, or other digital technologies. In addition, we gathered information on characteristics of MSE owners, such as their education, size of household, and family members' activities.

The survey utilized a computer-assisted personal interview (CAPI) mobile phone application developed by the World Bank. Similar mobile phones equipped with a Telkomsel SIM card were distributed to our enumerators. Telkomsel was chosen since it is the largest cellular operator in Indonesia. The CAPI enabled information on Telkomsel signal strengths in each survey area to be collected.

Among those interviewed, as many as 329 were MSEs owned by married women. The analysis of this research was limited to those

329 MSEs. The owners, who were all married women, were classified into two groups: one group consists of those utilizing internet and the other consists of those not using it. Hours of work are used as a measure of married women's labor force participation. In addition, we also control for individual characteristics, enterprise characteristics, and the number of base transceiver station (BTS) towers in a village.

Table 11.7 shows the descriptive statistics of micro survey data. The mean hours of work are around 8 hours per day, while the percentage of married women who use the internet is 71.3%. On average, the level of education of married women who are the owners of MSEs is around 11 years, which means that their education background was senior high school level. The Telkomsel signal strength at MSE locations is about 4.58 bars on average.

Table 11.7: Descriptive Statistics

Variable	Obs.	Mean	Std. Dev.
Hours of work (per day)	329	8.066	3.500
Internet use (1 = yes)	328	0.713	0.452
Telkomsel signal strength (0 = no signal, 1–5 bars)	329	4.586	0.756
Number of children below 5 years old (children)	329	10.844	14.016
Education (years of education)	323	11.368	3.734
Age (years)	329	46.273	12.286
Number of refrigerators	329	1.060	0.877
Number of washing machines	329	0.668	0.636
Number of mobile phones	329	3.863	2.254
Length of mobile phone access (hours)	259	3.276	2.306
Wages (million rupiahs per month)	329	2.931	9.428
Home based (1 = production process same residential)	329	0.598	0.490
Business sectors of micro and small enterprises (1 = manufacture, 2 = trade, 3 = services)	328	1.908	0.855
Number of base transceiver station towers	329	78.583	81.246

Source: Authors' estimation.

11.5 Basic Model

The following estimation model is used to estimate the impact of internet use on female labor force participation:

$$y_i = \beta\ Internet_i + X'_{i,j,k}\gamma + \lambda\ BTS_i + \mu_d + \mu_s + \varepsilon_i \qquad (1)$$

where y_i is female i labor force participation, measured by using hours of work in a day for married women who are the owners of MSEs; Internet is a measure of whether or not the individual has utilized the internet. It is equal to 1 if the individual has used the internet, and 0 otherwise. The coefficient of interest is β, which measures the impact of internet use on hours of work.

This model includes a vector of individual controls X'_i; the vector X_i contains the other explanatory variables that absorb individual i and household characteristic differences in using the internet and participating in the labor market. Here, we control for age, education, dummy location (rural or urban), number of children below 5 years old, wage, being home based (if the business site is the same place as the household residence), the ownership of household appliances—such as washing machines and refrigerators—and mobile phones, and the length of using a mobile phone. We also control for the number of BTS towers in each village since internet use depends on a mobile phone's signal availability from BTS towers. In addition, this model also includes district (Yogyakarta City and Bantul) fixed effects, μ_d, and business sector (manufacturing, trade, and services) fixed effects, μ_s. The inclusion of these fixed effects is to ensure the estimate coefficient on the internet is net of any differences across district and business sectors in terms of internet participation. Standard errors are clustered at the subdistrict level, since there are multiple MSEs within the same subdistrict as we suspect to be the case.

11.6 Instrumental Variable Estimation

Internet utilization may be endogenous. The endogeneity of the internet could arise because of reverse causality or simultaneity and the existence of omitted confounding variables. The simultaneity problem is a concern for the following reason. Female workers may increase their hours of work in the labor market because they can access the internet, yet likewise utilizing the internet may also be due to the increase in their hours spent for paid work, thus enabling them to afford the costs of internet usage. In the case of an omitted confounding variable bias problem, there could be some variables that are correlated with both the utilization of internet and female participation in the labor market, but we cannot include it in the model as shown in equation (1). These omitted confounding variables could be some abilities of female workers that we cannot measure. An ordinary least squares (OLS) estimation on equation (1), hence, will produce a bias estimate of β coefficient.

Instrumental variable (IV) estimation is used in this research to deal with the endogeneity issues of internet utilization. With an appropriate instrument, the IV estimation approximates the effect of the treatment on those individuals whose behavior is affected by the treatment. That is, the IV estimation provides an estimate of the causal effect for those individuals who change the treatment status because of the instrument.

The study by Blundell, Dearden, and Sianesi (2005) has shown that using good instruments, IV estimation can overcome the OLS bias that results from endogeneity of the explanatory variables. The instrument, however, needs to be correlated with the variable of interest, but uncorrelated with the dependent variable, which is called the exclusion restriction. That being the case, the only channel through which the instrument affects female labor participation is internet utilization. In the implementation, we should show that the instrument has a clear effect on internet use in the first stage of the regression; in the second stage of the regression, we observe a relationship between female labor force participation and internet use estimated from the first stage. According to Angrist and Pischke (2009), good instruments in many social science settings typically come from a combination of institutional knowledge and ideas about processes in deciding the variable of interest.

The treatment effect that we estimate is the average treatment effect for those who adjust their treatment status because they react to the instrument. That is, the IV estimation produces the local average treatment effect (LATE) of the impact of internet use on a subset of individuals. Card (2001) suggests that LATE estimates from IV estimation could exceed those from OLS estimations, because they estimate average effects for a specific group, whereas OLS, in the absence of omitted variables and measurement error biases, estimate the average effect across individuals. Imbens and Angrist (1994), hence, argued that an IV estimation producing a LATE estimate could have two weaknesses: the IV estimation measures the effect of a treatment on a generally unidentifiable subpopulation, and the LATE estimate could vary depending on the particular instruments that are used.

This research used (mobile phone) signal strength as an instrument for internet use. This instrument fulfils the exclusion restriction requirement. It is highly correlated with the decision to utilize the internet, but there is no reason to believe this signal would correlate with any other variables that encourage female workers to participate in the labor market. Hence, the instrument should be uncorrelated with female hours of work beyond its impact through the likelihood of accessing the internet. Therefore, we acknowledge that, in the case of our study, our IV estimation produces a LATE for those whose internet use status is affected by the signal strength where they live.

Thus, the model that is used for our IV estimation can be written as follows:

First-stage equation:

$$Internet_i = \rho \; signal \; strength_i + X_i'\theta + \vartheta \; BTS_i + \sigma_d + \sigma_s + \mu_i \quad (2)$$

Second-stage equation:

$$y_i = \beta \; \widehat{Internet_\iota} + X_i'\gamma + \lambda \; BTS_i + \sigma_d + \sigma_s + \varepsilon_i \quad (3)$$

In the first-stage equation, the *Internet* dummy is the dependent variable. This study used signal strength as the instrument for internet use. The estimation result from the first-stage equation is used to predict internet use, $\widehat{Internet_\iota}$. This predicted internet use is utilized in the estimation of the second-stage equation.

11.7 Results

Table 11.8 shows the first-stage estimation for the basis of all IV estimates. The results indicate that the Telkomsel signal is positive and statistically significantly influenced our variable of internet use. This instrument also passed the test of weak instruments. We reject the null hypothesis of weak instruments. All the p-value tests of weak instruments are smaller than 0.01. In model (1), without controlling for other factors, the p-value is very small. In model (2), controlling for other factors, the p-value is statistically significant at 0.001. The probability of using the internet increases by around 8% when the signal is stronger by one bar.

Table 11.9 presents the estimation using OLS and IV estimation. The estimated coefficients of internet use from the OLS estimation (columns 1 and 2) are smaller than those from the IV estimation (columns 3 and 4). Without controlling for other factors, the OLS estimation suggests that working hours will increase by around 8 hours per day for married women who use internet. If we control for other factors, working hours are predicted to be increased by 1.8 hours per day.

On the other hand, for results from the IV estimation show that the estimated coefficient seems to be larger. Without controlling for other factors, married women who are the owners of MSEs and who use the

Table 11.8: First-Stage Estimation for the Instrumental Variable Estimates

Dept Variables: Internet Use	(1)	(2)
Telkomsel_signal	0.152***	0.079***
	(0.005)	(0.019)
Control and fixed effect	No	Yes
F stat of endogeneity test	348.675	4.794
F stat of weak instrument	786.202	16.070
Observations	328	256

Notes: Cluster standard errors at subdistrict level in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Control variables: age, education, number of children under 5 years old, wage, being home based, ownership of household appliances (e.g., washing machines, refrigerators, and mobile phones), the length of using a mobile phone, number of base transceiver station or BTS towers in the village, district fixed effects, and business sector fixed effect.

Source: Authors' estimation.

Table 11.9: Impact of Internet Use on Working Hours of Married Women

	OLS	OLS	IV	IV
	(1)	(2)	(3)	(4)
Variable	Working Hours	Working Hours	Working Hours	Working Hours
Internet use	8.038***	1.779***	11.111***	9.687***
	(0.366)	(0.527)	(0.480)	(4.179)
Controls and fixed effect	No	Yes	No	Yes
Observations	328	256	328	256

IV = instrumental variable, OLS = ordinary least squares.

Notes: Cluster standard errors at subdistrict level in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Control variables: age, education, number of children under 5 years old, wage, being home based, ownership of household appliances (e.g., washing machines, refrigerators, and mobile phones), the length of using a mobile phone, number of base transceiver station or BTS towers in the village, district fixed effects, and business sector fixed effect.

Source: Authors' estimation.

internet would like to increase their working hours by approximately 11.1 hours. If we control for other factors, working hours are predicted to increase by approximately 9.7 hours per day.

These findings are in line with the judgment of Card (2001), as mentioned before, that the estimates for an IV estimation is higher than those from the OLS estimation. This is because the IV estimation approximate average affects only a particular group, while the OLS estimation approximate average affects almost all individuals, without considering the absence of endogeneity bias. Hence, in the absence of the endogeneity issue, the coefficients of the OLS estimation show the average effect of internet use on married women working hours for the whole population, while the coefficients of the IV estimation measure the LATE of internet usage on married women's working hours because they receive a good signal from Telkomsel.

We conducted the Wu-Hausman test of endogeneity for the internet use variable. The probability values of the Wu-Hausman F test are very small without controlling for other factors and 0.043 if controlling for other factors. Since they are less than 0.05, we reject the null hypothesis that the OLS estimation result is the same as that from the IV estimation. Therefore, results from the OLS estimation may suffer endogeneity problems. A further implication of the results from this the Wu-Hausman endogeneity test is that results from the IV estimation may be more consistent than those from the OLS estimation. We use the results from the IV estimation to argue that there is a causal impact of using the internet and longer working hours among married women who own MSEs. Our decision is in line with Oreopoulos' argument (2006) that the results from an IV method are often used to evaluate programs' impacts, because the IV method can estimate a more consistent treatment effect than the OLS method. For showing the general correlation of using internet and married women's working hours, however, we refer to our OLS estimation results in column (2).

In order to understand the heterogeneity effects among different subpopulations of internet utilization on the working hours of married women in MSEs, we estimate separately by area, education, and also business sectors. Area is projected to be an important factor that affects married women in using the internet. Married women who live in the city of Yogyakarta, which is an urban area, are predicted to spend more working hours when they use the internet than those in Bantul district, which is a rural area. In addition, education is expected to influence married women in utilizing the internet. The higher the education of married women, the more working hours they may spend if they are internet users. Furthermore, for the business sector category, married women who work in manufacturing and trade industries are more likely to spend more working hours if they can use the internet than those who work for services.

The impact of the internet use on the working hours of married women by area and education is shown in Table 11.10. In terms of area,

Table 11.10: Impact of Internet Use on Working Hours of Married Women by Area and Education

	Area		Education		
Dept. Variables Hours of Work	Bantul (rural)	Yogyakarta (urban)	Primary School	Secondary School	University/ College
IV Estimation					
Internet use	7.350*** (2.041)	12.296*** (4.615)	36.322 (68.996)	6.217** (2.561)	3.519 (3.504)
Observation	175	84	17	159	79

IV = instrumental variable.

Notes: Cluster standard errors at subdistrict level in parentheses, *** p < 0.01, ** p < 0.05, * p < 0.1. Control variables: age, education, number of children under 5 years old, wage, being home based, ownership of household appliances (e.g., washing machines, refrigerators, and mobile phones), the length of using a mobile phone, number of base transceiver station or BTS towers in the village, district fixed effects, and business sector fixed effect.

Source: Authors' estimation.

when married women utilize the internet, the increase in the working hours of those living in urban areas is greater than those in rural areas. The impact of internet use on the working hours of married women by education is significant for those with a secondary (high) school education background. The impact is not significant among married women with primary school and among those with a university educational background.

Table 11.11 demonstrates the impact of the internet use on the working hours of married women by sector. The highest impact is in

Table 11.11: Impact of Internet Use on Working Hours of Married Women by Sector

Variables	Manufacturing	Trade	Services
IV Estimation			
Internet use	9.011**	12.789**	-9.100
	(3.682)	(6.484)	(13.794)
Observations	103	70	83

IV = instrumental variable.

Notes: Standard errors in parentheses. *** p < 0.01, ** p < 0.05, * p < 0.1. Control variables: age, education, number of children under 5 years old, wage, being home based, ownership of household appliances (e.g., washing machines, refrigerators, and mobile phones), the length of using a mobile phone, number of base transceiver station or BTS towers in the village, district fixed effects, and business sector fixed effect.

Source: Authors' estimation.

the trade sector, followed by the manufacturing sector. The impact on the services sector is not statistically significant. The sectoral estimation supports the finding that MSEs utilize the internet in order to promote products and to make online transactions. This activity mostly covers trade sectors.

Furthermore, we also use a dummy variable (work) for measuring married women's labor force participation. Work is equal to 1 if the individual works for at least 1 hour for receiving payments or salaries during the last week. Table 11.12 presents the results from two different estimations (OLS and logistic regression). Without controlling for other factors, all the estimations show that internet use affects the working hours of married women significantly. Yet, if we control for other factors, only OLS show that the result is statistically significant. Overall, the results prove that internet use will increase the probability of married women to get paid work.

Table 11.12: Impact of Internet Use on Married Women's Labor Participation

	(1)	(2)	(3)	(4)
Dependent Variable: Work	OLS	OLS	Marginal Effect (Logit)	Marginal Effect (Logit)
Internet use	0.656***	0.219***	0.151***	0.089
	(0.023)	(0.068)	(0.0205)	(0.064)
Control	No	Yes	No	Yes
Observations	326	326	326	326

OLS = ordinary least squares.

Notes: Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Control variables: age, education, number of children under 5 years old, wage, being home based, ownership of household appliances (e.g., washing machines, refrigerators, and mobile phones), the length of using a mobile phone, number of base transceiver station or BTS towers in the village, district fixed effects, and business sector fixed effect.

Source: Authors' estimation.

11.8 Conclusion

This research examined the causal impact of internet use on married women's labor force participation based on a firm survey conducted among MSEs in Yogyakarta Province. Our main findings are as follows. First, there is significant evidence that internet utilization increases the working hours of married women who own MSEs in Yogyakarta. In other words, internet utilization has allowed married women to increase their working hours per day. On average, being able to utilize the internet allows these women to spend approximately 1.8 hours more per day compared to their counterparts who do not utilize the internet in the MSEs.

Second, we find that utilization of internet allows both married women in urban and rural areas to increase their working hours. The increase in working hours has been higher among those in urban areas in comparison to those in rural areas. Third, these impacts of internet utilization on the increase in working hours of married women are particularly significant among those with secondary education and among those in trade and manufacturing sectors. Finally, we also find that being able to use the internet has encouraged married women to get paid work.

Evidence from this study is expected to suggest for policy makers that labor supply of married women is sensitive toward ICT progresses. Further improvement of the quality of the internet throughout the country is expected to encourage married women to join the workforce. Utilizing better internet will make it possible for married women to do business from home while taking care of household tasks. This ability to work from home would create additional family income and thus enhance family welfare. Furthermore, we expect married women who own MSEs to also be able to contribute to local development and economic growth.

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PART III

Digital Challenges and Opportunities for Macroeconomic Policy Makers

12

An Integrated and Smart Association of Southeast Asian Nations: Overcoming Adversities and Achieving Sustainable and Inclusive Growth

Cyn-Young Park and Bernard Yeung

12.1 Asia in the 21st Century

There is an expectation that the 21st century will be the Asian century. Indeed, Asia's economic significance has risen substantially over the past several decades, despite the 1997 Asian financial crisis and the 2008 global financial crisis. The People's Republic of China (PRC) has experienced phenomenal development, for example in gross domestic product (GDP) growth, in the expansion of the middle class, and in elevating millions of people above the poverty line. The Association of Southeast Asian Nations (ASEAN) countries have achieved much too, such as reducing poverty and developing a middle class. Further economic development in the region, with its massive population, requires very efficient utilization of resources and cross-border cooperation. Given the varying stages of development and complementary capabilities and resources, Asia has much to gain from economic cooperation and integration.

The recent geopolitical tension produces economic and political uncertainties with negative spillovers on a global scale. However, the silver lining is that the ongoing episodes increase the region's desire for more economic integration. Businesses tend to configure their activities where they expect market growth and where they can better control production and operation costs and risks. This tendency may lead to actions that bring about economic integration in Asia.

The coronavirus disease 2019 (COVID-19) pandemic has also led to devastating negative global demand and supply shocks and disruptions to the global trade and supply chains. To combat the pandemic and mitigate the precipitous economic damage, governments around the world have increased their fiscal spending, incurred large deficits, borrowed substantially, and expanded their money supply. Most Asian countries have contained the spread of the disease better and are recovering from the negative shock earlier than the West. However, the world economy has to watch dominant developed countries' management of their deficit, debt, and large central bank balance sheets. Any missteps may spoil the global recovery and generate financial volatility.

Amid the pandemic, however, the digital–Internet of Things (IoT)–artificial intelligence (AI) transformation has accelerated. Widespread adoption of these technologies will enhance productivity growth. These technological advancements may help ASEAN to bridge the infrastructure gap and the education gap, and improve its market institutions and government efficiency and effectiveness, all of which have been significant hurdles to further growth that is inclusive and sustainable. However, turning these possibilities into reality relies on effective investment in digital infrastructure and connectivity. In addition, governments ought to be wary of potential regressive distributional effects of the digital–IoT–AI transformation.

In this chapter, we first offer an overall perspective on maintaining sustainable and inclusive development in ASEAN—the broad trend and the barriers. We then discuss why ASEAN needs to become a more integrated economic system, counteracting the geopolitical tension between the United States (US) and the PRC. Afterward, we discuss the multifaceted impacts of the COVID-19 pandemic. In the end, governments can play a crucial role in maintaining sustainable and inclusive development. The conditions are there, and the desires are there, but the political will and leadership are wanting.

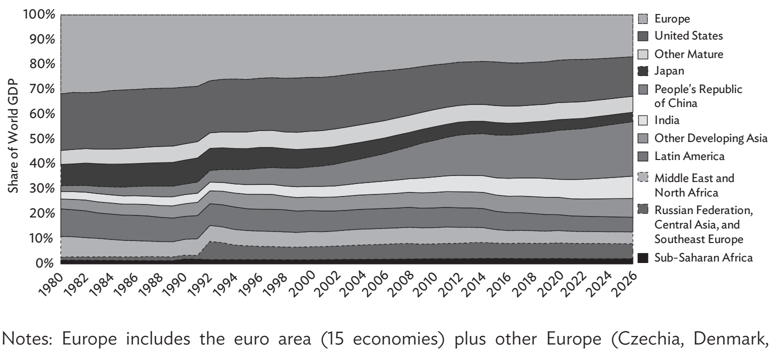
12.2 The Rise of Asia, the Path for ASEAN, and the Barriers

12.2.1 Historical Rise

The world economy's center of gravity is now shifting back toward the East after the First Industrial Revolution turned Europe into the global center of industrialization at the beginning of the 18th century. Industrialization first spread from the West to Japan in the second half of the 19th century, and later, the four Asian Tigers—Hong Kong, China; the Republic of Korea; Singapore; and Taipei,China—embarked on export-driven industrialization in the 1960s. However, it was not until the economic liberalization of the PRC, the world's most populous country, triggered its exponential growth after the 1980s that Asia reemerged in global economic history. In the 21st century, the PRC has enjoyed headline-grabbing phenomenal growth. Its per capita GDP grew by 10 times from 2000 to 2018; its total GDP surged to around $13 trillion. Economic spillovers from the PRC's growth have brought prosperity to the rest of Asia as well through strong intra-Asia trade and increased direct investment. ASEAN has been growing rapidly, with a per capita GDP that almost doubled from 2000 to 2018. India also joined, showing high growth rates since the turn of the 21st century.

Asia, with a population of billions, is now poised to become an integrated growing economy. Altogether, developed and emerging Asian economies nowadays make Asia economically the most significant continent. Figure 12.1 presents the percentage breakdown by regions of the world's GDP since 1980, validating the emerging significance of the Asian economies since the start of the 21st century.

Figure 12.1: Regional Distribution of the Gross Domestic Product, 1980–2026

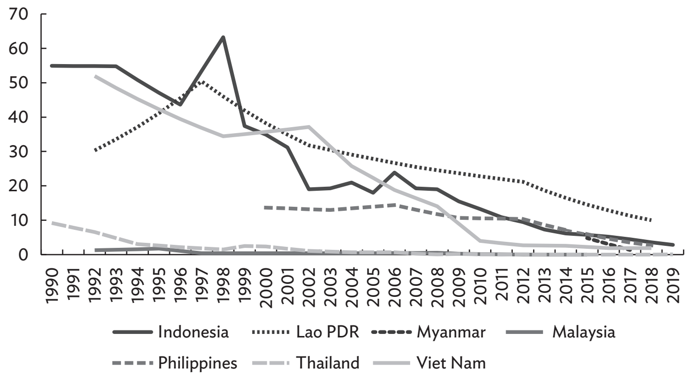


Notes: Europe includes the euro area (15 economies) plus other Europe (Czechia, Denmark, Hungary, Iceland, Norway, Sweden, Switzerland, and the United Kingdom). Other mature economies include Australia; Canada; Hong Kong, China; Israel; New Zealand; Singapore; the Republic of Korea; and Taipei,China. Other developing Asia includes Indonesia, Malaysia, Pakistan, the Philippines, Thailand, and Viet Nam.

Source: International Monetary Fund. World Economic Outlook April 2021 Database. https://www.imf.org/en/Publications/WEO/weo-database/2021/April (accessed 8 April 2021).

The region's spectacular growth has generated positive results in reducing poverty and lifting the living standards for more than a billion people. Figures 12.2 and 12.3 showcase the poverty reduction in ASEAN and the PRC. The numbers may have noise, but the trends are nevertheless impressive. The average growth has a positive impact even on the poorest.

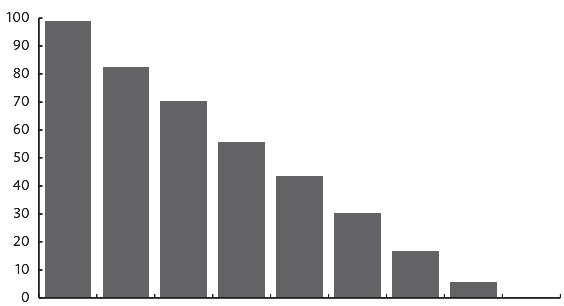
Figure 12.2: ASEAN Poverty Headcount Ratio at $1.90 a Day (2011 PPP), 1990–2019 (% of the population)



ASEAN = Association of Southeast Asian Nations, Lao PDR = Lao People's Democratic Republic, PPP = purchasing power parity.

Source: United Nations data. http://data.un.org/ (accessed 7 April 2021).

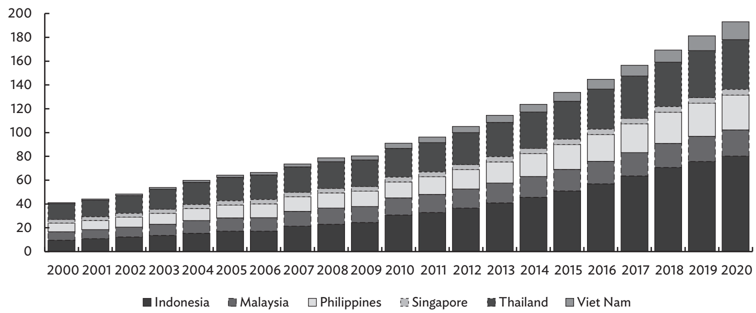
Figure 12.3: Number of Rural Residents in Poverty in the People's Republic of China, 2012–2020 (million)



Source: The State Council Information Office of the People's Republic of China. 2021. *Poverty Alleviation: China's Experience and Contribution*. Beijing: Foreign Languages Press Co. Ltd.

These regions' growth has also created a sizable middle class. Figure 12.4 shows that ASEAN has around 190 million middle-class residents (earning or spending $10–$100 per person per day). The PRC's middle class consisted of 588 million people in 2020. Figure 12.5 shows

Figure 12.4: The Rise of the ASEAN Middle Class: Middle-Class Population, 2000–2020 (million)

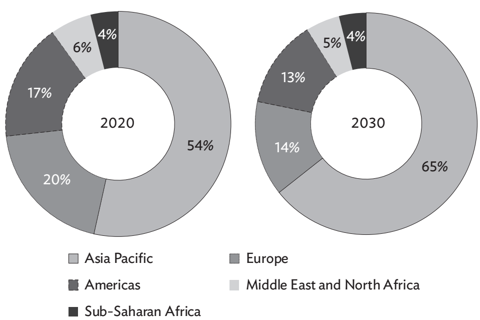


ASEAN = Association of Southeast Asian Nations.

Note: Middle class refers to the number of people living in households earning or spending between $10 and $100 per person per day (2005 $ purchasing power parity).

Source: Brookings. Development, Aid, and Governance Indicators. https://www.brookings.edu/interactives/development-aid-and-governance-indicators-dagi/ (accessed 10 April 2021).

Figure 12.5: The Rise of the Asian Middle Class: The Share of the Global Middle Class by Region



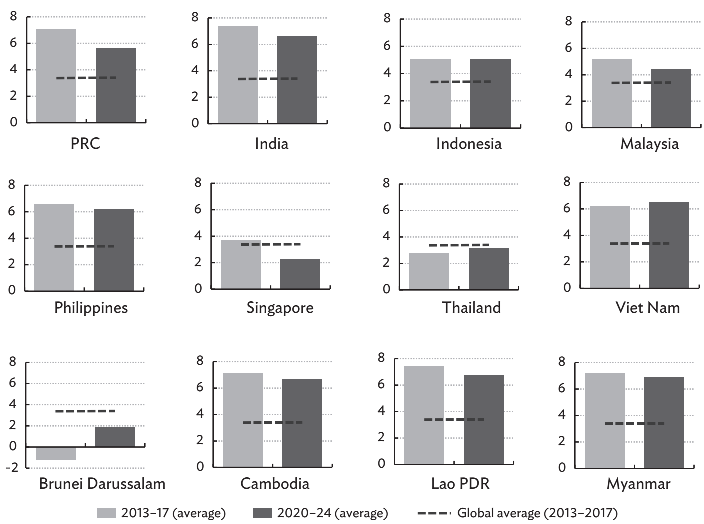
Note: Middle class refers to households with incomes between $11 and $110 per person per day (purchasing power parity) in 2011.

Source: Brookings Institution as cited in Buchholz. 2020. *This Chart Shows the Rise of the Asian Middle Class*. World Economic Forum: Agenda. 13 July. https://www.weforum.org/agenda/2020/07/the-rise-of-the-asian-middle-class.

that Asia had 54% of the world's middle class in 2020, and projections indicate that it will have 65% in 2030 (Buchholz 2020). These macro data prompt optimism about further development in Asia.

The growth of the middle class feeds back into further growth. Figure 12.6 shows the Organisation for Economic Co-operation and Development (OECD) Development Center's (2019) GDP growth projection for ASEAN, the PRC, and India. Their GDP growth rates and their projected growth rates from 2020 to 2024 all surpass the global average of 3.4% in 2013–2017 except for Brunei Darussalam, Thailand, and Singapore. (Singapore's per capita GDP was already among the top 10 highest in the world in 2019.)

Figure 12.6: ASEAN, the PRC, and India: GDP Growth, 2013–2017 and 2020–2024
(%)



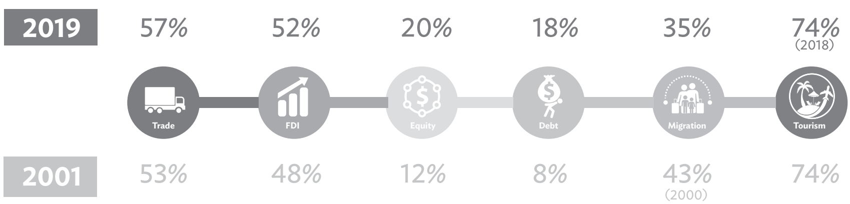
ASEAN = Association of Southeast Asian Nations, GDP = gross domestic product, Lao PDR = Lao People's Democratic Republic, PRC = People's Republic of China.

Source: Organisation for Economic Co-operation and Development (OECD) Development Center. 2019. *Economic Outlook for Southeast Asia, China and India 2020: Rethinking Education for the Digital Era*. Paris: OECD Publishing.

12.2.2 An Integrating Asia Economic System?

The above data support the idea that Asia has become a significant consumer market in its own right. The large Asian consumption markets elevate Asia's economic integration. Businesses contribute to economic integration because they tend to cluster their value chains around their markets. Figure 12.7 contains the Asian Development Bank's (ADB) report of measures indicative of Asia's regional integration. It shows that intra-Asia trade, direct investment, equity holdings, debt, and tourism have all increased in the past 2 decades (ADB 2021). The report commented that, despite the COVID-19 pandemic, "Asia immensely benefited from open trade and investment, with the region's export-driven growth strategy and attractiveness to foreign direct investment (FDI) lifting millions out of poverty over half a century" (p. 3).

Figure 12.7: Asia's Regional Integration: Intraregional Shares, 2001 and 2019 (% of total)



FDI = foreign direct investment.

Notes: Equity asset holdings and debt asset holdings are based on stock data, FDI on flows data, migration on outbound data, and tourism on arrivals data. Where 2019 and 2001 data are not available, the latest year with available data is indicated in parentheses.

Source: ADB. 2021. *Asian Economic Integration Report 2021 Highlights*. Manila.

However, there is still a significant gap between the living standards in Asia, including most ASEAN countries, and those in the developed Western economies. In 2020, the populations of Asia, North America, and Europe were, respectively, 4.3 billion, 0.369 billion, and 0.748 billion. These numbers show that Asia's share of the world's population is substantially larger than its share of the world's GDP. While Asia as a whole is gaining economic significance, many Asian countries, including the PRC, India, and ASEAN, have much catching up to do, for example as measured by the per capita GDP. The PRC also faces increasingly tight internal growth constraints, rising labor wages, and an aging population, like Japan and the Republic of Korea.

12.2.3 Reality Check

Strong economic growth and rapid progress in economic integration give a positive outlook for ASEAN. However, encompassing the populous PRC and India, Asia has more than 3.4 billion people, accounting for around 55% of the global population. ASEAN has an estimated 667 million people. Supposing that the growth goal of ASEAN economies, together with the PRC and India, is to attain middle-income-country status, or slightly above, they have to increase their per capita GDP by about $5,000. A flow of new GDP per capita of $5,000 translates into an annual flow of $17 trillion, roughly 81% of the total US factor earnings in 2020. For these countries to attain an advanced income country status, they need to have further per capita income growth of about $5,000. That is another $17 trillion per annual factor earnings, more than the PRC's earnings in 2020 of $14.7 trillion. Highly efficient and effective utilization of resources is the only way to enable our world to support the massive Asian populations in attaining developed country living standards. To achieve these, Asia has to adhere to sound economic principles and to overcome growth barriers.

Modern-day economic concepts suggest that economic prosperity relies on specialization and cooperation, following, for example, Smith (1776) and Ricardo (1817). These sound economic thoughts suggest extending the production scale to the minimum efficient scale and conducting trustworthy rule-based cooperation across specialized firms and trading nations. The implication is that the path to sustainable convergent growth in Asia, especially for emerging Asian countries, is market integration and the adoption of the principle of comparative advantage.

The potential of economic benefits from regional integration is huge, given the economic and demographic diversity across the region. Highly developed and capital-intensive regions in East Asia, like Japan, the Republic of Korea, and coastal areas of the PRC, are already feeling the pressure of the aging population and rising wages. In addition, to varying degrees, they are resorting to robotization in some industries. However, in the region as a whole, many countries have an abundance of labor and idle laborers. ASEAN remains young, and its population is still growing.

