DRIVERS OF PRODUCTIVITY GROWTH IN POLAND

A FIRM-LEVEL PERSPECTIVE ON TECHNOLOGY ADOPTION AND FIRM CAPABILITIES

European Commission
Ministry of Economic Development and Technology
Statistics Poland
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ABBREVIATIONS AND ACRONYMS

AI	artificial intelligence
BGK	National Economy Bank
bn	billion
BPS	Business Pulse Survey
BUR	Development Services Database
CEO	Chief Executive Officer
CRM	Customer Relationship Management
DESI	Digital Economy and Society Index
DG REFORM	Directorate-General for Structural Reform Support
DIH	Digital Innovation Hub
EC	European Commission
EIB	European Investment Bank
ERP	enterprise resource planning
EU	European Union
EUR	Euro
FDI	foreign direct investment
FPPP	Future Industry Platform
FTE	full-time equivalent
GBF	general business functions
GDP	gross domestic product
GPS	Global Positioning System
GUS	Statistics Poland
GVA	gross value added
HR	human resources
ICT	information and communication technologies
IIoT	Industrial Internet of Things
IT	information technology
M&E	monitoring and evaluation
MFF	Multiannual Financial Framework
MSMEs	micro, small, and medium enterprises
NGEU	NextGenerationEU
OECD	Organisation for Economic Co-operation and Development
PARP	Polish Agency for Enterprise Development
PFR	Polish Development Fund
PPP	purchasing power parity
R&D	research and development
SBF	sector-specific business functions
SMEs	small and medium enterprises

SOE	state-owned enterprise
SP	Annual Enterprise Survey
SRM	supplier relation management
TAS	Technology Adoption Survey
UK	United Kingdom
US	United States

EXECUTIVE SUMMARY

Why is technology adoption important?

Successful technology adoption in Poland can significantly improve productivity and strengthen the economy's resilience to external shocks such as the COVID-19 pandemic. Given the upcoming challenges — securing convergence with the Western countries while undergoing demographic transition and coping with the highly uncertain geopolitical situation — Poland must realize substantial economic growth based on productivity improvements. An empirical consensus has formed that digital technology adoption can bring significant productivity performance increases and improve firm-level economic resilience. The pandemic outbreak revealed the importance of digital technologies such as cloud storage, e-commerce, and mobile banking that not only help firms to improve their efficiency but also ensure business continuity. Even though firms have made significant progress in digitalization, especially since the beginning of the COVID-19 pandemic, the country still struggles to keep up with its European comparators.

Despite some progress in digitalization, the general attitude toward technology adoption among Polish entrepreneurs indicates the possible need for policy interventions to spur the country's digital transformation further and facilitate productivity improvements. Poland ranks at the bottom of the Digital Economy and Society Index Ranking (24th of 27 EU member states) that measures progress in digital technology adoption across the EU. At the same time, half of Poland's entrepreneurs are convinced that their firms do not need any further digitalization or investments in employee skills.[1] Skills upgrading and management practice improvements are as crucial for efficiency growth as is the technology itself, but since over half of the firms in Poland do not offer training to their employees, it seems that companies aren't taking this into account. Even though within-firm productivity growth has accelerated since 2017, little is known about its source.[2] Investigating firm-level technology sophistication can fill this gap.

1. World Bank. Business Pulse Survey: Poland, 4th edition. https://www.parp.gov.pl/storage/publications/pdf/Prezentacja-v7---FINAL.pdf

2. World Bank, *Paths of Productivity Growth in Poland: A Firm-Level Perspective* (Washington, DC: World Bank, 2021).

What is the Technology Adoption Survey (TAS)?

The Technology Adoption Survey (TAS) is a World Bank instrument designed to collect detailed firm-level information about the level of technology adoption and use and to create a comparable measure of technology sophistication. The TAS is an innovative tool for collecting firm-level information about the technologies that firms use to perform key business functions necessary to run businesses across sectors.[3] In cooperation with academics, sectoral experts, and technology consultants for each industry, business functions were defined and, for each business function, ranks were assigned according to their sophistication. The survey identifies the purpose of technologies adopted by a firm, through general business functions (GBF) and sector-specific business functions (SBF), and then, for each business function, it measures the technologies the firm adopted (extensive margin) and uses most frequently (intensive margin). For example, payment methods are one of the seven identified general business functions. For this business function, the survey asks whether the establishment accepts any payment method, from cash to virtual currency, and which method is the most commonly used (intensive margin). Similarly, for sector-specific business functions, for example, in the automotive sector, the survey asks what assembly methods the establishment employs, ranging from machines controlled by operators to numerically controlled computers, and which method is used most frequently. Thanks to the granularity of data, the survey creates a measure of firms' technology sophistication that is comparable across countries, sectors, and firms with different characteristics, such as size, ownership status, etc. This kind of firm-level measurement can be further aggregated by country, region, sector, or specific business function to identify the distance from the technological frontier, regional front-runners, or peer countries and pin down key enablers or obstacles and policies that could improve these results.

A representative sample of 1,500 Polish firms was surveyed to evaluate the country's technology sophistication and deliver evidence-based recommendations to foster technology adoption. The TAS survey was implemented in collaboration with Statistics Poland (GUS) and included a nationally representative sample of 1,500 firms with five or more employees across agriculture, manufacturing, and services. The survey was stratified across six firm-size groups to account for European and global firm-size definitions: (i) 5 – 9, (ii) 10 – 19, (iii) 20 – 49, (iv) 50 – 99,

3. X. Cirera, D. Comin, M. Cruz, *Bridging the Technological Divide: Technology Adoption by Firms in Developing Countries* (Washington, DC: World Bank, 2022).

(v) 100 – 249, (vi) 250+ employees. Eleven sectors were included: agriculture, food processing, wearing apparel, automotive, pharmaceuticals, trade, financial services, land transport, health services, other manufacturing, and service sectors. Finally, seven macro regions were also surveyed. Survey collection began in August 2021 and ended in December 2021.

The Republic of Korea is a comparator and aspiration peer for the level of technological sophistication sought by Polish companies. Pragmatic reasons support comparing Poland and Korea as well: the TAS has been so far implemented in ten countries, among which only Korea can set a benchmark for Poland. In fact, in the near future, both Poland and Korea will be benchmark countries, especially for countries in the region such as Romania, Bulgaria, or Croatia. Despite being geographically very distant, other reasons also make Korea a good comparator. First, both Korea and Poland are frequently called growth miracles and have been in the small group of the fastest-growing economies in the world. Second, both countries follow very similar paths of productivity growth. Third, both countries will face a significant aging challenge from the dramatic increase in the share of older people in their populations. Last, Korea is perceived as a global leader in innovation and technology, and Korean companies have been among key foreign investors bringing advanced technologies to Poland. Thus while substantial differences exist — e.g., the larger fragmentation of the Korean economy and a larger share of agricultural firms — Korea makes a good comparator for Poland.

How technologically advanced are firms in Poland?

In Poland, the technologies most frequently used to perform typical day-to-day business functions are relatively basic, even though firms have access to more advanced technologies. The General Business Functions (GBF) Index for Poland is 2.14 for the intensive margin, which indicates that an average firm most frequently uses rather basic general-purpose technologies. For example, the firm might employ computers with standard software to perform standard administration processes (HR, accounting, etc.). At the same time, the extensive margin of 2.92 indicates that on average firms had adopted already more advanced technology (e.g., quality control with computers), but are prone to use the less advanced ones. As expected, an average Polish firm is less technologically advanced than an average Korean firm, where the intensive margin amounts to 2.6. Surprisingly, while fewer companies use more sophisticated technologies in Poland than in Korea, more companies in Poland have access to sophisticated technologies compared to Korea, where the extensive margin equals 2.61.

The technologies used vary widely between firms, but the variation is even larger within firms: even the most sophisticated firms usually use frontier methods only in some areas of their operations. On average, payments and business administration processes are more advanced than quality control, marketing, and sales. As expected, technology sophistication varies widely across firms in Poland: the intensive margin GBF for the bottom 10th percentile firm is 1.38, while for the top 90th percentile it is 2.96. The gap is even larger for the average within-firm variation: for example, firms frequently use the most sophisticated Enterprise Resource Planning (ERP) software for administration, but basic manual processes for quality control. Not only is there a large variation in terms of technology sophistication across and within firms, but advancement varies significantly across business functions. At a relatively early stage of technology sophistication (GBF index around 2), firms are starting to use relatively advanced payments and business administration processes. At the same time, more advanced quality control, marketing, and sales technologies are adopted only at the later stages of average technology sophistication, and therefore by a small share of firms in Poland. Compared to Korea, Polish firms use more advanced payment methods and less advanced technologies for the remaining six business functions.

What are the factors associated with technology adoption?

