Bridging the Technological Divide

Technology Adoption by Firms in Developing Countries

OVERVIEW

Xavier Cirera
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WORLD BANK GROUP

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This booklet contains the overview, as well as a list of contents and other front matter, from *Bridging the Technological Divide: Technology Adoption by Firms in Developing Countries*, doi: 10.1596/978-1-4648-1826-4. A PDF of the final book is available at https://openknowledge.worldbank.org/ and http://documents.worldbank.org/, and print copies can be ordered at www.amazon.com. Please use the final version of the book for citation, reproduction, and adaptation purposes.

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Foreword

Poverty reduction and shared prosperity can be achieved only with sustained growth. But the global economy is increasingly vulnerable to global shocks. The COVID-19 (coronavirus) pandemic and its devastating impact on livelihoods has shown how vulnerable economies are. Potential future pandemics, climate change shocks, and political tensions threaten a sustainable recovery and future economic growth prospects. In this context, technology is emerging as a critical lifeline to increase the resilience of economies and boost economic growth. The pandemic has led to an unprecedented demand for the use of digital technologies by businesses and therefore provides a renewed opportunity to accelerate technology upgrading.

Since Joseph Schumpeter's pathbreaking work, technology has been recognized to be at the center of economic growth and development. Technologies used by firms are central to the process of creative destruction. Yet, existing measures of technology use fall short of providing a comprehensive characterization of technologies across and within firms, particularly for developing countries. This volume builds on a large effort to collect novel data through the new Firm-level Adoption of Technology (FAT) survey, providing a breakthrough contribution to address this knowledge gap. The new methods and data presented allow practitioners and policy makers to look inside the "black box" of technology adoption by firms and identify the key obstacles that constrain job creation through digital transformation and upgrading of business functions.

The volume's key findings contribute to the literature in three major directions. First, new measures of technology use show that most firms in developing countries are quite far from the technology frontier, and they may not be aware of the extent to which they lag. Second, new evidence shows that technology adoption is a key driver of long-term growth through its positive impact on productivity, jobs, and economic resilience. Third, in bridging the technological divide, access to reliable and high-quality infrastructure is a necessary condition for technology upgrading, but not a sufficient one. Developing countries need to enhance their institutions to promote market competition while shifting the focus from access to technology to the effective use of technology by firms.

The research presented here is part of the World Bank's Productivity Project led by the Chief Economist's Office of the Equitable Growth, Finance, and Institutions Vice Presidency. We are confident that researchers and development practitioners alike will highly value the new findings on technology adoption and the directions for development policies this volume contains.

Indermit S. Gill
Vice President, Equitable Growth, Finance, and Institutions
The World Bank

Preface

Productivity accounts for half of the differences in gross domestic product per capita across countries. Identifying policies that stimulate productivity is thus critical to alleviating poverty and fulfilling the rising aspirations of global citizens. In recent decades, however, productivity growth has slowed globally, and the lagging productivity performance of developing countries is a major barrier to convergence with income levels in advanced economies. The World Bank Productivity Project seeks to bring frontier thinking to the measurement and determinants of productivity, grounded in the developing country context, to global policy makers. Each volume in the series explores a different aspect of the topic through dialogue with academics and policy makers and through sponsored empirical work in the World Bank's client countries.

Bridging the Technological Divide: Technology Adoption by Firms in Developing Countries, the seventh volume in the series, breaks new ground in the empirics of technology adoption. Like *The Innovation Paradox* before it, this volume stresses the importance to economic growth of the flow of ideas and new practices. Indeed, recent studies suggest that differences in the evolution of technology diffusion across countries drive a corresponding evolution of productivity (total factor productivity) that can account for the divergence in the world income distribution over the last 200 years.

The agent that in practice undertakes technology adoption and drives technology diffusion is the firm. The Productivity Project opens the "black box" of the firm for the first time in a comprehensive way by developing and fielding the detailed Firm-level Adoption of Technology (FAT) survey in 11 countries. *Bridging the Technological Divide* brings together the first wave of findings from that effort, documenting the patterns of adoption of different types of technologies within and across firms, and the factors that facilitate or impede diffusion. The hope is that the volume will stimulate interest in exploring this critical dimension of growth generally, and exploiting these surveys in particular.

This book is a product of the Equitable Growth, Finance, and Institutions Vice Presidency.

William F. Maloney
Chief Economist, Latin America and the Caribbean Region
Director, World Bank Productivity Project series
The World Bank

Other Titles in the World Bank Productivity Project

Place, Productivity, and Prosperity: Revisiting Spatially Targeted Policies for Regional Development. 2022. Arti Grover, Somik V. Lall, and William F. Maloney. Washington, DC: World Bank.

At Your Service? The Promise of Services-Led Development. 2021. Gaurav Nayyar, Mary Hallward-Driemeier, and Elwyn Davies. Washington, DC: World Bank.

Harvesting Prosperity: Technology and Productivity Growth in Agriculture. 2020. Keith Fuglie, Madhur Gautam, Aparajita Goyal, and William F. Maloney. Washington, DC: World Bank.

High-Growth Firms: Facts, Fiction, and Policy Options for Emerging Economies. 2019. Arti Grover Goswami, Denis Medvedev, and Ellen Olafsen. Washington, DC: World Bank.

Productivity Revisited: Shifting Paradigms in Analysis and Policy. 2018. Ana Paula Cusolito and William F. Maloney. Washington, DC: World Bank.

The Innovation Paradox: Developing-Country Capabilities and the Unrealized Promise of Technological Catch-Up. 2017. Xavier Cirera and William F. Maloney. Washington, DC: World Bank.

All books in the World Bank Productivity Project are available free of charge at https://openknowledge.worldbank.org/handle/10986/30560.

Acknowledgments

This book was written by Xavier Cirera (senior economist, Finance, Competitiveness, and Innovation Global Practice, World Bank), Diego Comin (professor of economics, Dartmouth College), and Marcio Cruz (senior economist, Finance, Competitiveness, and Innovation Global Practice, World Bank), with the collaboration of a core team from the World Bank working on the Firm-level Adoption of Technology (FAT) project. Kyung Min Lee provided key contributions across this project as a core team member, from survey design to data implementation, and coauthorship of key background papers. Other core team members who provided key contributions on survey implementation and data analysis include Pedro Jose Martinez Alanis, Antonio Soares Martins Neto, Caroline Nogueira, and Santiago Reyes. Enrico Berkes (Ohio State University) and Jesica Torres contributed with coauthorship of background papers. Additional inputs were provided by Edgar Avalos, Ana Paula Cusolito, Sara Nyman, and Juni Zhu. The work was carried out under the guidance of Mona Haddad (global director, Trade, Investment, and Competitiveness, World Bank), Martha Martinez Licetti (practice Manager, Markets and Technology, World Bank), William F. Maloney (director, World Bank Productivity Project and chief economist, Latin America and the Caribbean Region), and Denis Medvedev (director, Economic Policy Research Department, International Finance Corporation).

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Overview

> Every body must be sensible how much labour is abridged and facilitated by the application of proper machinery. By means of the plough two men, with the assistance of three horses, will cultivate more ground than twenty could do with the spade. A miller and his servant, with a wind or water mill, will at their ease grind more corn than eight men could do, with the severest labour, by hand mills.
>
> —Adam Smith, *An Inquiry into the Nature and Causes of the Wealth of Nations*, 1776

The Imperative of Technology Adoption in Developing Countries

Technology is at the heart of economic growth. From historical accounts of how technological change since the Industrial Revolution has shaped economic development in Europe, such as David Landes' *The Unbound Prometheus* (Landes 2003), to endogenous growth models (Romer 1990; Aghion and Howitt 1992), technology has been identified as a key ingredient of growth and economic transformation. Measuring the uses of technology and understanding the drivers of and barriers to the adoption of technology are, therefore, critical to designing policies that facilitate economic development. Until the nineteenth century, the main source of cross-country variation in technology was whether new technologies had arrived in a country (Comin, Easterly, and Gong 2010). While there has been a widespread reduction in the time needed to acquire and adopt a new technology, current technological differences across countries originate mostly from differences in how intensively new technologies are eventually used once they arrive in a country (Comin and Mestieri 2018).

Technological catch-up happens through firms. Firms are the main actor for adopting more sophisticated technologies to be applied in the production of goods and provision of services. These upgrades are key to promoting gains in productivity, the engine of economic growth and prosperity. While technology can improve economic welfare through different channels, it is primarily through the process of adoption by firms that most workers are affected. Workers can have access to higher-productivity jobs and countries can achieve higher prosperity through the adoption of more sophisticated technologies. With very few exceptions of countries that are rich in natural resources, there is no successful example of a developing country that graduated to become an advanced economy without improving the technological level of its production through its firms, in either agriculture, manufacturing, or services.

Yet around the world, there is a large technological divide across firms. This divide is reflected in low productivity levels and a lack of better-quality jobs—particularly in developing countries, where the number of enterprises per worker relatively close to the forefront of technology sophistication (the technology frontier) is quite low and where firms are often confined to more rudimentary and less automated technologies. But this divide is not restricted to developing economies. In high-income countries the gap between frontier and laggard firms is also large and could potentially increase, which could, in turn, deepen challenges associated with income inequality across and within countries. The technological divide across firms also affects firms' varying ability to cope with and bounce back from economic shocks, given that more capable and technologically sophisticated firms are also more resilient.

Bridging the technological divide is thus an imperative for development policies. Understanding how technology is used and distributed across firms, and identifying the main drivers of adoption are critical to unpack the "black box" of the firm (Rosenberg 1983; Demsetz 1997), and, even more important, to design policies that can help accelerate adoption and convergence to the technology frontier. Addressing some of the most relevant development challenges, from eradicating global poverty to promoting environmentally sustainable economic growth, will require not only innovation but also technology upgrading of firms across the globe. The fact that most firms, particularly in developing countries, are far from the technology frontier suggests that this is not an easy challenge, but it also suggests that there are many opportunities for enhancing productivity and generating high-quality jobs in developing countries. To better understand this challenge at the firm level, we need to improve existing measures of technology and the body of data that can better reveal how firms make decisions and actually use (or do not use) technology in their operations. This will help answer the question of why firms, particularly in developing countries, are not adopting and using technology that clearly could benefit them. Armed with this understanding, policy makers and practitioners can design better policies and interventions to help firms adopt better and more sophisticated technologies.