With broader and deeper economic integration, the region can exercise greater economies of scale, and individual economies can benefit from comparative advantages by offering businesses and consumers unfettered access to markets while allowing free flows of physical, human, and financial resources. In this way, labor-abundant countries can serve labor-scarce countries; capital can flow to wherever the investment return is the highest; and goods and parts can flow to the users offering the best prices. The vision is a world of free competition where the first fundamental welfare theorem applies, as economists would recognize.

Reality, however, is less rosy. Capital-intensive aging countries are either adopting robotization or moving production to the less-developed areas within their borders, for example inland areas in the PRC. ASEAN economies have been benefiting from the relocation of production facilities and the redirection of investment from some multinational companies in a limited way. Some ASEAN economies accept migrant workers, but most deny them resident rights. Nevertheless, ASEAN economies face nontrivial growth and integration barriers: (i) an infrastructure development gap; (ii) an education gap; and (iii) a market institutions gap, especially in financial sectors, which is very much related to governance issues such as government inefficiency and policy ineffectiveness.

Below, we discuss some of these challenges in ASEAN economies.

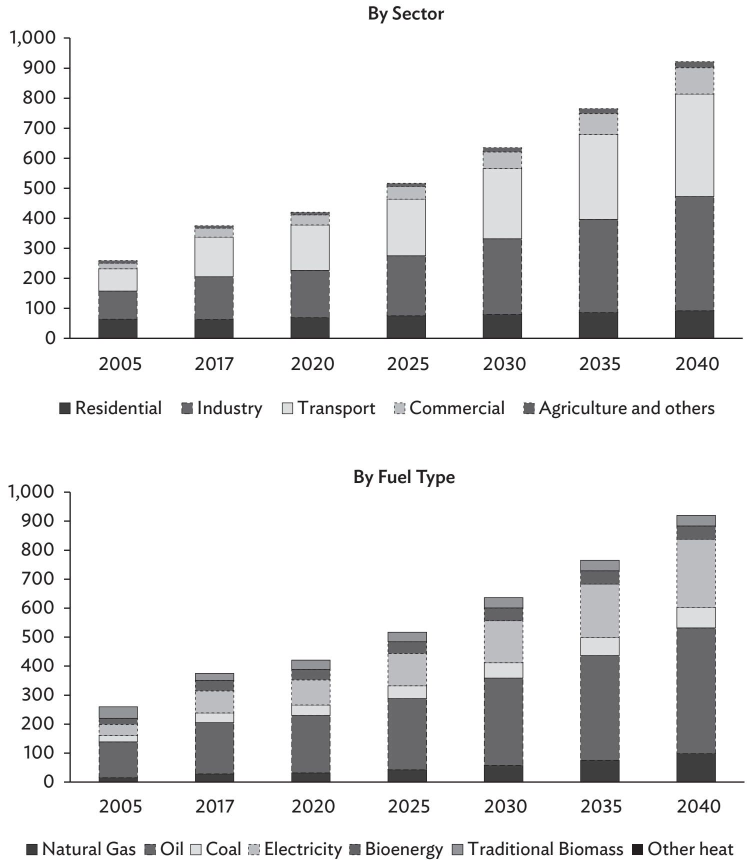
The Infrastructure Gap

ASEAN needs to invest more in infrastructure and upgrade its quality. The lack of an adequate supply of water, drainage, power, railroads, highways, piers, and airports will continue to cause under-utilization of resources, including labor, stifle productivity, and constrain growth in the region. Figure 12.8 shows ASEAN's total final energy demand by sector and by fuel type according to the baseline scenario in the *6th ASEAN Energy Outlook* of the ASEAN Centre for Energy (ASEAN 2020). To power its manufacturing and to meet rising consumption needs, ASEAN has to invest about $490 billion cumulatively between 2025 and 2030 under the Sustainable Development Scenario, according to the International Energy Agency's *World Energy Outlook 2020* (IEA 2020).

Infrastructure development is more than empowering production and transportation. Based on data from the Centre for Research on the Epidemiology of Disasters, developing Asia experienced 20.2% of the global disaster events in 2010–2020. Figure 12.9 shows a surge of incidents of flooding and storms in developing Asia. The cause could be global warming. ASEAN needs to build waterway infrastructure and other similar infrastructure to protect property and lives. Improved living conditions and protection for physical property, just like the power supply, attract both plant development and outside professionals to build businesses.

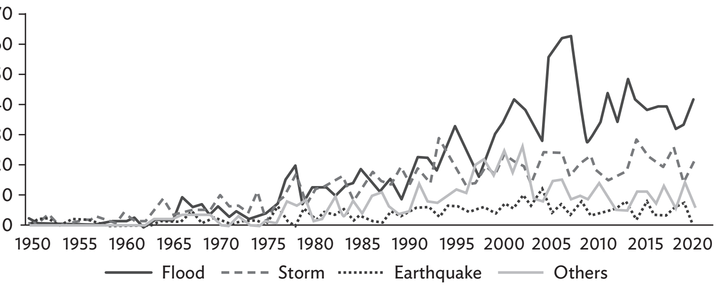
ADB estimated that the infrastructure investment needs will be around $26 trillion between 2016 and 2030, $1.7 trillion per year, in

Figure 12.8: Total Final Energy Demand by Sector and by Fuel Type, Baseline Scenario (million tons of oil equivalent)



Source: ASEAN Centre for Energy. 2020. *The 6th ASEAN Energy Outlook 2017–2040*. Jakarta. https://aseanenergy.org/category/publications/

Figure 12.9: Recorded Occurrence of Disasters in Developing Asia, 1950–2020



Notes: Other disasters include drought, epidemics, volcanic activity, landslides, extreme temperature, insect infestation, wildfire, and mass movements (dry). Developing Asia includes Afghanistan; Azerbaijan; Bangladesh; Bhutan; Cambodia; Georgia; Hong Kong, China; India; Indonesia; Kazakhstan; Kiribati; the Kyrgyz Republic; the Lao People's Democratic Republic; Malaysia; Maldives; Mongolia; Myanmar; Nepal; Pakistan; the People's Republic of China; the Philippines; the Republic of Korea; Sri Lanka; Taipei,China; Tajikistan; Thailand; Timor-Leste; Uzbekistan; and Viet Nam.

Source: Centre for Research on the Epidemiology of Disasters (CRED). Emergency Events Database. http://emdat.be/database/ (accessed 9 April 2021).

the Asia and Pacific region to maintain the region's strong growth momentum, continue the pace of poverty reduction, and make the necessary adjustments to climate change (Asia's total GDP is about \$31.6 trillion in 2019 US dollars). While that is affordable, the financing need is beyond the affordability of most governments. There is a need for a public–private partnership: combining public money and private sector investment to turn infrastructure investment needs into bankable project investments.

The Education and Skills Gap

As the ASEAN region makes advances in economic development, there is an increasing demand for skills, innovation, and knowledge. Most ASEAN economies have achieved middle-income status and are now striving to attain high-income status through skills, technology, and innovation (Singapore is an exception and is already at the top stage). Accordingly, ASEAN economies have to nurture the development of skilled labor. According to the World Bank's data on secondary enrollment, ASEAN countries have a mixed degree of educational attainment; many have attained a reasonably high level, although some still need to catch up. The gap is much more significant in terms of tertiary school enrollment.[1] To become a valued part of the value chains that developed countries lead and to advance in development, the region must continue to improve the education quality and skills training to meet the growing demand for skills. That means that the educational attainment level, especially in science, technology, engineering, and mathematics (STEM), has to catch up with countries with a higher level of development. The OECD Development Center estimated significant skilled labor shortages in Cambodia, Indonesia, and Thailand, as Figure 12.10 shows.

The Market Institution and Governance Gap

Successful businesses seize economic opportunities to create value added, thereby contributing to economic growth and cross-border economic cooperation. Businesses only thrive in an "ease of doing business" environment. Table 12.1 presents the World Bank's Ease of Doing Business ranking in 2020. The ranking includes subcategories showing how easily a business can start up, including registering and obtaining electricity, building permits, and credit. There are also measures to improve trust between businesses, for example protecting investor rights and contractual rights and resolving insolvency. Furthermore, the ranking includes the ease of trading across borders. Typically, the higher the ranking, the higher a country's development, for example as measured using the per capita GDP. Of course, other factors like social stability play a role, too. The rankings in the subcategories are illuminating. They indicate that starting a business in ASEAN, except in Singapore and Brunei Darussalam, is challenging. Registering property is testing in all ASEAN economies but Singapore.[2] Businesses in countries like Brunei Darussalam, Viet Nam, the Philippines, Cambodia, the Lao People's Democratic Republic (Lao PDR), and Myanmar have low access to credit. Some ASEAN countries, like Indonesia, the Philippines, Cambodia, and the Lao PDR, can use improvements in enforcing contracts. Finally, no ASEAN countries have a high rank in trading across borders. Table 12.1,

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1 The World Bank reported that, in 2019, the average secondary school enrollment rate was 76% for the world, 99% for the US, 100% for the European Union (EU), 88% for the PRC, and 99% for the Republic of Korea. For ASEAN, the rates were as follows: Brunei Darussalam 92%; Cambodia 45%; Indonesia 89%; the Lao PDR 66%; Malaysia 84%; Myanmar 68%; the Philippines 84%; Singapore 100%; Thailand 100%; and Viet Nam 87% (ASEAN Secretariat 2013). The average tertiary school enrollment rate was 38% for the world, 89% for the US, 75% for the EU, 54% for the PRC, and 96% for the Republic of Korea. For ASEAN, the rates are as follows: Brunei Darussalam 31%; Cambodia 15%; Indonesia 36%; the Lao PDR 14%; Malaysia 43%; Myanmar 19%; the Philippines 35%; Singapore 89%; Thailand 49%; and Viet Nam 29%.

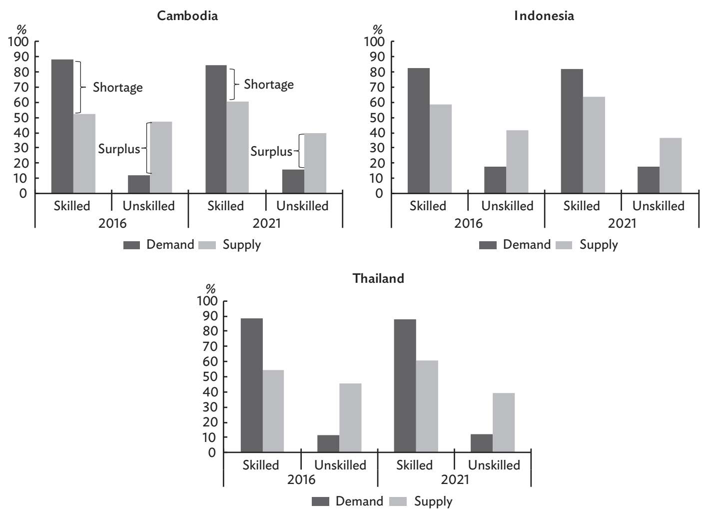
2 Interestingly, obtaining electricity is easiest in Thailand.

together with the overall ranking, indicates that ASEAN countries, except for Singapore, need to improve their business environment significantly, especially the institutional quality. They must all also put more effort into facilitating cross-border trade.

Governance is intimately related to the development of the business environment; that is, a low ranking in "Ease of Doing Business" reflects the underlying quality of the government. Figure 12.11 shows the World Bank's assessment of ASEAN's public governance; the longer the horizontal bar, the better the score.

The graphs show two noteworthy points. First, a country in which the government controls corruption and is more effective has a higher score in the Ease of Doing Business ranking in Table 12.1. The observation

Figure 12.10: The Current and Future Skills Demand and Supply in Three Emerging Asian Economies: Simulation



Notes: Skilled refers to all occupations above International Standard Classification of Occupations ISCO-08 level 1 and levels of education above International Standard Classification of Education ISCED 1997 level 1, while unskilled refers to all occupations of ISCO-08 level 1 and education ISCED 1997 level 1. Forward-looking data points are based on linear projections. We obtained the skill levels on the demand side by mapping ISCO-08 occupational categories from the Labour Force Surveys into the ISCO-08 skill levels according to the International Labour Organization (2019), merging levels 2, 3, and 4 as "skilled." The demand for skills refers to the occupational structure of employment. We obtained the skill levels on the supply side from the educational attainment variable in the Labour Force Surveys and mapped them to the ISCO-08 skill levels based on International Labour Organization (2012). We then compared the supply-side structure of skills with the demand-side data to determine mismatches.

Source: OECD Development Center. 2019. *Economic Outlook for Southeast Asia, China and India 2020: Rethinking Education for the Digital Era*. Paris: OECD Publishing. https://doi.org/10.1787/1ba6cde0-en

Table 12.1: Ranking of Ease of Doing Business, 2020

Economy	Global Rank	Starting a Business	Dealing with Construction Permits	Obtaining Electricity	Registering Property	Obtaining Credit	Protecting Minority Investors	Paying Taxes	Trading across Borders	Enforcing Contracts	Resolving Insolvency
New Zealand	1	1	7	48	2	1	3	9	63	23	36
Singapore	2	4	5	19	21	37	3	7	47	1	27
Denmark	4	45	4	21	11	48	28	8	1	14	6
Korea, Rep. of	5	33	12	2	40	67	25	21	36	2	11
United States	6	55	24	64	39	4	36	25	39	17	2
United Kingdom	8	18	23	8	41	37	7	27	33	34	14
Norway	9	25	22	44	15	94	21	34	22	3	5
Malaysia	12	126	2	4	33	37	2	80	49	35	40
Thailand	21	47	34	6	67	48	3	68	62	37	24
Germany	22	125	30	5	76	48	61	46	42	13	4
Canada	23	3	64	124	36	15	7	19	51	100	13
Japan	29	106	18	14	43	94	57	51	57	50	3
PRC	31	27	33	12	28	80	28	105	56	5	51
Brunei Darussalam	66	16	54	31	144	1	128	90	149	66	59
Viet Nam	70	115	25	27	64	25	97	109	104	68	122
Indonesia	73	140	110	33	106	48	37	81	116	139	38
Philippines	95	171	85	32	120	132	72	95	113	152	65

continued on next page

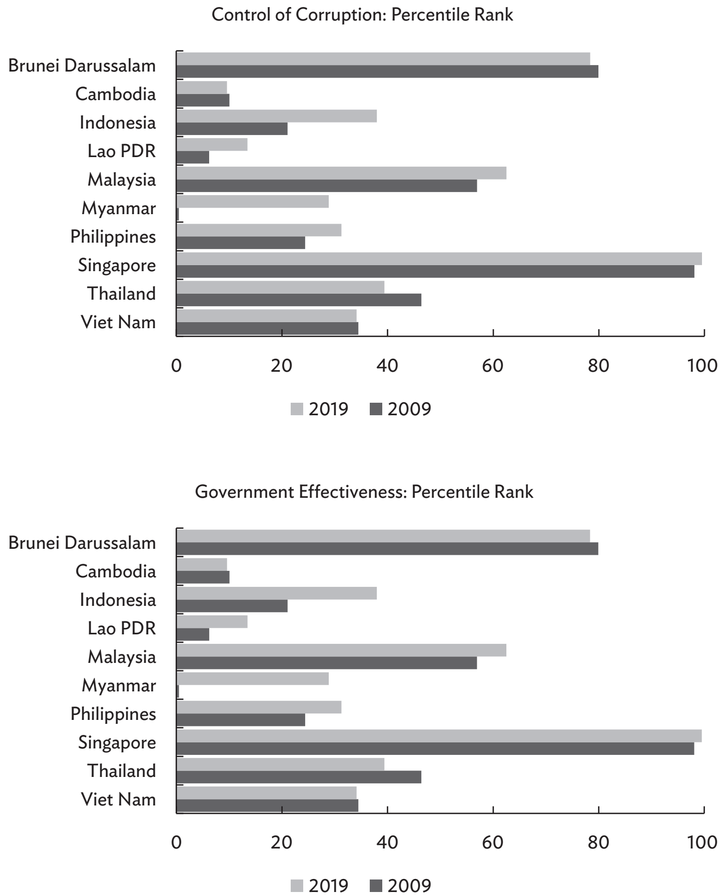
Table 12.1 *continued*

Economy	Global Rank	Starting a Business	Dealing with Construction Permits	Obtaining Electricity	Registering Property	Obtaining Credit	Protecting Minority Investors	Paying Taxes	Trading across Borders	Enforcing Contracts	Resolving Insolvency
Brazil	124	138	170	98	133	104	61	184	108	58	77
Cambodia	144	187	178	146	129	25	128	138	118	182	82
Lao PDR	154	181	99	144	88	80	179	157	78	161	168
Myanmar	165	70	46	148	125	181	176	129	168	187	164
Iraq	172	154	103	131	121	186	111	131	181	147	168
Somalia	190	188	186	187	153	186	190	190	166	116	168

Lao PDR = Lao People's Democratic Republic, PRC = People's Republic of China.

Source: World Bank Group. 2020. Ease of Doing Business Ranking.

Figure 12.11: Public Governance in ASEAN Economies, 2009 and 2019



ASEAN = Association of Southeast Asian Nations, Lao PDR = Lao People's Democratic Republic.

Notes: Control of corruption captures perceptions of the extent to which people exercise public power for private gain, including both petty and grand forms of corruption, as well as elites' and private interests' "capture" of the state. Government effectiveness captures perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies. The percentile rank indicates the country's rank among all the countries that the aggregate indicator covers, with 0 corresponding to the lowest rank and 100 to the highest rank. We adjusted the percentile ranks to correct for changes over time in the composition of the countries that the World Bank's Worldwide Governance Indicators cover.

Source: World Bank. Worldwide Governance Indicators. In *World Development Indicators*. https://databank.worldbank.org/reports.aspx?source=World-Development-Indicators (accessed 8 April 2021).

supports the assertion that the quality of public governance is related to the ability to nurture sound businesses and attract both domestic and foreign investment. For example, the Government of Singapore has the best score in controlling corruption and being effective, and Singapore ranks second globally in the Ease of Doing Business. In the same manner, Malaysia is a distant second among the ASEAN countries in the World Bank's global Ease of Doing Business ranking; its control of corruption and government effectiveness are only behind Singapore and Brunei Darussalam among the ASEAN countries.

Second, notice that ASEAN countries have not improved their public governance much over the past decade. They need to rein in corruption and raise government efficiency and policy effectiveness. While the positive external pull factors, such as strong growth and the rising middle-income class, in Asia are eliciting development in ASEAN, strengthening the intrinsic push factor can be critical for all ASEAN economies to achieve inclusive and sustainable growth and advance in the quality of living standards.

In summary, ASEAN has a growing economic system that has become more integrated over the past 2 decades. While ASEAN economies, in general, have made visible progress in socioeconomic development, especially in reducing poverty and growing a middle-income class, significant variation remains in their achievements across and within economies. To facilitate economic growth and development further and achieve the region's economic convergence, ASEAN has to overcome gaps in quality infrastructure and educational attainment. ASEAN countries also have to improve their domestic business environment, including allowing easier business entries, better access to credit, better contract enforcement, and easier cross-border trading. More importantly, ASEAN governments need to improve their institutional quality while strengthening their efficiency and effectiveness.

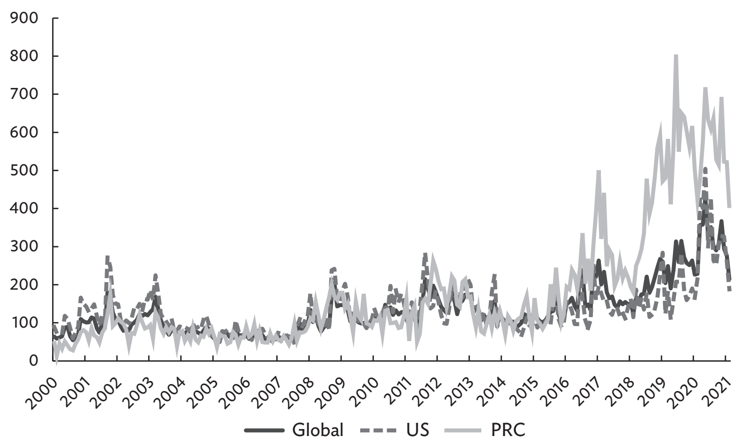
12.3 Geopolitical Tension, Decoupling, and Regional Comprehensive Economic Partnership

The rise of Asia, particularly with the PRC emerging as the world's largest economy (on a purchasing power parity basis) and competing as a global superpower, has been reshaping the global economic and political landscape over the past 2 decades. Heightened geopolitical tension and economic competition between the world's largest economies and trading partners have economic consequences for the rest of the world, particularly Asia. The tension is not going to ease soon, and ASEAN is caught in the middle. The impact on ASEAN's convergent growth is more complicated.

Multiple factors drive this tension. On the economic and commercial side, competition has intensified for the globally dominant status on goods and financial markets. Losing global market shares can potentially weaken the US dollar's dominance in the international payments system and the T-bills' dominance and unique position as safe assets (Brunnermeier, Merkel, and Sannikov, 2021; Gourinchas 2021). Furthermore, both economies have a strong awareness of a change in the technology landscape. Leading technology companies from the PRC and the US compete fiercely in sectors with very significant dynamic economies of scale, that is, the "winners take all" sectors. The competition escalates to debates on the superiority of political systems, social beliefs, and even values. The tension has led to noncooperative policies between the US and the PRC. The consequence is uncertainty in global economic policies, especially in cross-border trade and investment. Figure 12.12 shows the Economic Policy Uncertainty Indices for the PRC and the US.

Of course, not all the movement of the indices can be attributed to mutually hostile economic policies. For example, the PRC has been pursuing economic rebalancing from export- to consumption-driven

Figure 12.12: Economic Policy Uncertainty Index, January 2000–February 2021



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

Source: Economic Policy Uncertainty. https://policyuncertainty.com/ (accessed 7 April 2021).

and more inclusive growth since 2009 and has launched many reform programs and related policy changes. In the past 4 years, the US has also experienced internal political and policy uncertainty. Nevertheless, the rising and volatile indices since 2016, to a large extent, reflect the noncooperative US–PRC relationship or at least the visible escalation of economic conflicts between them. The US–PRC Summit in Alaska in March 2021 crystalized the nature of the tension. Thomas Wright (2021), director of the Center on the United States and Europe and a senior fellow of the Brookings Institution, wrote:

> Historically, the most volatile periods of rivalry between major powers is in the early stages; think of the late 1940s and the 1950s in the Cold War. The red lines become apparent only through interactions in crises. The greatest risk is for either side to miscalculate the resolve or intentions of the other. By getting real in Anchorage, both sides have taken the important first step toward a more stable relationship by acknowledging the true nature of their relationship.[3]

12.3.1 Rising Regionalization

Given the intensified geopolitical tension, businesses have to manage risks. Businesses will always consider where the market is and configure their value chains to save on production and transportation costs. They will also mitigate operational risks, financial and economic risks, and political risks. It is difficult to fathom the full impact of the Group of Two (G2) tension. However, the trend in 2019 provides hints for how events may transpire. (In 2018–2019, the conflict between the US and the PRC intensified, but the pandemic had yet to arrive.)

The following is an excerpt from an anonymous quote from a PRC company executive:

> 2019 was a challenging year for our North American market. Faced with uncertainties stemming from the Sino-US trade war, we quickly responded through all the staff's efforts. Our factory in Viet Nam has achieved approximately 90% of our previous final shipment to North America in a year.

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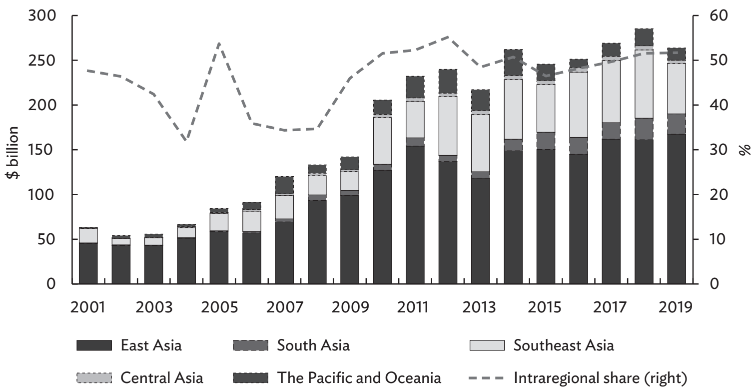
[3] The nature of the relationship is as in the previous paragraph: an intense competition between two systems and mutual resistance to letting the other dominate. In other words, it is not likely that the two sides will explore re-cooperation and even the possibility of a détente soon.

> We reduced the possible subsequent impact of the Sino-US friction on us. We expedited recruitment and ramped up production capacity in ASEAN, which ended up enhancing our competitiveness, our exports, and overseas market shares.

This is typically a rational firm-level response to political uncertainty. The micro-level example shows up in systematic macro-level data. The United Nations Conference on Trade and Development (UNCTAD) data show that, while the world's total inward FDI contracted by 13.4% year on year, inward FDI to Asia rose by 6.3% to $559.7 billion in 2019. In particular, more than half of the FDI inflows to Asia were intraregional—according to the Balance of Payments data (Figure 12.13). In 2019, intraregional FDI flows in Asia reached 51.7% of the total inward FDI flows to Asia. Similarly, while the world trade shrank in 2018–2019, Asia's intraregional trade increased by 1.5%. These observations may signal that businesses are turning their attention to the growing Asian production capability and consumer markets. The political risks and related economic policy uncertainty that the G2 tension produces are inducing them to reorient their value chains in Asia, increase their emphasis on the Asian consumer markets, and thus enhance Asia's economic integration.

Figure 12.13: Asia's Intraregional FDI Inflows, 2001–2019



FDI = foreign direct investment.

Source: ADB. 2021. *Asian Economic Integration Report 2021*. Manila; data from the Association of Southeast Asian Nations Secretariat, Eurostat, Organisation for Economic Co-operation and Development, United Nations Conference on Trade and Development, and national sources.

The Regional Comprehensive Economic Partnership Agreement (RCEP), which the region finalized in November 2020 after more than 8 years of negotiations, signifies crucial momentum to advance its economic integration efforts. It also reflects ASEAN economies' desire to expedite the economic integration process and realize the ASEAN Economic Community's agenda. They will also have access to the markets and resources in the broader Asia and the Pacific region. The ASEAN Secretariat (2020) stated:

> The Regional Comprehensive Economic Partnership (RCEP) Agreement is an agreement to broaden and deepen ASEAN's engagement with Australia, the PRC, Japan, [the Republic of] Korea, and New Zealand. ... The objective of the RCEP Agreement is to establish a modern, comprehensive, high-quality, and mutually beneficial economic partnership that will facilitate the expansion of regional trade and investment ... Accordingly, it will bring about market and employment opportunities to businesses and people in the region.

The **RCEP Agreement** clarifies regulations on "rules of origin," "customs procedures and trade facilitation," "sanitary and phytosanitary measures," and "standards, technical regulations, and conformity assessment procedures." ASEAN's summary statement ended by stating that "The RCEP Agreement will work alongside and support an open, inclusive, and rules-based multilateral trading system market and its factors of productions." If the RCEP gains full ratification, the agreement will enhance economic integration and co-growth in the Asia and Pacific region.

12.4 The COVID-19 Pandemic

The COVID-19 pandemic broke out in 2020. Due to the highly contagious nature of the disease, nearly all economies have introduced measures to curtail face-to-face contact and restrict mobility. Accordingly, the world has suffered from very significant supply and demand shocks. The interlinked global supply chains have amplified the supply shock. Financial interdependence across firms and markets has magnified the liquidity stress and deepened the bankruptcy concern. In response, many, if not all, governments have also deployed multiple fiscal policies to limit unemployment and bankruptcy. Central banks around the world have injected a large amount of liquidity to forestall widespread financial stress. Nevertheless, the COVID-19 pandemic will have a long-lasting impact on the world and the region.

12.4.1 Short-Term Implications

A machine search on the National Bureau of Economic Research and Centre for Economic and Policy Research working paper series, focusing on only empirical papers on COVID-19 in 2020 and January 2021, yielded about 500 articles. While the vast volume of papers called for a meta-analysis, these research papers broadly showed that the more effective a government is in containing the spread of COVID-19, the less costly the problem is to the government and its economy. Simultaneously, the research showed that the more people are aware of the highly contagious nature of the disease and its severe impact on personal and community health, the more they adopt social distancing and cooperate in lockdowns (Agarwal, He, and Yeung 2020). As many Asian economies experienced severe acute respiratory syndrome (SARS) in 2003, they understand the nature of such a disease and are better prepared than countries in the West. Their residents also tend to be more cooperative with authorities than their counterparts in the West. So far, with a few exceptions, Asian economies have performed better than Western countries in limiting the spread of COVID-19 and managing its damage to the economy.

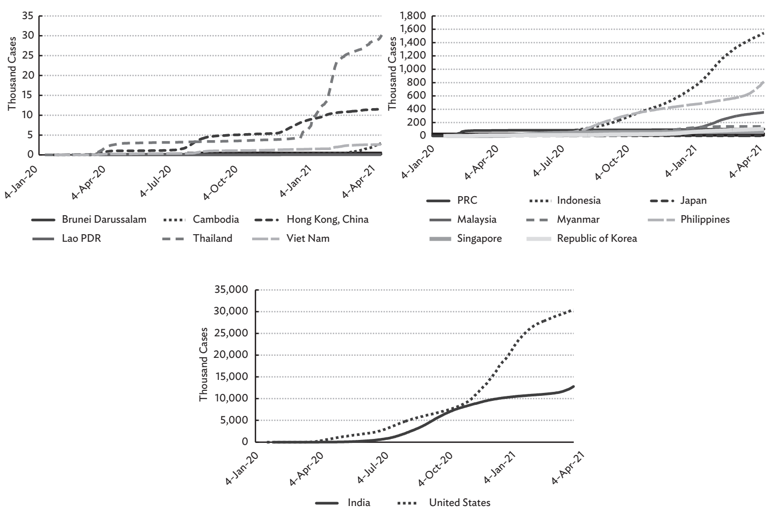
Some circumstantial evidence supports these points. Figure 12.14 shows that Asian economies, other than India, have far fewer cases of infection than the US. For example, Indonesia's population is about 83% of that of the US; however, its infection cases are only 5% of those of the US. As of 7 April 2021, World Health Organization data reveal that the US had more than 30 million infection cases and around 552,000 deaths, while Indonesia had 1.5 million cases and almost 42,000 deaths. These vast gaps cannot be due just to underreporting. They indicate that Asia has contained the COVID-19 pandemic much better than the West.

Asian economies have suffered less economic damage than the West as well. Figure 12.15 shows graphically that, in the 2020 pandemic year, the surge in unemployment in the US was substantially larger than in all the Asian economies except India and the Philippines. Estimations indicate that economic growth in developing Asia contracted by −0.4% in 2020, but East Asia has registered positive growth of 1.6%, reflecting a faster-than-expected recovery in the PRC (ADB 2020). Meanwhile, the US GDP contracted by 3.5%; its fiscal deficit reached $3.314 trillion (the fiscal spending was $6.5 trillion, and the year's GDP was $20.93 trillion).

Thus, there is plenty of evidence, albeit circumstantial, that the more successfully a country contains the coronavirus disease, the less costly the shock is. Asia is likely to stage a faster and stronger recovery from the pandemic shock. The consequence is that world resources will flow toward Asia, particularly the PRC, the first country to recover from the pandemic-driven economic shock. Indeed, Hansen (2021) wrote:

As the world struggled to contain the coronavirus crisis, foreign direct investment in the United States plummeted 49% in 2020 while investment in [the People's Republic of] China rose 4%, making China the largest recipient of foreign inflows for the first time (UNCTAD Global Investment Trend Monitor 38 report, January 24 2021). ... China pulled in $163 billion in new investments from foreign businesses in 2020 while the U.S. fell into second place with $134 billion. ... The U.S. and China had broadly different responses to the pandemic, with China's government instituting strict, large-scale lockdown measures in early 2020 while the United States' response was far less centralized and far less effective in curbing the spread of the virus. ... That prompted a major shift in the global economy—while the United States and other Western countries struggled to contain the pandemic, China went back to work, manufacturing picked up, and as a result China was the only major economy to report economic expansion in 2020.

Figure 12.14: Cumulative Confirmed Cases of COVID-19 in East and Southeast Asia, India, and the United States

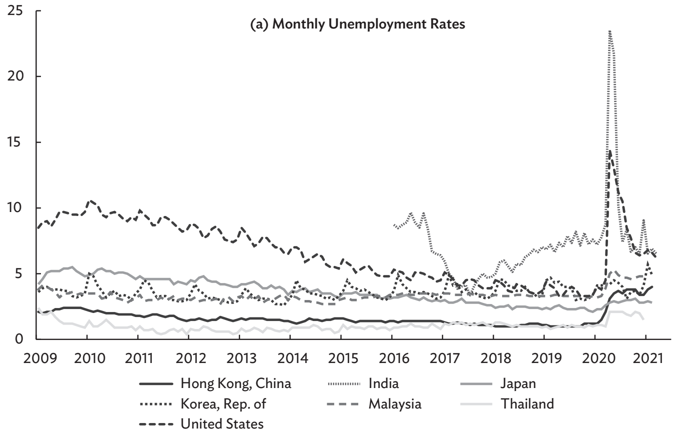


COVID-19 = coronavirus disease, Lao PDR = Lao People's Democratic Republic, PRC = People's Republic of China.