Technology sophistication in performing general functions increases with firm size and is positively associated with foreign ownership and international trading. Still, even among firms with similar characteristics, technologies adopted and used vary widely. Strong empirical evidence shows that the level of technological adoption is most frequently related to the scale of a business: the most sophisticated technologies are adopted and used almost exclusively among larger companies. Compared to Korea, the largest gap in the use of GBF technologies is among companies employing between 5 and 100 employees, and it drops to almost zero for large companies. This indicates that at least two paths exist to bridge the technological gap between Poland and more advanced countries: by narrowing the technology gap for each size class, and by changing the structure of the Polish economy and increasing the share of non-micro companies. The pharmaceutical and automotive sectors are on average the most technologically advanced in general business functions; however, in all sectors, some firms operate close to the technology frontier, while other firms frequently use the most basic technologies. Foreign ownership is associated with significantly higher general business function technology, as foreign firms tend to use more advanced technologies in business administration, planning, and marketing, but not with sector-specific technologies. Regardless of the ownership, firms that export and import use more advanced technologies, particularly for sourcing and sales.

Management capabilities and practices are crucial for general purpose technology adoption and seem to be more important than the skills of workers. Technology adoption in general business functions increases with education, but not with vocational training. However, the share of workers with a college degree is what really matters for the technology adoption: having a manager with at least a bachelor's degree is associated with significantly more advanced technology adoption, and the correlation is even stronger if the manager has studied abroad (which is likely a proxy for better knowledge of foreign languages and greater open-mindedness). Moreover, better managerial practices correlate with a higher level of technology adoption. However, it is important to stress that strong correlations do not indicate that better capabilities/practices lead to higher technology adoption. While this is likely, the opposite may also be true: more advanced technologies require higher-skilled workers.

Does technology sophistication matter for productivity?

In Poland, firms with more advanced technologies are on average more productive. The country has high productivity growth potential, as moving only the bottom 25 percent of firms to the median level of technology sophistication for general technologies would increase productivity by an additional 1 percent. A strong positive relationship exists between productivity and availability and use of technology in Poland: on average, the higher the general business function index (both intensive and extensive), the higher the productivity (controlling for firm size, region, and sector). It is expected that the positive correlation will also hold at higher average technology sophistication levels, a relation also found in Korea. These findings indicate high untapped productivity growth potential. Indeed, if the bottom 25 percent of firms (intensive GBF below 1.67) caught up to the median firm (intensive GBF equals 2.08), the average firm-level productivity would increase by 1 percent. The switch is not unrealistic, as the technologies are easily available, still relatively unadvanced, and used by many other companies in Poland.

What inhibits and enables technology adoption?

Firms in need of technological upgrading may be the most reluctant to adopt new technologies due to overconfidence and self-assessment bias. The vast majority of firms in Poland tend to position themselves above the median compared to other firms in Poland and at a relatively similar level of technology adoption, regardless of their actual technological advancement. The gap between the perceived and actual level of advancement is the largest for the least technologically sophisticated companies. When firms compare themselves to other firms in the world, their assessment is closer to their level of technological development. In both cases, the most sophisticated firms underestimate their level of technological advancement. If the firms' judgment is truly biased, firms need support to correctly identify their gaps and needs.

Polish firms consider themselves financially constrained or assume that returns on technology adoption are not sufficient, which differentiates Poland from other countries. Compared to other countries, Polish firms appear to be less concerned about their competition and list depreciation as the main reason for technology adoption. On average, around 60 percent of firms list finance-related barriers, namely costs or lack of finance, as their main obstacles to technology adoption, a significantly higher percent than in other countries. On the other hand, lack of capacity for technology is significantly less frequently mentioned compared not only to Vietnam and Brazil but also to Korea. Moreover, the differences in obstacles between small and large firms in Poland are more significant than in other countries. When providing reasons for technology adoption, 80 percent of Polish enterprises state they adopt a new technology when they are forced to replace an old one; this response is much more frequent in Poland than in comparator countries where either competition or an attempt to reduce costs is the main driver.

What should be done to increase productivity through technology adoption?

The level of technology sophistication in Polish firms could be increased by reforms in five key areas: building awareness, supporting firm-level technology adoption, strengthening firm capabilities, reducing barriers to scaling up, and improving coordination and use of data. Based on the outcomes of the report, as well as previous World Bank analyses, the report outlines a list of recommendations for key stakeholders and priority levels. The highest priority is assigned to reforms directly related to the design and implementation of EU co-financed investments in public support instruments for the 2021 – 2027 financial perspective, as the implementation has not started yet.

Enterprises' awareness of their gaps in and returns from technology adoption could be increased by including obligatory needs assessments in the instruments supporting technology adoption, as well as by enhancing the capabilities of the Future Industry Platform, the Digital Innovation Hubs network, and other business support institutions. The survey's results on Poland, similarly to the vast literature on the topic, indicate that many firms are unaware of their actual gaps related to technology and organization and overestimate their level of technological sophistication and managerial capabilities. Moreover, most Polish firms perceive technology adoption as an exchange tool but not as a way to upgrade. To reduce the gaps and improve the selection of the most appropriate technologies and services, high quality and standardized audits and assessments for critical areas related to technology adoption and firm capabilities should be developed and included as requirements in applications for technology adoption support. Moreover, Future Industry Platform could play a critical role in raising awareness about the benefits of adopting all types of technologies, going beyond currently covered Industry 4.0 technologies. The currently developed Digital Innovation Hub network should serve as a one-stop shop for information on addressing the wide technological needs of enterprises, while other business support institutions should be able to provide basic services and refer interested companies to appropriate public and private service providers.

The findings of the report indicate the need to support widespread adoption of off-the-shelf general business function technologies, including less advanced technologies, by a broader group of MSMEs. Complementary firm capabilities should be supported, as well as linkages between SMEs and larger companies (including foreign companies). The programs should take into account heterogeneity in the adoption paths of various technologies. The TAS results show that firms still often rely on the most basic technologies to conduct some of their everyday operations, but even simple technology upgrades offer high potential for productivity improvements. Policies supporting technology adoption should include objectives related not only to diffusion of frontier technologies, but should also promote incremental, gradual upgrades. In addition, embracing standardized technology audits to account for the heterogeneity of needs and adoptions paths and an online marketplace with certified off-the-shelf solutions might decrease the search costs and costs of adopting technologies. Results of the TAS confirm the relation evidenced in the literature that successful adoption of technologies is conditional on the complementary investments in, for example, managerial and digital skills and new product development. Thus, introducing nonreturnable components for complementary capabilities to programs offering returnable support for investments in technology acquisition would enhance the creation of capabilities necessary to exploit the full benefits of the new solutions. Moreover, opportunities for scaling up demand, in both domestic and foreign markets, provide incentives for firms to make the technological switch. Stimulating connections between SMEs and larger firms (including foreign firms) can lead to cross-firm learning through standards, requirements, and provision of knowledge from larger to smaller entities.

Since large establishments are on average more technologically sophisticated, there is an empirical call for removing regulatory barriers to firm scale-up and for improving the efficiency of resource allocation, especially in manufacturing. Results from the Technology Adoption Survey, particularly the recent study on drivers of productivity among Polish enterprises, especially in the manufacturing sector, provide additional evidence of barriers in the flow of capital and labor between firms. The results show the existence of weak external incentives for adopting technologies, like anti-competitive regulations or subdued demand. Overall regulatory barriers for competition in Poland are higher than the OECD average, with a high degree of public ownership and excessive administrative burdens on the business.[4] When highly productive or technologically advanced firms encounter larger barriers to increasing their market share, and low-productivity firms remain on the market longer, the need for businesses to upgrade is limited. Liberalization of competition regulation has the potential to drive the pace of technology adoption by providing market incentives for adoption and accumulation. While anti-competitive barriers should be addressed across the economy, the manufacturing sector requires particular attention, as it faces sector-specific challenges that significantly hold back allocative efficiency.

To ensure continuous learning, monitoring and evaluation procedures must be strengthened. To do so, it is necessary to establish functional coordination mechanisms for technology adoption policies and to enhance supplementary capabilities undertaken by various institutions. The M&E system of all support

4. OECD, *2018 Product Market Regulation Country Note — Poland* (Paris: OECD, 2019).

instruments is predominantly driven by the objective to maintain legal compliance with EU regulations. For this reason, it is focused on collecting information on activities and outputs of support instruments, with limited insight into its medium and long-term impact on beneficiaries. Information for M&E must be gathered in a timely and systematic manner, creating actionable information to adapt instruments, which is particularly important in technology areas given the heterogeneity of factors driving technology adoption and the fast pace of technological development. Moreover, given the substantial number of institutions responsible for technology adoption, a functional body is needed for ongoing coordination of various initiatives and analysis of their fit with broader policies for private sector development. This coordination body should be supported by a unit with strong analytical capabilities that can generate knowledge based on the beneficiary's data and rich data available in Statistics Poland.