This volume focuses on the adoption and use of technology by firms. The firm is at the center of the analysis. This implies that we need to understand how technologies are applied to the main tasks that firms need to carry out to produce and sell goods and services. This requires opening the black box of the firm further and documenting the types of technology and the processes used to perform firms' tasks. To this end, the volume presents a new method to measure technology at the level of business functions particular to the operations of that firm. This approach allows us to understand what technologies are used, how they are used, and why they were chosen by firms, which is a critical step to understand the process of technology diffusion and the overall technological progress of an economy.

The volume is organized in three parts aiming to address to following questions:

- Where is the technology frontier and how far from it are firms in developing countries?
- What are the implications of the technological divide for jobs, growth, and resilience?
- What can countries do to bridge the technological divide?

This seventh volume in the World Bank Productivity Project series contributes to the literature in several ways.

- It describes a new methodology for measuring technology adoption at the firm level.
- It presents new evidence of the firm-level technological divide across different dimensions, such as countries, regions, sectors, firms, and business functions, using a novel data set covering firms in agriculture, manufacturing, and services from a representative set of countries.
- It uncovers the richness of the variation for technology sophistication across sectors and the association with firms' practice to outsource certain business functions rather than performing them in house.
- It provides new evidence on the effects of technology readiness on resilience.
- It offers novel findings regarding the limitations of improving access to digital infrastructure on technology adoption.
- It summarizes the tools available to policy makers aiming to promote technology upgrading.

The Firm-level Adoption of Technology (FAT) survey data can serve as a benchmark for firms, regions, and countries to understand their distance from the technology frontier. The survey can also be used as a firm-level diagnostic, helping policy makers and practitioners set areas to be prioritized when designing and implementing measures to support technology adoption.

Part 1. Measuring the Technological Divide

Moving from Measuring Adoption of GPTs to Measuring the Actual Use of Technologies for Particular Business Functions within the Firm

Despite significant progress in the last two decades, existing measures of technology still fall short of providing a comprehensive characterization of technologies used by firms. First, the number of technologies covered is rather limited when compared to how many technologies are involved in production and management processes. Second, their focus on the presence of advanced technologies makes it impossible to understand how production takes place in firms without such advanced technologies. This concern is most relevant in developing countries where advanced technologies have diffused more slowly. Third, because their unit of analysis is the firm, existing surveys are not designed to examine technology at the finer level of business functions undertaken by firms and measure which business functions benefit from each particular technology. This drawback is particularly problematic for general-purpose technologies (GPTs, such as standard computers, cell phones, and the internet) that can be relevant for multiple business functions. Finally, existing surveys largely omit questions about how intensively a technology is employed in the firm. Therefore, they do not reveal whether a technology that is present is widely utilized or used only marginally.

Opening the Black Box of the Firm: The Firm-level Adoption of Technology (FAT) Survey

This volume proposes a new approach to measure technology that shifts the unit of analysis from the firm to the business function. This approach, described by Cirera et al. (2020b), led to the development of a new survey instrument by the World Bank Group. The FAT survey has been designed to collect detailed information for a representative sample of firms about the technologies that each firm uses to perform key business functions necessary to operate in its respective sector of economic activity. The FAT survey has been piloted through both face-to-face interviews and by telephone to a representative sample of firms in 11 countries in different regions and at different levels of economic development.[1] The survey applies to firms in agriculture, manufacturing, and services and includes a module measuring sector-specific technologies in 12 sectors. The data were collected between 2019 and 2021. More than 13,000 establishments were interviewed, representing around 1.3 million establishments. Much of the analysis in this volume draws on results from the survey and comparisons with other surveys and studies.

The development of the FAT survey involved intensive research and interaction with more than 50 industry experts with experience in firms in advanced economies as well as in developing countries. They helped identify the technology frontier and the array of technologies (the technology grid) available for a firm to perform a task, including the most relevant technology options—from most basic to most sophisticated. More specifically, the methodology identifies the relevant business functions conducted by the firm. They are split between general business functions (GBFs) that are common to all firms, such as business administration and payment methods, and sector-specific business functions (SBFs) relevant to specific sectors, such as harvesting for agriculture, sewing for wearing apparel, and merchandising for retail.[2] Then, for each of these business functions, the FAT survey identifies a grid of technologies available to perform that task, and with the guidance from industry experts, it ranks them according to their level of sophistication.

To measure technology sophistication, the technology options are combined into an index capturing the proximity to the technology frontier for each business function. The index varies between 1 and 5, where 1 stands for the most basic level of technology and 5 reflects the most sophisticated. With the help of experts for each industry, a rank was assigned to the technologies in each business function according to their sophistication. The sophistication of a technology measures its complexity, which corresponds to its capacity to conduct more tasks and/or tasks of greater difficulty or to perform them with greater accuracy or precision. Naturally, technology sophistication tends to be correlated with the novelty of the technology, and many of these advanced technologies are digital. This technology index is calculated at the level of business function conducted by the firm based on the most frequently used technology (intensive margin).[3] This index is aggregated across many dimensions (such as firms, sectors, regions, and countries) and used across this volume to provide granular measures of the technological divide.

Facts about Technology Adoption by Firms

The transition from previous industrial revolutions is incomplete in developing countries. The simultaneous rapid spread of information and communication technology (ICT) alongside the persistence of a large share of firms still struggling to access reliable electricity is one of the many paradoxes of technology in developing countries (figure O.1). First, it shows the power and the limits of technology disruptions associated with the digital revolution. Second, there is large variation in terms of the quality of supply and potential for network effects through the diffusion of knowledge and technology across firms and through different uses of digital technologies.[4] Thus, while the focus of the media and policy makers is on the latest technological transition (or industrial revolution), many firms, particularly in developing countries, have yet to complete previous transitions. This is partly due to the quality of the infrastructure underlying these technologies, but also partly due to other factors to be discussed next. But one clear lesson is that these technology differences are not visible using standard measures of access to GPTs.

FIGURE O.1 **Firms Vary Widely in the Status of Their Adoption of General-Purpose Technologies**

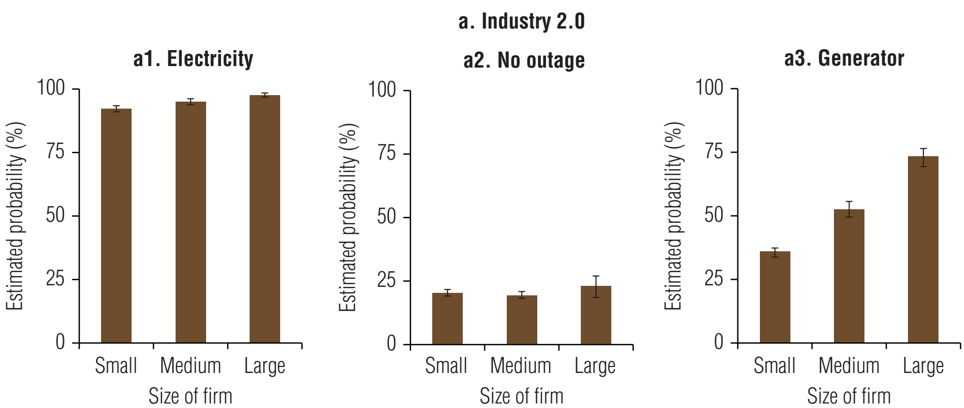

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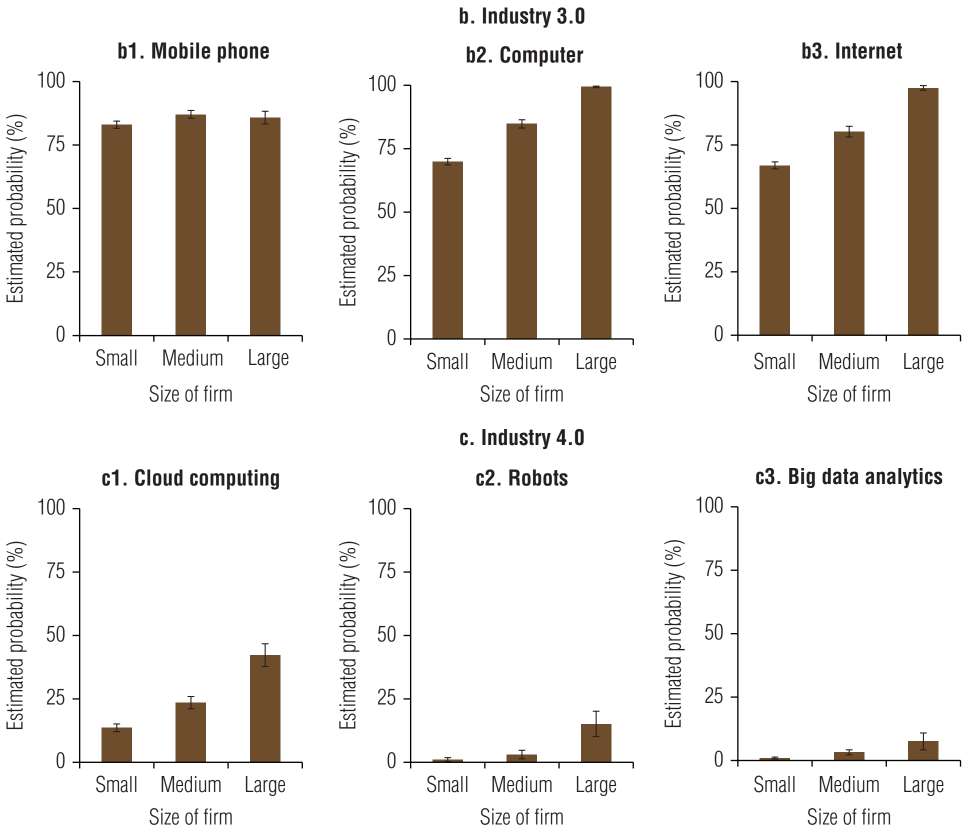
FIGURE O.1 Firms Vary Widely in the Status of Their Adoption of General-Purpose Technologies *(continued)*