Note: Data as of 7 April 2021.

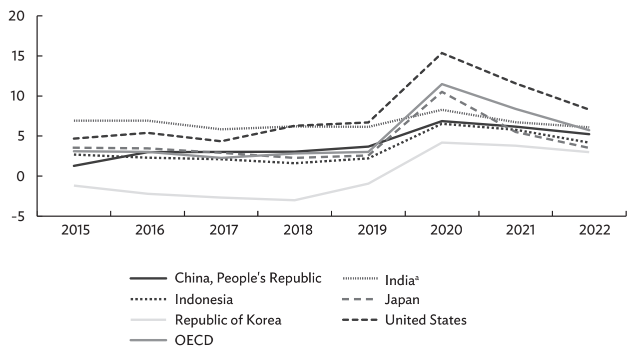
Source: World Health Organization and Centre for Health Protection; downloaded from CEIC Data.

Figure 12.15: Unemployment Rates in Asian Economies and the United States (%)



Source: CEIC.

Figure 12.16: Government Deficit, 2015–2022 (% of nominal GDP)



GDP = gross domestic product, OECD = Organisation for Economic Co-operation and Development.

[a] Fiscal year.

Notes: The financial balances include one-off factors, such as those resulting from the sale of mobile telephone licenses. The data for OECD countries are on a national accounts basis, while the data for non-OECD countries follow country-specific definitions. For more details, see the Sources and Methods of the OECD Economic Outlook (http://www.oecd.org/eco/sources-and-methods.htm).

Source: OECD.Stat. Economic Outlook No. 108—December 2020. https://stats.oecd.org/viewhtml.aspx?datasetcode=EO108_INTERNET&lang=en (accessed 7 April 2021).

There are some risks. Globally, governments have incurred huge fiscal deficits to combat the pandemic. Figure 12.16 shows that the pandemic caused the governments in OECD economies to incur a double-digit government deficit, far beyond that of Asian economies, except for Japan. It will take some years for the heightened government debts to subside.

In the fourth quarter of 2020, the US federal debt surged to 129% of GDP. The US money velocity (GDP/M1) dropped to 1.22 due to the expansionary monetary policy to counter the COVID-19 shock, according to data from the Federal Reserve Bank of St. Louis. The money velocity is as low as in 1968, the beginning of the high US inflation regime that ended in 1983–1984. Thus, the US currently faces a high government deficit, increased government debt, and historically low money velocity. With the rapid deployment of vaccines in the US, its recovery prospect in 2021 has brightened. However, if the forced savings during the pandemic turn to pent-up consumption, inflation might follow.[4] Inflation expectations have already pushed long-term interest rates higher in the US economy, rattling global financial markets in February 2021. Overall, high-income economies with rapid vaccination campaigns face a qualitatively similar situation. These countries have to strike a very delicate balance: raise taxes to enhance government revenue, curtail government spending, slightly tighten the money supply, and yet protect a tentative recovery. The US particularly has to avoid the temptation to activate seigniorage tax (taking advantage of the universal use of the Treasury bill as a safe asset). Mismanagement of these conditions could have negative global spillovers, triggering global inflation, financial volatility, and recession.

Another concern is widening income and non-income inequality during the pandemic. The pandemic has cost many jobs, but the employment effect has been uneven, more negatively and directly hitting face-to-face jobs, many of which are in service industries—retail, food and restaurant service, entertainment, and labor-intensive manufacturing—all in low-skill and informal sectors.

Furthermore, the fiscal and monetary stimulus programs may have regressive distributional effects if they fail to reignite growth and generate employment successfully. Lowering the interest rates reduces the value of liabilities with a floating rate (e.g., mortgages) and raises the value of assets. Households with housing and mortgage loans benefit. Fiscal support that incentivizes companies to retain employees may induce them to keep essential and high-performing workers who may be able to work elsewhere or even virtually. Job losses will concentrate

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4 Research has shown that consumers' consumption experiences affect their inflation expectations–the more expensive goods they buy, the higher their inflation expectations (Agarwal, Chua, and Song 2020).

on low-skilled and informal workers with limited re-employment value. Consequently, there are many reasons to suspect that the pandemic has a regressive income and wealth redistribution effect.

12.4.2 Longer-Term Implications

An interesting impact of the COVID-19 pandemic is that it has accelerated the adoption of digital technology, leading to many changes with contradictory economic effects.

Digital–IoT–AI Transformation

Computing technology allows enormous data storage and extremely speedy data processing. Naturally, digital transformation follows: we can digitize many observations into data, even those that we previously believed to be qualitative observations. Then, data analytics, machine learning, computer vision, and natural language processing enable "machines" to perform tasks that normally require human intelligence, such as visual perception, speech recognition, decision making, and even translation between languages. The AI age has arrived.

The digital–IoT–AI transformation fundamentally changes every aspect of human behavior. It expands our speed, scope, and accuracy in collecting, organizing, and processing information and in making predictions. Machines can often perform some human tasks (including non-routine ones) much better than humans themselves. For example, machines are more able than humans to identify regular and distinctive patterns. Hence, in medicine, AI helps to decipher scans and X-ray images to improve the reading of patients' physiological condition. Airports can use facial recognition to process passengers through boarding pass control, luggage tagging, and so on. Police forces use the same to identify criminals. In agriculture, farmers use drones equipped with AI to count flowers, enabling them to make sharp and reliable yield predictions.

In businesses, data analytics, AI, robots, and drones change the design, production, logistics and distribution, retailing, and so on. Universities now offer courses and programs in such subjects as accounting technology, marketing technology, and human resources technology. Some financial institutions use intelligent robots to help serve customers, while others use machine learning to identify trustworthy borrowers or worthy investment prospects. The digitized payment system substantially raises transaction efficiency and speed, locally and internationally. Fintech may also raise financial inclusion and small and medium-sized firms' access to credit.

The application of blockchain technology changes contractual boundaries. The technology allows the development of "smart contracts," that is, self-executing contracts with the terms of the agreement between buyer and seller directly input into lines of code. These can strengthen the trust between contracting parties without relying on extrinsic monitoring.

In construction, AI aids in building maintenance, surveying, and railroad construction and maintenance. In city planning, AI helps to coordinate traffic lights to improve traffic flows and guide emergency vehicles to find efficient routes to their destinations. There are more examples than one can cite, and there are many more exciting future developments. These new capabilities have a substantial impact on every aspect of human life: communication, education, dating, transportation, production, business, governance, and so on.

The digital–IoT–AI transformation is part of the "general-purpose" technological breakthrough, which the World Economic Forum coined as the Fourth Industrial Revolution (Schwab 2016). Rational balancing opinions offset the excitement. Summers (2020) raised the concern about a savings glut and a systematic decline in the demand for investment. The implication is sluggish growth. Gordon (2018) advanced the secular stagnation view, providing useful empirical observations. The US GDP growth slowed by more than half from 3.2% in 1970–2006 to 1.4% in 2006–2016. Part of the slowdown is due to demographic changes, declining immigration, and decreasing labor participation. However, half of it is due to slower productivity growth stemming from education attainment and return to innovations. Gordon (2018) argued that information technology, robots, and AI lead to evolution rather than revolution.

These respectable arguments can be compatible with the idea that macroeconomic data may not properly measure the productivity growth due to digitization, IoT, robotization, and AI or that productivity growth takes time to materialize. First, the digital–IoT–AI transformation could indeed save investments in bricks and mortar and heavy machinery. Second, the may not measure improvements in efficiency and effectiveness that, for example, stem from the more informed and reliable consumption choices that the digital–IoT–AI transformation allows. Third, these arguments are compatible with the assertion that general-purpose technological breakthroughs have long-delayed impacts.

Many fundamental innovations have significant delayed impacts because translating them into material practices takes time. Electricity dramatically affects our life. However, we did not feel the effect widely until we had power plants and electric wires and had developed electricity-driven machine tools and electrical household appliances. Furthermore, there is network externality. Telephony would not be very useful without the majority of the population having a phone. Finally, the spreading of innovations always faces resistance. There was a time when the Luddites destroyed textile machinery in Nottinghamshire, England, in the 18th century. In the US, Connecticut and New York used to have a speed limit of 12 miles per hour, and an automobile had to reduce its speed when meeting or passing horse-drawn vehicles; they had to coexist safely. The same prolonged delay applies to the digital–IoT–AI transformation.

Accelerated Changes Due to COVID-19

However, the pandemic mutes resistance and indeed accelerates changes. A relevant aspect of the digital–IoT–AI transformation is that it allows telepresence; humans can act without physiological presence (Baldwin 2019). This is highly valuable in a pandemic. All sectors of human activities are expanding their adoption of virtual technology to conduct as much business as possible without face-to-face contact. Thus, classes, meetings, shopping, entertaining, client–physician interfacing, and many other activities have become virtual. The mass media have widely reported the accelerated changes; for example, as The Economist reported on 16 November 2020, "The World in 2021—Covid-19 Forced Businesses To Experiment." The same applies to consulting companies. McKinsey & Company, in October 2020, published a survey that showed "How COVID-19 Has Pushed Companies over the Technology Tipping Point—and Transformed Business Forever." PWC, Deloitte, KPMG, and so on have all produced similar reports.

Recall that ASEAN faces hurdles to its sustainable convergent growth—the infrastructure gap, the educational gap, and the government efficiency and effectiveness gap. Digital–IoT–AI technology can make contributions to bridging these gaps. For example, technology allows better estimation, better monitoring, and more robust cost control in infrastructure construction. It can also tokenize investment—tokenization allows many more people, including the non-high-net-worth type, who benefit directly from an infrastructure project to invest their savings in the project. In addition, the technology can create smart contracts to raise the private sector's confidence in gaining a return. The application of the technology thus may increase the possibility of public–private partnerships sharing the investment burden.

The potential of digital technology in education is well known. Because of the pandemic, governments have either banned or restricted face-to-face meetings and classroom activities. From kindergarten pupils to university students and teachers, as well as researchers, people have adopted the technology. They have all discovered expanded boundaries for teaching and research. The whole sector is continuing to develop new insights into and approaches to using the technology to disseminate information, enrich discussions, and deliver impactful feedback. Then, it is also apparent that the technology can expand the student–teacher ratio without reducing the teaching effectiveness. The same happens in the training sector. Many small and medium-sized enterprises have emerged to conduct teletraining in, for example, languages, financial literacy, job skills, and so on. The trend can contribute to bridging the education gap in ASEAN.

By the same token, the application of the technology can raise public governance and government efficiency and effectiveness. For example, by adopting the technology, a government can simplify and reduce the burdens of registering a business, obtaining licenses and permits, and paying taxes. It can also keep better records and can better monitor and thus enforce regulations. These measures both elevate government efficiency and reduce the chance of extracting bribery. Regulatory authorities should also prevent fraudulent activities and mitigate the risks of data privacy breach, intellectual property infringement, and consumer rights violations.

Remaining Challenges

The rise of e-commerce, digital payments, online work, cloud storage, and other digitally enabled services underlines the extent to which digital transformation has penetrated deeply into many socioeconomic systems. A new ADB (2021) report*, Asian Economic Integration Report, 2021: Making Digital Platforms Work for Asia and the Pacific*, discusses the opportunities and challenges of digital economies.

A few points in the report are worth emphasizing. First, while the private sector may be ready, states need public investment in digital infrastructure and connectivity to deliver affordable mobile and broadband services. Many pockets in ASEAN with nontrivial populations have this need. Second, upgrading education and labor market policies remains crucial for making digital transformation inclusive and reaping the benefits of digital economies. Third, as the digital–IoT–AI transformation spreads in ASEAN, governments need to adopt rigorous redistribution programs.

The digital platform penetration index using digital platform data shows that digital platform use and activity vary significantly across economies (Table 12.2), but the index is generally higher in high-income economies in the region, together with the PRC, Malaysia, and Viet Nam. The largest economies in Southeast Asia and South Asia, namely

Indonesia and India, appear immediately after this group, followed by Brunei Darussalam, the Philippines, and Thailand among the ASEAN economies.

The issue of the digital divide, with its deep entrenchment in underlying economic, social, political, and cultural inequalities, can also restrain the success of the digital economy. With such disparities, the distribution of the benefits of the platform economy will not be equitable within and across countries. The digital divide also emerges due to the existing gaps in income, education, gender, and social status. While digital connectivity and infrastructure remain crucial for safe and affordable access to digital technology, digital skill is an essential element to bridge the gap. Studies have also shown that the better skilled have better access to technology.

Physical infrastructure, education, and skills remain integral components of facilitating digital transformation and enabling it to drive more inclusive growth. However, governments need to be cognizant that income inequality may worsen with the rise of the digital economy. Greater use of technology for economic opportunities may leave some groups of people behind. There should be plans to redistribute the incomes and benefits from the digital economy more broadly to avoid sharp deterioration in income distribution. The digital economy is well known to have vast dynamic and static economies of scale and scope. Furthermore, Gordon (2018) was right that digital–IoT–AI transformation generates a lot of evolution, which means a lot of job displacement.

We therefore have to be empathetic for displaced workers beyond middle age. We also need to be concerned that job creation in the new age will tilt against the low human capital type. Children in poorer households could easily lag behind plainly because they lack equipment and training. Indeed, all graduates need to be proficient in data analytics and technology. Inclusive growth entails helping the disadvantaged and preparing the future generation with the right skills. Finally, in the digital world, companies can inadvertently conduct statistical discrimination in pursuing efficiency and profits. For example, some older and less healthy individuals may end up paying a higher insurance premium or having to raise consumer credit at a higher cost.

Finally, we have to be concerned about the long-term negative impact of COVID-19 on the lower-income group via the 2020 education stoppage. Due to the pandemic, many schools closed. Intuitively, poor children have less access to Wi-Fi, laptops, and smartphones (while rich children have all these and tele-tutors). Children in low-income households also have a less stimulating home environment than their peers in more affluent households. The long-term implication of this

Table 12.2: Digital Platform Penetration Index, 2019

Economy	DPP Index	Digital Platform Penetration Sub-components			
		Revenue-to-GDP Ratio	Per User Spending, Proportion of per Capita Income	User Accounts-to-Population Ratio	Revenue-to-Population Ratio (PPP Adjusted)
PRC	2.58				
Korea, Rep. of	2.53				
Australia	2.10				
Hong Kong, China	2.03				
New Zealand	1.88				
Japan	1.78				
Singapore	1.76				
Malaysia	1.10				
India	1.02				
Viet Nam	0.94				
Indonesia	0.92				
Brunei Darussalam	0.83				
Philippines	0.82				
Armenia	0.81				
Pakistan	0.80				
Kazakhstan	0.79				
Thailand	0.79				
Azerbaijan	0.78				
Sri Lanka	0.65				
Georgia	0.58				
Kyrgyz Republic	0.50				
Uzbekistan	0.48				
Nepal	0.46				
Fiji	0.46				
Cambodia	0.44				
Tajikistan	0.42				
Bangladesh	0.39				
Myanmar	0.39				
Bhutan	0.31				
Mongolia	0.28				
Lao PDR	0.25				
Timor-Leste	0.25				
Papua New Guinea	0.21				
Turkmenistan	0.16				

DPP = digital platform penetration, GDP = gross domestic product, Lao PDR = Lao People's Democratic Republic, PCA = principal components analysis, PPP = purchasing power parity, PRC = People's Republic of China.

Notes: The sub-components are normalized. Low- to high-value spectrum:

We estimated the PCA using data from 2017 to 2019. The divisions represent the groups above and below the 33rd and 66th percentiles. Users in the second column refer to AdTech-exposed internet users.

Source: ADB. 2021. *Asian Economic Integration Report 2021*. Manila; data from Statista. Digital Market Outlook. https://www.statista.com/outlook/digital-markets; and Statista. Mobility Market Outlook. https://www.statista.com/outlook/digital-markets.

gap awaits studies. We speculate that the pandemic-related education stoppage is a lot more costly for poorer children in the longer term.

12.5 Conclusion: Reflection on Governments' Role

Asia is facing a precarious time due to the pandemic, which has posed multiple challenges in addition to the increased geopolitical tensions between the world's largest economies. A tension-mounted time is an excellent time to reflect. Reviewing Asia's (and ASEAN's) economic journey in the past 2 decades and the challenges due to the G2 tension and the pandemic, we identify some important economic lessons.

First, ASEAN has a strong desire to develop; its hard work is yielding impressive results. Many parts of Asia, especially ASEAN, are still emerging economies. Their governments have crucial roles in the nations' attainment of sustainable development. A time-honored point is prominent: businesses deliver factor earnings and goods and services to consumers; they drive growth. However, businesses rely on both hard and soft infrastructure. Both are public goods that governments have the responsibility to develop.

The former, of course, includes efficient infrastructure that facilitates production and transportation. In the era of global warming, it should also include infrastructure that protects properties, lives, and the environment. Long-term survival is a universal human goal; infrastructure for sustainability is a precondition for long-term prosperity.

The latter is exceptionally fundamental. Soft infrastructure pertains to efficient and effective market institutions (e.g., transparent, simple, and enforced rules and regulations) that channel people's energy to seek and actualize business opportunities. It includes protecting rights to facilitate the establishment of trust between savers and borrowers.

Maintaining financial and economic stability is also part of the governments' responsibilities. The necessary policies additionally include building safer and healthier societies and designing sensible redistribution across income classes and generations to progress in harmony. Such an environment induces people to invest time and effort in developing physical, organizational, and human capital patiently. They will be more willing to pool their savings to support the building of a better future, including infrastructure developments and education. The governments in ASEAN can gain great mileage from sustainable development in building sound market institutions, catering to financial and economic stability, and establishing sound health care and redistribution programs.

Our second point of reflection is that, while crises or big shocks will happen, there are always silver linings. The Asian financial crisis prepared Asia for the great financial recession. The SARS virus prepared Asia for the COVID-19 pandemic. The G2 tension may have induced more integration and cooperation in Asia. The devastating COVID-19 pandemic is accelerating the adoption of the digital–IoT–AI transformation and may spur productivity growth. Humans are resilient—we survive because we find solutions to overcome adversity. In this spirit, governments and private sectors can work together. Governments in the region should seize the moment to promote deeper regional economic integration, invest in digital infrastructure and wireless access, and invest in the training of workers and companies to tune into the virtual technology. They should partner with the private sector to multiply the gains from the opportunities that crises present.

Our third point of reflection is the need for policy makers to anticipate challenges. The pandemic has produced obvious challenges. Developed economies may inadvertently take missteps due to the challenge of protecting a recovery, a large deficit, and debt and inflation worry. Governments should consider what they should do now to mitigate the potential damage and how they can prepare their economies for future shocks. Furthermore, governments should consider strategies for effective income redistribution and manage income and non-income inequality if embracing the digital–IoT–AI technology creates winners that take all and concentrate the market power. With accelerating digital transformation, governments should ensure safe and affordable access to digital technology while protecting data and privacy security.

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13

New Financial Technologies, Sustainable Development, and the International Monetary System

Eswar Prasad

13.1 Introduction

This chapter provides a broad analytical overview of how new financial technologies are likely to influence various aspects of the process of economic development. While the advent of decentralized cryptocurrencies such as Bitcoin has received considerable attention, a broader set of changes caused by advances in technology are likely to eventually have a more profound and lasting impact, particularly on emerging market and developing economies.

New financial technologies—including those underpinning cryptocurrencies—herald broader access to the financial system, quicker and more easily verifiable settlement of transactions and payments, and lower transaction costs. Domestic and cross-border payment systems are on the threshold of transformation, with significant gains in speed and lowering of transaction costs on the horizon. However, many of these benefits come with attendant risks and costs. For instance, the efficiency gains in normal times from having decentralized payment and settlement systems need to be balanced against their potential technological vulnerabilities and the repercussions of loss of confidence during periods of financial stress.

Multiple payment systems could improve the stability of the overall payment mechanism in the economy and reduce the possibility of counterparty risk associated with the payment hubs themselves. At the same time, privately managed payment systems without official backing could be severely tested in times of crisis of confidence and serve as channels for risk transmission. Decentralized electronic payment systems are also exposed to technological vulnerabilities that could entail significant economic as well as financial damage. Thus, governments and regulators face a difficult balance in fostering innovation and decentralization while keeping risks under control.

Meanwhile, rapid changes are underway that could change the structure of financial markets and the role of central bank money as a payment system. The potentially transformative potential of cryptocurrencies was highlighted by Facebook's 2019 announcement that it plans to issue a cryptocurrency called "Libra" (the project was recently renamed "Diem"). The cryptocurrency will actually be issued and managed by the Libra Association, although Facebook is likely to retain a dominant role.

Facebook envisions Libra as a digital currency that will be limited to serving as a medium of exchange and that will be fully backed by a reserve constituted of a basket of safe assets denominated in major hard currencies, an approach that is in some ways akin to the issuance of a currency under a currency board arrangement. According to Facebook, the goal is to create a more inclusive financial system as well as a more efficient and cheap payment system for both domestic and cross-border transactions. The fully backed nature of Libra suggests that it will provide a stable store of value and will not have any monetary policy implications. The latter proposition is of more direct concern to regulators, who are equally worried that Libra could serve as a conduit for the flow of illicit funds, both domestically and across national borders.

It is an intriguing, and in some ways disturbing, prospect that other large nonbank financial institutions and nonfinancial corporations could also become important players in financial markets, perhaps even issuing their own tokens or currencies. Such digital tokens issued by Facebook and other well-known nonfinancial corporations such as Amazon could end up being seen as stores of value as well, given the scale and financial might of these corporations. The major implications of such developments would not just be a reduction in the demand for central bank money as mediums of exchange or stores of value, but the consequences they would have for the business models of banks and other existing financial institutions.

Financial institutions, especially banks, could face challenges to their business models, as new technologies facilitate the entry of institutions (or decentralized mechanisms) that can undertake financial intermediation and overcome information asymmetries. Banks will find it difficult to continue collecting economic rents on some activities that cross-subsidize other activities. The emergence of new institutions and mechanisms could improve financial intermediation but will pose significant challenges in terms of regulation and financial stability.

The rapid rise of new financial technologies and digital payment systems, including cryptocurrencies, has elicited a range of responses from central banks and governments, from trying to adapt the changes to their advantage to resisting certain developments due to concerns about monetary and financial instability. One response has been for central banks themselves to innovate in the means for producing money. In particular, many central banks are exploring the possibility of issuing digital versions of their fiat currencies.

At a basic level, central bank digital currencies (CBDCs) are digital forms of central bank money. The scope of CBDCs encompasses both retail and wholesale payment systems. Wholesale CBDCs entail some efficiency improvements but not fundamental changes to the interbank payment system managed by central banks, since balances held by commercial banks at the central bank (reserves) are already in electronic form. Retail CBDCs, which would be a digital complement to, or substitute for, physical cash, would be more of a revolutionary change. Retail CBDCs can take one of two forms—either token-based or value-based. These have very different implications for monetary and other policies.

The motives for issuing retail CBDCs range from broadening financial inclusion to increasing the efficiency and stability of payment systems (Prasad 2021). For instance, Sweden's Riksbank is actively exploring the issuance of an e-krona, a digital complement to cash, with the objective of "promoting a safe and efficient payment system." Both of these considerations are relevant for developing economies. CBDCs could function as payment mechanisms that provide stability without necessarily limiting private fintech innovations or displacing privately managed payment systems. Other central banks that have already issued, or are considering issuing, CBDCs, especially those in developing economies, seem to give higher priority to providing households with easier access to electronic payment systems.

There are many potential advantages to switching from physical to digital versions of central bank money, in terms of easing some constraints on traditional monetary policy and providing an official electronic payment system to which all agents in an economy, not just financial institutions, have access. The basic mechanics of monetary policy implementation will not be affected by a switch from physical currency to CBDCs. However, other technological changes that are likely to affect financial markets and institutions could have significant effects on monetary policy implementation and transmission.

New forms of money and new channels for moving funds within and between economies could also have implications for international capital flows, exchange rates, and the structure of the international monetary system. The proliferation of channels for cross-border capital flows will make it increasingly difficult for national authorities to control these flows. Emerging market economies will face particular challenges in managing the volatility of capital flows and exchange rates, and could be subject to greater monetary policy spillovers and contagion effects.

13.2 Overview of Financial Inclusion and Digitization in Developing Economies

Cash still remains an important method of payment in many economies, although a few of them are increasingly shifting toward electronic forms of payment for retail transactions rather than using cash. This is true of some developed economies as well as some emerging market and developing economies, although the patterns are not uniform in either of these groups of countries. In this section, I examine the relative importance of cash, as well as changes in indicators of that importance, in different regions of the world.

13.2.1 Changes in Currency Stocks Relative to Monetary and Real Indicators

Table 13.1 examines the ratio of currency to M2, an indicator of the relative importance of cash in an economy's total money supply, as measured by a broad money aggregate.[1] In most Asian economies this ratio declined from 2004 to 2020. The exceptions are, interestingly enough, three high-income economies—Japan; the Republic of Korea; and Taipei,China—where this ratio actually went up over this period, along with one low-income economy, Bangladesh. In Japan, for instance, this is partly a reflection of the rapid expansion of the central bank's balance sheet through unconventional monetary policy operations, which included printing money to buy government bonds and other financial assets. In the People's Republic of China (PRC), the ratio fell

1 The regional averages referred to in this section are unweighted, cross-sectional averages.

Table 13.1: Some Financial Statistics for Selected Asian Economies

	Currency to M2 (%)		Currency to GDP (%)		Size of Informal Economy (% of GDP)	
	2004	2020	2004	2019	2004	2015
Bangladesh	13.25	13.62	4.72	6.67	36.50	27.60
Cambodia	38.00	11.11	5.40	11.91	46.74	33.85
PRC	8.45	3.85	13.27	7.71	14.31	12.11
India	18.64	15.38	13.27	11.77	23.87	17.89
Indonesia	12.51	10.59	5.42	5.04	25.18	21.76
Japan	8.02	8.40	16.49	21.23	11.09	8.19
Rep. of Korea	2.57	4.58	2.99	6.50	26.23	19.83
Taipei,China	2.89	4.64	5.99	11.40	32.04	28.97
Thailand	9.47	9.11	10.55	11.33	49.45	43.12
Viet Nam	22.05	12.07	14.00	19.81	18.40	14.78
Average	13.58	9.33	9.21	11.34	28.38	22.81

GDP = gross domestic product, PRC = People's Republic of China.

Notes: Estimates of the size of the informal economy are from Medina and Schneider (2018). Currency and M2 data are based on the amount in December of that year or the latest available month for the 2020 data. For India, M3 is used instead of M2. The averages shown in the last row are unweighted cross-sectional averages.

Source: Data provided by central banks and compiled by CEIC Data.

from 8.5% to 3.9%, making it the country with the lowest ratio in the group. The ratio is close to 10% in both Indonesia and Thailand, and about 15% in India.

The ratio of currency to nominal gross domestic product (GDP), another indicator of the importance of cash in an economy, is shown for 2004 and 2019 in the second block of Table 13.1. The pattern is similar to that in the first block, with the ratio rising for Japan; the Republic of Korea; and Taipei,China, as well as a few other economies. The ratio is below 8% for Bangladesh, the PRC, Indonesia, and the Republic of Korea, and over 21% for Japan. In short, cash remains important in much of Asia, although, at least based on these crude indicators, its importance has declined in most emerging markets while rising in developed economies.

The final block of Table 13.1 shows measures of the size of the informal economy, which often tends to be positively correlated with the usage of cash. Estimates of the size of the informal economy, based on work by Medina and Schneider (2018), show that the relative size of the informal economy as a ratio to GDP fell in all Asian economies over this period. In 2015, the range of estimates of this ratio was from 8% in Japan to 43% in Thailand. In every Asian economy examined here, the relative size of the informal economy declined over the period 2004–2015.

Table 13.2 shows similar data for a selected set of African countries. Relative to Asia, the share of currency in M2 is much higher in Africa, although it has declined sharply in a number of countries in the region. For instance, in Kenya, where mobile payment technologies have become widely prevalent in recent years, the ratio fell from 15.9% in 2004 to 8.4% in 2020. The sharpest fall in this ratio is in Nigeria, which is now the largest economy in Africa—from 24.1% in 2004 to 7.3% in 2020. On average, the currency to M2 ratio has fallen in Africa, but the ratio of currency to GDP has risen slightly. Virtually every African economy is estimated to have a large informal economy, with only modest progress in reducing the relative size of the informal economy in 2004–2015. Interestingly, Nigeria has one of the lowest ratios of currency to M2 in the group, the lowest ratio of currency to GDP, but also the highest ratio of the estimated size of its informal economy to measured GDP.

Table 13.2: Some Financial Statistics for Selected African Countries

	Currency to M2 (%)		Currency to GDP (%)		Size of Informal Economy (% of GDP)	
	2004	2020	2004	2019	2004	2015
Algeria	23.59	34.14	14.23	26.90	27.76	23.98
Egypt	13.37	13.23	12.95	11.18	33.92	33.32
Ghana	36.64	20.52	9.56	4.39	42.90	39.97
Kenya	15.91	8.38	5.53	2.75	34.64	33.43
Morocco	22.89	25.11	16.90	21.73	33.92	27.13
Nigeria	24.11	7.28	3.06	1.86	56.72	52.49
South Africa	5.88	5.01	3.73	3.27	26.58	21.99
Zambia	15.41	12.21	2.84	3.37	47.60	32.99
Average	19.72	15.73	8.60	9.43	38.01	33.16

GDP = gross domestic product.

Notes: Estimates of the size of the informal economy are from Medina and Schneider (2018). Currency and M2 data are based on the amount in December of that year or the latest available month for the 2020 data. The averages shown in the last row are unweighted cross-sectional averages.

Source: Data provided by central banks and compiled by CEIC Data.

Table 13.3 provides similar data for a group of Latin American economies. On average, the share of currency in M2 for the countries in the region was 21.8% in 2020, which is higher than the average for Asia and Africa. A number of economies, such as Argentina, Bolivia, and Paraguay, reported ratios above 25%. The average ratio of currency to nominal GDP in the region rose from 5% in 2001 to 7% in 2019.

Table 13.3: Some Financial Statistics for Selected Latin American Countries

	Currency to M2 (%)		Currency to GDP (%)		Size of Informal Economy (% of GDP)	
	2004	2020	2004	2019	2004	2015
Argentina	36.80	31.10	6.89	4.29	24.30	24.99
Bolivia	59.00	43.41	5.34	17.40	66.70	62.30
Brazil	8.90	9.37	2.48	3.64	37.30	37.60
Chile	5.20	9.00	2.50	4.94	16.90	16.70
Colombia	16.00	19.33	5.05	8.39	35.30	37.60
Costa Rica	11.00	-	2.62	-	24.00	16.70
Mexico	13.60	16.51	4.66	7.12	29.80	24.50
Paraguay	38.00	27.98	3.98	6.07	36.30	33.60
Peru	7.80	17.87	1.78	8.07	53.50	31.70
Uruguay	53.74	21.31	5.16	3.90	40.70	34.50
Venezuela	12.00	-	2.57	-	36.20	52.40
Average	23.82	21.76	4.95	7.09	36.45	33.87

GDP = gross domestic product.

Notes: Estimates of the size of the informal economy are from Medina and Schneider (2018). Currency and M2 data are based on the amount in December of that year or the latest available month for the 2020 data. The averages shown in the last row are unweighted cross-sectional averages.

Source: Data provided by central banks and compiled by CEIC Data.

A case study for Colombia reinforces the point about the importance of cash in Latin America (see Arango-Arango, Suárez-Ariza, and Garrido-Mejía 2017). A survey of the general public and small traders in the country's five main cities was conducted by the Banco de la República. The survey indicated that even urban consumers who have a high degree of access to electronic payment instruments still make 97% of their payments in cash, mainly due to the limited acceptance of such instruments in their daily transactions. The reluctance of small businesses to accept electronic payments is attributed to their perceptions of the cost involved and the prospect of higher tax burdens. Electronic payments account for barely one-third of higher-value transactions (roughly above $470) and about 12% of the total value of all transactions.

13.2.2 Measures of Financial Inclusion and Digitization of Payments

The statistics reported in Tables 13.1–13.3 are buttressed by a review of the levels of financial inclusion in different regions. In Table 13.4, drawing on the World Bank's Findex Database, I present some data on basic aspects of financial inclusion and also some measures of access specifically related to digital payment and banking technologies. Table 13.4 shows data for 2017 for selected Asian economies. Based on a broad measure of financial inclusion—having an account at a financial institution—on average 68% of adults in Asian countries have direct access to the formal financial system. This measure ranges from 22% in Cambodia to 80% in the PRC and India, and to over 90% in Japan; the Republic of Korea; and Taipei,China.