INTRODUCTION

Securing convergence to its main aspirational peers, improving the living standard of its citizens, and supporting high-quality employment will require Poland to realize substantial productivity improvements. A country's ability to improve its standard of living over time depends almost entirely on its ability to raise productivity (Krugman 1994). The Polish gross domestic product (GDP) per capita tripled after the economic transition to a market economy in the early 1990s, and the country reached high-income status in 2009. Despite this remarkable growth performance, Poland still lags behind many European comparator countries, with an income per capita currently at two-thirds of the EU15 average. Factors delaying it from catching up include weak innovation performance, insufficient technology adoption, and labor force digital skills below the EU average.[5] With investment at an all-time low — as of 2021, the investment rate was the lowest since the 1990s and amounts to less than 17 percent of GDP — and challenges related to the demographic transition, Poland's long-term growth will increasingly depend on productivity advances, likely more so than in other advanced economies.

Digitization and technology adoption[6] can lead not only to significant productivity improvements but can also increase the economy's resilience to external shocks, such as the COVID-19 pandemic. Evidence suggests that digital technology adoption can bring substantial productivity-enhancing and competitiveness-increasing benefits.[7] First, adopting digital technologies can, for example, increase efficiency by automating manual processes and intensify participation in the global market through e-commerce.[8] Second, digitalization can increase economic resilience by strengthening firms' ability to

5. European Commission, *2021 European Innovation Scoreboard* (Luxembourg: European Union, 2021).

6. While the report focuses on technology adoption regardless of the form of the technology, more advanced technologies are almost always associated with digitization.

7. P. Gal, G. Nicoletti, T. Renault, S. Sorbe and C. Timiliotis, *Digitalisation and productivity: In search of the holy grail — Firm-level empirical evidence from EU countries*, OECD Economics Department Working Papers, No. 1533 (Paris: OECD, 2019).

8. M. Draca, S. Raffaella, and John Van Reenen, *Productivity and ICTs: A review of the evidence*, The Oxford handbook of information and communication technologies (2007).

adapt quickly and ensure business continuity with, e.g., digital payments technology. Third, on the firm-level, digitalization can lead to employment growth through the expansion effect[9] and wage premiums even for low-skilled workers.[10] Despite these undeniable benefits, Poland struggles to deliver substantial progress in this area.

The weak digital performance of Poland's enterprises consists of low transactional and informational technology adoption compounded with inadequate digital skills among the labor force. The European Commission uses the Digital Economy and Society Index (DESI) to monitor the digital technology adoption progress of member states in four categories: broadband connectivity, human capital, integration of digital technology, and digital public services. In 2021, Poland ranked 24th of 27 EU member states in DESI, surpassing only Bulgaria, Greece, and Romania. Poland's poorest performance concentrates in two areas: human capital and integration of digital technology. Those categories compare the labor force's basic and advanced digital skills as well as the use of technologies such as electronic information sharing, big data, and the cloud (informational technologies) and the degree of e-commerce use (transactional technologies). While Poland is making progress in those areas, so are other countries in Europe. Hence, Poland's competitive position has not improved, and the country still lags significantly behind most European comparator countries.

The COVID-19 pandemic forced Polish firms to adopt new digital technologies to an extent. The Business Pulse Survey (BPS) is a global tool implemented in 79 countries, including Poland, to quickly assess the impact of COVID-19 on business operations.[11] According to survey results, at the beginning of the pandemic, more than half of the firms in Poland did not use any digital solutions (e.g., allowing for possible remote work, conducting Internet activities, investing in digital solutions, and performing online sales), while a year later more than two-thirds of Polish firms use at least two digital solutions. Yet, those digital solutions were rather basic and did not indicate a strong digitalization wave among Polish firms. Moreover, more than half of surveyed firms declared that the company had not implemented any digital solution that would be useful in

9. G, Dosi and P. Mohnen, *Innovation and employment: an introduction*, Industrial and Corporate Change 28.1 (2019): 45 – 49.

10. P. Aghion, *The innovation premium to soft skills in low-skilled occupations*, available at SSRN 3489777 (2019).

11. The Business Pulse Survey has been carried out in Poland five times since the beginning of the pandemic starting in spring 2020 and going through fall 2021/winter 2022. The results are representative for the population of micro, small, and medium companies across sectors in Poland.

facing the COVID-19 crisis. However, to objectively evaluate whether Polish establishments are genuinely and adequately equipped with digital tools, one needs to access more detailed firm-level data.

Even though Polish firms made significant progress in digitalization during the pandemic, their general attitude toward training and technology adoption continues to indicate the possible need for policy interventions that can facilitate the digital transformation of the economy. According to the BPS, half of Polish enterprises are convinced they do not need further digitalization. Also, over half of the firms did not offer training to their employees, and among them as many as two-thirds think their employees' skills are adequate. BPS findings also point out the slow adoption of good managerial practices. Only half of the surveyed firms use management improvement techniques, such as monthly measurement of sales targets, regular marketing, or awarding promotions based only on performance and ability factors. Only a handful of firms (3 percent) introduced one of these three management practices after the pandemic outbreak. Digitalization without skills upgrading and management practice improvements is more likely to be unsuccessful because the staff will simply not be able to use ICT effectively.[12] Hence, interventions that focus on just financing (with loans or subsidies for capital equipment) and ignore managerial capabilities and skills upgrading will not yield the full benefits of digital technology adoption.[13]

Adequate technology adoption level and sufficient labor force skills should manifest in substantial productivity advances resulting from within-firm efficiency improvements. Productivity can grow through three main channels: (i) efficiency improvements within firms, such as adopting better technology, increasing managerial skills, or innovating (the "within" component); (ii) reallocation of resources to more efficient firms and sectors (the "between" component); and (iii) entrance of high-productivity firms and exit of less successful establishments (the "dynamic" component). One would expect that if Poland's entrepreneurs, as claimed, are investing enough in technology adoption (e.g., digital solutions) and have a sufficiently skilled labor force, coupled with good managerial practices, then aggregate productivity should constantly grow due to the within component. This, however, is not quite the case.

12. OECD, *2018 Product Market Regulation Country Note — Poland* (Paris: OECD, 2019).

13. N. Matteucci, M. O'Mahony, C. Robinson and T. Zwick, *Productivity, workplace performance and ICT: Industry and firm-level evidence for Europe and the US*, Scottish Journal of Political Economy, 52(3), 359 – 386.

Since 2017 the aggregate productivity growth in Poland has been driven by efficiency improvements within firms, but the firms show considerable heterogeneity across different characteristics, such as size and the sector in which they operate. According to the report investigating patterns of productivity growth in Poland in the years 2009 to 2019, starting in 2017, productivity growth accelerated, such that the within component drove most of the productivity improvements.[14] However, it was not evenly distributed across all firms and sectors: some manufacturing, construction, and service sectors even experienced negative productivity change. Besides heterogeneity, one should also note that the within-firm improvements achieved indicate a fairly broad catalog of scenarios and hypotheses that could explain the productivity boost after 2017. Due to methodological limitations, to some degree, the within component embodies the demand-side effects of productivity increases reflecting demand shocks and whatever drives price variation. Also, improvement might simply result from firms' adopting better technology, increasing managerial skills, or innovation. Without looking specifically at what drives firms' efficiency, this within component remains a black box. Luckily, the Technology Adoption Survey (TAS) helps to open it.

The firm-level Technology Adoption Survey (TAS) is an instrument for collecting detailed information from a representative sample of firms about technologies they use, ranking those technologies on the sophistication ladder, and creating a comparable measure of within-firm technology sophistication. The Technology Adoption Survey is designed to collect firm-level information from a country-representative sample of the micro, small, medium, and large firms across agriculture, manufacturing, and service sectors about technologies that each firm uses to perform key business functions necessary to run businesses in its respective sector of economic activity. In addition, it creates a measure of technology sophistication that is comparable across countries, sectors, and firms with different characteristics such as size, ownership status, etc. Moreover, the firm-level approach allows researchers to investigate the multidimensionality of technology adoption and use, including existing heterogeneity, sector differences, the impact of firm performance, and the main barriers and drivers that explain technology adoption and use. Given the international nature of the instrument, the survey's results allow detailed comparison of technology sophistication across countries and identification of regional and world adoption leaders and front-runners.

14. World Bank, *Paths of Productivity Growth in Poland: A Firm-Level Perspective* (Washington, DC: World Bank, 2021).

This report provides detailed knowledge on firm-level technology sophistication in Poland, and, by identifying the main barriers and drivers to adoption, it delivers evidence-based policy recommendations to foster technology adoption across different firms and sectors. The analysis based on the TAS is divided into two parts. The main report first describes the new approach to measuring technology sophistication, the structure of the Technology Adoption Survey, and its implementation in Poland. Second, Chapter 2 provides key insights from the results by linking technology adoption with productivity, managerial skills, and firms' capabilities. It also investigates heterogeneity in technology sophistication across firms with different characteristics and the main drivers and barriers to adoption. The analysis is enriched by providing an in-depth comparison of technology sophistication between Poland and Korea. Chapter 3 briefly explains the heterogeneity of technology sophistication across sectors in Poland. This report concludes with a policy recommendation chapter that is based on the results of the TAS and the assessment of current policies supporting technology adoption (Chapter 4). The second separate report entitled "Sectoral approach to the drivers of productivity growth in Polish sectors. A firm-level perspective on technology adoption and firm capabilities" complements this report and focuses on the sectoral differences in technology adoption. Each sector — agriculture, food processing, wearing apparel, automotive, pharmaceuticals, trade, financial services, and land transport — is analyzed in detail, not only through the lens of the TAS but also from the perspective of the general economic situation in the sector. Moreover, the series includes also a policy note "Do usług? (At your service?) The promise of services-led development in Poland" that describes the role that the service sector can play in spurring productivity growth.