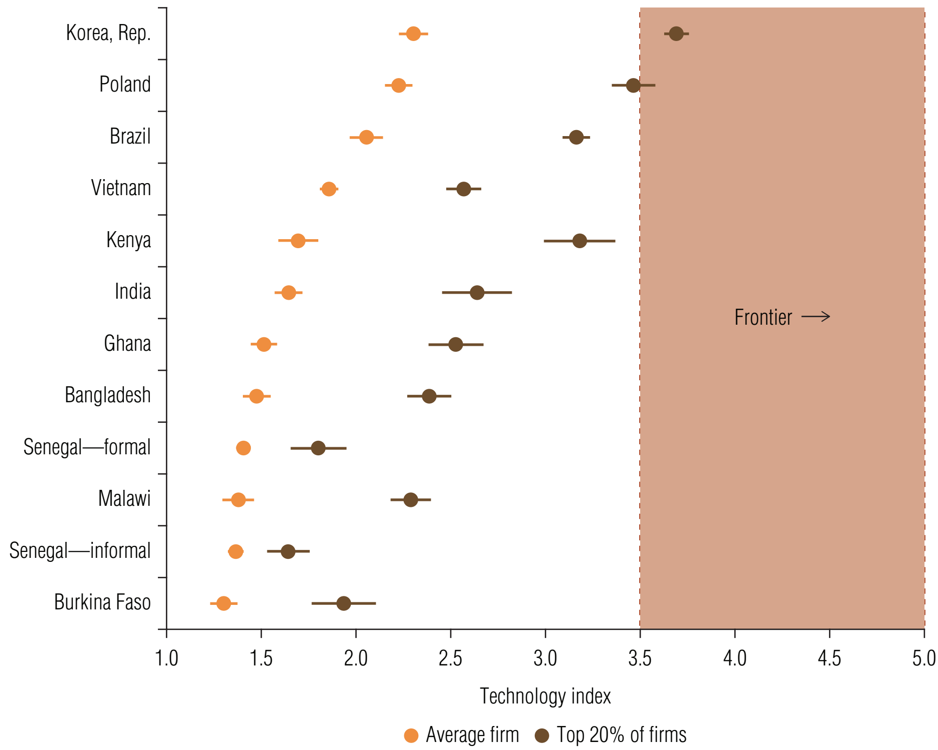
Source: Original figure based on Firm-level Adoption of Technology (FAT) survey data.

Note: The data cover 11 countries: Bangladesh; Brazil (only the state of Ceará); Burkina Faso; Ghana; India (only the states of Tamil Nadu and Uttar Pradesh); Kenya; Korea, Rep.; Malawi; Poland; Senegal; and Vietnam. Firm size refers to the number of workers: small (5–19), medium (20–99), and large (100 or more). Estimates are weighted by sampling weights.

Most firms are far from the technology frontier.

Most firms, especially in developing countries, are far from the technology frontier. Figure O.2 presents the estimated country average of technology sophistication in manufacturing firms, using the top (20 percent) manufacturing firms in the Republic of Korea and Poland as a benchmark to the frontier. First, the figure shows that the average firm (orange dot) in each country is far from the frontier (starting in the shaded area). Second, most firms in developing countries, including their best firms (brown dot), are far from the frontier. The country rankings based on average technology sophistication tend to coincide with country income levels. The results also show a gap between formal and informal firms in Senegal. To move firms closer to the frontier, developing countries not only need to improve the technological capabilities of existing firms, but also build the conditions to optimize the reallocation of resources toward more capable firms and attract more entrepreneurs to increase the entry of high-quality

FIGURE O.2 **Estimated Technology Sophistication by Country—Manufacturing**



Source: Original figure based on Firm-level Adoption of Technology (FAT) survey data.

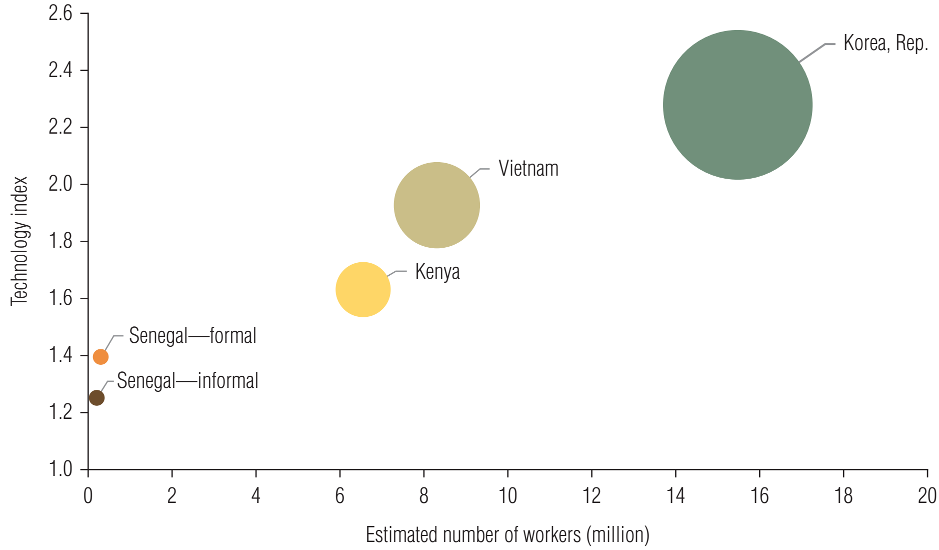
Note: This figure plots for each country the estimated average and top 20th percentile of the firm-level technology sophistication index across all business functions (ABFs), including general business functions (GBFs) and sector-specific business functions (SBFs). Results are based on ordinary least squares (OLS) estimation using sampling weights and controlling for sector, country, formality, firm size group, and age group.

firms and induce the exit of low-productivity firms, as highlighted by the second volume in the World Bank Productivity Project series (Cusolito and Maloney 2018).

Advanced economies have many more sophisticated firms.

The technology gap across countries (and regions) is driven not only by the sophistication of average firms, but also by the density (per capita quantity of those firms using sophisticated technology). There is a large difference between the number of formal firms across countries. Comparing Korea and Kenya, countries with similar populations (around 50 million), not only is the average firm in Korea closer to the technology frontier but there are also many more of those firms (with 5 or more workers) absorbing many more workers. The number of firms in Korea in the top 20 percent in terms of technology sophistication is almost double the total number of formal firms with 5 or more workers in Kenya. Figure O.3 shows that the gap between Vietnam, Kenya, and Senegal with respect to Korea is explained not only by the average sophistication (vertical axis), but also by having many more firms with those technologies (circle size)

FIGURE O.3 Cross-Country Differences in Technology Are Also Explained by the Number of Firms Using Sophisticated Technology



Source: Original figure based on Firm-level Adoption of Technology (FAT) survey data.

Note: Technology index estimates at the firm level across all business functions. Results are based on ordinary least squares (OLS) estimation controlling for sector, country, formality, firm size group, age group, and using sampling weights (vertical axis), number of workers (horizontal axis), and number of firms (size of the bubble). All estimations are based on sampling weights. For Senegal, the total number of workers is adjusted based on the latest establishment census to cover firms from all regions.

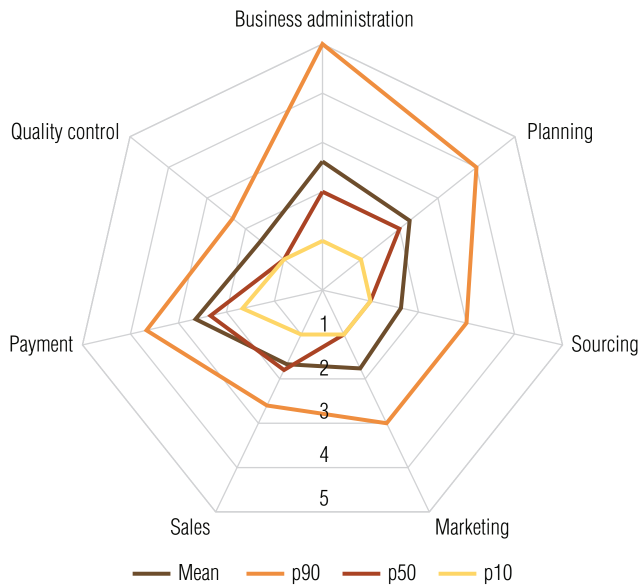
and more workers absorbed by those firms (horizontal axis). This highlights the importance of more capable entrepreneurs that are able to operate in developing countries' markets, absorb the knowledge created elsewhere, and grow, their firms (see the third volume in the World Bank Productivity Project series, Grover Goswami, Medvedev, and Olafsen 2019).

Technology sophistication varies across business functions.

Firms are closer to the technology frontier in some business functions than in others. Figure O.4 compares the average technology sophistication in seven GBFs—business administration (accounting, finance, and human resources); production or service operations planning; sourcing, procurement, and supply chain management; marketing and customer relationship management; sales; payment methods; and quality control—across top firms (those in the 90th percentile, p90) with the average across all firms (mean) and the median firms (50th percentile, p50), as well as with firms in the bottom 10th percentile (p10) of technology sophistication. While, on average, firms in the 90th percentile have higher scores than those in the 10th percentile, there is great variation in proximity to the frontier across functions. Top firms tend to score well on business administration but poorly on quality control. The gap between firms in the 90th and 10th percentiles is also larger in business administration than in other GBFs. An important characteristic of some of these functions (such as sourcing, marketing,

FIGURE O.4 **The Level of Technology Sophistication for General Business Functions Varies Greatly**

Intensive margin



Source: Original figure based on Firm-level Adoption of Technology (FAT) survey data.