The average shares of adults with a debit card and a credit card are 47% and 23%, respectively, suggesting that electronic means of payment are still not used by large swaths of the populations in these countries. There is again a wide discrepancy among regional economies. For instance, the proportion of adults with a credit card is 10% or lower in Bangladesh, Cambodia, India, Indonesia, Thailand, and Viet Nam, while it is over 50% in Japan; the Republic of Korea; and Taipei,China. Credit and debit cards seem to be pervasive in these developed economies and play key roles in facilitating digital payments. In the PRC, 61% of the adult population report having made digital payments in the previous year, indicating how other digital payment systems have proliferated and reduced the need for debit and credit cards to make noncash payments. Mobile money accounts are not widely prevalent in a majority of the Asian economies for which data are available (Bangladesh being a notable exception).

In Africa, financial inclusion is much lower than in Asia. The one exception is Kenya, where the share of adults with an account at a financial institution is 82%. In Kenya, the mobile payment system M-Pesa has served as a conduit to a bank account. Reflecting the low income levels in these countries and other factors that have limited the penetration of financial institutions, especially in rural areas, access to debit and credit cards is quite limited across the entire region. Kenya also stands out as a country with much higher digital payment usage than in the rest of Africa, with three-quarters of the adult population having made a digital payment over the past year (Table 13.5).

Finally, I examine the same measures of financial inclusion for Latin America. This region has an average financial inclusion ratio that is between the averages for Africa and Asia. The ratio is below 50% in Argentina, Colombia, Mexico, and Peru, while it is 70% or higher in Brazil, Chile, and Venezuela. Even among adults who have such an account, only a small proportion use the internet or mobile phones to conduct financial transactions through that account.

The average share of adults with a debit card and a credit card are 43% and 20%, respectively, suggesting that electronic means of payment are still not used by large swaths of the populations in these countries. There is again a wide discrepancy among regional economies. For instance, the proportion of adults with a credit card is 10% or lower in Bolivia, Ecuador, and Mexico, while it is 30% or higher in Chile

Table 13.4: Measures of Financial Inclusion and Digital Access in Asia (% of the adult population)

	Account at Financial Institution	Used Mobile Phone or Internet to Access Account	Debit Card	Credit Card	Made Digital Payments in Past Year	Mobile Money Account
Bangladesh	50	13	6	0	30	21
Cambodia	22	6	7	1	12	6
PRC	80	50	67	21	61	-
India	80	6	33	3	20	2
Indonesia	49	14	31	2	27	3
Japan	98	34	87	68	89	-
Rep. of Korea	95	71	75	64	91	-
Taipei,China	94	35	74	53	69	-
Thailand	82	20	60	10	43	8
Viet Nam	31	25	27	4	16	3
Average	68	27	47	23	46	7

PRC = People's Republic of China.

Notes: Data shown are for 2017. Adult population refers to individuals aged 15 years or older. The second column indicates what proportion of households with accounts used mobile phones or the internet to access their accounts. Debit Card and Credit Card columns represent the share of the population that have them. The averages shown in the last row are unweighted cross-sectional averages.

Source: Data were obtained from the World Bank's Global Findex Database.

Table 13.5: Measures of Financial Inclusion and Digital Access in Africa (% of the adult population)

	Account at Financial Institution	Used Mobile Phone or Internet to Access Account	Debit Card	Credit Card	Made Digital Payments in Past Year	Mobile Money Account
Algeria	43	5	20	3	16	-
Egypt	33	4	25	3	6	2
Ghana	58	28	19	6	43	39
Kenya	82	57	38	6	76	73
Morocco	29	4	21	0	9	1
Nigeria	40	18	32	3	24	6
South Africa	69	25	34	9	43	19
Zambia	46	35	20	4	33	28
Average	50	22	26	4	31	24

Notes: Data shown are for 2017. Adult population refers to individuals aged 15 years or older. The second column indicates what proportion of households with accounts used mobile phones or the internet to access their accounts. Debit Card and Credit Card columns represent the share of the population that have them. The averages shown in the last row are unweighted cross-sectional averages.

Source: Data were obtained from the World Bank's Global Findex Database.

Table 13.6: Measures of Financial Inclusion and Digital Access in Latin America (% of the adult population)

	Account at Financial Institution	Used Mobile Phone or Internet to Access Account	Debit Card	Credit Card	Made Digital Payments in Past Year	Mobile Money Account
Argentina	49	21	41	24	32	2
Bolivia	54	12	28	7	33	7
Brazil	70	18	59	27	46	5
Chile	74	34	60	30	56	19
Colombia	46	16	26	14	29	5
Costa Rica	68	26	52	14	46	-
Ecuador	51	9	28	9	22	3
Mexico	37	15	25	10	23	6
Peru	43	10	28	12	25	3
Uruguay	64	25	56	41	53	-
Venezuela	73	40	66	29	65	11
Average	57	21	43	20	39	7

Notes: Data shown are for 2017. Adult population refers to individuals aged 15 years or older. The second column indicates what proportion of households with accounts used mobile phones or the internet to access their accounts. Debit Card and Credit Card columns represent the share of the population that have them. The averages shown in the last row are unweighted cross-sectional averages.

Source: Data were obtained from the World Bank's Global Findex Database.

and Uruguay. On average, only about 39% of adults in Latin American countries report having used any form of digital payment over the past year. The share is higher than 50% in only three economies—Chile, Uruguay, and Venezuela (Table 13.6).

The share of adults with a mobile money account is in single digits for most countries. In general, there have been only modest increases in the indicators shown here over the last few years (the Findex database has data for 2011 and 2014, in addition to 2017). Thus, both in terms of financial inclusion and digitization of payments, there is considerable room for progress in Latin American economies.

13.2.3 Implications

Tables 13.1–13.6 show the challenges across various regions of the world in providing access to the formal financial system, the continued prevalence of cash, and also the low level of digitization of payments in many countries. At the same time, in many middle-income countries such as the PRC and Kenya, there have been significant improvements in the extent of digitization of payments.

One intriguing question that arises from reviewing the data discussed above is what the relationship and direction of causality are between the usage of cash, the level of financial inclusion, and the degree of informality of economic activity in a country. There is some suggestive evidence of a positive (unconditional) cross-sectional relationship between the usage of cash and the degree of informality, although there are some notable exceptions such as Japan and Nigeria. That is, in general, countries that use more cash seem to have more informality. There is also a weak negative relationship between the level of financial inclusion and the degree of informality. In other words, economies with higher levels of financial inclusion generate more economic activity in their formal than in their informal sectors.

Even if these relationships were to hold up in more formal statistical analysis, the issue of causality would be difficult to disentangle since there could in fact be alternative factors that account for these relationships. Indeed, it is likely that these phenomena, as well as that of dollarization, have common origins. For instance, a high tax burden creates incentives for shifting economic activity into the informal sector, shrinking the tax base and often leading governments to resort to monetary financing of public deficits. This can result in high and variable inflation, which in turn affects the stability of the value of the official medium of exchange, and can in turn lead to dollarization. Thus, macroeconomic policies ultimately are key determinants of the multiple phenomena discussed here.

Nevertheless, these data suggest that if digitization of retail payments accomplishes the twin objectives of greater financial inclusivity and reduced reliance on cash, then an added benefit could be a reduction in the informality of economic activity. By bringing more economic activity out of the shadows, a developing country could broaden its tax base without raising tax rates. It could also help formalize employment and bring more of a country's population into the ambit of the social safety net. Digitization, by reducing reliance on cash, could also help in controlling public corruption and reducing leakage in government benefit transfers to households.

This raises an important question: Given the many potential benefits of greater digitization, what role should the government play in order to foster private sector innovation but also provide a basic technological infrastructure that provides a neutral and level playing field for private sector innovators? How best can this be done without creating undue financial system risks and while ensuring adequate consumer protection? It turns out that India has forged a path that other countries—including ones that have relatively low per capita incomes and where the extent of digital connectivity is limited—might be able to use as a template.

13.3 India's Approach to Financial Inclusion through Digital Technologies

India's approach has a number of useful lessons for other developing (as well as developed) economies about how the government can play a supporting but not intrusive role. India's government has taken a more comprehensive approach than most countries to improving its citizens' access to digital payments as well as financial inclusion more broadly. This approach has also had implications for small and medium-sized enterprises (SMEs), many of which are of very small scale and have had little access to the formal financial system.

13.3.1 Elements of the "India Stack"

India has developed a version of the technology stack that has come to be known as the "India Stack."[2] With the goal of creating a central platform rather than undertaking multiple technological projects, India has built one of the world's most comprehensive public goods—a digital system that allows both public and private sector participants to gain access to

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2 For more details, see D'Silva et al. (2019) and DigFin (https://www.digfingroup.com/what-is-india-stack/).

the digital economy, while protecting their privacy. The creation of this digital infrastructure has provided the foundation for a system that is capable of allowing millions of people working in the informal sector, or otherwise excluded from the formal financial system, to become a part of the digital economy by providing them with a tool that takes care of their identity and payments.

In 2009, India launched the world's first initiative to provide biometric identities for a country's entire population. The program, called Aadhaar (which means foundation), created an "identity rail" that provides unique digital identifiers for each citizen. This made it possible for everyone to get a bank account easily.

The government then helped create a public digital infrastructure with open access that provides easy entry for payment providers, thus encouraging innovation and fostering competition. This "payment rail," the Unified Payments Interface (UPI), is interoperable, which means that it allows transactions to be conducted seamlessly across various payment providers and financial institutions. This approach differs from the stand-alone private payment providers such as Alipay and WeChat Pay that now dominate retail payments in countries such as the PRC.

The UPI can be described as an addressing system built on top of a regulated payment system that enables people to obtain aliases or addresses (such as a mobile number or a nickname) linked to a bank account or a card. This addressing system operates compulsorily on every single bank account in the country, thus enabling a person to use a payment app provided by a regulated service provider to make and receive payments at the click of a button. The UPI is the first national addressing system for payments that operates as an open system and as a public good.

The third element is a "data sharing rail" managed by authorized account aggregators that allows individuals to control their digital data trails and use the information to obtain access to financial services and products such as loans.

These three elements, taken together, have given even low-income and rural households easy access to a broad range of financial products and services. Private technological innovations can be plugged into various parts of this publicly provided digital infrastructure that has come to be known as the India Stack on account of its modular nature. Biometric identification of account holders, official certification of participants in the UPI, and licensing of account aggregators help maintain regulatory oversight. To address concerns about privacy, the government has mandated that customers' data can be shared only with their knowledge and consent, building confidence in what might otherwise be seen as just an intrusive government program. Thus, India has shown how the government can play a constructive role in creating a technical and regulatory infrastructure that allows private sector-led innovations to flourish on a level playing field for big and small innovators.

The India Stack can be thought of, alternatively, as just a set of standards or application programming interfaces that facilitates interoperability and sharing among all the participants in the ecosystem that adopt these interfaces. This serves both the financial services providers and customers, including households and businesses.

The way the three rails or pillars connect with each other could be illustrated as follows: the first step to financial inclusion is a bank account, and Aadhaar (along with related government initiatives) made it possible for everyone to get a bank account easily, but most of these accounts were dormant. So the next step was to facilitate payments directly from the bank accounts, and this is what the UPI did. Now that there were banking transactions, the final step was to empower people to use their banking transaction data to access other financial services like credit, and this is what the Account Aggregator hopes to do.

The emphasis on bank-led financial inclusion is an important characteristic of India's approach. In many other countries, payments have served as the route through which digital technology enhances financial inclusion. Some low- and middle-income countries, such as Kenya and Tanzania, have allowed a mobile money system to develop and serve as an entry point that provides access to basic financial services. However, in many such cases, the mobile money system acts as an alternative to bank accounts and escrow accounts provide only a loose link to the banking system, implying that access to a broader range of financial products, such as those for saving and credit, is not provided by this system. By contrast, India has emphasized bank-led inclusion, an approach that, as discussed below, has provided a range of other benefits as well.

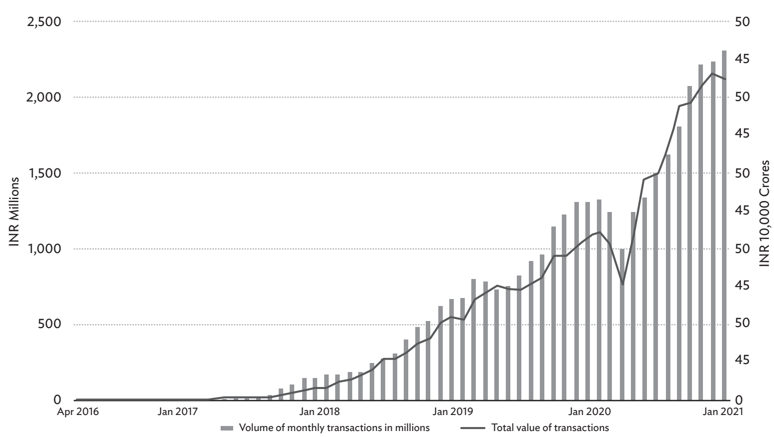
13.3.2 What Has the India Stack Accomplished?

Some outcomes of the India Stack are quite remarkable. About 95% of India's population (amounting to more than 1.2 billion people) is now registered with Aadhaar. This broad coverage is especially impressive given the shares of India's rural population and low-income households.

Another measure of the success of the India Stack is the rapid proliferation of the UPI network—the digital system that powers multiple bank accounts into a single mobile application—in India's domestic commerce. In 2016, the system got off the ground with barely 20 banks in the network. Five years later, as of February 2021, the UPI had partnerships with more than 201 banks. In that month, the network recorded 2.3 billion transactions, which had a total value of roughly ₹4.2 trillion ($58 billion at the March 2021 exchange rate).[3] This implies that the average transaction size amounted to less than ₹2,000 ($27), which includes business-to-business transactions as well as transactions between customers and businesses. Figure 13.1 shows how rapidly the value and volume of monthly transactions in the UPI network have surged over the past few years, showing the strong latent demand that existed in India for digital payment services.

One question is whether the India Stack has had a material effect on the use of cash for quotidian transactions. There is evidence that, even in the early stages of its rollout, the effects had already become important. Figure 13.2, which is based on World Bank data, shows that the use of cash has been reduced for transactions that encompass payments of

Figure 13.1: India's Unified Payments Interface: Volume and Value of Transactions (monthly)

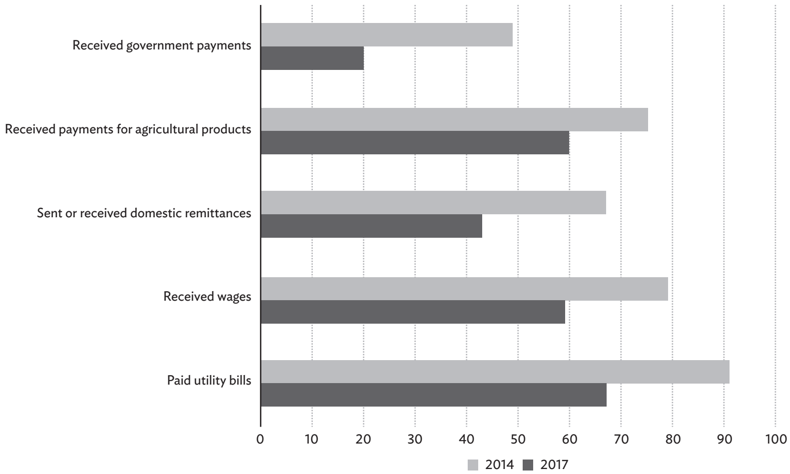


INR = Indian rupees.

Source: National Payments Corporation of India. UPI Product Statistics. https://www.npci.org.in/what-we-do/upi/product-statistics

[3] The statistics and data discussed in this section are taken from the AADHAAR Dashboard (https://uidai.gov.in/aadhaar_dashboard/) and UPI Product Statistics (https://www.npci.org.in/what-we-do/upi/product-statistics).

Figure 13.2: India: Transactions for Different Purposes Using Cash (%)



Notes: This chart shows the proportion of cash-based transactions.

Source: Data provided by World Bank Global Findex Database.

utility bills, private sector wages, payments for agricultural products, domestic remittances, and government payments.[4]

In fact, one of the most striking changes has been the shift to direct benefit transfers (DBTs) from the government. The DBT scheme was initiated in early 2013.[5] World Bank data show that, just from 2014 to 2017, the share of government benefits paid by cash rather than electronically fell from 50% to 20%. The primary components of the DBT scheme include a beneficiary account validation system and a reconciliation platform integrated with the Reserve Bank of India, the National Payments Corporation of India, and various public and private sector banks, including regional rural banks and cooperative banks. The Aadhaar Payment Bridge system uses the Aadhaar number as a central

4 The latest available data are for 2017. It is highly likely that the trend of shifting away from the use of cash has picked up pace since then, particularly in view of the coronavirus disease 2019 (COVID-19) pandemic and the desire on the part of both customers and businesses for contactless digital payments.

5 For more on the DBT scheme, see the National Informatics Centre blog article (https://www.nic.in/blogs/direct-benefit-transfer-a-blessing-during-the-time-of-pandemic/).

key for digitally transferring the government benefits to the Aadhaar enabled bank accounts of the intended beneficiaries.

DBTs allow the government to transfer cash benefits as well as various kinds of subsidies to individuals directly through their Aadhaar-linked bank accounts rather than in the form of cash. This has had a number of benefits, including reducing leakages and delays, and improving the efficiency of the process. Over the past 9 years, government institutions have been able to electronically transfer more than $100 billion to beneficiaries. The DBT scheme has proved particularly valuable during the coronavirus disease 2019 (COVID-19) pandemic, when it has been used by the government to quickly ramp up benefits to help buffer the adverse effects of lockdowns on the economically vulnerable segments of the population.

The India Stack has also created a base for other innovations. One service that uses the India Stack and the PayTM application is FASTag—a recently launched system of contactless payment at toll booths on Indian highways. The system facilitates automatic digital payments when special sensors at toll booths are used to automatically detect a special tag on vehicles, deducting the toll amount from the digital wallets of the passengers. This innovation, too, has proven especially helpful during the COVID-19 pandemic by enabling contactless payments for interstate travel and commerce.

The India Stack has also had important benefits for SMEs, which play an important role in growth and development. They are also important for employment and account for a significant proportion of India's exports. However, a large number of SMEs, including microenterprises, lack access to credit. Some estimates of India's business credit gap suggest that more than 50 million SMEs lack access to credit or have to rely on informal sources to get financing. The reasons for this include the lack of credit information and the high cost and high risk of, and low profits from, providing financial services to SMEs. Furthermore, even when it is available, access to financing from formal institutions requires collateral and involves complex documentation, strict repayment terms, and high interest rates. SMEs are also burdened by a lack of technology, including operation technology, accounting systems, and digital financing applications.[6]

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[6] For a discussion on the constraints faced by SMEs, see Indian Institute of Banking and Finance report (http://iibf.org.in/documents/reseach-report/Report-30.pdf) and Tata Capital blog (https://www.tatacapital.com/blog/business-loan/top-challenges-faced-by-sme-msme-financing-in-india/). For a discussion on the roles of the India Stack and OCEN in lending to SMEs, see LendFoundry webpage (https://lendfoundry.com/role-of-india-stack-in-lending-sector/) and Financial Express (https://www.financialexpress.com/money/what-does-ocen-mean-for-small-businesses/2071398/).

The India Stack has made it easier for SMEs to obtain access to credit by digitizing various aspects of loan application, processing, and servicing. In particular, the Open Credit Enablement Network (OCEN) is putting in place a set of frameworks and protocols that can enable democratization of credit for segments that need it the most. The OCEN is creating an infrastructure protocol that enables consent-based access to verified information from multiple public and private data sources and connects borrowers with lenders through an ecosystem that offers access to affordable credit. The system will leverage the innovations of the India Stack, including Aadhaar-based eKYC, eSign, the UPI, and the Account Aggregator framework.

13.3.3 The Government's Role

Finally, it is worth reviewing the role of the government in the innovations described in this section. The driving philosophy behind the data sharing rail in India is different from that in other countries and regions. Take, for instance, the "open banking" concept in Europe. While open banking is focused on competition and leveling the playing field, data sharing in India is motivated by empowering the consumer with his or her data, especially how these data can be used to gain access to other services.

The "open access" aspect of the network comes with a caveat that the National Payments Corporation of India (NPCI) still needs to certify UPI participants. Any third-party apps such as Google Pay or WhatsApp need to partner with a bank. Thus, there are two levels of regulatory checks. The government has not yet mandated that consent is needed to share customers' data, although there is clearly an intention to pass relevant legislation—the Personal Data Protection Bill is making its way through the legislative process. For now, the Reserve Bank of India (RBI) Account Aggregator guidelines specify that the Account Aggregator operates as a consent manager.

The framework also includes various consumer protection measures. For instance, nonbank finance companies play an important role in the network, but they are not allowed to hold customer cash and, instead, have to maintain ties with banks and store the money in escrow accounts. This is in contrast to the situation in the PRC where, for instance, until recently some payment providers such as Alipay were allowed to use the "float" on payments, from the time when the platform received the customer payment to when it is transmitted to the merchant, to provide consumer credit. In India, technology companies offering payment products have to tie up with banks, and there are guidelines limiting the liability of consumers on account of unauthorized transactions.

Moreover, the digital infrastructure, including the structure for payments, is seen as a public good that provides a level playing field for all private sector participants. This is different, for instance, from the M-Pesa system in Kenya that is owned and operated by a private telecommunications company. The UPI and Account Aggregator are not directly government-owned or government-managed initiatives, though they are public in nature. The UPI is actually built by the NPCI on top of the National Financial Switch (which was handed over to the NPCI by the RBI). Account aggregators are entities licensed by the RBI. Thus, the government has played a critical role in catalyzing and overseeing the system but does not have direct involvement or ownership.

13.4 The International Dimension

New forms of money and new channels for moving funds both within and between economies could have implications for international capital flows, exchange rates, and the structure of the international monetary system. The proliferation of channels for cross-border capital flows will make it increasingly difficult for national authorities to control these flows. Emerging market economies will face particular challenges in managing the volatility of capital flows and exchange rates, and could be subject to greater monetary policy spillovers and contagion effects.

Set against these considerations are the considerable benefits that could be realized from advances in payment systems. International payments present particular challenges since they involve financial institutions in different countries, money passing through different national payment systems, and various regulatory requirements affecting cross-border financial flows. Consequently, such payments tend to be costly, slow, and inefficient. Another layer of complications results from cross-border payments involving exchange rates between currencies. Exchanging small amounts of money from one currency to another can result in disproportionately high fees. Moreover, slow transactions that take hours or, in some cases, days to be settled raise issues about whether the exchange rate that should be used for a particular payment is the one employed when the transaction is initiated or completed. Different countries have varying regulations about such matters and reconciling them can be a challenge. Thus, compared to domestic payments, fintech has even greater potential to resolve such shortcomings and change the landscape of international payments.

13.4.1 Remittances

Traditional cross-border transfers are expensive for both individuals and businesses. Remittances, which are funds sent by international migrants to their home countries, account for the bulk of such transfers by individuals. The World Bank estimates the global average cost of sending remittances to low- and middle-income countries at 7% of the transfer value. Intraregional remittance costs are even higher among the low-income economies of sub-Saharan Africa, averaging 9%. Poorer countries, which rely more on remittances, often seem to face higher costs. In 2019, Haiti received $3.2 billion in remittances, amounting to about one-third of its GDP. Haitian workers laboring in nearby countries such as the Dominican Republic and in faraway countries such as France face fees of 8%–9% on money sent back to their families.[7]

There is clearly a big opportunity for improvement in the area of cross-border transfers, especially in the context of remittances. The World Bank estimates that annual remittance flows to low- and middle-income countries reached $554 billion in 2019. Adding in money sent to high-income countries raises that figure to $714 billion.

A number of companies have tapped into this opportunity. TransferWise, a United Kingdom-based online money transfer service founded in January 2011, handles 49 currencies.[8] As of March 2020, the company had more than 7 million customers and was processing transactions amounting to £4 billion (roughly $5 billion) each month. The company charges an average fee of about 0.7% on each transaction, with fees as low as 0.4% for transactions involving just the major currencies. According to the company, a quarter of the transactions are completed within 20 seconds, which is remarkable as it means that money leaves a user's bank and arrives in the recipient's bank account, in a different country and in a different currency, practically instantaneously. The average speed of transactions is also impressive—41% of transactions

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7 For reported remittance prices, see World Bank report (https://remittanceprices.worldbank.org/sites/default/files/rpw_report_march_2020.pdf). The reported average prices are for a typical remittance transaction of about $200. For estimates of remittance flows and remittance fees in 2019, see Knomad brief (https://www.knomad.org/sites/default/files/2020-05/Migration%20and%20Development%20Brief%2032.pdf).

8 For details about TransferWise and statistics about the company, see webpages at: https://transferwise.com/gb/blog/annualreport2019 and https://transferwise.com/gb/blog/mission-update-q1-20.

take less than 1 hour, and 72% take less than 24 hours. TransferWise also makes it possible for transacting parties to get more competitive exchange rate quotes than those typically offered by commercial banks.

Another online money transfer service, WorldRemit, enables senders in 56 countries to send money in 90 currencies to 150 countries across the world.[9] Depending on the country combination, customers can send money to bank accounts as cash to local cash pickup agent locations or for door-to-door delivery, to mobile wallets, or as airtime top-ups (a popular option for migrants to stay connected with their friends and family back home). In fact, a third of money transfers using the service are apparently received on mobile phones, leading the company to claim that it is now the leading sender of remittances to mobile wallets worldwide. The company has over 4 million customers and states that over 90% of the transfers on its platform are authorized within minutes. WorldRemit charges a flat fee, usually between $4 and $25, depending on the amounts and currencies involved, although there are indications that its exchange rate quotes are less favorable to customers than TransferWise.

Both WorldRemit and TransferWise have formed partnerships with the PRC's Alipay, giving Alipay users access to these platforms for cross-border payments.[10] For now, this arrangement is just for payments originating abroad and going into the PRC, but it shows the potential for linking up domestic and cross-border digital payment systems. These examples show how financial technologies now make it possible to meet specific needs for payments and other services, bringing improvements in both cost and efficiency that are particularly valuable to lower-income households, small businesses, and developing economies.

13.4.2 Portfolio Diversification

There are significant changes in store for retail investors as well. Fintech firms might eventually make it possible for retail investors to invest directly in stock markets around the world at a low cost. In a country such as the United States (US), for instance, one can already do this simply by buying shares in a mutual fund that invests abroad. Such funds typically charge higher fees than funds that might invest in US stocks and bonds. New investment platforms are likely to lead

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9 For information about WorldRemit, see webpages at: https://www.worldremit.com/en/about-us and https://www.monito.com/en/send-money-with/worldremit.

10 For descriptions of partnerships with Alipay, see webpages at: https://www.worldremit.com/en/news/worldremit-partnership-alipay and https://transferwise.com/us/blog/new-send-cny-instantly-to-alipay-users.

to lower costs, forcing even existing investment management firms to reduce their fees.

Fintech firms are reducing the costs both of getting information about foreign markets and of investing in those markets. Moreover, new investment opportunities are also being opened up by technologies that allow for more efficient pooling of small savings amounts of individual households into larger pools that can be deployed more effectively.

These opportunities make sense from the perspective of individual investors. Finance theory indicates that, in order to improve returns while reducing risk through diversification, investors should hold a "world portfolio," essentially a portfolio of holdings in stock indexes of all major stock markets around the world, with the proportion of holdings in each stock index depending on the total dollar value of all the stocks traded on that index. This would mean, for instance, that an investor would hold about 39% of their portfolio in an investment that tracked major US stock market indexes, 9% in an investment that tracked the PRC market, 7% in Japan, and about 5% each in India and the United Kingdom. This proposition is independent of which country the investor lives in, although the tax laws in their country regarding domestic and foreign investments could influence the structure of this desirable portfolio. It is, of course, not trivial to diversify in this way but should become easier as stock markets around the world open up to foreign investors and as the costs of transacting across national boundaries fall.[11]

Actual investment patterns look nothing like this hypothetical desirable portfolio. In 2014, US investors allocated nearly 80% of their stock portfolio to domestic stocks. In Japan, the share was 55%. In most countries, the share has been declining gradually but remains well above 50%. Investors thus exhibit extensive "home bias"—they tend to heavily favor investments in their domestic stock markets rather than diversifying their portfolios. In principle, they could do far better in terms of improving the risk-return trade-off of their portfolios through international diversification.

Home bias might not be as extensive as might appear just by looking at investors' holdings of different stocks. A large and increasing portion

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11 According to the World Federation of Exchanges, global stock market capitalization was about $94 trillion at the end of 2019, measured at end-of-year market exchange rates. The share of the US is based on the total market capitalization of the NASDAQ and the New York Stock Exchange; for the PRC: Shanghai and Shenzhen exchanges; for India: the Bombay Stock Exchange and National Stock Exchange; for the United Kingdom: the London Stock Exchange. The data are available from the World Federation of Exchanges report at: https://www.world-exchanges.org/our-work/articles/2019-annual-statistics-guide. The figures on estimated home bias in stock holdings are from the Vanguard report at: https://personal.vanguard.com/pdf/ISGGAA.pdf.

of Apple's revenue and profits now comes from outside the US. So investing in Apple is now not just a bet on the company's performance in the US but in markets around the world. Taking account of investments in multinational companies and in companies that are based abroad but list their stocks on US stock exchanges puts a dent in the evidence for home bias, but the extent of the puzzle still remains large.

One of the next frontiers in the fintech evolution is likely to be the intermediation of capital flows at the retail level, enabling less wealthy households and smaller firms in both rich and poor economies to more easily gain access to global financial markets. Fintech firms that help overcome information barriers, reduce costs and other frictions in international capital movements, and create new savings and financial products are likely to experience significant demand for their services. Of course, as with any financial innovations, there will be risks in this process and financial regulators will face the usual trade-offs between facilitating innovations and managing those risks. In fact, the capital flows themselves pose risks not just to individual investors but also at the country level.

13.4.3 Monetary Policy Spillovers

Greater financial integration has a large number of benefits. These potential benefits come at a price, however, especially for smaller and less developed economies. This group is particularly vulnerable to whiplash effects from volatile capital flows, with this volatility being caused in part by monetary policy actions of the major developed economies. When the US Federal Reserve (the Fed) lowers interest rates, money looking for better returns tends to flow into emerging market economies (EMEs). These economies tend to have higher interest rates on their government and corporate bonds than comparable bonds in developed economies. These higher returns are in part because emerging market governments and corporations are seen as riskier investments, but investors are sometimes willing to accept such risks when the alternative is to earn close to a zero rate of return on government bonds in "safe" countries such as the US (or, for that matter, Germany and Japan, which in recent years have had even lower interest rates).[12]

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[12] Rey (2018) makes the case for a global financial cycle in capital flows, asset prices, and credit growth, and the constraints this imposes on the monetary policy independence of EMEs. Thailand's imposition of capital controls in December 2006, including the reasons for the controls and the fallout from their imposition, was reported in the New York Times (https://www.nytimes.com/2006/12/19/business/worldbusiness/19iht-baht.3954800.html).

Some of these EMEs are smaller and have underdeveloped financial markets. A relatively modest amount of money (by global standards) streaming into Thai stock markets in 2006 was enough to lead to roaring stock prices, which further enticed investors eager to ride the boom. This led to the Thai baht appreciating sharply and quickly, hurting Thai exporters. The government tried to clamp down on inflows into the stock market, before setting off a sharp selloff and a big currency depreciation. A repeat of this cycle of events occurred in 2010. Such large swings in exchange rates can cause complications for exporters and importers, and also for firms that have foreign currency-denominated loans.

Money flowing into emerging markets tends to be volatile. When the Fed lowers rates, investors are willing to take on more risk to get a better yield. When the Fed hikes rates, money tends to flow out of emerging markets as investors opt for a decent rate of return in a safe investment rather than a higher return but riskier investment. Such "risk-on" and "risk-off" investor behavior leads to volatile swings in capital flows to emerging markets. To the exasperation of policy makers in these countries, they end up being subject to such volatility even when their policies are disciplined and their economies are doing perfectly well. In other words, they end up becoming collateral damage when a central bank such as the Fed uses monetary policy levers to achieve its own ends, with little regard for the effects of those policies on other economies.

New and relatively friction-free channels for cross-border financial flows could exacerbate these "spillover" effects across economies. These new channels could not only amplify financial market volatility but also transmit it more rapidly across countries. This is a particular concern for EMEs that are already subject to whiplash effects on account of conventional and unconventional monetary policy actions of the Fed and other major developed economy central banks. In other words, the availability of more efficient conduits for cross-border capital flows could intensify global financial cycles and all the domestic policy complications that result from them.

13.4.4 Currency Competition

The demand for Bitcoin as a store of value rather than as a medium of exchange has stoked discussion about whether such cryptocurrencies could challenge that role of traditional reserve currencies. It is more likely that, as the underlying technologies become more stable and as more efficient verification mechanisms are developed, such decentralized nonofficial cryptocurrencies will start playing a bigger role as mediums of exchange. Even that proposition is a tenuous one given the high levels of price volatility experienced by such currencies recently. Nevertheless, this shift could occur over time as the utilitarian functions of cryptocurrencies and the underlying payment verification and transfer systems take precedence over the speculative interest in them.