This study is part of the project Technological Readiness and Management Skills — Productivity Growth Drivers in Poland, conducted in collaboration with DG REFORM. The project aims to support the Ministry of Economic Development and Technology in enhancing the effectiveness of firms' support systems in Poland by providing evidence-based information on firms' capabilities, context, and barriers to productivity growth. The project consists of three phases. Phase 1 focused on understanding firm-level productivity dynamics and analyzing instruments supporting managerial skills and technology adoption. It was concluded with the report "Paths of Productivity Growth in Poland — A Firm-Level Perspective." Phase 2 provides evidence-based information on Polish firms' capabilities by implementing and analyzing a Technology Adoption Survey. Phase 3 aims to build capacity and support for the Polish Agency for Enterprise Development to redesign instruments to build firms' capabilities. The following report is the main output of Phase 2, the second in a series investigating productivity growth drivers in Poland.

II

FIRM-LEVEL TECHNOLOGY ADOPTION IN POLAND

Methodology and implementation of the survey in Poland

1 The Technology Adoption Survey (TAS) was designed and implemented by the World Bank to provide detailed information on firm-level technology sophistication, and it draws upon the knowledge of experts in production and technology in various fields and sectors.[15] The survey differentiates between the **general business functions (GBFs)** that all firms conduct, regardless of the sector they operate in: (1) business administration, (2) production planning, (3) sourcing and procurement, (4) marketing, (5) sales, (6) payment methods, and (7) quality control; and the **sector-specific business functions (SBFs)** relevant only for firms in the sectors selected for the survey: (1) crops and livestock (agriculture), (2) food processing, (3) wearing apparel, (4) pharmaceuticals, (5) automotive, (6) wholesale and retail, (7) financial services, (8) land transport, and (9) health services.

2 The survey asks two types of questions about technologies employed: (1) whether the firm adopted a given technology to conduct the tasks of the given business function, and (2) which of these technologies is the most frequently used for a given business function. Hence, the technology sophistication for a given business function is measured on the **extensive margin**, the sophistication of technologies adopted, and on the **intensive margin**, the technology most frequently used. Compared to the intensive margin, the extensive margin does not reflect how much each technology is used but rather the sophistication of all the technologies adopted and used, not just the most relevant one (that is, the most frequently used).

3 The survey was implemented in collaboration with Statistics Poland (GUS) and conducted via phone interviews. It included a nationally representative sample of 1,500 firms with five or more employees across the agriculture, manufacturing, and service sectors. The survey began in August 2021 and ended in December 2021.

15. X. Cirera, D. Comin, M. Cruz, *Bridging the Technological Divide: Technology Adoption by Firms in Developing Countries* (Washington, DC: World Bank, 2022).

Technology Adoption Survey

The Technology Adoption Survey (TAS) is a firm-level survey developed by World Bank in cooperation with academics and external sectoral technology experts and consultants. The survey is composed of five modules. Module A collects information on the general characteristics of the firm, such as location or ownership structure. Modules B and C cover the technologies used by the firm. Module D focuses on barriers and drivers of technology adoption, while module E gathers information about the firm's balance sheet and employment, to compute labor productivity and other finance-related measures. The survey differentiates between general business functions (module B), such as accounting, that all firms conduct regardless of the sector in which they operate or their size; and sector-specific business functions (module C), relevant only for firms in a given sector (for example, parts assembly for the automotive sector). The role of the sectoral experts was hence twofold. First, they identified both the general and sector-specific business functions and relevant technologies used to perform these business functions, and second, they provided a ranking of the technologies in each business function based on the sophistication of the technology. The sophistication of technology can be manifested in the capacity to conduct more tasks or tasks of greater difficulty or to carry out tasks with greater accuracy, precision, or speed. Clearly, technological sophistication is associated with novelty of technology.

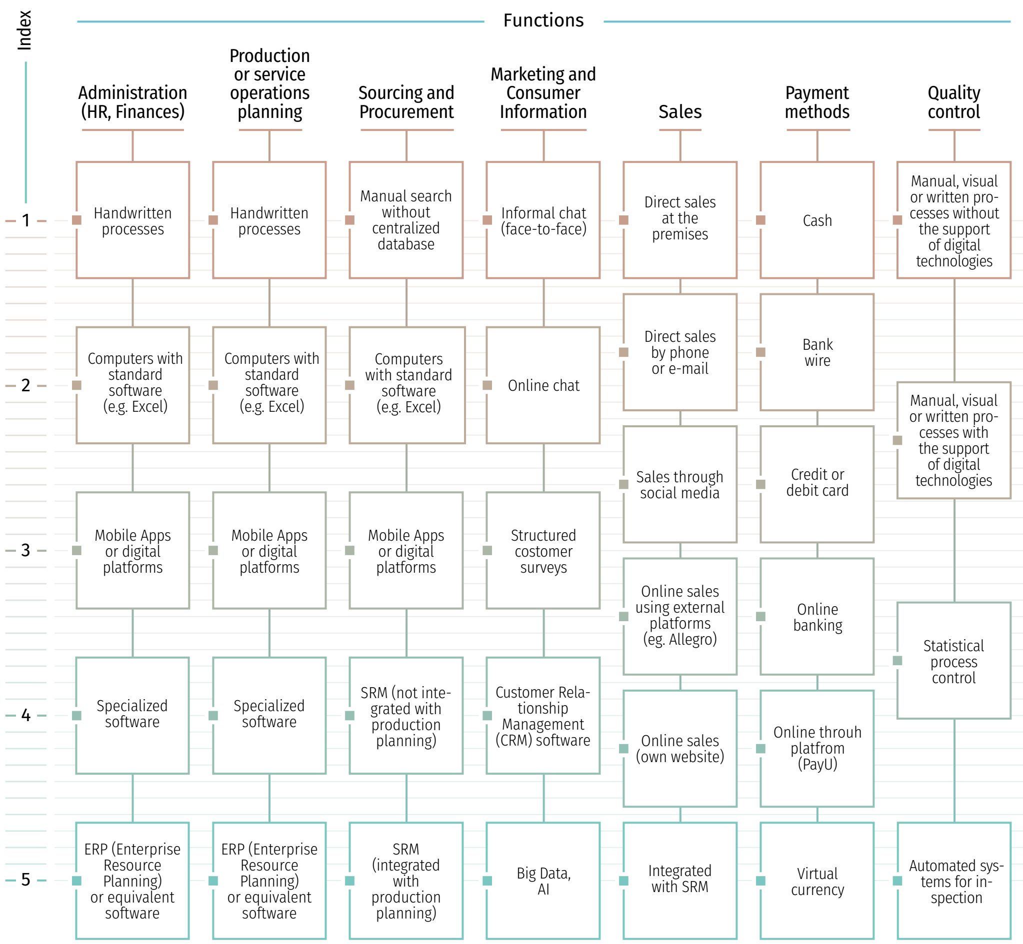
The firms in the survey were asked two types of questions about the technologies they employed: adoption and frequency of use (in module B and module C). First, the survey asked whether, for the given business function, the firm used each of the technologies to conduct the tasks. Second, after determining the technologies that the firm uses in a business function, the survey asked which of these technologies were used most frequently for that function. The first set of questions thus worked as a filter to define options available to the respondent when stating the most frequently used technology. The technology sophistication indices are constructed based on responses to these two types of questions.

General Business Functions

General business functions (GBFs) are tasks carried out by an enterprise to support or perform production or service functions that all firms conduct regardless of the sector and country in which they operate or the firm's characteristics. Hence, they provide a good comparison across firms, sectors, and countries. Figure 2.1 describes the key GBFs covered by the survey and the technologies associated with them: (1) business administration; (2) production planning;

(3) sourcing and procurement; (4) marketing and customer information; (5) sales; (6) methods of payment; and (7) quality control. The technologies associated with most business functions follow a ladder of sophistication that goes from the most basic (e.g., handwritten process for production planning) to the most sophisticated (e.g., Enterprise Resource Planning systems for production planning). It is worth noting that even though technology upgrade (going up the sophistication ladder from 1 to 5) is a continuous process, there is a significant difference between each level of sophistication. For instance, using excel for business administration follows closely the adoption of computers and Internet, but there is a larger gap between adopting specialized software and introducing ERP systems in the firm.