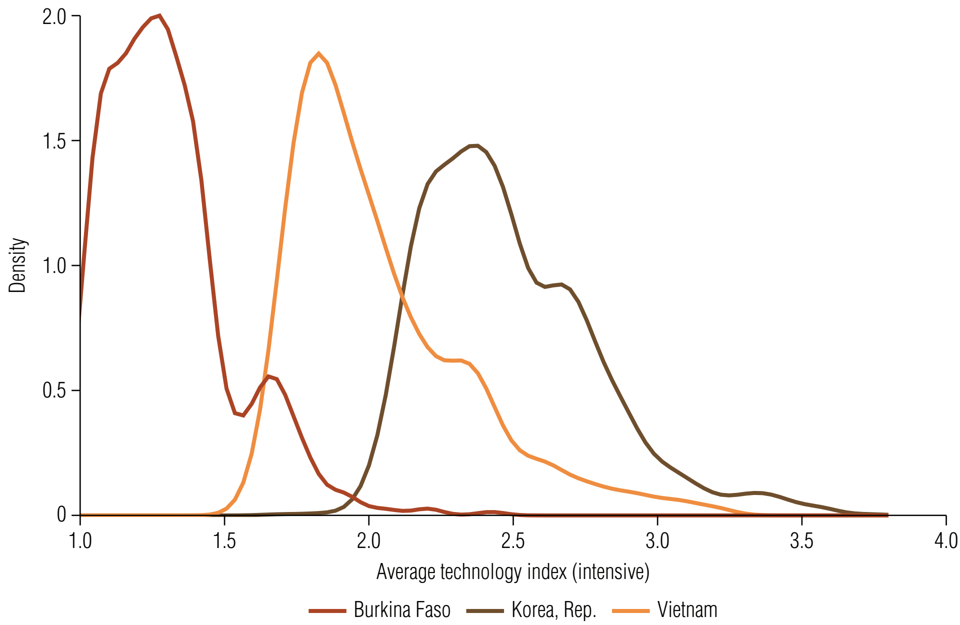
Note: The figure covers all 11 countries in the sample. The intensive margin refers to the most frequently used technology to perform that particular task/business function. p90, p50, and p10 refer to the 90th, 50th, and 10th percentiles of firms, respectively. The mean is the average across all firms, using sampling weights.

sales, and payment methods) is that the intensive use of some of these technologies often also requires their adoption by customers and suppliers through network effects, which may explain the distance from the frontier even among top firms. Many of these firms are using more sophisticated technologies in those functions, but not as the most intensively used technology.

There is a large technological divide across firms within countries.

Underlying the significant differences in the average technology sophistication across countries, regions, sectors, and firm size lies a large variation of sophistication across firms. A key advantage of a firm-level data set such as the one from the FAT survey is that it allows researchers and practitioners to go beyond country or regional comparisons of average technology sophistication by characterizing the entire distribution of technology sophistication across firms. Figure O.5 plots the kernel density of the distribution of the firm-level technology sophistication for Burkina Faso, Korea, and Vietnam. Visual inspection of the densities suggests the possibility of consistent rank orderings (first-order stochastic dominance), which suggests that for any point of the cumulative distribution of technology across firms in each country, firms in Korea tend to be more or at least as sophisticated as firms in Vietnam, which tend to be more or at least as sophisticated as firms in Burkina Faso.

FIGURE O.5 Rank Orderings of the Distribution of Technology Sophistication Are Consistent across Select Countries



Source: Original figure based on Firm-level Adoption of Technology (FAT) survey data.

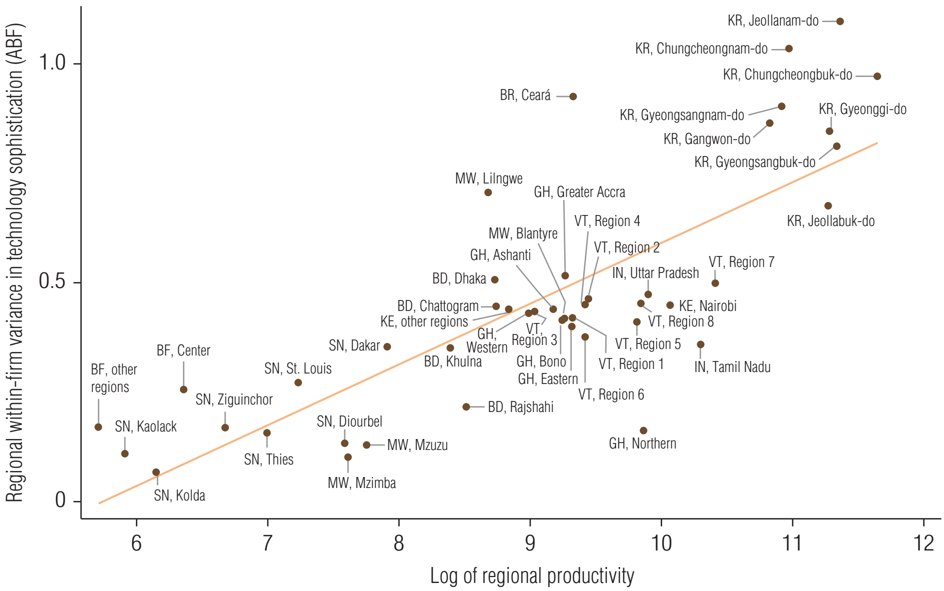
Note: Average technology index (intensive) reflects the average sophistication of the technology most frequently used to perform all business functions performed by the firm, using sampling weights.

The variance in technology sophistication is larger within countries than between countries. Cirera et al. (2020b) find that there is significant dispersion in technology across firms within each country, which is consistent with large cross-firm dispersion in management practices, as highlighted by Bloom and Van Reenen (2007). The findings suggest that cross-firm differences in technology sophistication are larger than cross-country differences, regardless of the technology measures considered and whether the focus is on general, sector-specific, or all business functions. The implication of this finding is that contrary to some popular beliefs that tend to associate technology gaps with cross-country differences, the largest technology gaps occur within countries. The significant variation associated with technology and productivity across regions within a country, and the reasons explaining the lag in regions, are also explored in the sixth volume in the World Bank Productivity Project series (Grover, Lall, and Maloney 2022).

There is a large variation in technology sophistication within firms, and it is positively correlated with regional productivity.

There is a larger variation in technology sophistication within firms than across firms. The findings from Cirera et al. (2020a) suggest that firms relatively closer to the frontier use more sophisticated technologies for some functions than for others. Cirera et al. (2020a) explore this topic in more detail with data from Brazil, Senegal, and Vietnam.

FIGURE O.6 **Within-Firm Variance of Technology Sophistication Is Positively Associated with Regional Productivity**



Source: Original figure based on Firm-level Adoption of Technology (FAT) survey data, following Cirera et al. 2020a.

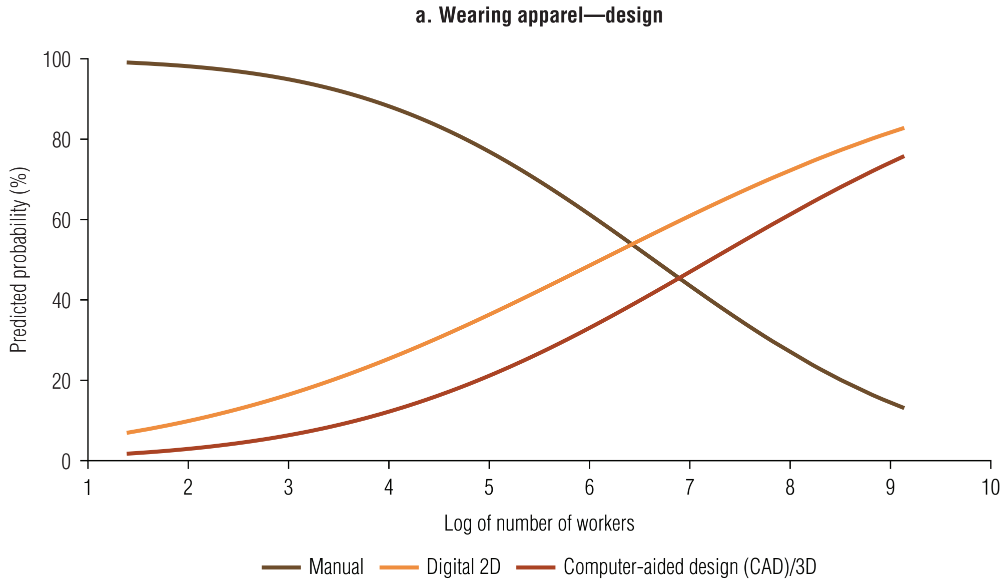
Note: The regional-level within-firm variance of technology sophistication for the average business function (ABF) is on the y-axis. The regional productivity is on the x-axis. The regional productivity is measured as the average value added per worker based on a representative sample of the FAT data for each region using sampling weights and adjusted by purchasing power parity. Countries are as follows: Bangladesh (BD); Brazil (BR); Burkina Faso (BF); Ghana (GH); India (IN); Kenya (KE); Korea, Rep. (KR); Malawi (MW); Senegal (SN); and Vietnam (VT). The eight regions sampled in Vietnam (VT) are: Region 1 (Bắc Ninh, Hài Phòng, Ninh Bình); Region 2 (Bắc Giang, Thái Nguyên); Region 3 (Bình Đinh, Hà Tĩnh, Thanh Hoá); Region 4 (Kon Tum, Lâm Đông); Region 5 (Bình Duong, Đòng Nai); Region 6 (Long An, Vĩnh Long); Region 7 (Hà Nôi); and Region 8 (Hò Chì Minh City).