The decline in transaction costs and easier settlement of transactions across currency pairs could have a more direct and immediate impact—a decline in the role of vehicle currencies such as the US dollar that are used to intermediate transactions across pairs of other currencies. The dominance of the dollar as a vehicle currency, followed by the euro, is related to the depth and liquidity of most currency pairs with the dollar (and the euro), which reduces the associated transaction costs. This dominance is unlikely to persist and could even result in an erosion of the dollar's role as a unit of account. For instance, the denomination of all oil contracts in dollars could easily give away to denomination and settlement of contracts for oil and other commodities in other currencies, perhaps even emerging market currencies such as the renminbi.

Notwithstanding any such changes, the role of reserve currencies as stores of value is not likely to be affected.[13] Safe financial assets—assets that are perceived as maintaining most of their principal value even in times of extreme national or global financial stress—have many attributes that cannot be matched by nonofficial cryptocurrencies.

The key technical attributes include liquidity and depth of the relevant financial instruments denominated in these currencies, such as US Treasuries. More importantly, both domestic and foreign investors tend to place their trust in such currencies during times of financial crisis since they are backed by a powerful institutional framework. The elements of such a framework include an institutionalized system of checks and balances, the rule of law, and a trusted central bank. These elements provide a security blanket to investors that the value of those investments will be largely protected and that investors, both domestic and foreign, will be treated fairly.

While reserve currencies might not be challenged as stores of value, digital versions of extant reserve currencies and improved cross-

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13 Gopinath and Stein (2018) offer a different perspective, arguing that the US dollar's dominance is largely the result of its prominence as a medium of exchange. This suggests that the two roles are tied together and that a decline in the dollar's medium of exchange function in international transactions could weaken its dominant reserve currency status. By contrast, Prasad (2014, 2016) makes the case for continued dollar dominance as the reserve currency even if its importance as a unit of account or medium of exchange in international finance should decline, particularly with the advent of the renminbi and given some of the factors discussed in this chapter that would reduce the need for a vehicle currency in international trade transactions.

border transaction channels could intensify competition among reserve currencies themselves. In short, the finance-related technological developments that are on the horizon portend important changes to domestic and international financial markets but not a fundamental ordering of the international monetary system.

13.5 Concluding Remarks

Given the extensive demand for more efficient payment services at the retail, wholesale, and cross-border levels, private sector-led financial innovations could lead to significant welfare gains for households and corporations. In this respect, the key challenge for central banks and financial regulators is how to balance financial innovation with risk management. A passive approach to these developments could risk limiting financial innovation, with the potential risk of the payment systems shifting outside national borders and therefore outside domestic regulatory jurisdictions.

A related question faced by emerging market central banks is whether to issue digital versions of their fiat currencies. The potential benefits of CBDCs include lower transaction costs, easier verification and settlement of payments through sophisticated financial technology, reduced information asymmetries, and elimination of the nominal zero lower bound on policy interest rates. In addition, well-designed retail CBDCs can also broaden financial inclusion, a particular priority for developing economies, and serve as a backstop to the infrastructure of privately managed payment systems.

However, the issuance of CBDCs will not in any way mask underlying weaknesses in central bank credibility or other issues such as fiscal dominance that affect the value of cash. In other words, digital central bank money is only as strong and credible as the central bank that issues it. In considering a shift to digital forms of retail central bank money, it is important to keep in mind that the transitional risks could be higher in the absence of stable macroeconomic and structural policies, including sound regulatory frameworks that are agile enough to be able to recognize and deal with financial risks created by new types of financial intermediaries.

It should also be recognized, notwithstanding the potential benefits, that there are many unanswered questions about how the new financial technologies could affect the structure of financial institutions and markets. Questions also abound about whether retail CBDCs will in any significant way affect monetary policy implementation and transmission. These uncertainties suggest a cautious approach to embracing the concept of CBDCs but not shunning it altogether.

One interesting point to note is that small developed economies such as Canada, Singapore, and Sweden, along with developing economies such as the PRC seem to be taking the lead in pushing forward with exploration and development of digital versions of their fiat currencies. Even the issuers of the major reserve currencies—the Bank of Japan, the European Central Bank, and the Federal Reserve—have recently shown more openness to the concept of a CBDC. Developing countries, particularly those that suffer from a high degree of dollarization, might find such developments particularly challenging as they could further erode the demand for money, either physical or digital, issued by their national central banks.

In fact, such challenges to domestic fiat currencies might be more imminent than previously thought, now that major multinational social and commercial platforms such as Amazon and Facebook are developing their own digital tokens. Given the easy access that developing-country households have to these platforms and the enormous financial and commercial clout that such corporations have, such stablecoins could further reduce the domestic demand for fiat currencies, both as mediums of exchange and stores of value.

Developing-country central banks and governments may be left with little choice but to proactively develop a strategy that helps harness the benefits of the developments in financial technologies discussed in this chapter. Some caution is certainly warranted in light of economic and political constraints in these economies. Still, an active approach could help improve the benefit–risk trade-offs of new financial technologies, while a passive approach increases longer-term risks and delays the potential benefits that economies in the region stand to gain.

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14

Forecasting Private Consumption with Digital Payment Data: A Mixed-Frequency Analysis

Debasis Rooj and Reshmi Sengupta

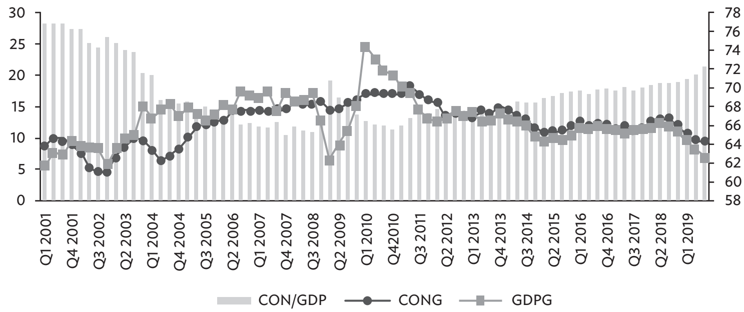
14.1 Introduction

Private consumption is the single most significant component of the aggregate economic activity or gross domestic product (GDP) in India. We can see that over the last decade, private consumption has consistently contributed almost 70% of the nominal GDP (Figure 14.1). Moreover, the nominal consumption expenditure growth rate has exceeded the nominal GDP growth rate in recent times. Therefore, consumption is one of the primary drivers of the aggregate economy, and predicting private consumption would provide an understanding of the dynamics of the overall economic scenario in India.

A limited but growing body of literature is now using high-frequency leading indicators to predict consumption. These indicators include survey-based data on consumer confidence (Dreger and Kholodilin 2013), Google Trends (Vosen and Schmidt 2011), and electronic payment systems (Duarte, Rodrigues, and Rua 2017). These indicators are useful for predicting macroeconomic indicators, especially during macroeconomic uncertainty (Vosen and Schmidt 2011).

The world has witnessed a digital revolution during the last few decades. Cashless means of payment are becoming the required forms of transactions across the globe. Digitalization has transformed the payment and settlement systems by providing the common man with a varied range of payment options to complete a transaction (Reserve Bank of India 2020). Further, the data on various digital payments are

Figure 14.1: Consumption Share and Consumption Growth in India (%)



GDP = gross domestic product, Q = quarter.

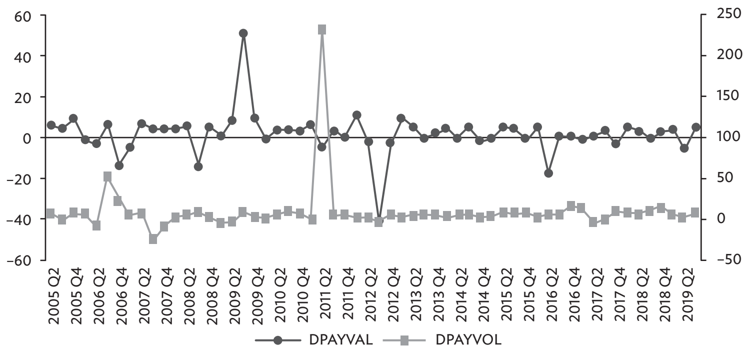
Note: CON/GDP is the share of nominal consumption to GDP (right-hand axis); CONG is quarter on the quarterly growth rate of nominal private consumption expenditure; GDPG is quarter on the quarterly growth rate of nominal gross domestic product.

Source: Authors' own calculations.

now available at higher frequencies than macroeconomic aggregates. According to a recently published report by the Internet and Mobile Association of India, as of November 2019, the number of wireless and wired broadband facilities available to consumers had increased considerably. Both the value and volume of digital payments have increased significantly in India (Figure 14.2). We also observe a close link between the digital payment system and consumption growth in India (Figure 14.3).

In recent times, technological progress has encouraged the development and widespread use of electronic payment systems, providing possible new data sources to monitor economic activity (Duarte, Rodrigues, and Rua 2017). A significant advantage of such data stems from the fact that they are electronically recorded within a given class and hence available quickly and free of measurement errors (Galbraith and Tkacz 2018). Generally, such data include cash withdrawals at ATM terminals and debit and credit card payments, allowing consumers to pay for their purchases by having funds transferred immediately from the cardholder's bank account or on a deferred payment basis, respectively, and other digital payment wallet

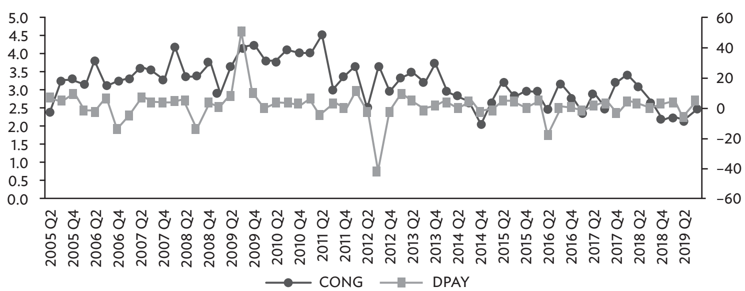
Figure 14.2: Growth of Digital Payment System in India (%)



Note: DPAYVAL is the quarterly growth rate of the value of the digital payment in India; DPAYVOL is the quarterly growth rate of the volume of digital payment in India.

Source: Authors' own calculations.

Figure 14.3: Consumption Growth and Digital Payment in India (%)



Note: CONG is the quarterly growth rate of nominal private consumption expenditure; DPAY is the quarterly growth rate of the value of the digital payment in India.

Source: Authors' own calculations.

systems. Moreover, Aprigliano, Ardizzi, and Monteforte (2019) argue that data on payment instruments such as checks, credit transfers, direct debits, and payment cards trace economic transactions. Hence, these data are a source of information for forecasting short-term economic activity.

However, the literature on using such data in empirical analysis is also limited and primarily relates to the developed economies. For instance, Galbraith and Tkacz (2013) show that daily electronic debit and checking data can track aggregate household spending during extreme events such as the 9/11 terrorist attacks and the severe acute respiratory syndrome (SARS) epidemic during 2003. In a recent work, Galbraith and Tkacz (2018) provide empirical evidence that payment system data that include debit card transactions and checks that clear through the banking system help reduce nowcast errors for GDP and retail sales in Canada. Duarte, Rodrigues, and Rua (2017) also show that ATM and point of sale (POS) data have predictive power to explain Portugal's private consumption.

A significant challenge arises from the fact that key macroeconomic aggregates, such as GDP and consumption, are primarily available at a quarterly frequency. On the other hand, a large number of monthly indicators encompassing a broader set of economic dimensions can be useful for monitoring aggregate economic activity. In a standard empirical analysis with time series data, the traditional way to deal with mixed data samples is to aggregate the highest-frequency data to reduce all data to the same frequency. Then, in the next step, a standard regression model is used with prefiltered data. However, temporal aggregation may adversely impact statistical inference (Silvestrini and Veredas 2008). The resulting consequence based on the aggregated effects could be problematic. It could lead to an erroneous conclusion that does not reflect the true nature of the impact (Kilian and Lütkepohl 2017).

A growing body of literature is now exploiting the higher-frequency variables for nowcasting and forecasting the main quarterly macroeconomic variables to overcome these challenges. This methodology is often referred to as the "mixed data sampling" (MIDAS) regression models pioneered by Ghysels, Santa-Clara, and Valkanov (2004). Moreover, Ghysels, Santa-Clara, and Valkanov (2006), Ghysels, Sinko, and Valkanov (2007), and Ghysels, Kvedaras, and Zemlys-Balevičius (2020) provide further evidence of the usefulness of MIDAS regression. Therefore, a vast body of literature is now exploiting this methodology to forecast quarterly macroeconomic variables using monthly and daily data (e.g., Clements and Galvão 2008; Marcellino and Schumacher 2010; Ghysels and Wright 2009; Monteforte and Moretti 2013).

Therefore, this chapter aims to forecast private consumption using a high-frequency electronic payment system, including data on mobile banking transactions. While Duarte, Rodrigues, and Rua (2017) use nondurable consumption in their analysis, India's aggregate consumption data do not have separate components of spending on both durables and nondurables, so we focus on the aggregate private consumption data that include durables, nondurables and services. The payment system data are available at a higher frequency than quarterly private consumption data, which are available quarterly.

Therefore, we use the MIDAS regression approach proposed by Ghysels, Santa-Clara, and Valkanov (2006) and Ghysels, Sinko, and Valkanov (2007) and utilize monthly data to predict quarterly observations on private consumption. To the best of our knowledge, this is the first study to use the MIDAS approach to forecast private consumption using data on the digital payment system that also incorporate information on mobile banking. Our empirical results suggest that digital payment data have strong predictive power in forecasting private consumption growth in India. We also find that the MIDAS framework offers better predictability than other time series counterparts such as the autoregressive (AR) and autoregressive distributed lag (ARDL) models.

14.2 Brief Literature Review

A growing body of research uses data on electronic payment systems to forecast several macroeconomic indicators. In one of the earlier works, Rodrigues and Esteves (2010) use data on ATM and POS cash withdrawals and payments in Portugal from 1998 to 2009 to nowcast private consumption. They show that such payment data provide a better out-of-sample forecasting performance across several classes of models. Carlsen and Storgaard (2010) analyze the role of electronic payments made by Dankort card (a type of debit card provided by Danish banks) in forecasting households' retail purchases. Using monthly data from 1998 to 2009, the authors show that Dankort transactions have a significant out-of-sample forecasting ability with respect to volume index for retail sales. On the other hand, Barnett et al. (2016) show the usefulness of credit card data for predicting GDP in the United States. Using the mixed-frequency dynamic factor model and data from 2003 to 2015, they show that monthly credit card volumes produce the most accurate nowcasts of nominal GDP growth.

Similarly, Duarte, Rodrigues, and Rua (2017) use monthly data on ATM cash withdrawals and POS payments and several other predictors from 2000 to 2014 for forecasting quarterly private consumption in

Portugal. They find that the use of high-frequency data and MIDAS regression improves the forecasting performance, and the most significant gain comes from the use of ATM and POS data. Aprigliano, Ardizzi, and Monteforte (2019) use mixed-frequency regression analysis to forecast Italian GDP and its components, including consumption and investment. They find that payment system data that include credit transfers, checks, direct debits, and debit cards improve the forecasting accuracy compared to a model that does not include such data. Our study attempts to use monthly digital payment system data to forecast quarterly private consumption data in India using mixed-frequency regression analysis.

Methodologically, since the pioneering work of Ghysels, Santa-Clara, and Valkanov (2004), a growing body of literature has used MIDAS to forecast lower-frequency data utilizing high-frequency data. For instance, Clements and Galvão (2008, 2018); Kuzin, Marcellino, and Schumacher (2011); Marcellino and Schumacher (2010); and Schumacher and Breitung (2008) provide empirical evidence of improvements in quarterly forecasts from using monthly data. On the other hand, Andreou, Ghysels, and Kourtellos (2013); Ghysels and Wright (2009); and Monteforte and Moretti (2013), among others, show the usefulness of higher-frequency data for forecasting lower-frequency variables. Dreger and Kholodilin (2013) use a survey-based consumer confidence indicator reported by the European Commission for the euro area to forecast private consumption using the MIDAS methodology. They argue that data-driven aggregation methods should be used to determine the weights of the individual ingredients.

In the Indian context, Rooj and Sengupta (2020) show that large payments through electronic payment systems positively impact economic growth. However, the application of MIDAS regression using Indian macroeconomic data is limited. For instance, Rooj and Sengupta (2018) show that MIDAS performs better in recovering the causal relationships between monetary policy and private investment than the conventional common low-frequency approach. Similarly, Maji and Das (2016) use MIDAS to forecast monthly inflation in India using daily treasury yield information. Their results show that MIDAS has better predictive power for forecasting inflation in India than other standard time-aggregation approaches.

The study in this chapter is the first to examine the ability of digital payment data to forecast consumption expenditure, focusing on India, which uses a broad set of digital payment indicators. For instance, unlike previous studies (Duarte, Rodrigues, and Rua 2017), which primarily use only ATM and POS truncations with debit and credit cards, our digital payment system data also include data on prepaid payment instruments, and mobile banking. We also use other macroeconomic indicators such as personal loans and the Index of Industrial Production. The inclusion of these predictors improves forecasting performance. Further, using several MIDAS specifications, we confirm that mixed-frequency regression analysis provides improved predictability and forecast performance compared to the linear time series models, such as the ARDL model.

14.3 Empirical Methodology

MIDAS models have been extensively used as a forecasting device in macroeconomics (Clements and Galvão 2008) and financial environments (Ghysels, Sinko, and Valkanov 2007). The idea behind MIDAS is as follows: Suppose y_t is sampled at some fixed time, say, annual. Moreover, let $x_t^{(m)}$ be sampled m times faster, so for our example with quarterly data, m = 12, $x_t^{(m)}$ is sampled monthly (Ghysels, Kvedaras, and Zemlys-Balevičius 2020).

The simple MIDAS regression model can be written as

$$qey_t = \beta_0 + \beta_1 \, B\left(L^{\frac{1}{m}};\theta\right) x_t^{(m)} + \varepsilon_t^{(m)}$$

where $B\left(L^{\frac{1}{m}};\theta\right) = \sum_{k=0}^{K} B(k;\theta) L^{\frac{k}{m}}$ is a polynomial of length K, $L^{\frac{1}{m}}$ is a lag operator such that $L^{\frac{k}{m}} x_t^{(m)} = x^m{}_{(t-k/m)}$, and the lag coefficient in $B(k;\theta)$ of the corresponding lag operator $L^{\frac{k}{m}}$ is parametrized as a function of a low-dimensional vector of the hyper-parameters θ. The quarterly example would imply that the above equation is a projection of quarterly y_t on to monthly x_t using up to K lags. This leads to improvements in efficiency. Hence, the practice of aggregating all data to the common least frequently sampled process will always be less efficient than a MIDAS. There also exist several variations of MIDAS. Foroni, Marcellino, and Schumacher (2011) study the performance of a variant of MIDAS (U-MIDAS), which does not resort to functional distributed lag polynomials. In the paper, the authors discuss how unrestricted MIDAS (U-MIDAS) regressions can be derived in a general linear dynamic framework, under which conditions the parameters of the underlying high-frequency model can be identified. The second one is the Autoregressive MIDAS (AR-MIDAS) model. Since autoregressive models often provide competitive forecasts to those obtained with models that include explanatory variables, the introduction of an autoregressive term in the MIDAS model is a desirable extension, albeit not straightforward. Ghysels, Santa-Clara, and Valkanov (2004) show that the introduction of lagged dependent variables creates efficiency losses.

Moreover, it would result in the creation of seasonal patterns in the explanatory variables. Most economic time series tend to exhibit persistence, and therefore allowing for dynamics in both the predicted and the predictor series may offer more robust estimates. The exponential Almon lag polynomial proposed by Ghysels, Sinko, and Valkanov (2007), which can take many shapes, is adopted as the weighting scheme. We also consider an alternative model with the AR-MIDAS that shares similar features except for the data frequency for completeness. This model is described as the Autoregressive Distributed Lag [ARDL(p,q)] model (Pesaran, Shin, and Smith 2001). However, the major disadvantage of the ARDL model comes from the fact that it can only deal with data that are in uniform frequency, while the AR-MIDAS model can incorporate data in mixed data frequency. Thus, the AR-MIDAS model allows the relationship between private consumption and payment system data to be evaluated without imposing the uniform frequency assumption despite the availability of alternative data frequencies. Therefore, we are able to examine the sensitivity of the relationship based on the predictive model and choice of data frequency. In our analysis, we also consider the historical average model, which is a simple random walk model, as an alternative specification. A detailed discussion related to various MIDAS specifications is presented in Andreou, Ghysels, and Kourtellos (2013), Duarte, Rodrigues and Rua (2017), and Ghysels, Kvedaras, and Zemlys-Balevičius (2020).

Apart from regression analysis involving both uniform and mixed-frequency data, we also conduct forecast analysis to assess the role of the digital payment system and other macroeconomic indicators such as private loans and the Index of Industrial Production (IIP) in forecasting future private consumption expenditure. The forecasting performance of ARDL and AR-MIDAS models and historical average models are compared to the standard univariate AR model using the Clark and West (2007) test.

14.4 Data

Our study aims to forecast quarterly private consumption using data on the digital payment system and other macroeconomic indicators. With regard to private consumption, we use private consumption (CON) data from Quarterly National Accounts, Organisation for Economic Co-operation and Development. Unlike Duarte, Rodrigues, and Rua

(2017), our data include both durables and nondurables. For India, data on durables and nondurables are not separately available at a quarterly frequency. Since the focus of this chapter is on assessing the information content of high-frequency digital payment systems (DPAY) data, we use data on credit cards (including both ATM and POS use), debit cards (ATM and POS use), prepaid payment instruments (including m-wallet, PPI cards, paper vouchers), and mobile banking data. These data are available from the RBI data on the payment system. The sample period for both CON and DPAY is January 2005 to September 2019.

It can be argued that the consumption of durables is primarily financed by bank transfers or loans (Carlsen and Storgaard 2010; Rodrigues and Esteves 2010). Therefore, we use the personal loan (PLOAN) data available monthly from the RBI as an additional control high-frequency variable in our analysis. However, PLOAN is only available from March 2007. As the data on DPAY and PLOAN are not seasonally adjusted, we use the seasonal adjustment procedure utilizing the X-13ARIMA-SEATS, Seasonal Adjustment Program, by the United States Census Bureau to convert these variables into seasonally adjusted series. Further, we also include the IIP and money supply (M1) as additional controls in our analysis. The data on the IIP are available from the Federal Reserve database, while data on money supply are available from the RBI.

Given that MIDAS requires all the variables to be stationary, we take the log first difference of the variables in our analysis. The stationary test confirms that the first differences are stationary for all the variables in our study (Table 14.1). A detailed description of the data is provided in Appendix Table A14.

Table 14.1: Summary Statistics

Variable	Frequency	Mean	Std Dev	Skewness	Kurtosis	ADF
CON	Quarterly	3.196	0.581	0.063	2.451	–5.835***
DPAY	Monthly	3.319	19.734	10.455	129.138	–10.177***
PLOAN	Monthly	1.084	0.944	0.22	3.84	–13.629***
IIP	Monthly	0.058	0.716	–2.115	12.922	–3.303***
MS	Monthly	1.002	2.663	–6.030	72.819	–11.287***

ADF = augmented Dickey-Fuller.

Source: Authors' own calculations.

14.5 Empirical Results

14.5.1 Predictability

We first evaluate the statistical significance of the predictor, DPAY, in CON by performing a full-sample AR-MIDAS regression of quarterly CON on monthly DPAY. We further consider several specifications in our analysis. Table 14.2 presents the estimated coefficients from the conventional AR, ARDL, and their respective combinations and different AR-MIDAS model specifications, including the introduction of the control variables PLOAN, IIP, and MS. From all combinations of AR (1) and ARDL (1,1) considered in our study, we observe that the estimated coefficient of the first lag of CON is statistically significant. The finding supports the persistence of CON. Therefore, we include an autoregressive term of the lower-frequency variable, CON, for the MIDAS models to account for the persistence observed in AR and ARDL to improve our model fit. The lag length for our AR-MIDAS is based on the AIC criterion. As is standard in the literature, we also use the Almon polynomial distributed lag (PDL) weighting for mixed-frequency weighting. For all the MIDAS specifications, we observe that first, all the AR components are statistically significant. Moreover, we also find that the slope estimates are higher in magnitude (for significant values) than the ARDL specification.

We find that for the MIDAS specification with only DPAY, the estimated slope coefficient is positive and statistically significant. Moreover, we also represent the results of individual specifications for each control variable to check our model robustness. Further, when we augment the MIDAS (DPAY) by adding the control variables PLOAN, IIP, and MS, the slope coefficients remain positive and statistically significant. We also observe that the estimated polynomial distributed lag coefficients (PDL01 and PDL02) are statistically significant for DPAY and IIP versions of the AR-MIDAS only. Thus, the consideration of a higher frequency for the predictor variable seems to enhance predictability.

In summary, the AR-MIDAS confirms the hypothesis that digital payment is an important determinant of India's private consumption. Thus, our findings are consistent with the results of Duarte, Rodrigues, and Rua (2017). Moreover, we establish that the direct elasticity of CON to DPAY is 0.030, which is greater than the elasticity (0.011) captured in the traditional single-frequency models. The elasticity increases when we include additional control variables in our other MIDAS specifications.

Table 14.2: Predictability of DPAY for CON

		Independent Variable			Control Variable		
Model	AR	Slope	PDL01	PDL02	Slope	PDL01	PDL02
AR Benchmark	0.581***						
	(0.000)						
ARDL (DPAY)	0.534***	0.011*					
	(0.000)	(0.059)					
ARDL (MS)	0.595***	0.035					
	(0.000)	(0.325)					
ARDL (IIP)	0.572***	0.004					
	(0.000)	(0.974)					
ARDL (PLOAN)	0.595***	−0.071					
	(0.000)	(0.568)					
ARDL (DPAY, PLOAN)	0.545***	0.003			−0.100		
	(0.000)	(0.579)			(0.414)		
ARDL (DPAY, IIP)	0.536***	0.002			−0.183		
	(0.000)	(0.697)			(0.877)		
ARDL (DPAY, MS)	0.555***	0.003			0.048		
	(0.000)	(0.554)			(0.179)		
MIDAS (DPAY)	0.715***	0.030*	−0.018**	0.002**			
	(0.000)	(0.088)	(0.047)	(0.037)			
MIDAS (PLOAN)	0.548***	0.039	−0.612	0.008			
	(0.000)	(0.816)	(0.555)	(0.555)			
MIDAS (MS)	0.617***	0.066**	−0.049**	0.001**			
	(0.000)	(0.018)	(0.016)	(0.019)			
MIDAS (IIP)	0.570***	0.763**	−0.757**	0.152**			
	(0.000)	(0.044)	(0.029)	(0.026)			
MIDAS (DPAY, PLOAN)	0.773***	0.059*	−0.034*	0.004**	0.016	−0.038	0.007
	(.000)	(0.085)	(0.058)	(0.049)	(0.921)	(0.702)	(0.620)
MIDAS (DPAY, IIP)	0.751***	0.035**	−0.021**	0.003**	1.194**	−1.32***	0.304**
	(0.000)	(0.045)	(0.021)	(0.015)	(0.016)	(0.013)	(0.015)
MIDAS (DPAY, MS)	0.604***	0.009***	−0.006***	0.001***	0.048**	−0.015	0.001
	(0.000)	(0.0059)	(0.0042)	(0.007)	(0.033)	(0.180)	(0.213)

DPAY = digital payment systems, CON = private consumption.

*** Significant at or at less than 1% level.
** Significant at or at less than 5% level.
* Significant at 10% level.

Source: Authors' own calculation.

14.5.2 In-Sample and Out-of-Sample Forecast Evaluation

This section compares the model adequacy of the different specifications of the MIDAS-based models, ARDL, AR, and the historical average model. We conduct both in-sample and out-of-sample forecast evaluations based on two criteria. Following Duarte, Rodrigues, and Rua (2017), we evaluate the models' forecasting performance based on the root mean squared forecast error (RMSFE). We present the relative RMSFE for each of the models vis-à-vis the univariate AR (1) benchmark. A ratio that is lower than 1 denotes a forecasting gain by the specific model over the benchmark AR (1) model.

In contrast, a value higher than 1 means that the univariate model AR (1) outperforms the alternative model. Subsequently, we also use the Clark and West (2007) test. In each case, a positive and significant value indicates a preference in favor of the benchmark AR (1) model; otherwise, we prefer the specific model against which the benchmark model is being compared. We split our sample into an estimation period from the second quarter (Q2) of 2005 to Q4 2016 and an out-of-sample evaluation period from Q1 2017 to Q2 2018. Multiple out-of-sample forecast horizons covering two-, four-, and six-quarters ahead forecast horizons are analyzed using a recursive approach. Table 14.3 presents the results for both the in-sample and out-of-sample forecast results. We consider all the competing models discussed in the previous section for the forecast evaluation to determine the model with the best forecast accuracy. The forecast accuracy is particularly important in a situation where both ARDL and AR-MIDAS models validate the inclusion of DPAY in the predictive regression model for growth.

We find that the relative RMSFE for all MIDAS specifications is less than 1 when compared to AR, ARDL, and historical averages. The initial findings indicate that MIDAS is superior to ARDL (1,1) and AR (1) models in terms of in-sample forecast performance. We also find that MIDAS with MS has the lowest relative RMSFE for the in-sample horizon. While MIDAS with MS enhances the forecasting performance by around 26% vis-à-vis the univariate benchmark AR, the improvement with only DPAY is close to 21%. Further, we formally compare the in-sample forecast performance of MIDAS and ARDL with AR (1) models using the Clark and West (2007) test, and the statistical insignificance of the coefficients indicates that MIDAS specifications are superior to AR (1) in terms of in-sample forecast performance.

In other words, allowing for high-frequency data on DPAY, PLOAN, IIP, and MS in the low-frequency CON growth model will enhance the accuracy of forecasts over and above the predictive powers of the

Table 14.3: In-Sample and Out-of-Sample Forecast Performance

	Forecast Horizon							
	In Sample		H = 2		H = 4		H = 6	
Model	Relative RMSE	CW Test	Relative RMSE	CW Test	Relative RMSE	CW Test	Relative RMSE	CW Test
AR Benchmark	1.000		1.000		1.000		1.000	
HA	4.970	14.090***	4.851	9.851*	5.275	10.693***	6.621	11.658***
		(0.000)		(0.091)		(0.0021)		(0.000)
ARDL (DPAY)	0.947	0.000541	1.009	0.0037	0.959	−0.0126	0.958	−0.0098
		(0.9822)		(0.756)		(0.482)		(0.387)
ARDL (MS)	0.908	−0.0421****	0.594	0.151	1.019	0.161**	1.014	0.117**
		(0.0047)		(0.138)		(0.053)		(0.049)
ARDL (IIP)	0.969	0.031**	1.045	0.017	1.043	0.016	1.034	0.009
		(0.044)		(0.166)		(0.153)		(0.235)
ARDL (PLOAN)	1.002	−0.0248**	0.868	−0.0414	0.867	−0.039	0.904	−0.0199
		(0.058)		(0.449)		(0.183)		(0.359)
ARDL (DPAY, PLOAN):	0.961	0.0342	0.769	−0.064	0.723	−0.063	0.803	−0.031
		(0.374)		(0.458)		(0.243)		(0.428)
ARDL (DPAY, IIP):	0.947	0.043	1.000	0.0004	0.957	−0.136	0.958	−0.010
		(0.131)		(0.967)		(0.451)		(0.372)
ARDL (DPAY, MS):	0.863	0.003	0.724	0.218**	0.995	0.162**	0.986	0.116**
		(0.887)		(0.048)		(0.036)		(0.043)
MIDAS (DPAY)	0.794	0.0279	0.767	−0.0602	0.824	−0.0399	0.809	−0.0318
		(0.598)		(0.572)		(0.368)		(0.256)
MIDAS (MS)	0.801	0.0151	0.269	0.110	0.434	0.088	0.581	0.102
		(0.775)		(0.526)		(0.382)		(0.1394)
MIDAS (IIP)	0.901	0.008	0.888	−0.008	0.814	0.0131	1.045	0.0799
		(0.708)		(0.904)		(0.871)		(0.385)
MIDAS (PLOAN)	0.890	0.037	1.116	0.0571	1.048	0.0261	1.137	0.0551
		(0.549)		(0.425)		(0.467)		(0.156)
MIDAS (DPAY, PLOAN):	0.815	0.0305	0.571	−0.0319	0.624	−0.039	0.632	−0.0306
		(0.638)		(0.822)		(0.562)		(0.468)
MIDAS (DPAY, IIP):	0.741	0.0246	0.514	−0.085	0.506	−0.0575	0.921	0.0658
		(0.658)		(0.487)		(0.366)		(0.544)
MIDAS (DPAY, MS):	0.739	0.016	0.349	0.169	0.265	0.104	0.441	0.082958
		(0.692)		(0.459)		(0.251)		(0.170)

*** Significant at or at less than 1% level.
** Significant at or at less than 5% level.
* Significant at 10% level.

Source: Authors' own calculations.