FIGURE 2.1 General Business Functions and Technologies



Source: Adapted from Cirera, Comin, and Cruz (2022).
Note: X. Cirera, D. Comin, M. Cruz, *Bridging the Technological Divide: Technology Adoption by Firms in Developing Countries* (Washington, DC: World Bank, 2022).

Sector-Specific Business Functions

Sector-specific business functions (SBFs) are tasks associated with core production or service provision activity, which vary across sectors. The TAS in Poland has specific sets of questionnaires for ten sectors: (1) agriculture (crops); (2) agriculture (livestock); (3) food processing; (4) wearing apparel; (5) pharmaceuticals; (6) automotive; (7) retail and wholesale; (8) land transportation; (9) financial services, and (10) health services. This report analyzes the first nine sectors. Details on the technologies used in a specific sector are presented in the Appendix, but more comprehensively are described in the complementary report entitled entitled "Sectoral approach to the drivers of productivity growth in Poland. A firm-level perspective on technology adoption and firm capabilities." It should be highlighted that adopting technologies applicable to general business functions is significantly different than for sector specific functions. Low cost digital technologies (e.g. using social media for marketing) are easily available to perform some of the GBFs, while the SBFs usually requires more sophisticated and customized application of digital technologies, usually embedded in expensive machines (e.g. GPS in tractors or equipment controlled by computers for mixing and cooking). For that reason some technologies, especially SBF, are usually only available for larger establishments (see more in Chapter 3).

Technology Sophistication Index

The survey asks for information on more than 300 technologies associated with almost 50 business functions. To analyze the level of adoption of a technology and its use in a systematic and comparable way, the technology sophistication index for each business function was constructed. The index varies between 1 and 5, where 1 stands for the most basic level of technology being used and 5 reflects the most sophisticated level being used. With the help of technology experts for each industry, the technologies in each business function were ranked according to their sophistication. If for a given business function, more or less than five technologies were identified, the numbers were recalculated to fit the 1 to 5 scale (see Figure 2.1). Then, two indices were constructed: (1) the extensive margin, and (2) the intensive margin. The extensive margin identifies if the firm is adopting a technology to perform a given task. This is based on a yes or no question for the adoption of technology to perform a specific task. The intensive margin is based on the technology most frequently used to perform the same task. By construction, the intensive margin index equals or is smaller than the extensive margin index.

The Technology Adoption Survey in Poland

The TAS in Poland was implemented in collaboration with Statistics Poland (GUS) and included a nationally representative sample of 1,500 firms with five or more employees across the agriculture, manufacturing, and service sectors. Thanks to the cooperation with Statistics Poland, for firms reporting to the Annual Enterprise Survey (SP), financial and employment data was prefilled before the interviews, lowering the burden for respondents. The survey was stratified along three dimensions — sector, firm size, and region — to construct a representative measure of technology for aggregates along these dimensions. The sector stratification had eleven strata: agriculture, food processing, wearing apparel, automotive, pharmaceuticals, wholesale and retail trade, financial services, land transport, health services, and others from manufacturing and services. The survey was stratified across seven macro regions and six firm-size groups to account for the European and global firm-size definitions: (i) 5 – 9, (ii) 10 – 19, (iii) 20 – 49, (iv) 50 – 99, (v) 100 – 249, and (vi) 250+ employees. The sample size was aligned with the sample's degree of stratification. Sampling weights were based on the inverse probability of selecting establishments within each stratum. Details on the sample are described in Table A1.1 and Table A1.2 of the Appendix. Survey collection began in August 2021 and ended in December 2021. The average response rate was around 50 percent. Details on the implementation procedure can be found in Cirera, Comin, and Cruz (2022).[16]

BOX 2.1 What did we learn from the Technology Adoption Survey results from other countries

The World Bank's flagship report "Bridging the Technological Divide: Technology Adoption by Firms in Developing Countries" provides an extensive body of knowledge on the cross-country differences in technology sophistication and universal patterns in firm-level technology adoption. Since investigating the technology sophistication in Poland is the primary interest of this report, the document includes the country-level analysis with some elements of country comparisons (see Chapter 2) but most cross-country analyses are excluded from this report. We provide a review of the cross-country findings on the technology adoption:

1. **Advanced economies have many more sophisticated firms than less developed countries** but still most firms are far from the technological frontier. In all surveyed countries (Bangladesh, Brazil, Burkina Faso, Ghana, India, Kenya, Korea, Malawi, Poland, Senegal, and Vietnam) the distribution of the firm-level technological sophistication is rightly skewed. The technological gap across countries is not only driven by the sophistication of average firms, but also by the quantity of those firms.

16. X. Cirera, D. Comin, M. Cruz, *Bridging the Technological Divide: Technology Adoption by Firms in Developing Countries* (Washington, DC: World Bank, 2022).

2. **Technology sophistication varies significantly across business functions and differences across countries are not maintained at the business function level.** For example, there is a large gap in the technologies used more intensively for business administration or planning across countries, and the differences are very narrow for quality control or payment systems, where low adoption is common across countries regardless of income.

3. **Scale and size are important in explaining technology sophistication.** The adoption and use of more sophisticated technologies are positively correlated with the size of the firm. The comparison of the likelihood of using advanced digital technologies—in the frontier of different GBFs—across size groups of firms shows that the gap between small and large firms regarding the adoption of these technologies varies significantly. For example, the gap between small and large firms is much wider for ERP than for e-payment.

4. **The within-country variation in technology sophistication is larger than between countries.** Underlying the significant differences in the average sophistication across countries, regions, sector, and size, lies a large variation of sophistication across firms. There is a significant dispersion of firm-level technology sophistication 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 cross-firm differences in technology sophistication are larger than cross-country differences, regardless of the technology measure—general and sector-specific.

5. **Leapfrogging is rare.** Technology upgrade by firms is mostly a continuous process. Even though there are some frequently used examples of leapfrogging, such as the diffusion of mobile phones in the 2000s across low- and middle-income countries, technology adoption is a gradual process with early adopters (larger firms) likely move significantly faster in the use of more sophisticated technologies than the laggard firms (smaller establishments).

6. **Average technology sophistication is significantly associated with regional productivity. Also, the dispersion in regional technology sophistication is positively associated with regional productivity.** Even though these findings are confirmed across Bangladesh, Brazil, Kenya, India, Korea, Senegal, and Vietnam, the relationship doesn't hold for Poland. One possible reason for that is the fact that in Poland potential rural-urban differences and differences between firms located in big cities or industrial hubs are hidden due to data confidentiality on firm location. The macro regions in Poland were arbitrarily chosen in order to prevent the breach of statistical confidentiality.

What do we know about technology adoption in Poland?

Results discussed in this chapter are based on the Technology Adoption Survey implemented in Poland.

1 Most firms in Poland employ rather unsophisticated methods to run their businesses. An average firm uses manual procedures for quality control and to search for suppliers. Most firms sell their products directly on the premises or via phone or email. The marketing and consumer feedback methods are the most basic: two-thirds of all companies use face-to-face chat only. Administration processes such as accounting or HR are mostly performed with standard or specialized computer software. At the same time, however, some Polish firms are already at

the technological frontier, employing sophisticated methods such as Enterprise Resource Planning (ERP) or Supplier Relation Management (SRM) for day-to-day management. Also, online banking is widespread in Poland, and the majority of firms use it frequently for payments.

2 Improvements in technology adoption are positively associated with improved productivity. Poland has great potential for efficiency improvement that does not require adopting very expensive or highly sophisticated processes; rather, Polish firms can increase their use of technologies at current levels of complexity in all general business functions.

3 The within-firm variance in technology sophistication is significantly larger than the cross-firm variance. This means that firms are usually neither at the frontier nor using basic technologies for everything they do; they tend to use more sophisticated technologies for some activities, and less sophisticated technology for others.

Frequency of use and access to general business function technologies

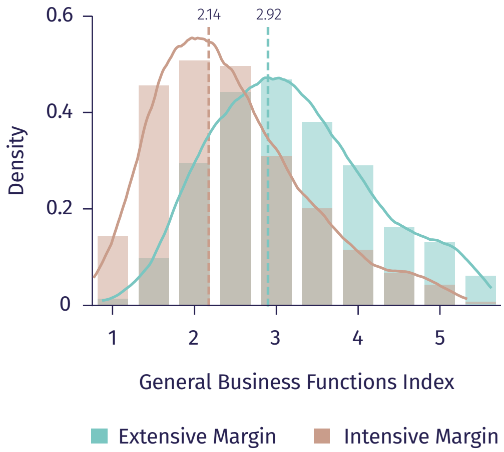
An average firm in Poland most frequently turns to rather basic technologies to perform typical day-to-day business functions. The General Business Function Index for Poland is 2.14 for the intensive margin and 2.92 for the extensive margin (Figure 2.2 and Appendix Figure A1.1 to Figure A1.7). Thus an average Polish firm is most likely to sell its products directly, either on the premises or via phone or email. It employs manual (handwritten) processes for quality control and standard computer software for planning (either production or services) and procurement. Administration processes such as accounting or HR are most likely performed with specialized or standard software, and enterprises benefit from online banking or simply pay with cash. The marketing and consumer feedback methods are the most basic: firms use face-to-face chat rather than sophisticated marketing techniques. The difference between intensive and extensive margin means that even though firms might have access to more advanced processes to run their businesses, they are prone to use less advanced ones or a shift to new technology is underway. However, the technology sophistication varies significantly across business functions, and the gap between intensive and extensive margin also depends on business function (Figure 2.2).