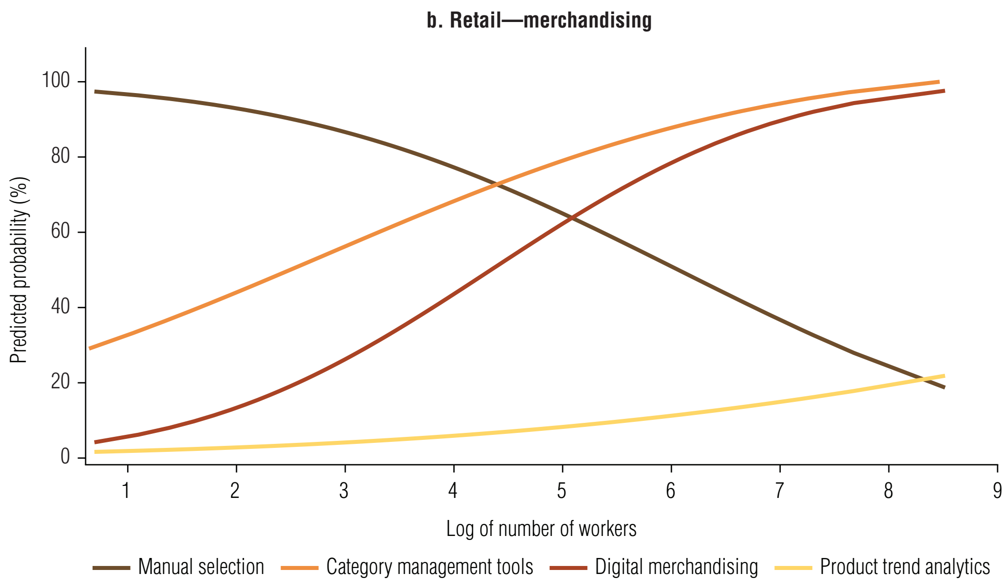
They observe that the paths of technology upgrading are different across business functions, reflecting the existence of heterogeneous costs and benefits of the different available technologies. The analysis also highlights the positive relationship between within-firm variance and productivity across regions. Figure O.6 plots the average within-firm variance in each of the 44 subnational regions against the log of regional productivity. The figure reveals a strong positive correlation between both variables (0.76).

Leapfrogging a technology in a business function is rare.

It is unusual for firms to jump stages by adopting more sophisticated technologies. This pattern becomes clear when examining technology adoption by firm size. Large firms tend to be early adopters of technology, while smaller firms tend to be later adopters. If leapfrogging occurs, the data should reveal smaller firms jumping the ladder by using more sophisticated technologies to perform a given task. This is, for example, what the FAT survey data reveal for certain communication technologies, such as fixed telephone lines compared to mobile phones. However, this is not what the FAT data generally reveal across business functions, with a few exceptions. Panel a of figure O.7,

FIGURE O.7 **Technology Upgrading Is Mostly a Continuous Process, as Illustrated by the Specific Business Function of Design in the Wearing Apparel Sector and Merchandising in the Retail Sector**





Source: Original figure based on Firm-level Adoption of Technology (FAT) survey data.

Note: The figure presents estimates of the probability of adoption across all 11 countries in the FAT survey sample for the extensive margin (whether a technology is used or not) as a function of the log of the number of workers based on a probit using sampling weights and controlling for firm's age group. For panel a, 2D = two-dimensional; 3D = three-dimensional. Panel b refers to the following options: manually selecting products (manual selection); deciding how many products of each category to sell (category management tools); retail merchandising systems with specialized software that considers turnover, inventory, and space (digital merchandising); and forward-looking strategies based on big data analytics or machine learning (product trend analytics). Panel b does not include Bangladesh, for which data on retail are not available.

for example, shows the diffusion curve of technologies used for the sector-specific business function of design in the wearing apparel sector, based on the predicted probability of adoption along firm size. The likelihood of adopting more sophisticated technologies (the orange and red lines) increases with firm size and follows the order of sophistication of the technologies available. Panel b shows an example for merchandising in retail. While the likelihood of using manually selected products decreases with firm size (the brown line), category management tools, digital merchandising with specialized software, and product trend analytics (based on big data analytics and machine learning) (the orange, red, and yellow lines, respectively) increase with firm size, following the order of sophistication captured by the FAT survey. The results support the hypothesis that technology upgrading is mostly a continuous process and is common across business functions. In the case of the design function, about 10 percent of firms outsource design to other firms. Yet, firms that perform this function tend to be more sophisticated technologically on average.

Part 2. The Implications of the Technological Divide for Long-Term Economic Growth

Technology, Productivity, and Jobs

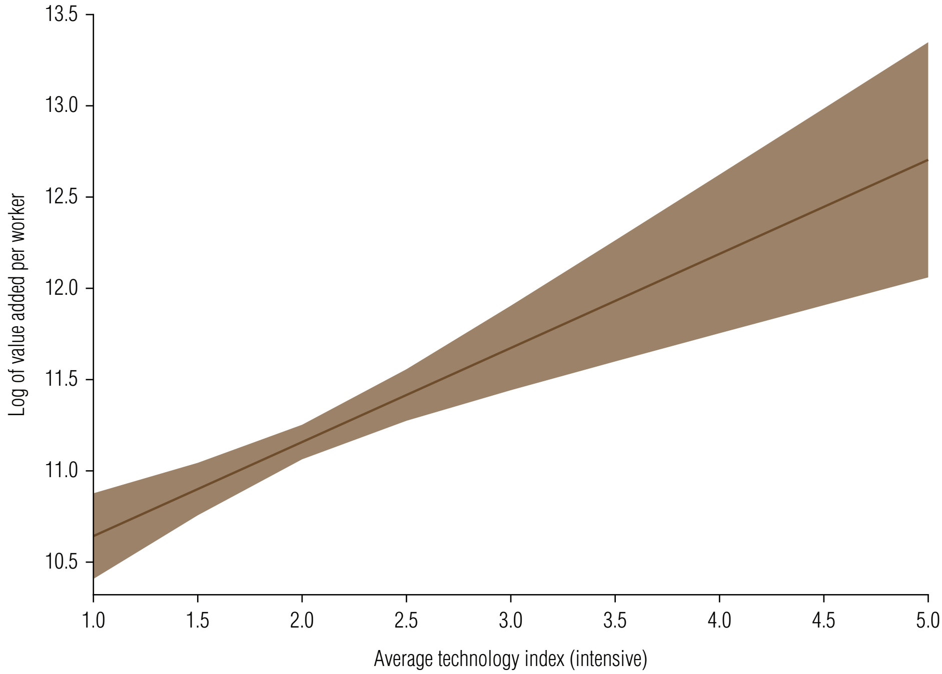
There is a strong and positive association between technology sophistication and labor productivity.

Evidence from the FAT survey data shows a positive and robust relationship between technology and labor productivity. Because it is difficult to estimate total factor productivity (TFP) robustly without longitudinal data, the analysis focuses on aggregate effects of technology on the productivity of one factor: labor. Specifically, the correlation between labor productivity (value added per worker) and technology is estimated. Figure O.8 plots the relationship between labor productivity and the measure of the average sophistication of the technology index for all business functions at the intensive margin (that is, the average sophistication of the technologies most intensively used for all business functions). While causal interpretations cannot be drawn, the results reinforce the finding that the various measures of technology used in this analysis are positively and significantly associated with labor productivity.

Technology sophistication is positively associated with job growth.

For centuries, some groups and commentators have argued that technological advances can lead to mass unemployment. In the past decade, this negative view of the effects of technology adoption on employment has gained significant traction with the emergence of advanced labor-saving technologies and evidence in more advanced economies of job polarization (Acemoglu and Autor 2011; Autor 2015), with considerable decreases in the demand for routine and often medium-skilled occupations and resulting increases in income inequality. This evidence focuses mainly on advanced economies. The few studies that focus on developing countries find different dynamics of polarization (Maloney and Molina 2016). This discussion

FIGURE O.8 **Technology Sophistication Is Correlated with Labor Productivity**



Source: Original figure based on Firm-level Adoption of Technology (FAT) survey data.

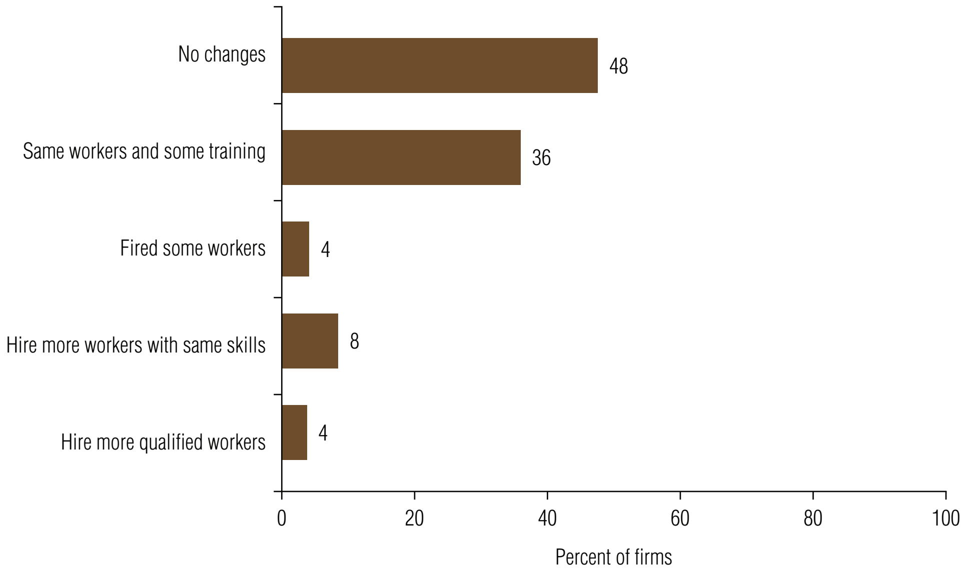
Note: The figure plots the predicted productivity as a function of technology sophistication using sampling weights and controlling for country, sector, formality, and employment. Estimates based on 10 countries in the FAT survey sample (productivity data for Poland were not available). The x-axis plots the estimated average technology sophistication across all business functions (ABFs) at the intensive margin. ABFs include general business functions (GBFs) and sector-specific business functions (SBFs).

of the impact of technology on employment, including the literature on polarization, usually refers to economywide effects over the medium and long term—which is not being analyzed with FAT survey data.

However, the FAT survey explores effects on employment by directly asking firms how they adjust their employment levels after they adopt new technologies: specifically, after they acquire a new machine, piece of equipment, or software. The survey results are summarized in figure O.9 The vast majority (84 percent) of firms report that they do not change the number of workers (48 percent reported no changes at all; 36 percent reported they offer some training to current workers). Only a small share of firms (4 percent) reports a reduction in the number of workers as a mechanism of adjustment for the acquisition of new technologies. This share is smaller than the share of firms that report an increase in the number of workers with the same skills (8 percent), and close to the percentage that hire more workers with higher skills (4 percent). At face value, there is little evidence that technology upgrading in these firms has led to job losses.