MIDAS regression. Consequently, it suffices to say that the MIDAS model improves the linear time series models with uniform data frequency. The additional information provided by incorporating the high-frequency digital payment indicators in the forecast of a lower-frequency consumption growth variable lowers the in-sample forecast bias.

Finally, to further validate our analysis, we conduct out-of-sample forecast evaluation for all the models used in this analysis. We find that based on the relative RMSFE, the MIDAS (DPAY, MS) model provides the most robust forecasting performance for most of the forecast horizons considered in our analysis.

Similarly to the in-sample forecast performance, all the MIDAS models outperform the univariate autoregressive model for all the forecast horizons for the out-of-sample evaluation. The findings indicate that although the MIDAS model is superior to both the AR (1) and ARDL (1,1) models in terms of out-of-sample forecast performance, the MIDAS (DPAY, MS) model has the lowest relative RMSFE for the majority of the out-of-sample horizon. The out-of-sample results reveal that the MIDAS (DPAY, MS) model increases the forecast performance by around 73% and 56% for the four- and six-quarters ahead forecast horizons, respectively. Further, the MIDAS (MS) model performs better for the two-quarters horizon vis-à-vis the benchmark univariate autoregressive model. Thus, the validity of the MIDAS models' predictive power holds again with the inclusion of multiple predictors in the regression exercise.

Overall, our findings are in line with Duarte, Rodrigues, and Rua (2017). The results confirm the effectiveness of the digital payment transaction data for forecasting private consumption expenditure. The results also hold when we include other macroeconomic controls such as PLOAN, IIP, and MS. Moreover, the MIDAS models outperform the univariate autoregressive models for different forecasting horizons.

14.6 Conclusion

This chapter attempts to use high-frequency data on the digital payment system to forecast private consumption available at low frequency. We consider the newly developed MIDAS regression approach to examine the role of monthly payment system data on quarterly consumption data. Moreover, we also use other variables that may be informative to track private consumption, such as personal loans and consumer confidence. We also compare the MIDAS model's forecasting performance with the standard AR and ARDL models, which use single-frequency data.

We find that digital payment data are an important predictor of private consumption in India. Several model specifications confirm this hypothesis. We find that the relative forecast performance of MIDAS is more robust than the linear time series models, such as the AR model and ARDL model.

We find that MIDAS regressions offer better predictability and improve the forecasting performance compared to other standard models such as AR, ARDL, and historical averages, and that ignoring this data-driven feature may lead to wrong conclusions. Hence, our results suggest that high-frequency data on digital payment and personal credit should be considered as potentially valuable inputs for predicting macroeconomic variables, especially private consumption. The findings also indicate that digital payment data could be brought more into the mainstream for policymaking purposes. The decision to publish a Composite Digital Payment Index by the RBI from March 2021 onward based on various parameters is the right step toward that goal.

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Appendix A14

Table A14: Data Description

Abbreviation	Frequency	Variable Name	Source
CON	Quarterly	Nominal Private Consumption Expenditure	OECD Quarterly National Accounts database, https://stats.oecd.org/Index.aspx?DataSetCode=QNA#
DPAY	Monthly	Total Value of Digital Payments and Mobile Banking Data	Payment system indicators, Reserve Bank of India, https://dbie.rbi.org.in/DBIE/dbie.rbi?site=statistics
PLOAN	Monthly	Personal Loan Data	Data on Sectoral Deployment of Bank Credit, Reserve Bank of India, https://www.rbi.org.in/Scripts/Data_Sectoral_Deployment.aspx
IIP	Monthly	Index of Industrial Production	Federal Reserve Bank of St. Louis, https://fred.stlouisfed.org
MS	Monthly	Money Supply (M1)	Reserve Bank of India, https://www.rbi.org.in/Scripts/Data_MSupply.aspx

15

Challenges and Opportunities for Digital Transformation in the Public Sector in Transition Economies: The Case of Uzbekistan

Gulnoza Kuldosheva

15.1 Introduction

The most recent landscape of the world is characterized by intensive use of technologies, which has transformed almost all aspects of life—to a certain extent, in a disruptive way. Blended with information flow, it admittedly has enabled high efficiency and productivity, and led to a high level of connectivity among countries, organizations, businesses, and individuals. It should be highlighted that these trends are regarded as the signs or features of a so-called "information society," a concept that was at the center of a number of studies that primarily shed light on the effects of information and communication technology (ICT) in all aspects of life, including economy, education, health, finance, and governance. The ability to use and manipulate information, and the rise of human capital with cognitive skills paired with spatial, technological, and occupational changes are the key markers of an informational or network society (Bell 1974, Castells 1996).

A new trend of easily accessible information and cost reductions through automation and computerization initially triggered changes in the nature of competition and demand for a skilled labor force (from physical to cognitive) in the profit-driven private sector (Ndou 2004; OECD 2017). The public sector, not keeping up the same pace as the private sector in terms of ICT applications, has recently started recognizing the potential of digital initiatives in revitalizing their responsiveness to the changing needs of citizens, efficiently using limited public resources, and most importantly encouraging more just and inclusive governance, or participatory democracy (Tappscott and Caston 1993, cited in Ndou 2004). So, apart from the fact that the recent technological advances can bring managerial efficiency in the public sector, it has also become obvious that citizens with a new "digital mind" are more informed than ever, networked with each other, conscious about their rights, and more demanding than before, thereby forcing the public sector to adopt ICT to improve their transparency and accountability, and their interaction with the government. In recognizing the transformative potential of ICT in public administration to increase efficiency, transparency, and citizen engagement, including the provision of public services to end users and communities, countries are thus increasingly being encouraged to adopt and invest in the concept of e-government by international organizations, or democracy observers.

Yet, the pattern of the digital shift in the public sector, such as motives for, and purposes of, adopting this concept, is highly dependent on the context of countries globally. In Western democracies, the shift to digital governance occurs with having a transparent, open, and accountable government already in place, predominantly with the purpose of optimizing public service delivery and empowering citizen participation (Tapscott and Agnew 1999). However, the rise of a networked society with ICT advancements in developing countries has provoked extra burdens and challenges that might delay the anticipated outcomes of e-government in terms of openness, accountability, and citizen engagement. On the other hand, another group, so-called "transition developing economies," are forced to synchronize reforms of the core public management system (usually with high corruption levels and bureaucracy) with digital governance (Khodjaev 2004), as they are on the way to transforming from a centrally planned system to free-market reforms. Johnson and Kolko (2010) observe that e-government is likely to involve the manipulation of digital technologies to strengthen the government's central power rather than facilitating dialogue between different domains of the society in authoritarian or less democratic governments. In particular, the last line of the observations (Johnson and Kolko 2010) is interesting to explore by virtue of the fact that digitalization of public services has earned massive popularity in the transition economies of eastern and central Europe, as well as in Central Asia in recent years. Also, many political and economic changes have taken place in these countries since the study was conducted, which is why it is reasonable to investigate the previous assertion about digital transformation in authoritarian regimes.

Therefore, this work aims to explore the directions of electronic government reforms in post-Soviet transition countries through the case of Uzbekistan, one of the developing economies in the Central Asian region that has set e-government strategies as a priority in recent public administration reforms. Under the clear hypothesis drawn from previous studies (Ndou 2004; Siddiquee 2016) stating that ICT-enabled reforms bring administrative efficiencies, more involved public participation, and an overall increase in service quality if successfully implemented, we intend to evaluate the current status of e-government development, then identify challenges in the ICT-led development in the public sector. Subsequently, we try to recommend potential policy interventions. Specifically, the research questions this work seeks answers for are the following:

- How is e-governance defined by transition economies, and what are the preconditions for digital transformation in the public sector implementation stages?
- Does increased online presence of e-government mean better delivery of public services, better trust, and transformation?
- What are the issues prevailing in the implementation of digital technologies in the public sector, and what are the potential ways to intervene for successful realization?

Based on the debates on, and conceptual grounds of, ICT applications in public administration, a multidimensional framework has been developed to explore the abovementioned research questions. The multidimensional framework, which includes a number of aspects such as socioeconomic and political components of the e-government phenomenon, was employed in a study on the e-government development of Kazakhstan (Kassen 2019). Because in transition post-Soviet countries, the e-government phenomenon has become one of the top priorities in reforming the public sector, the research in this direction is still in its infancy. There is thus a need for a holistic approach to evaluate the current development stage of e-government, and a multidimensional framework provides the opportunity to have a complex look at digital transformation in transition countries through observation and policy analysis.

While previous research has mainly focused on policy analysis and examination of the legal and institutional framework, this research is the first of its kind as it employs multidimensional analysis that is aimed at learning about e-government as a whole system. The main practical implication of this study is that it attempts to demonstrate the true value of e-government from different perspectives, both socioeconomic and political. There is a high chance that countries might only focus on bringing ICT-enabled transformation into public service delivery without paying much attention to how services are designed and what ultimate impact this digital shift might have in terms of user experience, improved accountability and openness, or the so-called "social value of digital government."

15.2 Theoretical Background and Conceptual Framework

15.2.1 Definitions of Electronic Government

A clear trend of ICT application in the public sector, both in developing and developed countries, can be observed in the light of the recent technological transformations and shifts toward a knowledge-based economy (UNECE 2003). Studies exploring digitalization in the public sector lie in the cross-section between investigations of public administration and studies on ICT for development. There is an ongoing debate on the research of the true purpose and clear definitions of e-government: Is an ICT-driven public sector a tool for achieving better governance, or is the digitalization of public services itself the final objective for governments? International development organizations such as the United Nations (UN), the World Bank, the Asian Development Bank (ADB), the Organisation for Economic Co-operation and Development (OECD), the Inter-American Development Bank (IADB), and others have identified good governance as one of the dimensions of major development issues, binding it into their strategy documents (World Bank 1992). The potential of ICT for transforming governance in terms of administrative efficiency (Heeks 2000), transparency, and accountability (Ghere and Young 1998; Heeks 1998; Yildiz 2007) and its implications for democratic transformations and trust (Bannister and Connolly 2011) have been recognized worldwide by scholars, institutions, and governments. So, implications of ICT for public sector transformations emerged as a popular new direction to explore.

Since definitions of electronic government vary considerably depending on perspectives and the context of a particular country, international research on e-government still does not have a universally applied and standardized approach to defining a digital government. Some define e-government as a new, digitally enabled way of engaging between government authorities and citizens in the provision of public services, while others indicate that e-government is beyond a technical shift in governance. According to evidence (Heeks 2003; Stanforth

2007), e-government initiatives do not bring expected outcomes in a number of countries due to a lack of understanding of its concepts, its narrow definition, and failure to accept it as a complex system. A narrow definition of e-government restricts the opportunities it may bring to the public sector. A summary of the definitions of e-government by different literature is presented in Box 15.1.

Box 15.1: Definitions of Electronic Government

Tapscott (1996) describes e-government as an internet-based government, which internally connects new technologies with a legal system and externally connects government information infrastructure with individuals and entities such as tax payers, businesses voters and other institutions.

United Nations Division for Public Economics and Public Administration (UNDPEPA) and the American Society for Public Administration (ASPA) (2001, 8) indicates that "e-government is the public sector's use of the most advanced and innovative ICT, like Internet to deliver citizens improved public services, reliable information, and greater knowledge in order to facilitate access to governing process and encourage citizen participation."

Randeep (2005, 79) defines electronic government (e-government) as "the use of ICTs by government to enhance the range and quality of government information and services provided to clients in an efficient, cost-effective and convenient manner, while making government processes more accountable, responsive and transparent."

European Commission (2003, 7) defines e-government as "the use of information and communication technologies in public administrations – combined with organizational change and new skills – to improve public services and democratic processes and strengthen support to public policies."

World Bank (2005) states that e-government is a system of information and communication technologies owned by government, the aim of which is to transform relations with citizens, public and private organizations in order to empower citizen participation, and strengthen transparency and accountability, enhancing service delivery by government authorities.

Since e-government definitions might differ depending on the context and purposes of ICT implementation in a certain country, it is reasonable to outline the definition of electronic government from Uzbekistan's perspective. The Law of the Republic of Uzbekistan "On electronic government" (2015, Article 3) states that "Electronic government is a system of technical tools, administrative and legal measures on providing electronic coordination between organizations and rendering public services by government authorities to individuals and entities through applying ICT." The law outlines the main purposes and principles of e-government, and also defines the duties and responsibilities of certain institutions in implementing e-government projects. According to the same law, transparency in government authorities, equal rights for users in e-government services, standardization of document systems, information security, and constant improvement of online public services are the main principles of the e-government system of Uzbekistan (Article 4).

All of the definitions of e-government outlined above suggest one commonality: e-government is the electronic provision of government services, enabled by the latest communication technologies, usually through the internet, aimed at transforming and improving public administration, operations, and interaction within organizations, and providing better public services. Randeep (2005) asserts that it is not "technology" that lies at the core of electronic government, but rather it is "government" that is expected to be the central point in the concept of a digitalized public service system. The World Bank considers ICT to be one of the driving forces or tools of development. The World Bank (Schware 2005) argues that the "success of ICT-led development (or e-development) should not be measured by the diffusion of technology, but by advances in development itself: economic growth and, ultimately, achievement of the Millennium Development Goals."

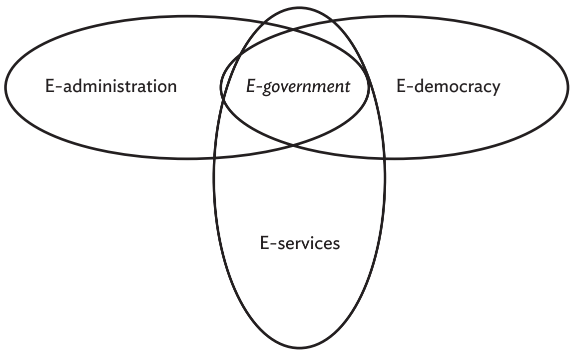
In analyzing the domains of e-government, e-administration, e-services, and e-democracy are highlighted as the constituents of the e-governance process according to the literature and handbooks from international organizations (Ndou 2004; UNDPEPA and ASPA 2001; Sakowicz 2003).

E-administration or an online public administration refers to automation and computerization of administrative operations through balancing the needs of external (citizens or corporate customers) and internal (public sector staff or administrative back office) groups. More specifically, e-administration includes organizational activities, policy development, and knowledge management within public authorities in implementing an e-government system (UNDPEPA and ASPA 2001, 61).

E-services is the domain that involves delivery of online state services, including e-health, e-education, e-taxation, and so on. It covers all levels of public or private bodies under agreement: local, regional, and national governments rendering services that range from giving general information to managing transactions and payments (Ndou 2004; Six 2004).

E-democracy can be described as e-governance in which e-government contributes to a higher level of transparency and accountability by public authorities, and thus improved civic engagement in policy making and democratic processes. E-democracy, according to Six (2004), is not only online voting for representatives or legislative changes by citizens or entities, but it is also managing a system of consultation, and satisfaction surveys between public authorities and citizens. This domain of e-government is considered to be a higher stage or relatively mature level of e-government. We will look more closely at e-government maturity stages later in the literature discussion.

Figure 15.1: E-Government Domains



Source: Reproduced by the author from Ndou (2004), UNDPEPA and ASPA (2001), and Sakowicz (2003).

These distinct domains or areas of e-government are interlinked with each other (Figure 15.1), and this interrelationship within domains takes the form of government to government (G2G) or government to businesses (G3B) or government to citizens (G2C) (Ndou 2004; Yildiz 2007; Sakowicz 2003).

As noted above, the studies on electronic government lie in the spectrum of studies from innovations in public management to studies on ICT for development (Yildiz 2007). The next subsection explores the academic studies on ICT-led public sector transformations and their trends brought into traditional governance, and also sheds light on the implications of digital transformation for the public sector of a developing world.

15.2.2 Paradigm Shift in Public Services Delivery: Opportunities of E-Government

Since the technological and informational explosion in the second half of the 20th century, researchers of public administration and digital government have been exploring the impacts of the digital revolution on the private sector, followed by its influence on the functions and performance of governments. As suggested by a number of studies, a new digital shift caused traditional centralized departmentalization, hierarchical structures, and strict internal rule-based organizations to change to networked, flexible, innovative entrepreneurship and horizontal integration, and to adopt customer-centric strategies (Kaufman 1977; Tapscott and Agnew 1999; Tat-Kei Ho 2002; Ndou 2004). These profound technological advancements and the easily available information sharing system in turn resulted in paradigm shifts in the public sector as well, which took place later than the private sector's ICT penetration (see Table 15.1).

It is now widely accepted by scholars of public administration (Moon, Lee, and Roh 2012) and digital government (Gil-García and Pardo 2005) that applying ICT in the private or public sector offers a wide range of opportunities and benefits. A number of studies identified the areas of investigation in ICT for governance and suggest bringing research together and integrating studies on public management and digital government (Yildiz 2007). In particular, topical and methodological suggestions to improve research on e-government made by Yildiz (2007) deserve particular attention, as he highlights the true challenge and nature of e-government research, which is expressed in its complexity and context specificity. E-government is, admittedly, a problematic study area as it covers governance and policy making, challenged by and blended with a new way of thinking such as innovation and ICT, thus creating chaos in identifying a certain pattern in the development of e-government (Yildiz 2007).

In an effort to learn about patterns in e-government development and transformational areas of ICT application to the public sector, several frameworks and models have been developed (see Appendix A15.1). One approach to framing e-government implementation is analyzing evolutionary or maturity stages of e-government in local, municipal, national, or regional contexts. These stagist or evolutionary models of e-government, proposed by different researchers, present similarities with a few distinctions. In general, the establishment of an online presence by government authorities, preparing regulatory and legal grounds for e-government, is considered to be the basic or online presence stage. The next stage is the increase in the number of state online services, which is characterized by an ability to make basic transactions on e-government platforms such as registration or the ability to file an application for certain public services. According to the United Nations Division for Public Economics and Public Administration and the American Society for Public Administration (UNDPEPA and ASPA 2001) and Laynee and Lee (2001), a mature level of e-government presents horizontal integration across government authorities; as widespread two-way transactions between users and the government through e-government platforms prevail, citizens are engaged in a democratic decision-making process through online voting, thereby interacting with public officials. The abovementioned models thus assume that mature e-government is expected to contribute to open government and democratic processes in which e-government turns into one single system connecting all domains and levels, which include G2C, G2G, and G2B.

Table 15.1: Paradigm Shift in Public Service Delivery in the Information Age

	Bureaucratic Paradigm	E-Government Paradigm
Orientation	Production cost-efficiency	User satisfaction and control, flexibility
Process organization	Functional rationality, departmentalization, vertical hierarchy of control	Horizontal hierarchy, network organization, information sharing
Management principle	Management by rule and mandate	Flexible management, interdepartmental teamwork with central coordination
Leadership style	Command and control	Facilitation and coordination, innovative entrepreneurship
Internal communication	Top–down, hierarchical	Multidirectional network with central coordination, directed communication
External communication	Centralized, formal, limited channels	Formal and informal, direct and fast feedback, multiple channels
Mode of service delivery	Documentary mode, and interpersonal interaction	Electronic exchange, non-face-to-face interaction (so far)
Principles of service delivery	Standardization, impartiality, equity	User customization, personalization

Source: Tat–Kei Ho (2002).

However, stagist approaches to e-government implementation have faced serious questioning by a number of scholars (Yildiz 2007; Coursey and Norris 2008) as evolutionary assessment has not been able to demonstrate the existing patterns of e-government development in certain countries. In practice, e-government initiatives in some countries do not necessarily follow this linear order, because separate analysis of online public services has shown that individual services might be in different stages simultaneously (Yildiz 2007; Coursey and Norris 2008). Also, the study of e-government practices of many developing countries has shown that those emerging economies in particular are able to quickly adopt the best practices of successful cases and develop several online services simultaneously, which partly undermines the practical validity of the evolutionary model (Yildiz 2007). However, we argue that a maturity-level framework is still a helpful tool for setting standards for e-government development levels and having an overall understanding of its state, which is why this framework is widely referred to in evaluating the status quo of e-government initiatives (Khodjaev 2004; Makoza 2016; Kassen 2019).

If we elaborate more on the link between these broad thematic areas or transformational aspects of governance with the evolutionary stages, it has been indicated by some studies (OECD 2009; Johnson and Kolko 2010) that political and legal effects of digital transformation tend to take place in the more mature stages of e-government, and mostly prevail in Western democracies. As Johnson and Kolko (2010) argue, in transition or authoritarian contexts, technological advances rather facilitate more routine interactions such as access to information or registration and application between government and users, while having a less notable effect on the political participation of citizens in decision-making. We question these findings during our analysis of our case from one of the transition economies. The following subsection thus offers some contextual insights into e-government implementation in transition economies, possible benefits of a technology-enabled shift in the public sector, and existing barriers to their e-government initiatives.

15.2.3 Opportunities for, and Challenges of, E-Government Implementation in Transition Economies

When we discuss the promises of e-government in terms of enhanced services delivery, effectiveness, and cost-efficient public administration and improved citizen participation, one cannot ignore the fact that the extent of these effects depends considerably on the context and enabling environment in the country of interest. Since we aim to discuss the implications of e-government for transition economies, it should be made clear what "transition economies" or "economies in transition" mean.

According to the International Monetary Fund (2000) and United Nations (2018a) classification, transition economies comprise around 30 countries of eastern and central Europe and Central Asia that during the 1990s chose the course of moving from centrally planned economic regimes toward a market-oriented economy in order to raise their efficiency and achieve better economic growth. What makes the transition economies interesting, despite starting their journey at the same time under very similar economic and political conditions, is that they have reached quite varying levels of economic development and political systems. In most transition countries, the shift in economic system has been followed by political transformations that include moving toward a multiparty parliamentary democracy and abandoning the one-party authoritarian system (IMF 2000). Countries within this typology require comprehensive analysis as many of them can be placed into more than one category depending on different economic and political characteristics (UN 2018a). In particular, transition economies of Central Asia (Kazakhstan, the Kyrgyz Republic, Tajikistan, Turkmenistan, and Uzbekistan) can also be categorized as developing countries according to their per capita income levels, so the focus of this study is placed on these transition economies, which currently have a similar economic development pattern and governance system.

E-government implementation in transition economies of Central Asia has not been sufficiently explored yet (Johnson and Kolko 2010; Bershadskaya, Chugunov, and Dzhusupova 2013; Bershadskaya, Chugunov, and Trutnev 2013; Kassen 2019), while ICT-driven public-sector reforms generally in developing (Ndou 2004; Brown 2005; Stanforth 2007; Bwalya and Mutula 2014; Makoza 2016; Siddiquee 2016) and developed countries (Tapscott 1996; Tapscott and Agnew 1999; Tat-Kei Ho 2002; Brown 2005) have attracted a large number of scholarly groups. Most of the studies undertaken in economically developed countries and policy analysis by research institutes (OECD 2009, 2017) indicate that Western democracies set a high level of citizen and government online interaction, cross-border mobility, and interoperability as the priorities of e-government initiatives, as they clearly see the potential in digital government to maintain a more socially just and democratic society (Gil-García and Pardo 2005). Perceptions on the application of ICT in the public sector in developing countries, including transition economies, have, however, a different landscape from that of developed countries, and many studies (Ndou 2004; Siddiquee 2016) assert that the potential of e-government still remains underutilized. In contrast, some scholars are doubtful about the positive democratizing effects (Johnson and Kolko 2010) of e-government in authoritarian or less democratic countries around the world, claiming that digitalization in the public sector strengthens monopoly power further.

Some studies focusing on the innovative public sector reforms in the former Soviet socialist states of central and eastern Europe also show that these countries, having started public sector reforms under similar conditions to those in Central Asia in the 1990s, have achieved an extremely high level of digital development in the public sector.

Table 15.2: Opportunities and Benefits of Technology-Enabled Public Service Delivery in Developing and Transition Economies

E-Government Opportunities for Developing and Transition Countries	Examples	Benefits for Whom?
Cost reduction and efficiency	• Solution for shortage of personnel and inadequate facilities (Bwalya and Mutula 2014; Makoza 2016) • Decrease of document processing cost (Ndou 2004) • Cost and efficiency for citizens and other users (Madon 2009)	Supply and demand side
Improved transparency, accuracy, and accountability	• Facilitation of information transforming between government and customers (Alshehri and Drew 2010) • Decreased corruption (Lupu and Lazăr 2015; Nam 2018)	Supply side
Network and community creation	• Network and interoperability between different levels and departments of government and improved decision-making (Alshehri and Drew 2010; Bwalya and Mutula 2014) • Forums, and network between users (Ndou 2004)	Supply and demand side
Improved democratic processes	• Increased citizen participation through voting, organizing campaigns, and fundraising events online (Netchaeva 2002; Brown 2005)	General benefit for the society
Social benefits	• Access to health care, education, employment opportunities, funding sources, etc., thus achieving poverty reduction in communities (Makoza 2016)	Demand side

Source: Author’s elaboration based on different sources.

Specifically, Estonia and Poland have set examples for other developing countries in effectively utilizing the potential of ICT in the public sector and achieving a high coverage of the population with public services through digitalization (Kattel and Mergel 2018). For example, Estonia has been recognized as a leading post-Soviet European country in digital government, consecutively ranking in the top 20 on the United Nations E-Government Development Index in recent years. However, analysis of the e-government implication for democratic processes indicates that the majority of transition economies are still yet to achieve much progress in terms of citizen engagement, transparency, and democratic governance (Kattel and Mergel 2018; Knox 2019; Johnson and Kolko 2010).

According to the existing literature, the opportunities that ICT application is expected to bring to public service delivery tend to be similar for developed, developing, and transition countries. In this work, we synthesized from the literature the benefits or opportunities of e-government initiatives in developing and transition contexts both on the supply side (benefits for government authorities) and the demand side (citizens and other users of state online services) and the overall benefits of electronic government. These opportunities create motivation for governments to adopt ICT in public service delivery and reap technology-enabled benefits (Table 15.2).

Nevertheless, e-government initiatives do not always revolutionize public service delivery unless an enabling environment is created and certain implementation principles are maintained (Bwalya and Mutula 2014). The success and failure of ICT-led public sector reforms in developing and developed countries were thoroughly analyzed through government and user surveys, observations, and content analysis of government websites (Heeks 2003; Stanforth 2007; Madon 2009). Heeks (2003) demonstrates that among observed e-government projects in developing countries, 30% were not successful, 50% suffered partial failure, and only 15% became successful. To understand the causes of failure, the author suggests considering the "reality to design gap" between seven dimensions of e-government projects, such as information, process, technology, objectives, management, skills, time, and money. These dimensions also present barriers, risks, or challenges in transforming the public sector through ICT application, especially for developing or transition economies as they lack the necessary resources and skills. The challenges and problems that prevail in developing and transition economies in e-government implementation can be summarized as shown in Table 15.3.

In summary, the literature review indicates that e-government is an attractive strategy that comes with a number of opportunities for public service delivery. Yet there is accumulated evidence showing that ICT-driven development also poses serious challenges to governments in implementing e-government programs. To mitigate the risks and challenges, a digital shift in the public sector should be seen as a wide governance reform agenda that takes historical, socioeconomic, and cultural contexts into account to achieve the expected positive outcomes from digital transformation rather than blindly copying examples from other cases. The next subsection sheds light on the socioeconomic profile of Uzbekistan, the country that has been selected as the case for e-government analysis in transition or post-Soviet countries to understand the underlying reasons for adopting digital government reforms and the objectives of this change.

Table 15.3: Challenges and Problems of E-Government Reforms in Developing Countries

Category	Challenges or Problems
Technical and infrastructural	• Low levels of ICT infrastructure (lower penetration of electronic devices and the internet among population) • Poorer quality of information and overall e-government platforms • Absence of sound privacy and information security system • Low levels of computer literacy within population
Institutional or managerial	• Lack of clearly identified institutional approach to manage e-government (centralized or decentralized) • Lack of financial resources to manage widescale e-government projects • Lack of leadership skills in technology-led reforms in the public sector • Prevalence of doubt and resistance to change in traditional governance • Absence of policy guidelines • Lack of qualified and skilled personnel to work with ICT.
Legal and regulatory	• Lack of ability to create new legal and regulatory framework for e-government in protecting privacy and restricting online crime
Environmental context	• Reluctance to accept new technologies by individuals due to certain cultural and social factors (educational and cultural background, including social structure, language, religion, and economic and political ideology) • Lack of inclusiveness due to geographic and demographic context (geographically dispersed populations and large territories sometimes make ICT infrastructure difficult to access)

ICT= information and communication technology.

Source: Author's elaborations based on literature review (UNDPEPA and ASPA 2001; Ndou 2004; Gil-García and Pardo 2005; Rakhmanov 2009; Bwalya and Mutula 2014; Siddiquee 2016; Knox 2019).

15.2.4 Context of the Analysis: Socioeconomic and Political Profile of Uzbekistan

Uzbekistan is a Central Asian republic that became independent from the Soviet Union in 1991. Geographically, it is a double landlocked country (double landlocked with only one other country – Liechtenstein), bordering Kazakhstan, the Kyrgyz Republic, Tajikistan, and Turkmenistan, and it is the fourth-largest country by area among the Commonwealth of Independent States (CIS).[1] The government system is unitary, and administratively the country consists of 12 provinces and one autonomous republic.

As for its demographic profile, Uzbekistan is the most densely populated Central Asian republic (32 million), with over 50% of the population living in urban areas. With regard to its cultural profile, there are over 130 ethnic groups, with Uzbeks comprising the majority at 80%, Russians 5.5%, Tajiks 5%, Kazakhs 3%, Karakalpaks 2.5%, and other groups representing less than 1%. Religion- and belief-wise, the majority of the population are Muslims (88%) (SCS 2019).

After the dissolution of the Soviet Union in 1991, Uzbekistan faced the dilemma of developing all sectors of the economy from scratch and reforming the public sector from a new perspective in line with its new policy priorities. The country abandoned its centrally planned economic regime and set off with a new economic system based on private property and free-market forces. Previously, the country had been a resource-based economy, heavily specialized in cotton production and agriculture during the Soviet period for over 70 years. As the ties with processing and manufacturing companies broke in 1991, Uzbekistan was left in tough economic disorder and a transition recession. The country could not immediately liberalize currency and trade freely with the outside world; instead, it adopted a gradualist approach in all sorts of reformations (Tsereteli 2018). Despite these economic challenges, the country has taken major steps to restructure state-owned enterprises and the financial sector, promoting private small and medium-sized enterprises (SMEs), introducing land reforms, and reforming public sector institutions.

The post-Soviet economic, institutional, and political circumstances were reflected in the governance structure and public administration practices as well, characterized by the centralized and hierarchical nature of decision-making in Uzbekistan (Adams and Rustemova 2009; Johnson and Kolko 2010). Therefore, many

1 The Commonwealth of Independent States is a regional integration of 10 Eurasian countries formed following the collapse of the Soviet Union.

scholars adopt a positive approach in studying the potential opportunities presented by digital technologies to democratize the public sector, particularly in authoritarian countries. Johnson and Kolko (2010) undertook research on the implications of e-government for transparency in authoritarian regimes, with a focus on Central Asian republics in exploring the nature of e-government initiatives in nondemocratic countries. The authors conducted a comprehensive content analysis of national-, regional-, and local-level government websites of Kazakhstan, the Kyrgyz Republic, and Uzbekistan, and concluded that in less democratic or highly centralized countries, the online presence of government does not necessarily represent a more accountable, transparent, or responsive government (Johnson and Kolko 2010). Also, it has been highlighted as a conclusion that city- or local-level e-government tends to be more responsive and citizen oriented than their national-level counterparts (Johnson and Kolko 2010). However, we argue that the study was conducted before 2010 and reflects the situation of that period; therefore, a study reflecting the influence of recent or ongoing changes is needed to evaluate the potential implications of e-government for Uzbekistan.

As a conclusion to the section, existing literature on digital reforms in the public sector suggests that e-government offers a wide range of opportunities for both developed and developing states, including managerial efficiency, improved public services, and better transparency and accountability. In particular, there is a consensus among researchers that ICT-enabled public sector reforms might considerably encourage democracy and citizen participation in transition economies. However, there are also claims by scholars that increased online presence of authoritarian governments does not necessarily represent improved democratic processes, because developing transition economies encounter a number of challenges and barriers triggered by their socioeconomic contexts, which in turn might hinder the desired outputs of e-government reforms.

15.3 Analytical Framework and Research Methodology

This section presents the framework of analysis for investigating the questions and tools or methods to be used to evaluate each domain of our framework. In addition, descriptions of survey data collection and the limitations of the research are provided.