FIGURE 2.2 General Business Functions: Averages for Poland for the Intensive and Extensive Margin

Note: The radar graph plots the average values (population mean) for general business functions for the extensive and intensive margin, weighted with the sample weights.
Source: Original figure based on TAS in Poland.

Most firms rely on unsophisticated methods when running a business, but some firms are already on the technological frontier. Figure 2.3 plots the distribution of the technology index for general business functions across Polish firms. The thick left tail of the intensive margin suggests that most companies rely on rather basic technologies when performing typical business processes. At the same time, however, the long right tail (especially for the extensive margin) indicates that some Polish enterprises have access to state-of-the-art methods. Having the technology index above 3.5 for the intensive margin means that a company relies mainly on specialized software and digital platforms when performing general business functions, which can indicate being rather technologically sophisticated.[17] Also, even though some Polish firms are using more advanced methods on the extensive margin, the intensity of use of these methods remains low.

FIGURE 2.3 Distribution of General Business Functions Index Across Frms



Note: Solid lines represent Kernel densities. Vertical dotted lines show the averages. Values are weighted with sample weights.
Source: Original figure based on TAS in Poland.

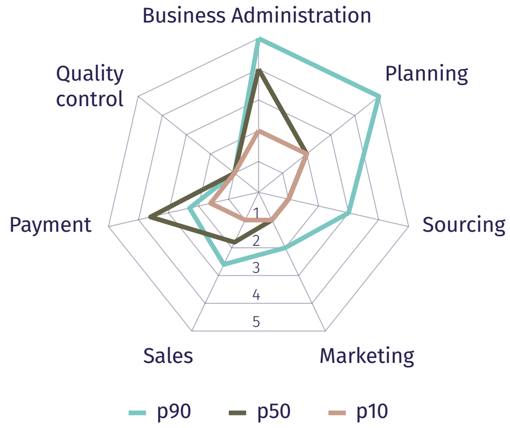
Firms usually do not present a clear-cut example of being either technologically backward or at the frontier in everything they do: they tend to use more advanced methods in some areas, and less advanced methods in others. The variation in technology sophistication within firms in Poland is greater than that between firms across Poland. The gap between general business functions indices of the most sophisticated firms (top 90th percentile) and the least developed ones (bottom 10th percentile) is smaller than the average gap between the levels of technology sophistication across business functions within firms (within-firms variance). Figure 2.4 plots technology sophistication across business functions for three firms: with the general business function index at the intensive margin in the 90th percentile, at the median, and in the 10th percentile. The most advanced firm of those three, with a GBF index on the intensive margin, amounted to 3; it uses the most sophisticated Enterprise Resource Planning (ERP) software, but at the same it doesn't employ any digital solutions for quality control and makes payments at the bank branch. The median firm is more advanced in terms of payments

17. Cirera, Comin, and Cruz (2022) also assumes that 3.5 is a breaking point for being a technologically advanced firm.

(it uses online banking), but it employs the most basic technologies for marketing and quality control, and it searches for suppliers manually without any centralized database. Those are not just alienated cases, as similar variation would be visible for other percentiles and other firms; rather, they exemplify of the large technology variation within firms (Appendix Figure A1.9).

Not only do firms vary widely in terms of technology sophistication, average technology sophistication varies significantly across business functions. In Poland, payment and business administration processes are usually performed using more advanced methods than are used for quality control, marketing, or sales (Figure 2.2 and Figure 2.4).

FIGURE 2.4 General Business Functions: Firm-Level Intensive Margin



Note: The radar graph plots the values of general business functions for the three firms with the GBF intensive index: (1) in the 90th percentile, (2) 50th percentile (median), and (3) 10th percentile.

Source: Original figure based on TAS in Poland.

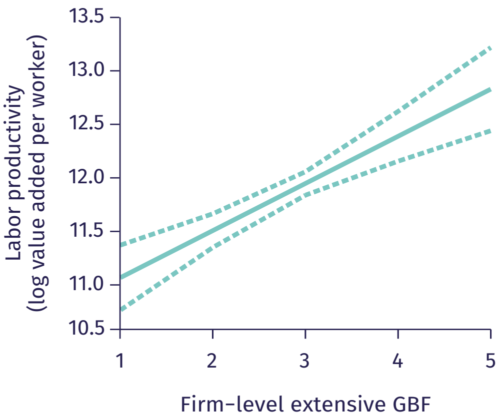
Relationship between technology adoption and productivity

Adopting more advanced technologies seems to pay off as firms employing more advanced methods have higher labor productivity. The positive relationship between labor productivity[18] and the firm-level general business functions index holds both for the extensive (Figure 2.5) and the intensive margin (Figure 2.6). However, the steeper slope in Figure 2.6 indicates that the correlation is greater for the intensive margin. This implies that while introducing more advanced technologies to a firm is associated with higher productivity, making these technologies the most frequently used is accompanied by even higher productivity levels. Of course, the relationship between labor productivity and technology sophistication is only correlational, so it might be an exaggeration to look for causality. What is also important when linking productivity with technical sophistication is to address the frequently voiced concerns that implementing cutting-edge technology will not be efficiency-enhancing. First, even though

18. We use the logarithm of value added per worker as a measure of labor productivity. Due to data limitation, a firm-level value added is defined simply as a difference between firm's total annual sales for all products and services deducted by total annual cost of raw materials and intermediate goods used in production or materials purchased to resell. The number of workers includes the number of all paid employees regardless of the futimell-time equivalent (FTE).

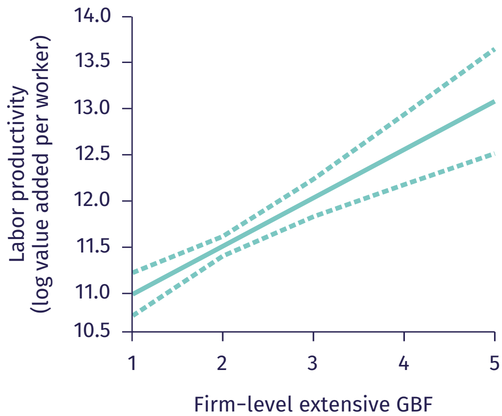
those concerns might be partly legitimate for AI solutions or Big Data Analytics at this stage of those technologies' development, the median firm in Poland uses the most basic technologies, namely manual and handwritten methods (without centralized databases or support of digital solutions) when searching for suppliers and performing quality control. Therefore, Poland is far from falling into the productivity trap. Second, the positive relationship between labor productivity and the firm-level general business functions index is also found in Korea, where the technology sophistication level is higher than in Poland. It might indicate that even in Poland's aspirational peer countries, the positive link still holds and the advanced technologies that might start to be unbeneficial for productivity are very far ahead.

FIGURE 2.5 Productivity and Extensive Technology Sophistication



Note: Graph plots predicted productivity as a function of technology sophistication considering sampling weights and controlling for employment, sector and region.
Source: Original figure based on TAS in Poland.

FIGURE 2.6 Productivity and Intensive Technology Sophistication



Note: Graph plots predicted productivity as a function of technology sophistication considering sampling weights and controlling for employment, sector and region.
Source: Original figure based on TAS in Poland.

Poland still has a high productivity growth potential realizable from within-firm technological upgrading: moving the bottom 25 percent of firms to median technology sophistication would increase labor productivity by an additional 1 percent. Aggregate productivity can grow through three main channels: efficiency improvements within firms, high-productivity firms increasing their market shares, and productive firm entry.[19] Employing the Technology Adoption Survey we can go beyond this framework to investigate

19. World Bank, *Paths of Productivity Growth in Poland: A Firm-Level Perspective* (Washington, DC: World Bank, 2021).

the within-firm channel further and to measure the potential for improvement that still lies within Polish enterprises. If the firms with an intensive GBF index below the 10th percentile (1.38) caught up to the median firm in terms of technology sophistication (intensive GBF index equal to 2.08), average labor productivity would increase by 0.8 percent.[20] If the bottom 25 percent of firms (intensive GBF index below 1.67) caught up to the median firm, average labor productivity would increase by 1 percent. Given that over the last ten years labor productivity grew on average 4 percent every year, such an improvement would be significant.[20] Such an upgrade does not seem unrealistic, as the technologies firms would have to adopt are easily available and still relatively unadvanced. Ceteris paribus, it would require the bottom 25 percent of firms to switch to online banking as the most frequent way of payment and, for instance, execute all administration, procurement, and planning processes using computer support (not necessarily with specialized software). Obviously, this is a hypothetical simulation, but it shows not only the scale of the potential and that substantial productivity improvements are not necessarily extremely costly.