Firms that use more sophisticated technology also have higher employment growth. Figure O.10 shows the association between technology sophistication and

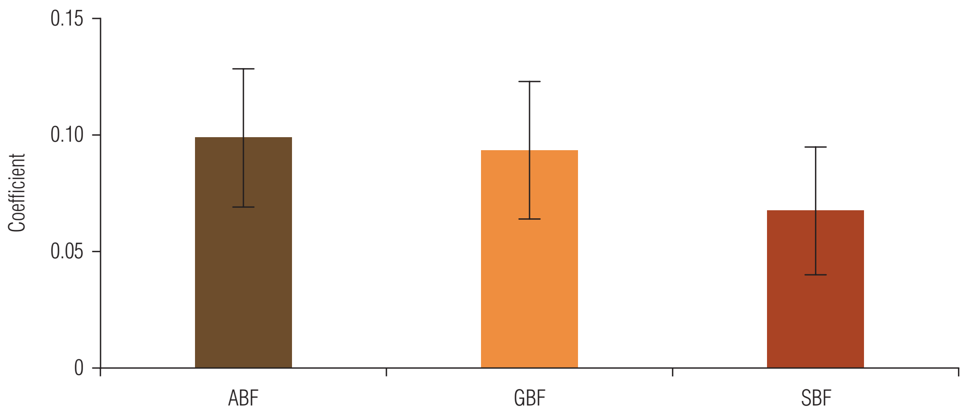
FIGURE O.9 **Firms Generally Keep the Same Number of Jobs When They Adopt New Technologies**



Source: Original figure based on Firm-level Adoption of Technology (FAT) survey data.

Note: The figure covers six countries (Bangladesh, Brazil (only the state of Ceará), India (only the states of Tamil Nadu and Uttar Pradesh), Malawi, Senegal, and Vietnam) in the FAT survey sample using sampling weights.

FIGURE O.10 **Firms That Have Adopted Better Technology Have Increased Employment**



Source: Original figure based on Firm-level Adoption of Technology (FAT) survey data.

Note: The figure provides the coefficients and 95 percent confidence intervals from regressions. Job growth is regressed on all business function (ABF), general business function (GBF), and sector-specific business function (SBF) at the intensive margin using sampling weights, while controlling for sector, firm size, and regions. It includes 10 countries in the FAT survey sample (data for Poland not included).

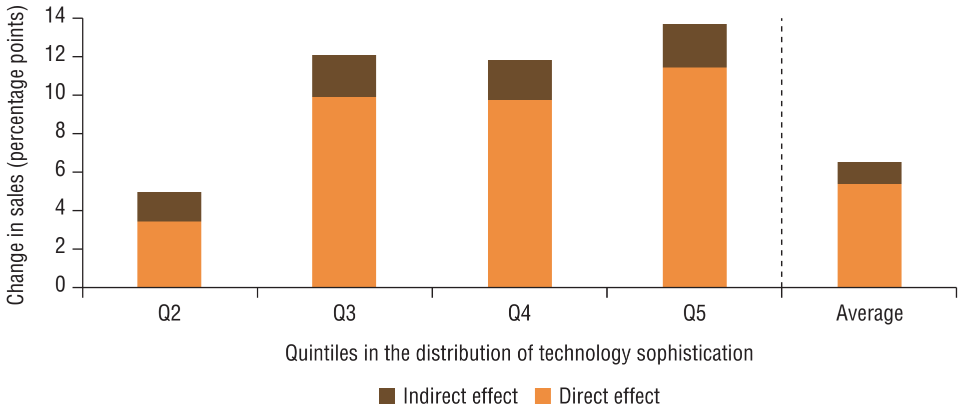
employment changes in the firm in the interval between the last fiscal year before the interview and two years earlier. The results suggest a positive and statistically significant association between employment growth and technology sophistication for all the technology indexes—for GBFs, SBFs, and the aggregate index for the average business function (ABF). Although these results do not infer a causal relationship, they are in line with other findings in the literature suggesting that firms with better technologies tend to be more productive and benefit from opportunities to expand. For example, evidence on the impact of innovation on employment also suggests an expansion effect (see evidence reviewed in Dosi and Mohnen [2019] and other articles on the impact of innovation on employment in the same volume).

Technology and Resilience to Shocks

Technologies play a critical role in increasing firms' resilience to shocks.
Firms with higher levels of technology before the COVID-19 pandemic were significantly more likely to start using or increase their use of digital technologies in response to the pandemic. To investigate the impact of technology on the performance of firms during the pandemic, Comin et al. (2022) combine information on digital adoption by firms before and after the COVID-19 shock. The analysis uses data from Brazil, Senegal, and Vietnam for which granular measures of technology readiness before the pandemic are available from the FAT survey, and information on digital response and firm performance during the pandemic is available from the World Bank Business Pulse Survey (BPS). First, the analysis examines the association between technology readiness, measured by the GBF technology index, and the likelihood of increasing the adoption of digital technologies. On average, a one-unit increase in the GBF technology index (intensive margin) corresponds to a 17 percentage point increase in the likelihood of starting to use or increasing the use of digital technologies in response to the COVID-19 crisis. This result is statistically significant.

Digital readiness helped firms become more resilient during the pandemic. The analysis uses the association between technology readiness and the digital response to COVID-19 to disentangle the direct and indirect effects of technology readiness. More sophisticated businesses, for example, could better plan production to reduce potential supply chain bottlenecks, or more quickly switch to home-based work (direct effects). Similarly, more sophisticated firms could more easily adopt additional technology and transition into digital platforms to sell their products online and reduce the impact of lower consumer mobility (indirect effects). Figure O.11 shows that the direct impact of technology sophistication before the pandemic on sales is significantly larger than the indirect effect through the adoption of digital solutions. Both direct and indirect effects on sales are positive and their magnitude increases with the firms' level of technology sophistication before the pandemic. The resulting total effect averages 6.5 percentage points (3.8 percentage

FIGURE O.11 **The Direct Effect of Technology Readiness before the COVID-19 Pandemic Is Much Larger than the Indirect Effect on the Change in Sales during the Pandemic**



Source: Comin et al. 2022.

Note: The figure shows the estimates of the direct and indirect effects of technology before the pandemic on the percentage change in sales following the treatment effect mediator framework, as described in Comin et al. (2022). The columns show the estimations across quintiles of the distribution from low (Q2) to the most advanced (Q5) technology sophistication, in relation to the most basic (Q1). The last column shows the total effect for the full sample.

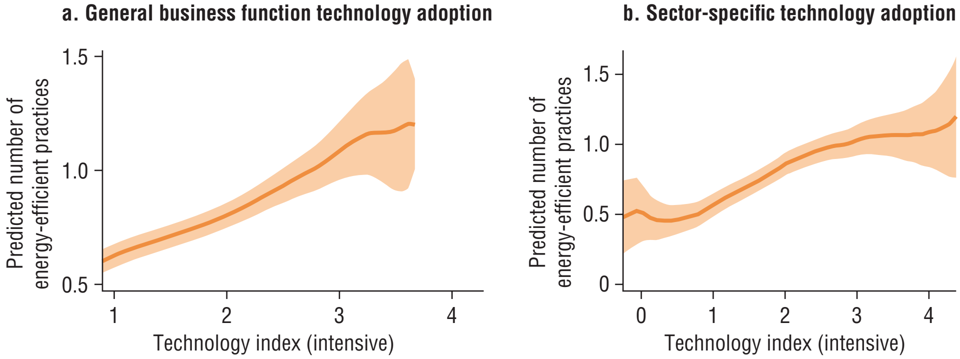
points for an increase of one standard deviation in technology sophistication), and ranges from 5 percentage points when comparing businesses in the second quintile to those in the bottom quintile (20 percent) to almost 14 percentage points for businesses in the fifth quintile.

Technology can act as an engine of resilience to adapt to and mitigate climate shocks.

Moving forward, minimizing the impact of climate shocks will require the adoption of new technologies. On the one hand, adaptation to climate shocks—such as rising temperatures, drought, fire, cyclones, and flooding—requires technologies that act in real time to adjust to weather changes in agriculture, reduce excess temperature in premises, and minimize sourcing risks in supply chains for manufacturing and services. On the other hand, mitigation efforts require greener and more energy-efficient production, especially in the context of rising energy prices and other geopolitical shocks.

There is a positive association between the adoption of "green" and "nongreen" technologies. A critical question for climate mitigation is related to how adoption of general-purpose and sector-specific technologies is associated with adoption of green technologies. In other words, are firms that use more sophisticated technologies for GBFs and/or SBFs also using more energy-efficient and green practices and technologies? Figure O.12 shows the correlation between the technology index and the adoption of energy-efficiency practices, based on recently collected FAT data in Georgia.

FIGURE O.12 **There Is a Positive Correlation between Technology Sophistication and Use of Energy-Efficient Technologies in Georgia**



Source: Original figure based on the Firm-level Adoption of Technology (FAT) survey for Georgia.

Note: The technology indexes used in panels a and b refer to the intensive margin, which captures the most widely used technology across business functions. The y-axis measures the number of energy-efficient technologies and practices used by the firm.