15.3.1 Analytical Framework

The literature overview shows that there is insufficient research on e-government development in Uzbekistan as e-government itself is a policy tool that has been introduced recently in the public sector reforms. Among the prominent works exclusively on e-government development in Uzbekistan, we can highlight the work of Khodjaev (2004) for the United Nations Development Programme (UNDP) project to develop an e-government system in Uzbekistan. Another work worth noting on the current status and challenges of digital transformation in Uzbekistan was conducted by Rakhmonov (2009). Reports by international organizations on ICT development and e-governance (UNDP 2013; UN 2018b; OECD 2019) and the works on innovative public sector reforms in Central Asia carried out by Adams and Rustemova (2009), Johnson and Kolko (2010), Brimkulov and Baryktabasov (2018), and Kassen (2019) have served as references in developing the framework, setting a number of assertions and proposals in this work.

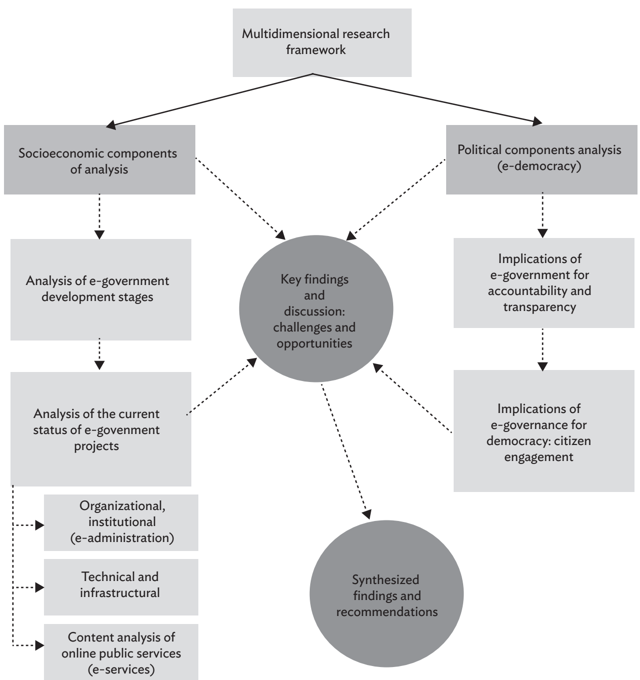
However, investigations solely reflecting the recent e-government progress in Uzbekistan are rare, and related data are limited, which also prevents a holistic and comprehensive overview of the e-governance of the country. In addition, there is hardly any work among the existing literature that sheds light on the recent developments in terms of the open data, civic engagement, and transparency dimensions of recent e-government initiatives in Uzbekistan. Therefore, we decided to build a multidimensional analysis (Kassen 2019) of the digital transformation in the public sector of Uzbekistan with available sources and analytical materials. The analytical framework is grounded in line with the approaches taken in previous studies related to the digital transformation in governance of Central Asian and other post-Soviet republics as we can draw a number of similarities in terms of the historical aspects of the development and governance structure, in spite of considerable differences in the current state of the socioeconomic profile. Our multidimensional framework has been developed to address the following research questions:

(1) What are the objectives and the status quo or the current stage of e-government in Uzbekistan as being one of the transition economies?
(2) What are the key challenges and progress that have been faced in e-government implementation?
(3) What progress has been achieved in terms of transparency and citizen engagement since the introduction of ICT-driven public sector reforms?

(4) How can these challenges be tackled to reap the benefits of e-government?

All things considered, the framework for analysis is built on the case study of Uzbekistan's digital reforms in the public sector. A separate conceptual framework (case study, maturity framework, user experience) was used to analyze each domain and was integrated into the given comprehensive framework (Figure 15.2).

Figure 15.2: Multidimensional Framework for Analysis



Source: Elaborated by the author based on Kassen's framework (2019).

15.3.2 Research Methodology

In line with the research questions and the framework, the current work is mainly based on the following secondary and primary data sources:

(1) The academic literature and studies on ICT-led public sector reforms
(2) Legislative and policy documents published by the Republic of Uzbekistan, as well as reports by international development organizations such as the UN, World Bank, and OECD
(3) Observation of the websites of national-, local-, and city-level public agencies through which the majority of online public services are offered

It is important to analyze the **socioeconomic contexts of the country** to understand the enabling environment for e-government, and its implications for the need for innovations in public administration. There is accumulated evidence from the literature that the success or failure of certain e-government strategies is highly dependent on the context of a particular country (Bwalya and Mutula 2014; Kassen 2019).

Further, **retrospective analysis** is conducted with the purpose of identifying the key development stages and prerequisites of ICT reforms in the public sector of Uzbekistan, and is undertaken from three different perspectives:

- Development of legal framework for e-government through legal acts and regulatory documents
- Analysis of e-government actors and institutional architecture through reports and websites
- Changes in the overall progress of e-governance assessed by observation of government reports, the UN E-Government Survey (UN 2018b), and other ICT development indicators through government statistics[2]

Analysis of the current status of government websites is conducted to assess the progress of e-government development through the following lenses: current **institutional**, **technical**, **environmental**, and **service quality** (G2C, G2B, and G2G) perspectives. The first three aspects are analyzed through secondary data such as government regulations and policy documents, as well as reports by international organizations. The quality-of-service analysis is evaluated through

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[2] The United Nations E-Government Survey is conducted every 2 years to assess the progress of e-government development at the national level among 193 countries. It measures the progress through the E-Government Development Index (EGDI), which is a composite index calculated through the weighted average of three indices: the Telecommunications Infrastructure Index (TII), the Human Capital Index (HCI), and the Online Service Index (OSI).

three methods: the first is observation of selected government websites through a maturity framework; the second is user experience survey results; and the third is previous literature on e-government. Unlike the content analysis of national- and local-/city-level government services from a transparency perspective conducted by Johnson and Kolko (2010), this work intends to undertake national-level content analysis of recently upgraded and relaunched government websites. Given the fact that Uzbekistan's e-government projects are of a centralized nature and are implemented by higher levels of government, it is reasonable to analyze selected e-government platforms through an evolutionary framework (presence, interaction, transaction, horizontal integration) as it is a fairly straightforward and simple analysis (Khodjaev 2004).

Political components of analysis are a relatively new area of study in the e-government of Uzbekistan. This subsection features two-way analysis: evaluation of the transparency, anticorruption, and accountability effects of e-government projects, on the one hand, and e-government's contribution to an increased participatory process in the policy making through improved civic engagement, on the other. Reviewing UN indicators such as the E-Participation Index[3] and Human Capital Index, along with observation of website contents and the results of the survey serve this purpose.

Survey Data Collection Method

In this research, a user-experience survey is employed in order to gain further understanding about the content of online services, as well as obtaining an overview of citizen engagement in decision-making (Appendix A15.6). In previous studies, user satisfaction surveys were mostly utilized to evaluate the "design-reality gap" (Heeks 2003) or to analyze user experience in order to identify the actual usefulness of online government services (Bwalya and Mutula 2014; Makoza 2016). In this work, the results of the survey are analyzed or given as evidence throughout the discussion in the relevant part.

The questionnaire was built through Google Survey and consists of 13 closed and open-ended questions in the local (Uzbek) language, and is divided into three sections. Splitting the survey into three parts helps us understand three patterns:

- Section 1 – overall satisfaction of users with e-government services

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[3] E-participation is a measurement introduced by the UN in 2001, an indicator that evaluates citizens' access to information and their involvement in decision-making (https://publicadministration.un.org/egovkb/en-us/About/Overview/E-Participation-Index).

- Section 2 – their access to ICT
- Section 3 – demographic characteristics

Individuals and entities from both urban and rural settings were invited to take part in the survey through a link randomly sent via Telegram, Facebook, and WhatsApp, which are widely used social media platforms in Uzbekistan. Overall, 94 responses were received during July–August 2019. The results were analyzed using descriptive statistics generated through Google spreadsheets, automatically imported from Google Survey.

It should be noted that conclusions cannot be drawn only from the survey results, but the survey is a useful source of information in terms of evaluating gaps between reality and the expectations of users from e-government projects, as well as examining the level of citizen engagement in public policy.

15.4 Findings and Discussion: The Case of E-Government in Uzbekistan

This section is dedicated to the analysis of digital transformation in the public sector of Uzbekistan. In accordance with the multidimensional framework, first of all, the evolution of e-government is discussed to nurture understanding about the current state and nature of e-government in the country. Then, discussions from organizational, infrastructural, content, and political perspectives are presented to identify challenges and possible solutions for e-government development.

15.4.1 Analysis of E-Government Development Stages in Uzbekistan

Retrospective examination or analysis of the evolution of e-government (Kassen 2019) allows us to understand development patterns such as how and for what purpose the reforms in the public sector were initiated, the extent to which the country has achieved progress in predefined goals over the last few years, and where e-government is now heading, all of which provide important insights in making recommendations for further e-government development. The retrospective analysis in this work is conducted from the standpoint of e-government strategy and policy planning through familiarization with historical government documents, regulations, and reports by international organizations. An important point to note is that, according to a careful observation of the materials, digital initiatives and e-government strategies in Uzbekistan are considered to be part of wider public sector reform, and digitalization itself is not the final target.

The Foundational Stage (1999–2002)

The base and enabling environment for ICT-driven public reform was initiated with the adoption of the "Program of Modernization and Development of National Data Transmission Network of the Republic of Uzbekistan for the Period 1999–2003."[4] The following were the main objectives of this program (UNECE 2003):

- To create the foundational requirements for building a national data transmission network.
- To develop a single system for centralized linkage of a data transmission network of the country, identifying major stages of technological and information modernization.
- To determine the sources for financing technical modernization of ICT systems, ways of attracting foreign investment, and formulation of state funds.

In short, initial efforts in the movement toward digitalization in the country were started by establishing the technical and other infrastructural bases for a national strategy for ICT development.

The First Phase (2002–2011): Building the Infrastructure and Legal Base of E-Government

Phase 1, which was a comparatively longer period, was mainly marked by building foundations for an information society, or an enabling environment for e-government,[5] including a legal and institutional landscape, developing ICT infrastructure. Implementation of ICT reforms in the public sector in Uzbekistan set out in 2002[6] as a part of the national ICT strategy when the presidential decree on ICT and computerization was passed (UNECE 2003; Khodjaev 2004; Rakhmanov 2009; ADB 2012). E-government initiatives in Uzbekistan became a major step in the country's attempt to transform public authorities' performance—namely, reducing pressure and workload, increasing efficiency, and reducing costs. At the World Summit on the

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4 Resolution of the Cabinet of Ministers No. 193, 22 April 1999.

5 According to UNDPEPA and ASPA (2001), the key areas of an enabling environment for e-government are institutional capacity, cultural and human resources conditions, ICT strengths, and political commitment. These are the core areas that governments need to evaluate the progress and opportunities, and identify challenges.

6 Presidential decree on the development of computerization and introduction of information and communication technologies (UP-3080, issued 30 May 2002).

Information Society in 2003, the Deputy Prime Minister of Uzbekistan announced the aspiration of the country to build an information society that was people oriented and would enable members of communities to freely search for, receive, and share information, which was a major commitment by the country to adopting ICT-enabled development in all spheres of life, including in the public sector (Aripov 2003).

A major policy project in e-government at this stage was the adoption of Introduction of Electronic Technologies into Governance for 2003–2010 by the national government,[7] which was aimed at introducing electronic circulation in government authorities. The other major policy papers that laid down the legal base were the following laws:

(1) No. 822-1 “On Telecommunications,” 20 August 1999;
(2) No. 560-II “On Informatization,” 11 December 2003;
(3) No. 562-II “On Electronic Digital Signature,” Tashkent, 11 December 2003;
(4) No. 611-II “Electronic Document Management,” 29 April 2004; and
(5) the concept of creating an integrated information system for state bodies, 2006.

As can be seen from the policy documents, the initial stage of digital transformation in the public sector started with binding informatization and introduction of ICT into the legal system. The creation of an institutional framework, the preparation of e-government preliminary legal conditions, and pilot projects in implementing software and hardware in public administration were the main highlights of the first phase.

The Second Phase (2012–2014): Furthering Development of ICT Infrastructure and Creation of Integrated System

The next stage of digital reform in the public sector is characterized by setting out to realize and implement the strategies set in the initial phase through presidential decrees and other state documents such as an e-government master plan on integrating ICT into the public sector and other broad areas such as the real sector of the economy.[8] Among the most important changes in terms of creating an enabling environment for ICT-driven public sector reform, the following achievements can be highlighted:

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7 Available at http://lex.uz/acts/973556 (in Russian).

8 See Appendix A15.2 for a list of policy papers during this second phase.

- Introduction of the action plan, which was a huge progress in the development of a national strategy for e-government: Program on Development of National Information and Communication System of the Republic of Uzbekistan for 2013–2020 (Rakhmanov 2009; UNDP 2017).
- Formation of institutional framework for ICT-enabled reform of public policy: E-Government Development Center, an agency exclusively responsible for shaping the strategy, capacity building, and technical expertise was established in 2013.
- An initial step in creating nationwide government and public interaction was taken by introducing a single portal of interactive public services on "single window" principle (www.my.gov.uz) was introduced, where public services in taxation, education, health care, pension system, etc. were made accessible from a single platform (EECA 2014).
- Formation of communication and service portals of certain government organs, such as a portal of housing and communal services (ek.uz), national education portal (Ziyonet), and national information search system (www.uz) (EECA 2014).
- Also, initial political and legal measures were taken in terms of transparency and accountability through passing of the law "On Transparency of Government Bodies," 2014.

In summary, the second stage of public sector reforms is marked by a significant shift toward the formation of a national e-government system, in which managerial, political, and technical domains of digital government also started to emerge and be integrated into a single system.

The Third Phase (2015–2020): Creation of New Landscape of E-Government with Political Implications

The third phase of e-government implementation is characterized by practical steps taken to realize the tasks set in the master plan for ICT development for 2013–2020, which included a broad range of spheres in terms of public sector reforms. Major efforts were made toward open government that have implications for increasing data sharing among government authorities, between the government and citizens, and between the government and businesses. In particular, the following transformations have taken place in the recent phase:

- Launch of the open data portal (www.data.gov.uz), which has political as well as economic impacts on overall development if managed successfully. Specifically, UNDP (2017) and Press Service (2019) stress that open data initiatives are crucial for realizing the potential of e-government, particularly enhancing the transparency of government agencies, providing an opportunity to make evidence-based policy through data, and boosting the investment climate through improving the country's attractiveness.

- Open law making or legislation initiative by introducing the platform www.regulation.gov.uz, which is publicly open and monitored for evaluating legal projects and regulations.
- Launch of a wide range of e-government platforms such as public participation and dialogue portals to file appeals or petitions, or propose projects (https://meningfikrim.uz/, http://jamoatfikri.uz/uz).
- Introduction of the concept of developing "E-Government in the Republic of Uzbekistan" in March 2019 (UZDaily 2019), a policy project that includes assessing the major challenges and opportunities of the digital reforms in the public sector, as well as determining further steps of action.

In short, the current phase of e-government development in Uzbekistan is a distinct stage in e-government policy formulation, which has laid a solid base for a new landscape of digital transformation through huge content upgrading and the introduction of government initiatives to employ ICT-driven government reforms for promoting open data and transparency.

Summary of the Retrospective Analysis

All development stages of digital government in Uzbekistan discussed above are summarized in Figure 15.3. According to Gartner's model of evolutionary stages (Noman and Hebbar 2016),[9] one can draw the following initial conclusion: Uzbekistan's current e-government development is still in the interaction stage, and is expected to pass along not an easy path as digital governance reforms are being implemented in parallel with the reforms in the core public administration (fight with bureaucracy, improving transparency, accountability of government organs). Also, the country is systematically moving toward scaling up transaction-enabled public services for citizens and businesses (NAPM 2019b), as emphasized in national documents and reports. However, the conclusion on the current maturity level of Uzbekistan's e-government should be drawn after analyzing the content of the services, backed up with the user-experience survey results in the next subsections.

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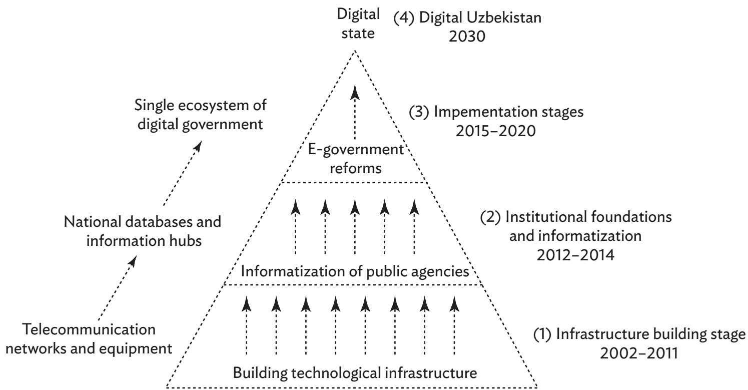
9 Gartner's maturity model of e-government is quite similar to that of the UN's evolutionary framework, which also includes presence, interaction, transaction, and transformation stages of e-government development.

Figure 15.3: Stages of Digital Transformation in the Public Sector in Uzbekistan



Source: Visualization by the author.

15.4.2 Analysis of the Current State of E-Government in Uzbekistan

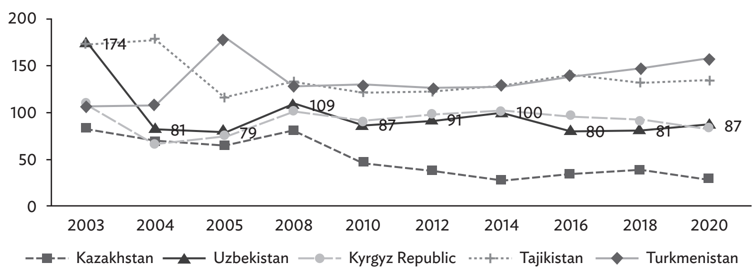
International development organizations, human right institutions, and scholars of ICT for development research suggest that recent technological advances offer significant benefits for overall development, especially in emerging or developing countries. In particular, the potential of ICT in revolutionizing public sector efficiency and improving the quality of services, and consequently nurturing participatory democracy and open governance, is stressed in almost all policy documents of the UN, World Bank, ADB, and other development institutions. In particular, the UN launched benchmarking for assessing e-government development in 2001 and introduced the complex indicator the E-Government Development Index (EGDI), which has been measured through the biannually conducted E-Government Survey since 2003.[10] There are also a number of subindicators, such as ICT infrastructure, human capital, and the level of innovation, which help us understand the state of the enabling environment of e-government. This subsection aims to examine the progress achieved by Uzbekistan in

10 For the framework, see https://publicadministration.un.org/egovkb/en-us/Reports/UN-E-Government-Survey-2003.

terms of e-government development since the government's initiatives took off in 2001 through these indicators, state statistics, and other analytical materials.

One can see that the national reports and analytical materials are positive about what has been achieved so far in terms of creating a legislative base, and the overall increase in the quality and number of government services in Uzbekistan. However, when analyzed through the EGDI, which compares countries' performance rather than assess the absolute progress of e-government, Uzbekistan's performance remains in the middle range, ranking 87 among 193 countries (UN 2020). Interestingly, neighboring Kazakhstan is acknowledged as being the regional leader since 2003 (Brimkulov and Baryktabasov 2018; Kassen 2019), having been ranked 39th and managing to deliver half of the government services online in 2018 (Kazakh TV 2019).

Figure 15.4: Comparison of EGDI Ranking Dynamics of Central Asia, 2003–2020



EGDI = E-Government Development Index.

Source: United Nations E-Government Survey, historical data (https://publicadministration.un.org/egovkb/en-us/Data-Center).

Uzbekistan was mentioned in many reports as a country with serious impediments with respect to ICT development (UNECE 2003; ITU 2014), which can also be observed in Figure 15.4. Among the three subindices of the EGDI (Appendix A15.3)—those for telecommunications and infrastructure (TII), online services (OSI), and human capital (HCI)—Uzbekistan was performing poorly, particularly with respect to ICT infrastructure (TII), which diverges widely from that of Kazakhstan. Both countries have shown a high level of human capital and a similar level of medium-quality online services. The reason for the limited telecommunications and infrastructure capacity over the years can be partly explained by the geographical and demographic conditions of the country. In comparison to other Central Asian republics and eastern and central Europe, Uzbekistan has the largest population, a sizable territory, and a geographic location with no direct access to the sea, all of which have implications for the country's overall income level and state budget for infrastructure, as well as a limited capacity to provide remote parts of the country with infrastructure.

Yet, the above indices alone cannot provide a full overview of the current state of e-government development. For example, Knox (2019) discussed a paradox concerning e-government in Kazakhstan, arguing that despite hitting the leading position in CIS countries in terms of e-government, Kazakhstan lacks in the true value of online public services, which has been discovered through interviews and surveys. Therefore, we also assert that there is a need for an in-depth examination of e-government domains; in other words, an enabling environment such as an institutional framework, infrastructure, and the quality of the services themselves, which is presented in the following subsections.

Organizational Landscape of E-Government of Uzbekistan

Institutional analysis indicates that from the beginning, the national government has been the initiator, implementer, and controller of the performance of all national strategies and programs in Uzbekistan, including ICT reforms, due to the centralized nature of governance inherited from the Soviet system. The law "On e-government," which was enforced in June 2016, provides an overview of the responsible government bodies in the creation and implementation of e-government projects, as well as insight into the nature of governance in the country, which is evidence of the centralized approach in e-government implementation policy. According to the document, the following are the main bodies that participate in the formulation, implementation, and delivery of the national e-government strategy (2015):

- **Cabinet of Ministers:** the body responsible for overseeing the implementation of the single state policy on e-government
- **Ministry for Development of Information Technologies and Communications of the Republic of Uzbekistan (MITC):** an authorized body responsible for realizing and implementing the unified policy for ICT and e-government, developing and proposing ICT projects, etc. (MITC 2019)
- **State Unitary Enterprise E-Government and Digital Economy Project Management Center (EGDC):** established under the National Agency for Project Management (NAPM) and responsible for managing e-government projects as a part of the "Digital Uzbekistan 2030" program, conducting expert

reviews of projects and regular monitoring of the progress of projects, and advancing proposals (NAPM 2019a)

- **Local ministries**
- **UZINFOCOM:** a unified integrator for creating content, software, or platforms for government services
- **UNICON:** a think tank that develops regulatory and legal frameworks in the ICT sphere, as well as a unitary company that develops interagency interoperability software, with a guarantee of information security.

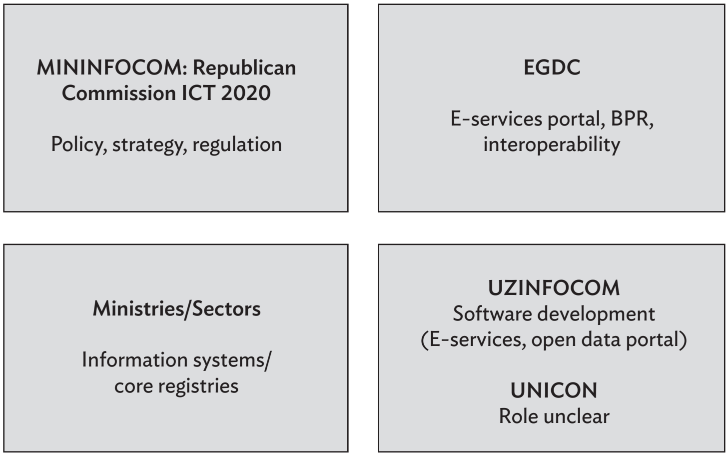
Among these institutions, the exact tasks and responsibilities of UNICON are blurred and not clearly identified (UNDP 2017). Having visited the website of the unitary company, we realized that the website does not function fully, and has missing links and descriptions about their operation.

Another point about institutions is that the responsibilities and tasks of local authorities in e-government implementation are not stated or clearly defined in the law "On e-government." According to Johnson and Kolko (2010), e-government services are more efficient when implemented at a city or local level, since online services rendered by lower levels of public agencies better represent the needs of citizens or businesses. Based on this logic, it is reasonable to promote and pay broad attention to the development of local- and city-level e-government services. However, our observation shows that in Uzbekistan this aspect is still in its infancy, and local public authorities are not yet given much freedom to take the lead and initiate e-government projects.

Further, there is a lack of collaboration between responsible institutions of the e-government system. At present, a body that efficiently coordinates with a good knowledge of the ICT-enabled government reform is missing from the organizational system (Figure 15.5). Despite the fact that the Cabinet of Ministers is the central body that controls the implementation of projects, other ministries have reported that none of the institutional e-government bodies cooperate efficiently with each other or are coordinated efficiently. For example, the EGDC remains the only body that is fully responsible for developing and proposing e-government projects, as well as working on funding plans without enough capacity to handle such massive responsibilities. There is a need for another independent body that will be responsible for overseeing compliance and monitoring the progress and implementation of digitalization (EGDC 2018). Another finding from the organizational aspects of e-government is the lack of qualified government personnel with ICT skills. The subcomponent of the ICT Development Index (IDI)[11] also confirms that

[11] For the IDI framework, see https://www.itu.int/en/ITU-D/Statistics/Pages/publications/mis2017/methodology.aspx).

Figure 15.5: Institutional Ecosystem of E-Government Strategy



BPR = business process redesign, EGDC = E-Government and Digital Economy Project Management Center, ICT = information and communication technology.

Source: United Nations e-government technical assistance.

Uzbekistan's tertiary education enrollment rate was just 9%, whereas the world and CIS regional average was 40% and 50%, respectively, in 2018 (Appendix A15.4).

Moreover, currently a unified and standardized system for recruiting government personnel does not exist. There is no system for monitoring the qualifications of government officials working in e-government projects (EGDC 2018).

Despite the fact that centralized governance might facilitate efficient implementation of national-scope programs in theory, Uzbekistan's digital government programs are facing challenges such as the unclear roles of e-government bodies, a lack of collaboration among institutions, absence of the same voice, and a lack of skilled professionals with ICT literacy.

Technical and Infrastructural Dimensions of E-Government

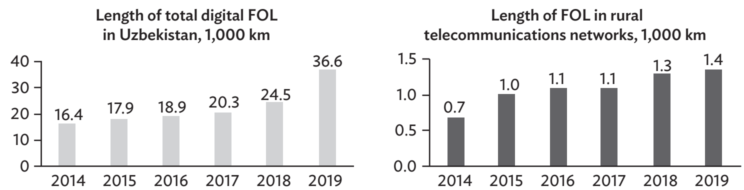
Infrastructure and technical preconditions are important requisites for ICT-led public sector reforms that will inspire a major turnaround in all spheres of life leading to a knowledge-based society. The initial stage of e-government development in most developing countries, including Uzbekistan, was the establishment of technological capacity and infrastructure (UNECE 2003; Kassen 2019).

If we look at the historical data on ICT penetration in Uzbekistan through the UN's Telecommunication Infrastructure Index (TII), which is a composite index of active mobile, computer, and internet users, and the rate of fixed or wireless broadband usage (Appendixes A15.3 and A15.4), the country's performance has increased threefold, reaching nearly 0.3 in 2018 starting from 0 in 2002. According to the IDI (Appendix A15.4), which is similar to the UN's TII, Uzbekistan ranked 95th among 195 countries in 2017, showing just 11% in terms of fixed broadband internet penetration, which is well below the regional (13.5%) and world (20.7%) average. The majority of the population access the internet through mobile devices, since the mobile subscription rate is notably high (74 per 100 inhabitants), but still lagging behind other CIS countries, for instance Kazakhstan, where a person owns on average 1.5 cellular phones. Nearly 90% of the survey respondents have access to the internet either on mobile or other electronic devices (personal computer, laptop, internet cafe). The mobile broadband internet subscription rate is 56 per 100 habitants, which is similar to the world and regional average. However, the percentage of households with a computer remains low, at 45%, which also inhibits access to online services, as the majority of e-government platforms are desktop based. Also, residents of remote or rural areas barely have access to the internet—if they do, they suffer poor connection quality, which is evidenced by the Speedtest Global Index.[12] The latest data show that Uzbekistan is ranked 136th, below the world average, and in particular 112th in terms of fixed broadband out of 175 countries, which clearly indicates that measures should be taken by telecommunication companies to update the infrastructure.

Nevertheless, the MITC is positive about current trends in improving infrastructure, stressing the fact that fiber-optic line (FOL) provision into rural areas has increased, and tariff reductions for internet plans at the time of using public services were introduced (Figure 15.6). However, the figures show that rural FOL provision makes up only 5% of overall FOL and has undergone only a very tiny increase over the years. Even though 20 million (60%) people in the country use smartphones, which increases the potential of expanding the government's online services (Ahmedkhadjaev 2019; MITC 2019), the low rate of internet

[12] The Speedtest Global Index compares internet speed data from around the world on a monthly basis (https://www.speedtest.net/global-index/about).

Figure 15.6: Length of Fiber-Optic Lines, 2014–2019 ('000 km)



FOL = fiber-optic line, km = kilometer.

Source: Ministry for Development of Information Technologies and Communications of the Republic of Uzbekistan (2019).

penetration does not allow online service coverage to be extended, which has unfavorable implications for the inclusiveness of government services.

The roots of the problem of internet penetration can be partly explained by the operation of a few telecommunication providers that compete with each other within the country; they are discouraged from investing in rural areas, where the population density is not high, thus making them concerned about low return on investment. Further, a lack of willingness to communicate and cooperate among existing mobile telecommunication providers is another cause of low efficiency in ICT infrastructure development, which has a direct impact on e-government development in Uzbekistan (MITC 2018). An oligopolistic approach with a lack of cooperation is causing a waste of financial resources as the investment in ICT infrastructure is being unevenly made across the regions without being well informed about each other's projects.

Furthermore, insufficient growth in the ICT sector and a scarcity of information technology (IT) professionals as a whole are further challenges slowing down the progress in ICT infrastructure. Specifically, the share of ICT companies in the services sector is still 3.3%, and the share of IT professionals in the total labor force is less than 1%. Also, it is known that a few of the big companies operating in the real sector of the country have not yet taken serious measures to integrate ICT into their operation (MITC 2018). Uzbekistan's position in the Global

Innovation Index (GII)[13] also shows that the sectors in the country have not yet embraced innovative solutions to a satisfactory extent (Appendix A15.5) compared to the neighboring countries. All these factors have an influence on the level of innovations and the cost of technologies in Uzbekistan.

To sum up, ICT infrastructure has received government attention as a priority since 2002, and has been the subject of a number of government programs to increase ICT investment, education, and research. However, telecommunications infrastructure needs further intervention with respect to the internet penetration (rural and urban), new ways of financing ICT projects that are not only dependent on public finance, and government programs that support upskilling or developing IT professionals.

Content Analysis of Online Public Services

The content or quality of online public services, as well as efforts by government to promote them and increase people's awareness, are other crucial factors of reaping the opportunity offered by digital innovation in the public sector. Content analysis of Uzbekistan's e-government platforms is conducted through observation of government websites, policy and analytical documents, and outcomes of the first section of the user experience survey (Appendix A15.6).

Actions recently taken to upgrade the quality of online services are one of the highlights of the current stage of the e-government reforms in Uzbekistan. In particular, the launch of a single interactive portal of state services (www.my.gov.uz) has enabled all applications from users to be collected and distributed to the relevant public authorities, offering benefits both for the users and processing agencies in terms of time and cost. Specifically, government agencies receive the applications in a simplified way, which allows them to process them in a timely manner and save costs as well.

Nevertheless, there is room for further upgrading and expanding of the content and usage of the interactive government portal at present. Uzbekistan's single interactive portal includes more than 140 online

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13 The GII comprises two subindices: the Innovation Input Sub-Index and the Innovation Output Sub-Index. They are built on seven key pillars. Input Index: 1) Institutions, 2) Human capital and research, 3) Infrastructure, 4) Market sophistication, and 5) Business sophistication; Output Index: 6) Knowledge and technology outputs, 7) Creative outputs (see https://www.globalinnovationindex.org/about-gii#framework).

services provided by public authorities, with more than 60,000 registered users (EGDC 2018), with around 40% of the applications coming from individuals and 60% from legal entities (Brimkulov and Baryktabasov 2018). For comparison, the regional leader in e-government Kazakhstan's single interactive portal has 165 types of government services and more than 8.5 million registered users, with 80% of government services being delivered online (Kazakh TV 2019). This might indicate a relatively low performance by e-government in Uzbekistan, bearing in mind that the country's population is twice as large as that of Kazakhstan.

According to Section 1 of the survey (Appendix A15.6), which concerns the perceived quality of online public services, slightly more than a fifth of those surveyed have never used any of the given websites. Three government portals were found to be the most popular among users: the interactive single portal (www.my.gov.uz); the legislative database portal (www.lex.uz); and the state committee of statistics website (www.stat.uz). The majority reported that they rarely complete transactions through government web portals; rather, they frequently download forms, access information and legal regulations, complete basic registering, or file an application (Appendix A15.6, question 2).

Reports and observations from government agencies also confirm that most of the recently introduced electronic services of the G2C and G2B categories do not satisfy the real needs of users (MITC 2018). Among the respondents, 47% believe that the most widely used government portals lack the online services relevant to a local context, which refers to the online services provided by local- or city-level government agencies. Slightly more than one-third (36%) of those surveyed find online portals complicated or not that simple to use. Other than these aspects, most of the selected portals now provide the content in both local languages (Russian and Uzbek) and update it regularly.