How do different firms adopt new technologies?

1. Firms vary widely in terms of technology adoption, including both across firms with different characteristics and among those with similar ones. General business function technology adoption increasaes with firm size and varies by sector, with the pharmaceutical and vehicle manufacturing sectors using, on average, the most advanced technology. However, in all sectors some firms operate close to the technology frontier while others lag behind on adoption and operate with only basic technologies. Small differences in technology adoption by ownership and gender of top managers disappear when controlling for firm size, sector, and region.

2. Strong empirical evidence shows that the scale of a business matters most for its level of technological sophistication. The chances that small businesses will adopt the most sophisticated technologies, like Enterprise Resource Planning (ERP) or Customer Relationship Management (CRM) systems, are slim, and technology advancements require firms to upscale. It is unnecessary to incentivize companies to adopt technologies they don’t need. Companies are so diverse internally in terms of their level of technological sophistication that each company has certain areas (business functions) it could improve, without forcing itself to the frontier at all costs.

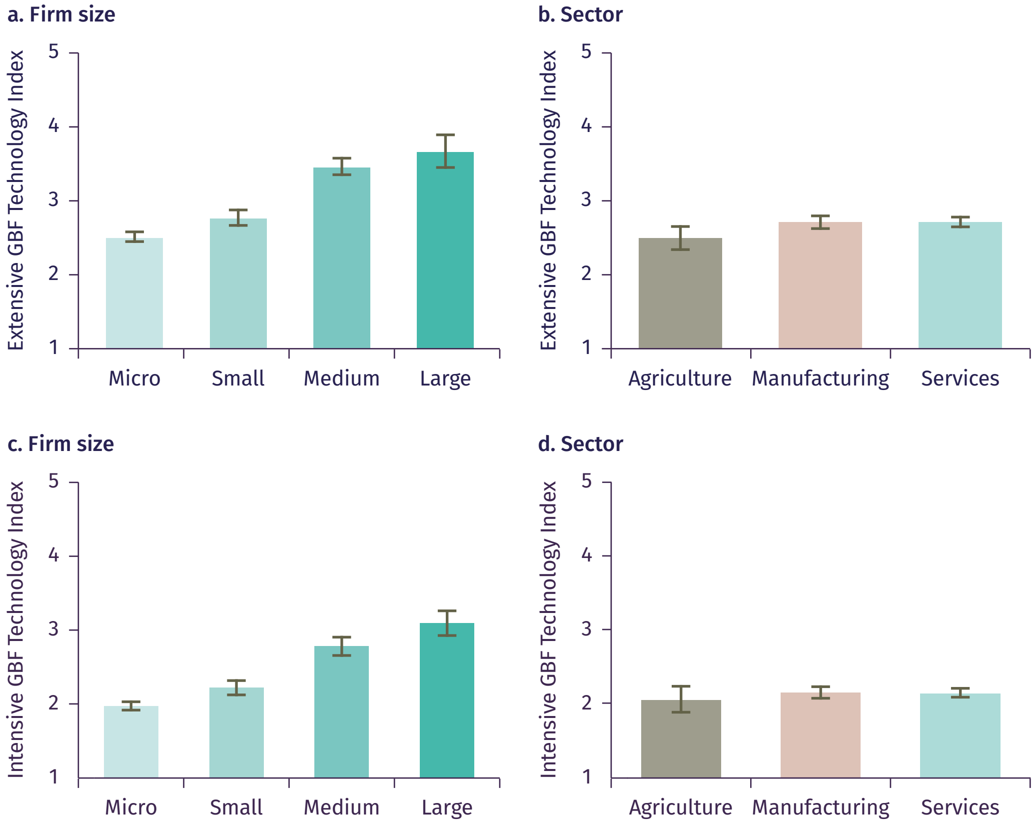
20. Predictions based on the estimated linear model for labor productivity, controlling for sector and region fixed effects.

3 Technology adoption correlates positively with skills, capabilities, and learning. The profitability of a firm does not seem to associate significantly with technology adoption, indicating that the costs firms perceive as the main obstacle to adoption are, in fact, not the main barrier to upgrading. Rather, firms use more advanced technologies if they employ managers with the knowledge and capabilities to introduce more technologically sophisticated processes. Moreover, firms that trade internationally or are foreign-owned are more technologically advanced. This suggests that the skills and capabilities of managers and workers, as well as exposure to the more advanced technologies used by foreign owners or headquarters of multinational companies and import and export partners, may create a learning effect and result in adoption of more advanced technologies. On the other hand, the reverse may also hold true. More advanced technologies might require higher skills from managers and workers, multinational companies may require Polish subsidiaries to adopt more advanced technologies, and import and export partners may require more advanced technologies from their Polish trading partners to establish or facilitate the trade and keep up with the international competition.

Technology adoption across firm sizes

Technology sophistication increases with firm size, but even large firms do not solely operate at the technology frontier. Large firms use more advanced general business function technologies than do smaller establishments, both on the extensive and the intensive margin, as illustrated in Figure 2.7 (controlling for other firm characteristics). This relationship also holds when breaking down the firm size differences by each of the six specific general business functions, as illustrated in Appendix Figure A1.12. Interestingly, the technology adoption gap by firm size is negligible for payment methods and quality control. Regardless of size, most firms in Poland rely on online banking and use the most basic technologies for quality control. Though firm size and technology adoption in general business functions shows a clear positive correlation, the gap between micro and large firms in terms of overall general business function technology adoption is 1.2 index points, which on a scale from 1 to 5 is not very large. (It is, however, bigger than the difference between bottom 10th percentile and the median index.) Even though some large firms use the most advanced technologies intensively, the mean value of the general business functions index for firms employing more than 250 people amounts to 3.85. This means that an average large firm in Poland uses specialized software for most business activities but not state-of-the-art methods like big data analytics or integrated SRMs.

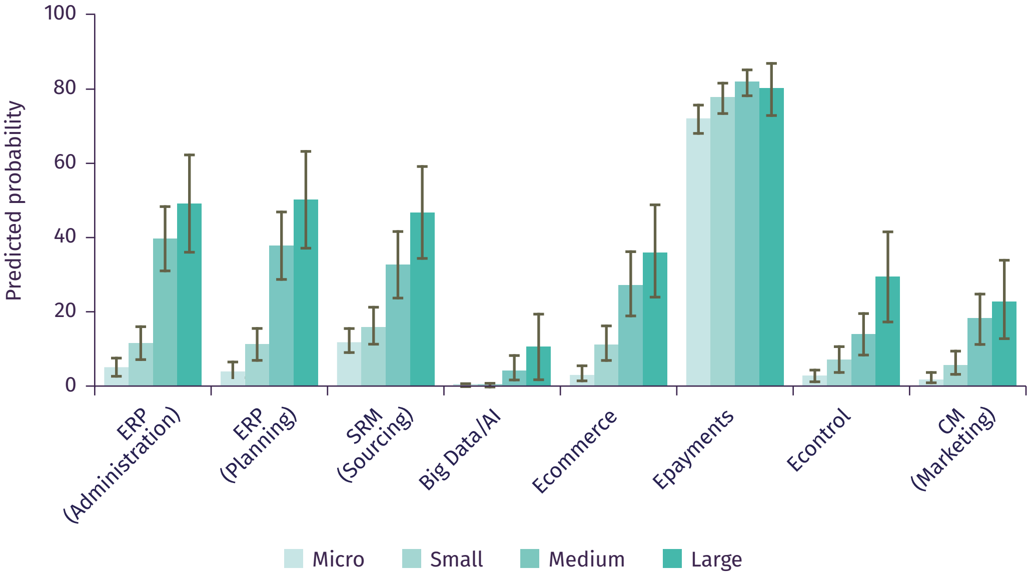
FIGURE 2.7 Heterogeneity in General Business Function Technology Adoption by Firm Size and Aggregate Sector



Note: The figure shows the predicted values of GBFs index by size and sector with confidence intervals from the regressions controlling for region and sector (for GBF index by size. figures on the left) and region and firm size (for GBF index by sector, figures on the right). All estimates are weighted by sampling and weights.
Source: Original figures based on TAS in Poland.