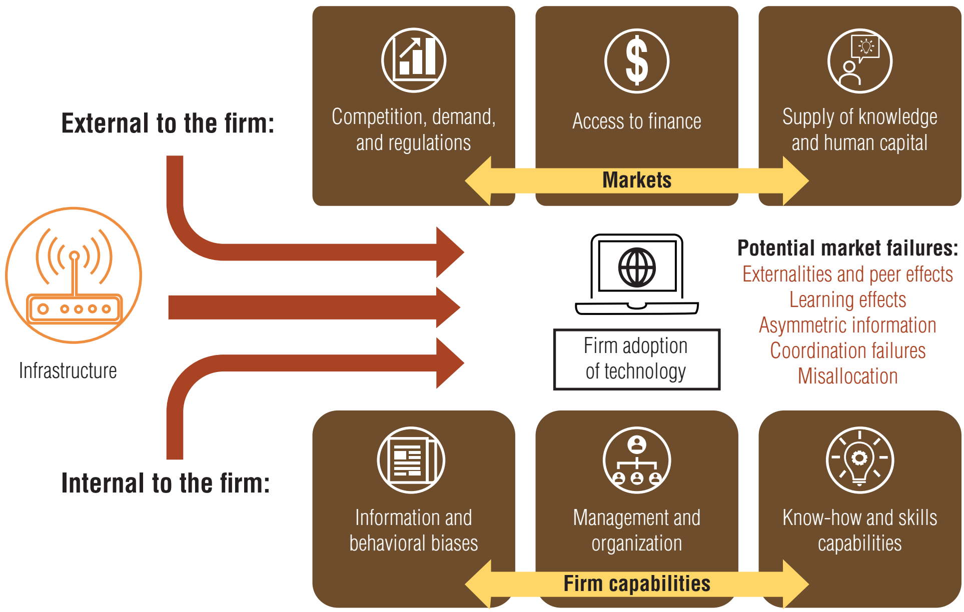
More technologically sophisticated firms, for both general and sector-specific business functions, tend to use more energy-efficient technologies.

The association between technology readiness and resilience, through the capacity to quickly adjust to shocks, highlights the risks of an increasing technological divide against the backdrop of climate change. A potential channel of complementarities in the adoption of green and nongreen technologies is the knowledge accumulated in the firm. More and better data are needed to measure and identify these complementarities. There is a clear need to understand green technologies from the perspective of the firm and how the dynamics of adoption relate to the drivers and obstacles that other technologies face and what obstacles and drivers are specific to green technologies.

Part 3. What Countries Can Do to Bridge the Technological Divide

If more sophisticated technologies lead to productivity gains and growth, why don't firms adopt and use them more intensively? Understanding what drives firms to adopt a specific technology is essential to improve the effectiveness of policies aiming to support technology upgrading. The literature has highlighted several factors that drive firm technology adoption (see Verhoogen, forthcoming). Some of these factors are outside the control of the firm and can affect the profits and returns of adopting a technology, but several factors relate to entrepreneurs and capabilities of the firm. Figure O.13 summarizes some of the key factors emphasized by the literature, organized in two complementary sets of drivers: one internal to the firm and one external. Organizing the discussion around these two broad sets can help policy makers identify instruments that are available to support technology upgrading.

FIGURE O.13 **Technology Adoption Depends on a Set of Complementary Factors That Are External and Internal to the Firm**



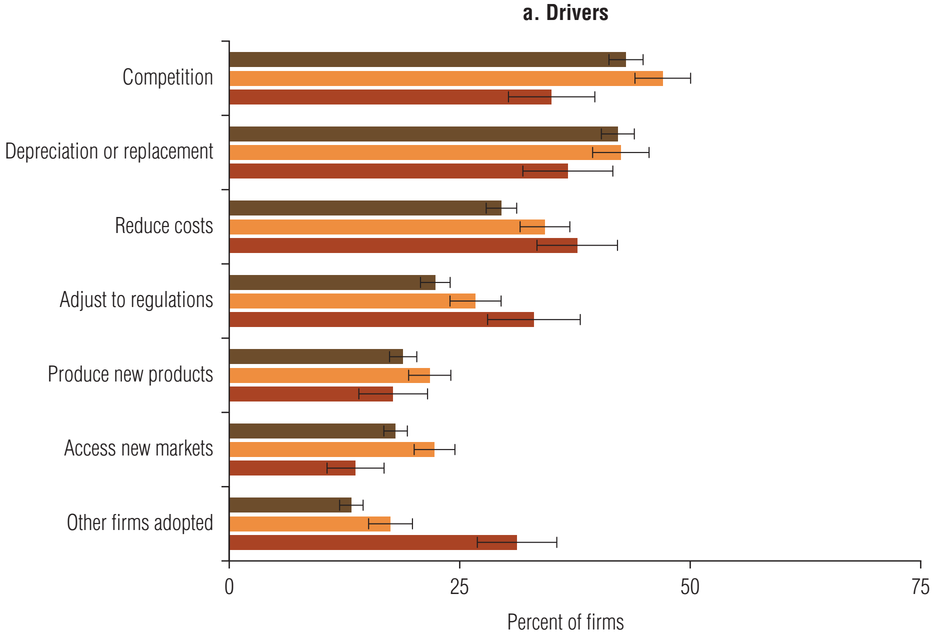
Source: Original figure for this volume.

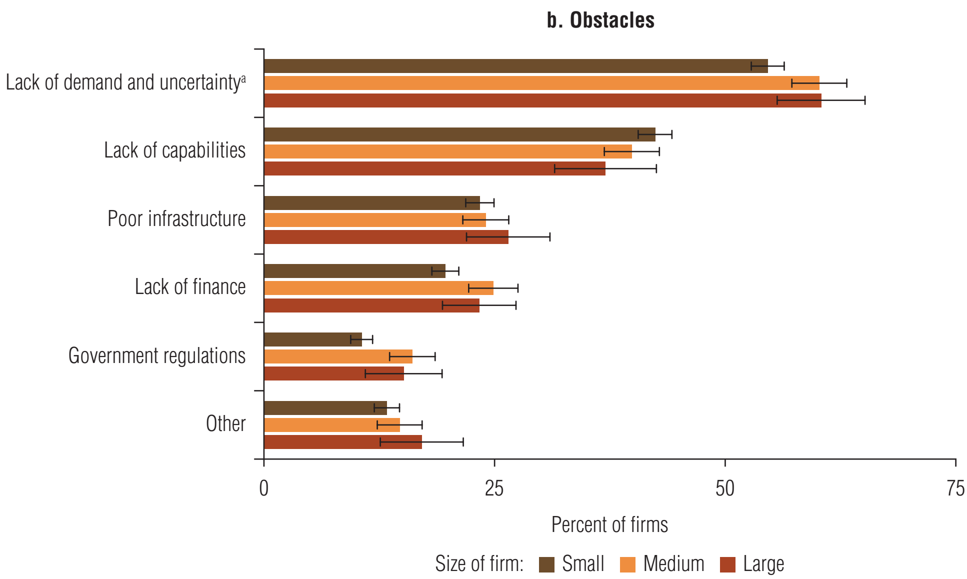
The FAT survey asks firms about their main motivations for upgrading technologies. Figure O.14 (panel a) shows the top motivations for adopting new technologies by firm size group. The pressure of competition—an external factor to the firm—is the main motivation reported by most firms. In particular, more than 40 percent of small and medium enterprises report this as their main reason. Panel b shows the share of firms reporting the top three obstacles to adoption by firm size group. The most common obstacle for all types of firms across countries is concern about sufficient demand to justify investment in new technologies. More than 60 percent of firms cite this concern, which is an external factor. The high percentage is homogeneous across firm size, from large to small firms. The second most common factor reported is related to lack of capabilities, which includes the overall technical skills and know-how to implement new technologies. This is the main internal factor cited.

Factors External to the Firm: An Enabling Environment

Beyond the perceptions of entrepreneurs, there are some important factors highly correlated with technology adoption that can be grouped as external or internal to the firm. One of the main external factors is quality of infrastructure. Yet improving access to infrastructure—including digital infrastructure—on its own may not be enough to promote uptake in more sophisticated digital technologies. A background paper for this volume (Berkes et al., forthcoming) shows that proximity to an internet node

FIGURE O.14 **Competition Is a Top Driver and Lack of Demand and Firm Capabilities Are Key Obstacles for Technology Adoption**





Source: Original figure based on Firm-level Adoption of Technology (FAT) survey data.

Note: The figure shows the share of firms reporting each driver as a top driver (panel a) or each obstacle as among its top three obstacles (panel b). Results are based on cross-country average using sampling weights. Firm size refers to the number of workers: small (5–19), medium (20–99), large (100 or more).

a. Uncertainty refers to uncertainty about future demand.

increases the likelihood that firms in Senegal will adopt the internet, but the quality of internet service can explain adoption only of more sophisticated technologies for GBFs at the extensive margin, but not for SBFs, on average, where digital technologies may be less prevalent and internet service is less of an enabler.

Access to international markets and competition in the domestic market are also important drivers of adoption. Access to international markets has large effects on productivity via competition and learning, and these channels can also result in the use of more sophisticated technologies.

Factors Internal to the Firm: Firm Capabilities and Management Quality Are Key Drivers

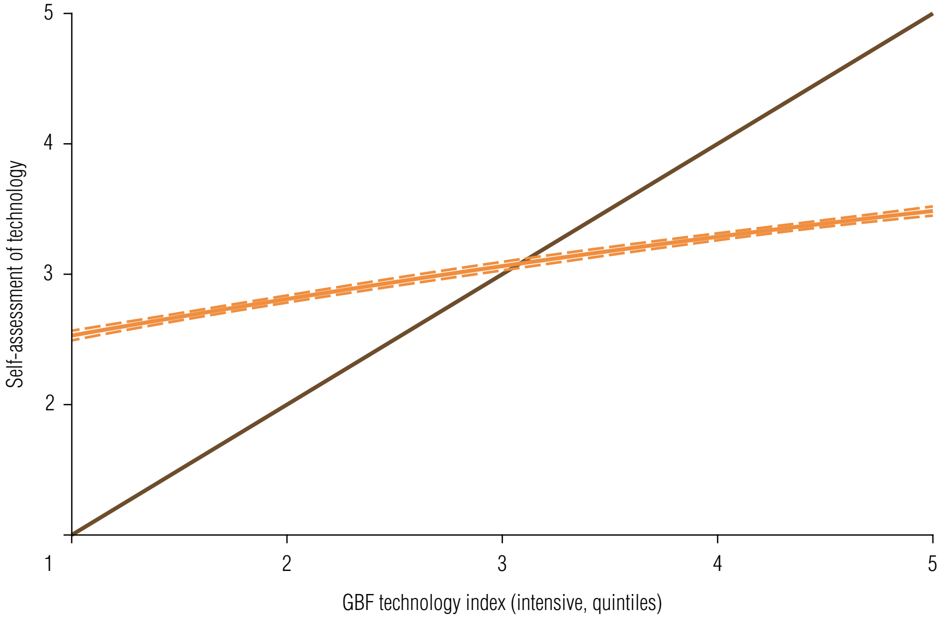
Human capital and management quality have been emphasized as important drivers of technology adoption by the literature, including the volumes in the World Bank Productivity Project series. The importance of these factors is also supported by the FAT data. The data allow comparisons of the relationship between a firm's management practices and technology adoption. As measures of the firm's overall management quality, the survey questionnaire asks (1) whether firms make use of formal incentives and (2) the number of performance indicators they use. This analysis uses these two measures and correlates them with the GBF technology index. The results show that firms that use formal incentives with workers have a higher index for both the extensive and intensive margin of technology sophistication. Similarly, firms that use more performance indicators use more advanced technologies. The results suggest that innovation and technology adoption are often driven by workers when they have incentives to do so, in line with previous findings in the literature (Atkin et al. 2017).