With respect to user perception of the possible benefits of e-government, more than half of those surveyed believe that online services save time and cost, and ensure better quality than the traditional way of receiving public services (question 6, Appendix A15.6). Around one-third of the respondents are not familiar with the benefits of receiving services online, even though there are updates in the quarterly reports about optimized public services that simplify procedures in terms of time and required documents (Appendix A15.7). In addition, recently the NAPM released a survey among individuals and legal entities to identify new public services they are willing to receive in an online form,[14] which listed more than 400 services in the single interactive portal. It is not

14 The survey can be accessed at: https://napm.uz/uz/press_center/adverts/siz-qaysi-davlat-xizmatlaridan/.

certain whether the survey might bring expected results as we noticed that channels for spreading these surveys have a limited audience.[15]

Another obvious issue with the use of online services seems to be insufficient promotion of online public services among the population – not least the rural population, who are almost excluded from online public services due to infrastructure deficiencies or a lack of knowledge about e-government, while just under half of the respondents from urban contexts had very limited awareness, with more than half not being aware of any programs, training, or campaigns for using online services. Some 70% (66/94) of the participants expressed a willingness to join training sessions or use educational programs to learn how to use online government services. This indicates that there is not enough promotion or a wide enough campaign by government to introduce or encourage online services, even among the city population who have better access to ICT infrastructure.

Our analysis implies that even though Uzbekistan's e-government system is currently at the initial stage of e-government development (Rakhmanov 2009; NAPM 2019b), transactional services are apparently available in a number of government portals (payment for communal services through single interactive portal, websites of the state tax committee, its local branches, and other web portals). However, the survey reveals that many e-government initiatives are still at the level of the interagency scope without broad expansion to actual use by citizens or businesses. The quality of online services might depend on a set of other factors, such as the lack of ICT skills of the users themselves, or a lack of promotion or campaigns that make them more popular and more user-friendly.

15.4.3 Implications of E-Government for Open Governance and E-Participation in Uzbekistan

This subsection is dedicated to the analysis of e-government from a political perspective—namely, the implications of ICT-led public sector reforms for open governance, open data, transparency, citizen engagement, and participatory democracy in Uzbekistan—which is not only a new dimension of digital governance but has also become a target in recent years by democracy observers such as the UN, Freedom House, and other institutions.

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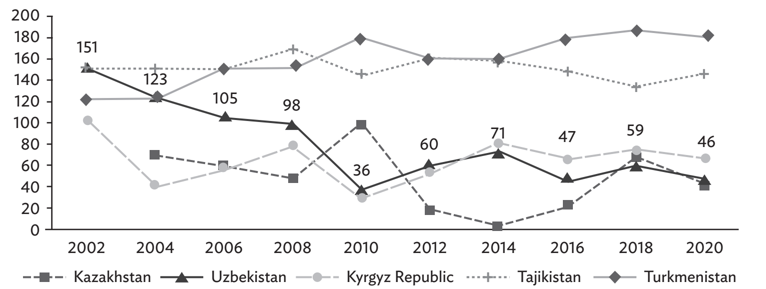
15 The Telegram page of EGDC "Digital Uzbekistan," which promotes and informs about e-government projects, has only 156 subscribers; similarly, the Facebook page under the same name has only 370 followers, which is quite limited compared to Uzbekistan's population of 32 million.

Figure 15.7: E-Participation Index Dynamics of Central Asia, 2003–2020



Source: United Nations E-Government Survey, historical data (https://publicadministration.un.org/egovkb/en-us/Data-Center).

If we look at the UN E-Participation Index dynamics for Uzbekistan, which provides a glance at the overall trend in terms of citizen engagement in democratic processes, the country's performance increased 2.5-fold, boosting its ranking from 151st to 46th out of 193 countries in 2020, which was closer to the regional leader Kazakhstan (Figure 15.7). The change in the ranking started to become obvious from 2014.

As mentioned earlier, Johnson and Kolko (2010), who provided insights into post-Soviet countries' e-government from the perspective of transparency and democracy, strongly argued that digital government in authoritarian or less democratic contexts might serve to expand the government's centralized power further, because all content and the platforms are still built, monitored, and controlled by government, and this does not contribute to citizen engagement or more democratic decision-making.

Interestingly, in Uzbekistan's case, we observed trends of serious commitment to achieving democracy and transparency, and open governance, through the tool of e-government, as the country let the world know that it was shifting toward an open society and more public value-oriented policy in late 2016 (NAPM 2019b).

Recent political changes with a new presidency are broadly discussed and expected to open a path for more open, less corrupt (OECD 2015, 2019), and democratic principles-driven governance (Bowyer 2018), which in turn has also been reflected in the recent trends of e-governance and e-participation. One of the directions in the newly introduced development agenda is the Administrative Reform Project,[16] which proclaimed strategies for introducing effective, more open government that is able to reliably protect rights and freedom in the society, and advance the competitiveness of the country at an international level. The open governance concept in Uzbekistan is being developed in three directions, which also corresponds to the three-dimensional model of open government described by Kassen (2019): open data, open law making, and open dialogue.

One of the notable shifts in the e-government of Uzbekistan has been the launch of an open data portal (https://data.gov.uz/), which holds more than 60,000 data sets from 134 organizations. In comparison with the results obtained by Johnson and Kolko (2010), noticeable upgrades in the structure and content of the portal were observed in terms of expansion of the target audience (legal entities, ordinary citizens, and other agencies), the type of information available, the availability of the content in local languages (Russian and Uzbek), the existence of feedback and suggestion sections, and sources of data and contacts (Appendix A15.8). Moreover, the Uzbek government is currently running a nationwide survey to discover user satisfaction and further strengthen the portal.

The open legislation and open dialogue dimensions of open governance are other critical aspects of increasing the transparency and responsiveness of government agencies, which is believed to allow citizens to participate in law and decision-making. An open law-making portal (www.regulation.gov.uz) has recently been launched to enable law and regulatory projects for open discussion, observation of the progress in the adoption of projects, and presentation of proposals. Another web portal (www.jamoatfikri.uz) was created to ensure effective and transparent implementation, and establish public control over the execution of acts or state regulations by the population, government officials, business entities, and nongovernment organizations.

When these websites were analyzed, low participation of citizens was found in discussions on law projects and legal acts, as well as projects on economy, education, health care, and other sectors. Uzbekistan implemented the practice of parliament considering proposals or petitions if a project accumulated a certain number of votes (10,000) on a number of open dialogue portals (jamoatfikri.uz, maningfikrim.uz). We observed a relatively passive nature among citizens involved in online discussions or forums presenting their proposals or projects (Appendix A15.9), regardless of the type of topic or sphere. Another

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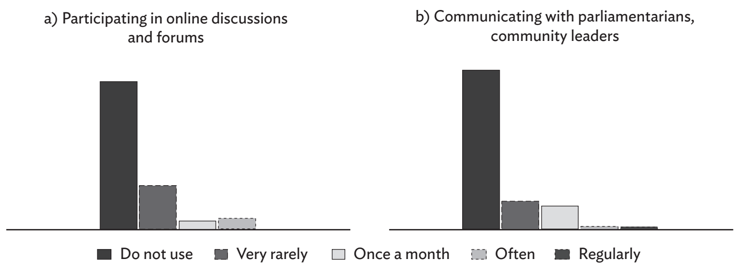
16 The Decree of the President of Uzbekistan "On approval of the concept of administrative reform in the Republic of Uzbekistan," 8 September 2017.

point to mention is that results of consideration or responses by public agencies to petitions are missing in these websites. One might argue that the observed passive trend of public participation might be due to the novelty or recent development of these open dialogue portals. The survey data also show that the percentages of respondents using meningfikrim.uz, regulation.uz, and jaoatfikri.uz to participate in decision-making or express their voice turned out to be 21%, 11%, and 7%, respectively (Appendix A15.6, question 2), in comparison with the users of lex.uz (73%) and my.gov.uz (76%), the portals of legal acts, and the set of interactive services. Also, the majority of those surveyed who use government portals rarely participate in online discussions or forums, and very rarely interact with state officials or community leaders through online platforms or e-mails (Figure 15.8).

Figure 15.8: For What Purposes Do You Use Uzbek E-Government Websites?



Source: Extracted from user experience survey results (Appendix A15.6), Section 1, question 3.

It has become clear that relentless technological advances and the increased worldwide promotion of classic governance that is open, transparent, and citizen oriented by default have laid new challenges for the Uzbek government to reinforce the public sector with ICT. Despite the noticeable interventions made, the country's e-government is in its initial stage, as the interventions to attain a more transparent, efficient, and citizen-empowered public sector through ICT-driven governance are still ongoing and challenged by a number of barriers that need to be addressed to maintain a smooth development.

Table 15.4: Summary of Findings: Challenges of E-Government in Uzbekistan and Policy Recommendations

Aspects of E-government		Challenges	Recommendations
Socioeconomic aspects	Institutional	**Organizational:** • Unclear roles of key stakeholders, sometimes overlapping roles by authorities in e-government realization (EGDC 2018) • Lack of integration, collaboration between different levels of government • Absence of prudent expertise of e-government projects, strong technical control over their realization (EGDC 2018)	• Clear definition of each authority involved in e-government implementation needs to be fixed in legal documents, which is important for accountability of government organs. • Introduction of currently missing central body in e-government landscape might increase coordination between other authorities that also conduct expertise and control over realization of the projects. • Giving more autonomy and support to local-level government authorities to develop their e-government systems might lessen the burden of national agencies.
		Financial: • Uzbek e-government system is financed mainly from the budget of central government and from recently established e-government fund, which is reported not to be sufficient for projects (EGDC 2018; MITC 2019)	• Encouraging public–private partnerships (PPPs) for e-government projects would solve financing and service quality problems as the private sector is assumed to have more resources and funding capacity. Since PPPs are a recent practice for Uzbekistan,[a] this path might be realized in the long run.
	Technical and online service quality	**ICT infrastructure:** • Slow rates of ICT market development • Insufficient share of innovation in the sectors of the economy • Slow expansion of telecom infrastructure into rural areas of the country • Existence of few players in the telecommunication industry, which has monopoly power over tariffs for internet and investment	• In private investment for ICT companies, projects should be encouraged through preferential stimulus in terms of finance or regulations. • Investment for innovations in the ICT sector and R&D should be encouraged. • Encouraging more telecommunication providers to compete might bring competitive operation, investment, and pricing for ICT infrastructure. • Incentive schemes may be considered for communication providers who invest in remote or rural areas.
		Information and data (service quality): • Majority of government websites still just for information access, without the option of completing online transactions • According to a UN report and the EGDC, Uzbek e-government portals lack consultations with end users • Still a large number of required forms to submit by citizens or business entities, which invalidate and complicate online services as well	• The creation of more comprehensive services with online transaction options is highly dependent on other factors such as strengthening the system of online payment gateways, privacy and user information, legislation in these aspects *(based on "User experience survey" results, Appendix A15.6, Section 1, Q3)*.

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Table 15.4 *continued*

Aspects of E-government		Challenges	Recommendations
		• Content of the online portals complicated for ordinary users.	• Each responsible body for e-government should design surveys for end users. Additionally, these surveys should be expanded and promoted among a wider audience, which is crucial to identify the usefulness of the online services *(based on "User experience survey" results, Appendix A15.6, Section 1, Q5)*. • Consideration should be given by government agencies to further simplify in terms of administrative forms and procedures, coming up with simplified online forms (*based on "User experience survey" results, Appendix A15.6, Section 1, Q4*). • The system of privacy and online data sharing need to be strengthened through involving research think tanks or universities.
	Policy and legal aspects	• Law on "Electronic commerce" is still under consideration, which impedes development of online payments. • It takes time until laws "On online crime," and data protection laws are reflected in further legal and normative acts, since these legal projects are still under consideration.	• The regulatory and monitoring framework should be updated and advanced in line with digital development, changes in systems, and needs of target audiences. • Implementation of legal acts in e-government system should be monitored effectively. • The system of privacy and online data sharing need to be strengthened through involving research think tanks or universities.
Political aspects	Open governance and participatory democracy	• Absence of a single body that monitors open governance dimensions in the country. Currently, the EGDC is overseeing open data portal, but the agency has a very broad set of responsibilities, which undermines its capacity to manage all directions. • Open data portal still under reinforcement and has not integrated data sets from a large group of authorities • Data sets in the open data portal, mainly have agencies as a targeted audience rather than citizens. Further, the data are in technical form, which requires prior processing. • Low level of awareness by population of open data, law making, and open dialogue portals, thus resulting in less citizen participation.	• Observation of institutional landscape shows that there is a need for a single responsible body for open governance and open data portal, which would facilitate the burden of the EGDC, and ensure quality compliance and implementation of open governance. • Greater responsiveness and regular interaction are required by government agencies, particularly in their work with citizens through open dialogue and open law-making portals to gain trust and increase transparency (*based on "User experience survey" results, Appendix A15.6, Section 1, Q3*).

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Table 15.4 *continued*

Aspects of E-government	Challenges	Recommendations
		• Educational and promotional efforts are needed to increase knowledge of population about policy making and boost their involvement in decision-making. Educational contents such as videos or guidance materials can be channeled through widely used social media platforms such as Telegram or Facebook, or via text messages (*based on "User experience survey" results, Appendix A15.6, Section 1, Q4*).

EGDC = E-Government and Digital Economy Project Management Center, ICT = information and communication technology. MITC = Ministry for Development of Information Technologies and Communications of the Republic of Uzbekistan.

[a] PPPs are a relatively new practice for Uzbekistan even in traditional areas such as education, health care, and infrastructure projects. The country passed the law on "Public Private Partnerships" on 10 May 2019.

Source: Developed by the author.

15.4.4 Synthesized Findings: Challenges of E-Government in Uzbekistan and Recommendations

In light of the above discussion, this subsection is dedicated to summarizing the findings, synthesizing the challenges in each aspect discussed earlier, and developing policy interventions in e-government implementation in Uzbekistan and drawing broader implications for other post-Soviet transition countries (Table 15.4).

This section has outlined major challenges drawn from analyzing the e-government development of Uzbekistan from two perspectives as described in our analysis framework: socioeconomic and political dimensions. The main conclusion from the section is that success in overcoming these challenges of e-government in Uzbekistan is highly dependent on the performance and leadership potential of national government agencies due to the centralized nature of the governance structure in the country, which needs to take the lead in implementing these policy interventions.

15.5 Conclusion

This research has been conducted to contribute to the analysis of digital reforms in the public service delivery in post-Soviet republics, through the case of Uzbekistan. We have been able to identify the initial purpose of e-government initiatives and how it progressed over the years, and what level of e-government has been achieved.

Having been referred to a country where governance is based on top–down principles and high centralization after the collapse of the Soviet Union, Uzbekistan and other fellow Central Asian republics have made serious commitments to adopt the path of a democratic civil society. In addition to the fact that the countries initially started e-government development reforms with a willingness to optimize the performance of the public sector institutions, at a later stage, they made significant steps to achieve open governance, participatory democracy, and an inclusive society, first moving these elements to the agenda of administrative reforms.

Empirical evidence and observation of e-government websites of Uzbekistan showed that e-government development in transition or developing countries does not necessarily follow the maturity stages of theoretical digital government. Rather, in these countries, existing government services are characterized by being at different stages, ranging from informative to transaction and active interaction stages. And there is a trend that developing countries are customizing and following the best practices of e-government at a fast pace. One of the most important conclusions on e-government infrastructure and content analysis is that a better online presence represented by international indicators or better portal structures do not necessarily represent better public services. This is mainly due to the fact that high ICT penetration or digitalization is not the target, but the broader implications, such as extending the public value of the services and letting citizens or other entities present their voice, thus ensuring a more just and equitable society, are the core objectives of digital initiatives in governance.

Uzbekistan has clearly targeted these broader implications of ICT reforms in the public sector. Hindering successful implementation of the digital reforms in the public sector, however, is the prevalence of a number of challenges, including both institutional and infrastructural ones, a lack of experience in generating online public services with high end user value, as well as other underlying causes such as the structure of the economy and the overall income level, and geographic and demographic conditions. Out of the aforementioned barriers to e-government implementation, the legal framework is the area that needs systematic and immediate addressing, as it lays the legal base for further actions. As for the institutional aspect, even though the centralized governance structure might seem to be a better approach to managing the whole e-government strategy in a systematic and coherent manner, as well as in determining the budget and finance for digital reforms, partnership with the private sector, civil society organizations, and nongovernment organizations would provide a wider range of sources for new ideas and financing projects.

Other aspects require further actions, and special attention needs to be given to further development of open governance aspects of the e-government system, particularly in transition countries by strengthening the role of a regulatory body for quality control. Citizen participation through online platforms is a relatively new experience for citizens of Uzbekistan. Therefore, the promotion of open governance platforms and other online services among users, as well as programs to increase the awareness of the population about participation in open data portals and dialogues, would clearly define the level of citizen participation. The achievement of all possible outcomes of e-government could transform the traditional government in Uzbekistan, not only from the perspective of administrative efficiency but also with respect to broader implications such as a more open and accountable, citizen-empowered government in the future, if the tasks are accomplished.

Due to the comprehensive nature of the e-government phenomenon itself, as well as the topic's relative novelty in the context of transition economies, it is challenging to adopt a certain conceptual framework to analyze e-government development (Heeks 2000; Brown 2005; Yildiz 2007). As regards the limitations of this research specific to the case of Uzbekistan, insufficient research and data, conducting the study from a distance, coupled with time constraints, have prevented our investigation from being more comprehensive. In particular, institutional and organizational aspects of e-government normally involve face-to-face interviews with government officials, which could give a more holistic overview of the current institutional landscape and challenges in e-government. Thus, there is scope for further in-depth research built on systematic user-oriented surveys and interviews with all stakeholders in a sufficient time frame to comprehensively understand the e-government phenomenon in Uzbekistan. Further up-to-date research on the impacts of wider systematic issues such as corruption, governance style, and the institutional landscape on e-government, as well as divergent paths of the post-Soviet world in e-government development, would boost our understanding of the root causes of why some digital initiatives succeed while others do not.

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Appendix A15.1: Evolutionary or Maturity Stage Models of E-Government Implementation

Source	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6
Layne and Lee (2001)		Catalogue	Transaction	Vertical integration	Horizontal integration	
Baum and Di Maio (2000)		Presence	Interaction	Transaction	Transformation	
Ronaghan (2001)	Emerging presence	Enhanced presence	Interactive	Transactional government	Seamless	
Hiller and Bélanger (2001)		Information dissemination	Two-way communication	Integration	Transaction	Participation
Wescott (2001)	E-mail and internal network	Enable interorganizational and public access to information	Two-way communication	Exchange of value	Digital democracy	Joined-up government

Source: Coursey and Norris (2008, 524).

Appendix A15.2: List of Policy Papers on ICT Development in the Second Phase of E-Government in Uzbekistan

(1) No. PP-2126, 2 December 2014, "On measures to organize the activities of the national mobile operator"
(2) No. PP-2058, 30 October 2013, "On approval of the updated structure of the State Committee for communications, information and telecommunication technologies of the Republic of Uzbekistan"
(3) No. PP-2053, 22 October 2013, "On improvement of management and use of radio spectrum"; Uzbekistan – ICT environment, innovation policies and international cooperation EECA CLUSTER 14
(4) No. PP-2045, 25 September 2013, "On measures for implementation of the investment project 'Development of national geographic information system'"
(5) No. PP-2042, 20 September 2013, "On measures to further enhance the stimulation of domestic software developers"
(6) No. PP-1843, 30 October 2012, "On measures to further improve the efficiency of information and communication system of the State tax service of the Republic of Uzbekistan"
(7) No. PP-1730, 21 March 2012, "On measures for further implementation and development of modern information and communication technologies"
(8) No. PP-1729, 20 March 2012, "On measures on organization of a National library of Uzbekistan named after Alisher Navoi – Information resource center".

ICT = information and communication technology.
Source: EECA (2014).

Appendix A15.3: Subindices of EGDI for Kazakhstan and Uzbekistan, 2003–2018

	2018	2016	2014	2012	2010	2008	2006	2004	2002
Online Services Index (OSI)									
Kazakhstan	0.86	0.77	0.74	0.78	0.52	0.32	0.45	0.39	0.18
Uzbekistan	0.79	0.69	0.44	0.49	0.37	0.27	0.27	0.23	0.00
Telecommunication Infrastructure Index (TII)									
Kazakhstan	0.57	0.56	0.57	0.35	0.17	0.13	0.063	0.06	0.06
Uzbekistan	0.33	0.24	0.23	0.20	0.08	0.03	0.05	0.04	0.05
Human Capital Index (HCI)									
Kazakhstan	0.83	0.84	0.86	0.91	0.96	0.97	0.93	0.92	0.92
Uzbekistan	0.73	0.69	0.72	0.82	0.88	0.90	0.91	0.91	0.91

EGDI = E-Government Development Index.

Source: United Nations E-Government Survey, historical data.

Appendix A15.4: ICT Development Index and Subindicators Comparison, 2017

Indicators	World Average	CIS Average	Uzbekistan
IDI 2017 (rank)	–	–	95
IDI 2016 (rank)	–	–	103
IDI ACCESS SUB-INDEX	5.59	6.6	5.24
Fixed-telephone subscriptions per 100 inhabitants	13.57	20.7	11.34
Mobile/cellular telephone subscriptions per 100 inhabitants	101.53	141.2	77.33
International internet bandwidth per internet user (Bit/s)	74,464	59,000	5,682.64
Percentage of households with computer	46.61	67.4	43.87
Percentage of households with internet access	51.46	68	75.40
IDI USE SUB-INDEX	4.26	4.79	3.93
Percentage of individuals using the internet	45.91	65.1	46.79
Fixed (wired)-broadband subscriptions per 100 inhabitants	12.39	15.8	9.13
Active mobile-broadband subscriptions per 100 inhabitants	52.23	59.7	55.89
IDI SKILLS SUB-INDEX	5.85	7.47	6.17
Mean years of schooling	8.52	11.6	12.00
Secondary gross enrollment ratio	84.00	98.7	95.92
Tertiary gross enrollment ratio	38.69	50.5	9.09

CIS = Commonwealth of Independent States, ICT = information and communication technology, IDI = ICT Development Index.

Source: International Telecommunication Union (2017, https://www.itu.int/net4/ITU-D/idi/2017/index.html#idi2017comparison-tab).

Appendix A15.5: Dynamics of Global Innovation Index in Uzbekistan and Kazakhstan

Year	Uzbekistan GII		Kazakhstan GII (regional leader)	
	Innovation Ranking	Innovation Index	Innovation Ranking	Innovation Index
2018	NA	NA	74	31.42
2017	NA	NA	78	31.50
2016	NA	NA	75	31.51
2015	122	25.89	82	31.25
2014	128	25.20	79	32.75
2013	133	23.87	84	32.73
2012	127	23.90	83	31.90

GII = Global Innovation Index.

Source: World Intellectual Property Organization. https://www.globalinnovationindex.org/analysis-indicator

Appendix A15.6: Sample of User Experience Survey

Note: the original survey was in the Uzbek language.

Link for Google Survey: https://forms.gle/NNgYU6zfswcmEekG6

Section 1. User experience of e-government

1. Have you ever visited or used e-government websites and applications?
- ☐ Yes (please go to Q2)
- ☐ No (please go to Q4)

2. If yes, which e-government websites have you visited?
- ☐ https://my.gov.uz/ru - Single interactive government services portal
- ☐ https://pm.gov.uz/uz#/ - Virtual reception of the President
- ☐ https://regulation.gov.uz/uz - Discussion of draft regulatory legal documents
- ☐ https://meningfikrim.uz/ - Platform for civil proposals
- ☐ https://e-visa.gov.uz/main - Electron visa portal
- ☐ http://www.cbu.uz/uz/ - Central Bank
- ☐ https://business.gov.uz/ - Portal for entrepreneurs
- ☐ https://lex.uz/uz/ - Database of legal documents
- ☐ https://uzimei.uz/ - Portal for mobile device registration
- ☐ http://jamoatfikri.uz/uz - Platform for monitoring law enforcement
- ☐ http://stat.uz/ - the State Committee of Statistics
- ☐ https://data.gov.uz/uz/ - Open data Portal
- ☐ https://www.minjust.uz/ - Ministry of Justice
- ☐ other (specify please)

3. For what purposes do you usually use Uzbekistan e-government websites?

Purposes of using e-government websites	Mark where appropriate				
	Do not use	Very rarely	Once a month	Often	Regularly
Retrieving and printing online forms					
Participating in online discussions and forums					
Electronic applications, e.g., passports, licenses, etc.					
Information search for government services					
Accessing government policy documents					

Purposes of using e-government websites	Mark where appropriate				
	Do not use	Very rarely	Once a month	Often	Regularly
Presenting petitions, proposals, or concerns					
Finding information about social care, employment, or education through government portals					
Making online utility payments					
Paying taxes online					
Communicating with parliamentarians, community leaders					
Others (________)					

4. Do you agree with the following potential barriers or issues while using Uzbekistan e-government websites and online services?

Potential challenges in using online public services	Mark where appropriate				
	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Internet speed is poor					
Internet is not affordable					
There are not sufficient online services relevant to local context					
There are not sufficient user-friendly e-government platforms (the content is too complex)					
ICT infrastructure (electronic devices) is not sufficient					
Personal fear about information safety and data privacy					
I do not trust in responsible authorities in processing online services					
My ICT skills are not good enough					
I am not aware of e-government services					
Online services are not available in my native language					
Other barriers (________)					

5. To what extent are you familiar with e-government initiatives in Uzbekistan?

	Mark where appropriate				
Please indicate your level of familiarity with the following	**Not aware at all**	**Slightly aware**	**Somewhat aware**	**Moderately aware**	**Fully aware**
e-government websites of city councils and websites of other local authorities in Uzbekistan					
Services and benefits of e-government portals in Uzbekistan					
Educational and training programs on overall features of e-government portals in Uzbekistan					
Campaigns or promotions about use of online government services in Uzbekistan					

6. Do you agree with the following statements on the value or usefulness of e-government portals?

	Mark where appropriate				
	Strongly disagree	**Disagree**	**Neutral**	**Agree**	**Strongly agree**
e-government websites allow/could allow me to fulfill tasks quickly					
e-government websites allow/could allow me to quickly obtain government information					
e-government websites enable/could enable me to accomplish tasks with no or less cost					
It is faster and more comfortable to obtain public services online than via traditional methods					
e-government websites have a wider selection of public services compared to interactions with physical government					
Other values (________)					

Section 2. Access to, or usage of, ICT

7. All questions in this section are about your access to electronic devices and the internet.

	Yes	No
I have access to a computer (PC, laptop, tablet) at home	☐	☐
I have access to a computer (PC, laptop, tablet) only at work or school	☐	☐
I have access to a computer (PC, laptop, tablet) only at a cybercafe	☐	☐
I have access to a landline telephone	☐	☐
I have access to a mobile telephone	☐	☐
I do not have any access to any computer technology (e.g., mobile phone, desktop, laptop, tablet, etc.)	☐	☐
I have access to an uninterrupted electricity supply	☐	☐
I have access to the internet at home	☐	☐
I have access to the internet only at work or school	☐	☐
I have access to the internet only at a cybercafe	☐	☐
I have access to the internet only on my mobile telephone	☐	☐

Section 3. Demographic information

8. Please select an appropriate category for the area you are currently residing in:

☐ Urban/City
☐ Rural/Countryside

9. What is your gender?

☐ Female
☐ Male

10. What is your age range?

☐ 18–25
☐ 26–35
☐ 36–45
☐ 46–55
☐ 56–65
☐ over 65

11. What is your highest level of education?

- ☐ Doctorate level
- ☐ Master's degree
- ☐ Bachelor's degree
- ☐ Secondary specialized education diploma (academic lyceum or technical college)
- ☐ Primary and secondary school education
- ☐ Not formally educated
- ☐ Other (please specify)

12. What is your current employment status?

- ☐ Employed (full-time)
- ☐ Employed (part-time)
- ☐ Employer (business or a company)
- ☐ Unemployed
- ☐ Retired
- ☐ Student

13. What is your income level?

- ☐ low income
- ☐ medium
- ☐ high income

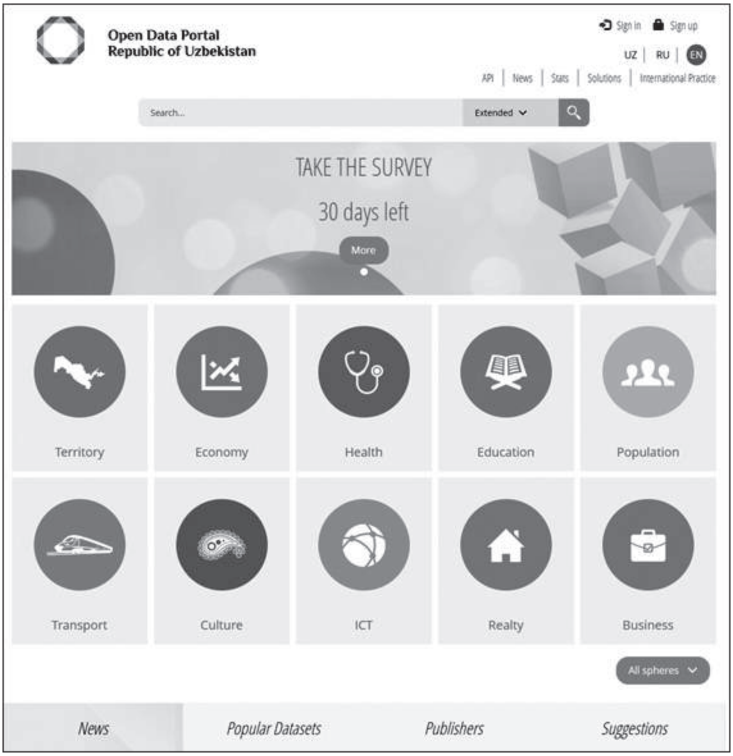
Thank you for your participation in the survey.

Appendix A15.7: List of Optimized Public Services Through Digitalization, 2018

Public Service	Outcomes: Reduction in the Number of Documents or Time
Military registration	Document: 4 -> 2
Submission of an electronic application for admission of children in a state preschool educational institution	Time: 15 -> 1 day
Obtaining a certificate of state registration of rights to a land plot	Time: 20 -> 7 days
Obtaining a decision on transfer of residential premises to the nonresidential category	Time: 11 -> 8 days Documents: 4 -> 3
Obtaining a license to provide medical activities	Time: 30 -> 20 days
Obtaining a new license for design, construction, operation, and provision of telecommunication network services	Time: 20 -> 16 days Documents: 10 -> 6
License for the production of jewelry and other products from precious metals and precious stones	Time: 15 -> 10 days Documents: 5 -> 1

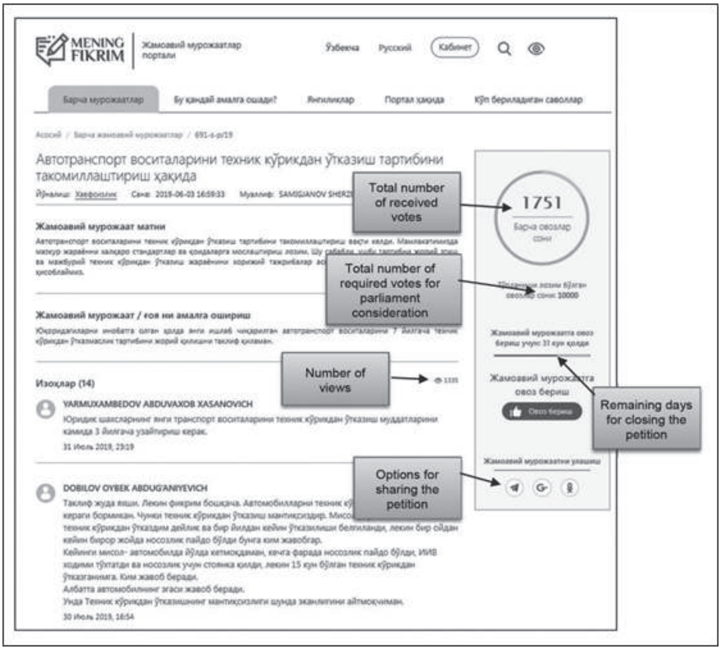
Source: Ministry for Development of Information Technologies and Communications of the Republic of Uzbekistan (2018).

Appendix A15.8: Open Data Portal of the Republic of Uzbekistan



Source: Open Data Portal, Republic of Uzbekistan. https://data.gov.uz/en

Appendix A15.9: Portal of Open Dialogue meningfikrim.uz, Features of Citizen Participation in Example of One of the Most Popular Petitions on Expertise of Vehicles



Note: The most popular petitions are shown by the website.
Source: Mening Fikrim. https://meningfikrim.uz/uz/petitions/view/3007