Behavioral Biases and Lack of Awareness Are Obstacles to Technology Adoption

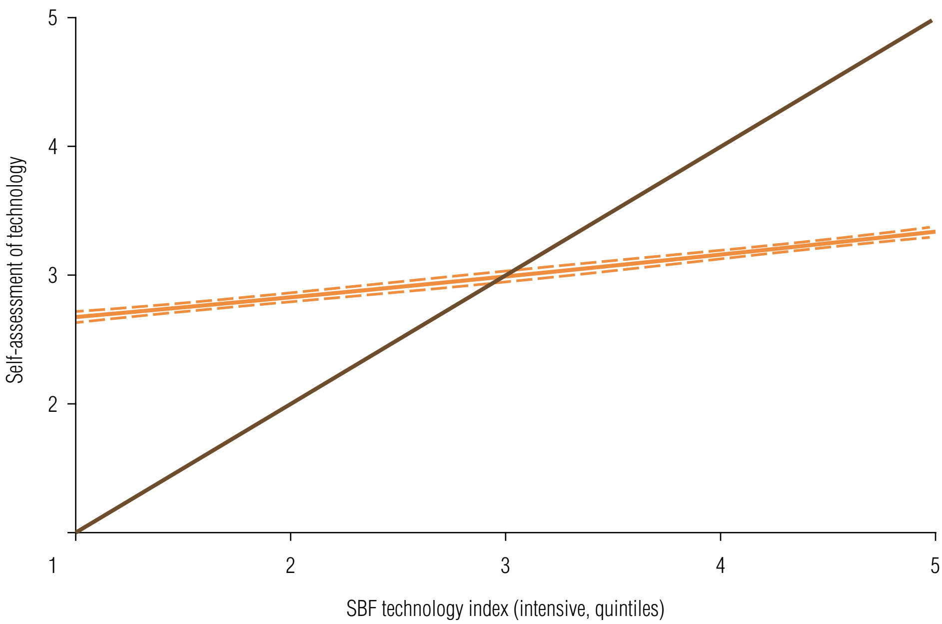
An important element to explain delayed adoption of more sophisticated technologies is the willingness to adopt. Entrepreneurs and managers can have important biases against adoption. For example, if they believe that they are already adopting more sophisticated technologies in relative terms, it is unlikely that they will invest in adopting new technologies. Then the question is whether firms are aware of their actual technology gap. The FAT survey asks for a self-assessment of technology from 1 to 10 (here rescaled to 1 to 5), comparing the respondent's firm with other firms within the country (here distributed by quintiles) (figure O.15). Along the 45-degree line, the predicted technology sophistication of the manager matches the actual level of sophistication. However, the results suggest that firms with lower levels of technological capabilities are more likely to overestimate their technological sophistication in relation to other firms. These results capture a type of behavioral

FIGURE O.15 Firms with Lower Levels of Technological Capabilities Tend to Overestimate Their Technological Sophistication

a. In relation to other firms in the country



b. In relation to other firms in the country



Source: Original figure based on Firm-level Adoption of Technology (FAT) survey data.

Note: The orange line shows the quadratic fit with 95 percent confidence interval using sampling weights. GBF = general business function; SBF = sector-specific business function.

bias labelled *reference group neglect* (Camerer and Lovallo 1999) by which entrepreneurs tend to underestimate their competitors' abilities—in this case, technological capabilities. The importance of this type of bias is that firms may not upgrade their technologies if they do not perceive that they need them to compete.

Policies to Support Technology Upgrading

Policy makers around the world have been trying to directly address the problem of lack of technology adoption with very varied results. A recent systematic review of impact evaluations of various instruments to promote technology adoption finds that the impact on both adoption and performance outcomes is mixed, at best (Alfaro-Serrano et al. 2021). More important, the results emphasize the importance of context-specific factors and suggest that there is no one-size-fits-all solution. Given the complexities that surround the design and implementation of technology adoption policies, it is important that policy makers structure policy support efficiently and minimize the risk of government failure.

Figure O.16 presents an initial checklist of questions for policy makers seeking to actively promote technology adoption. The first column highlights some of the key questions that policy makers should ask themselves when designing this type of policy and the considerations related to each question. The second column proposes policy instruments. It is important to undertake these analyses before designing the policy program to avoid policy failure. More important, the analysis is needed to better understand the local context because what has worked in one country will not necessarily work in another country. The FAT data can be used to guide policy makers and practitioners identify key bottlenecks to prioritize policy interventions. Moreover, the FAT survey can also be used as a firm-level diagnostic to support business advisory interventions.

Public agencies have an important role to play to address coordination and information failures. The starting point for policy makers should be to make sure that the enabling conditions to adopt technologies are in place to ensure access to infrastructure, information, and external knowledge that can improve the operations and management of firms, and to remove regulatory bottlenecks. As highlighted by the first volume of the World Bank Productivity Project series (Cirera and Maloney 2017), these complementary factors play an important role in innovation, as well as in technology upgrading.

When considering more direct support, public agencies should identify and measure the type of market failure they are trying to address and ponder whether their planned support can address these failures effectively. To this end, implementing good diagnostics to identify key technology gaps and better target firms, investing in adequate human and financial resources to implement the programs, and implementing good evaluation mechanisms are necessary conditions. The FAT survey and data can help with these diagnostics and evaluations.

FIGURE 0.16 **A Checklist for Policy Makers to Upgrade Technologies**

Question	Policy instrument(s)
Why are firms not adopting technologies that could enhance productivity and profitablity?	• Use diagnostics and benchmarking to identify existing gaps. • Incorporate factors external to the firm (e.g., regulations and infrastructure) and internal to the firm (e.g., know-how and skills capabilities).
What are the market failures that justify your intervention?	• Identify and quantify the main market failures to be solved and the ability of existing agencies to act on these issues.
What are the main regulatory bottlenecks?	• Undertake regulatory impact assessment to identify whether regulations enable the supply and adoption of technologies.
Is infrastructure adequate?	• Identify the key limitations with infrastructure (e.g., access to and quality of electricity, internet). • Identify a priority plan for key infrastructure projects.
Is the financial sector financing technology upgrading projects?	• Consider the use of loan programs through financial intermediaries or credit guarantees to finance technology upgrading.
Do firms have adequate information and access to skills and knowledge?	• Consider online tools to provide diagnostics and technology information. Work with sector associations on technology road maps and skills training needs. Improve the provision of business advisory and technology extension services.
Will the extensive adoption of technology generate large positive spillovers?	• Consider the use of vouchers for implementation of off-the-shelf digital solutions. • Consider grants or tax incentives for technologies with large spillovers or externalities, for example in green technologies.
Are there large network effects in the adoption of technologies with large externalities?	• Consider subsidies to first adopters.

Source: Original figure for this volume.

Some key policy instruments to support technology upgrading are described in detail in the volume. While there is evidence that some instruments are effective in some contexts and countries, there are still large gaps in the evidence, and positive results are very specific to a particular context, which makes it difficult to guide the choice of instrument. A critical objective of direct support instruments should be to address information and capability failures. The design and implementation of this type of policy instrument increase in complexity when moving from general to sector-specific business functions because these require more specialized knowledge support. Another critical type of support is related to the financing of technology upgrading projects, given that financial markets in many developing countries suffer from large market imperfections. Working with commercial banks to address this lack of finance can help facilitate technology upgrading, especially for firms that have higher capabilities to adopt but are financially constrained. However, these finance instruments may not work in cases of firms with very limited capabilities.

To sum up, the COVID-19 crisis has been a wake-up call for many businesses around the world about the need to upgrade their technologies, digital and nondigital. The pandemic has increased the incentives of businesses to upgrade, reducing some of the earlier overconfidence about their technological capabilities and making it more likely that they will undertake upgrading programs. Policy makers should seize this opportunity to minimize the risk of an increase in the technological divide across countries and firms and support steps to encourage technology upgrading and the digital transformation of businesses to promote more sustained growth and prosperity for their economies.

Notes

1. The initial 11 countries are Bangladesh, Brazil (only the state of Ceará), Burkina Faso, Ghana, India (only the states of Uttar Pradesh and Tamil Nadu), Kenya, the Republic of Korea, Malawi, Poland, Senegal, and Vietnam. Data collection is ongoing or planned for 2022 in Brazil (the state of Paraná), Cambodia, Chile, Croatia, Ethiopia, Georgia, Indonesia, Mauritania, and Peru.
2. For more details about the heterogeneity and importance of sector-specific technologies for productivity, see the fourth and fifth volumes in the World Bank Productivity Project series on agriculture (Fuglie et al. 2020) and services (Nayyar, Hallward-Driemeier, and Davies 2021).
3. The technology index is also calculated for the most advanced technology used by the firm based on information identifying whether a technology is used or not (extensive margin). These results are presented in chapter 6 of the full volume in the discussions related to drivers and obstacles of technology adoption. If not explicitly defined, the technology index presented in this volume is based on the most frequently used technology.
4. Network effects occur when the value of a technology, such as computers or automated teller machines (ATMs), increases the more users it has. Network effects are often accompanied by a production scale effect that reduces the cost of the technology.

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