The chances that small businesses will adopt the most sophisticated technologies are slim, and technology advancements will require firms to upscale. Except for payment methods, the larger the firm, the higher the probability it will adopt the most advanced technologies. Figure 2.8 shows the estimated probability of adoption of frontier technologies by firm-size groups. Those frontier technologies are (i) Enterprise Resource Planning (ERP) systems for business administration and production planning, (ii) Supplier Relation Management (SRM) systems for sourcing and procurement, (iii) Customer Relationship Management (CRM) systems for customer information, (iv) Big Data Analytics and AI for marketing and product development, (v) online sales through digital platforms (e-commerce) for sales, (vi) online payments through commercial banks or digital platforms (e-payments) for payments, and (vii) automated systems for quality control (e-control). The likelihood of adopting ERP systems, the most advanced technologies used for business administration and production planning, equals 40 percent and around 60 percent for medium- and large-sized firms, respectively. The likelihood that a company employing fewer than 10 people will adopt ERP technologies is below 10 percent. Big Data Analytics are adopted only by firms employing at least 50 people. While for most technologies the likelihood of adoption varies significantly across firm sizes, e-payments are an exception. These gaps between firms of different sizes can be explained by many factors. First, some technologies are used in large-scale business operations and are unsuited to use on a small scale. Second, advanced technologies require skills and capabilities that might be missing in smaller companies: a large company can employ a dedicated worker to introduce and maintain a new technology. Third, if technologies require customization, the costs may be prohibitive for small-scale businesses. Therefore, it is important to realize that technology advancements will be modest if firms do not upscale, and facilitating a firm's growth is inseparable from encouraging it to adopt more sophisticated technology.

FIGURE 2.8 Probability of Adopting the Most Advanced General Business Function Technology



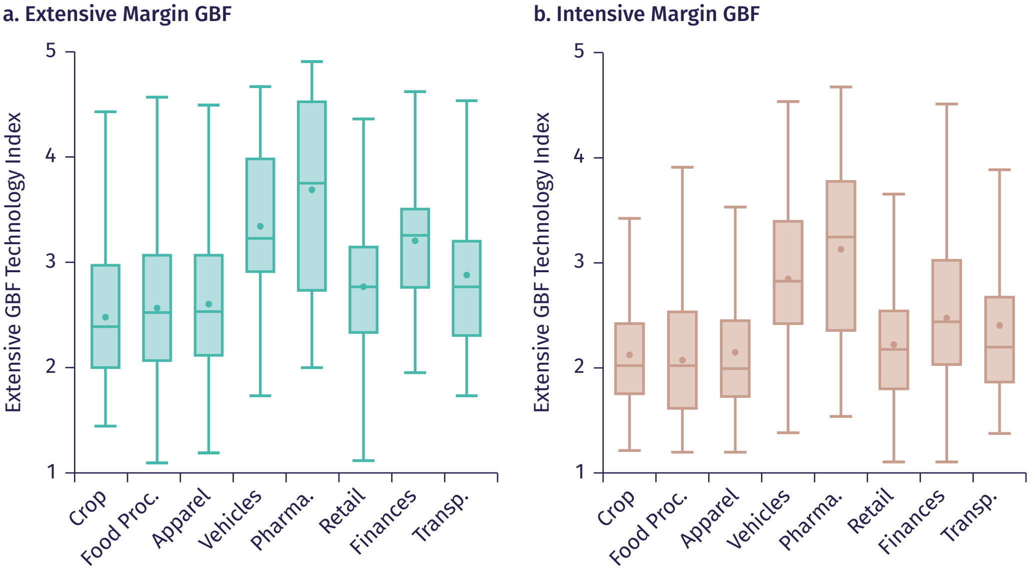
Note: Estimates are based on the probit regressions controlling for size, sector, and region. They show the current distribution and might change in the future with more firms adopting more sophisticated technologies.
Source: Original figures based on TAS in Poland.

Technology adoption across sectors and regions

The technology gaps between agriculture, manufacturing, and services are driven mostly by structural differences between those sectors and not by firm-level technology advancements. The average levels of general business functions indices differ between agriculture, manufacturing, and services, but when controlled by firm characteristics such as the firm size and region those differences become very small. Figure 2.7 shows that the services sector adopts slightly more advanced technologies for general business functions than do the manufacturing and agricultural sectors, but the differences by sector are negligible and of a much lower magnitude than those by firm size. It seems that firm size is the main driver of technological sophistication, but using a more detailed sector classification shows a large degree of heterogeneity in technology sophistication of general business functions within sectors as well.

The pharmaceutical companies in Poland (closely followed by automotive firms) use on average the most advanced general business function technologies. At the same time, pharmaceutical firms have adopted and used a wider range of GBF technologies than firms in other sectors, but again, those results stem from the differences in the structure of the automotive and pharmaceuticals sector. In the pharmaceuticals and automotive sectors, the intensive general business functions index is significantly larger compared to other sectors. Also, the gaps between the most and the least sophisticated firms in those sectors are the largest, as the within sector variance (the measure of dispersion) for the extensive and intensive margin GBFs indices is almost twice as large as in other sectors. This can be easily seen by the greater length of boxplots in Figure 2.9 (a) and (b). The large whiskers in the boxplot (Figure 2.9) illustrate the wide distribution of general business function technology adoption. The lowest levels of the technology sophistication measured by the extensive GBF index differ by sector: the pharmaceutical sector index starts at 2, significantly higher than the retail sector, where firms often use the most basic technologies like manual processes (index close to 1). Considering the GBF index on the intensive margin, only some firms in the pharmaceutical and vehicle manufacturing sectors most frequently use the most advanced general business technologies (index above 4.5), whereas firms in other sectors use less sophisticated technologies on a regular basis (index at most close to 4). Chapter 3 will address briefly sectoral differences in technology adoption but the analysis in greater detail, as many differences between sectors stem from the structural or sectoral characteristics (participation in the global value chains or ownership structure), is described in the complementary report "Sectoral approach to the drivers of productivity growth in Poland. A firm-level perspective on technology adoption and firm capabilities." For example, more than 30 percent of establishments in the automotive and pharmaceuticals industries employ more than 100 workers, whereas the country average amounts to only 3 percent, see Appendix Table A13. When controlling for different firms characteristics, there are no significant differences in general business functions technology sophistication across sectors.

FIGURE 2.9 General Business Function Technology Adoption by Detailed Sector



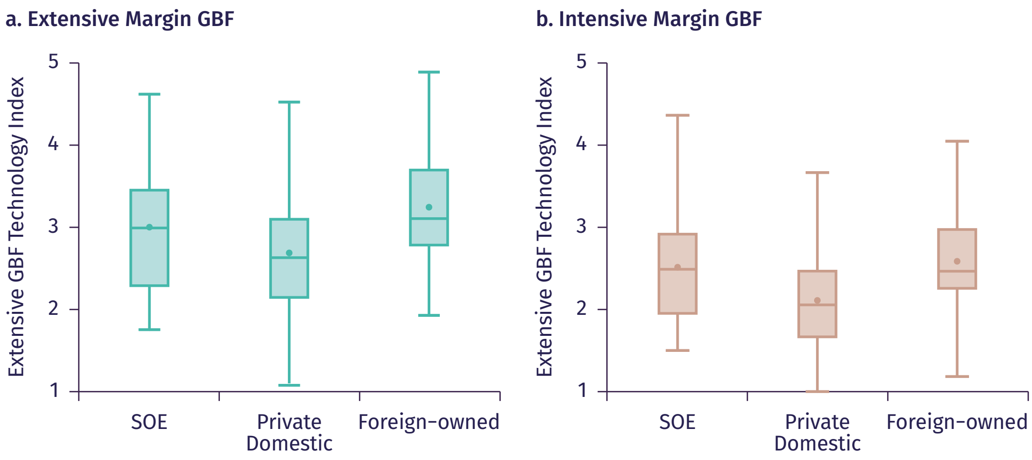
Note: Box plot shows median (horizontal line), average (dot), 25th percentile (lower hinge), 75th percentile (upper hinge), and both lowest and highest values of GBF indices across sectors.
Source: Original figures based on TAS in Poland.

No significant differences in the sophistication of general business function technology emerge by region, but data confidentiality on firm location may hide some differences. Based on the current classification of Poland into seven areas, firms do not display significant differences in technology adoption for general business functions by region. Potential rural-urban differences and differences between firms located in big cities or industrial hubs, such as Warsaw and Gdansk/Gdynia area, and those located elsewhere might emerge. Workers may face varying exposure to technology depending on location, and it may be worthwhile to look further into these effects to exclude potential regional differences not yet captured due to data restrictions.

Technology adoption and ownership

Foreign-owned enterprises, followed by state-owned firms, have adopted more advanced technologies than have private domestic firms, but the differences are not very large, and the results are partly driven by firm size. Figure 2.10a shows that foreign-owned enterprises, on average, have access to more advanced technologies than private domestic or state-owned firms. When considering the average level of GBF index on the intensive margin, though slightly higher for SOEs, hardly differs across ownership structures. However, among the private domestic and foreign-owned firms are some outliers with very low and very high general business function technology adoption, respectively (see longer whiskers in the boxplots of Figure 2.10b for the latter two ownership types). Moreover, in terms of technology adoption, family-owned firms do not differ from others. For the extensive or the intensive general business function technology index, it does not matter, on average, whether a firm is owned by the founder or by a second or later generation family member or is not family-owned at all (see Figure A1.13 in the Appendix). Controlling for firm size, region, and sector, Figure A1.15 in the Appendix shows that differences in technology adoption across ownership firms decrease, as state-owned enterprises tend to be larger on average and firm size greatly determines the technology sophistication.

FIGURE 2.10 General Business Function Technology Adoption by Ownership

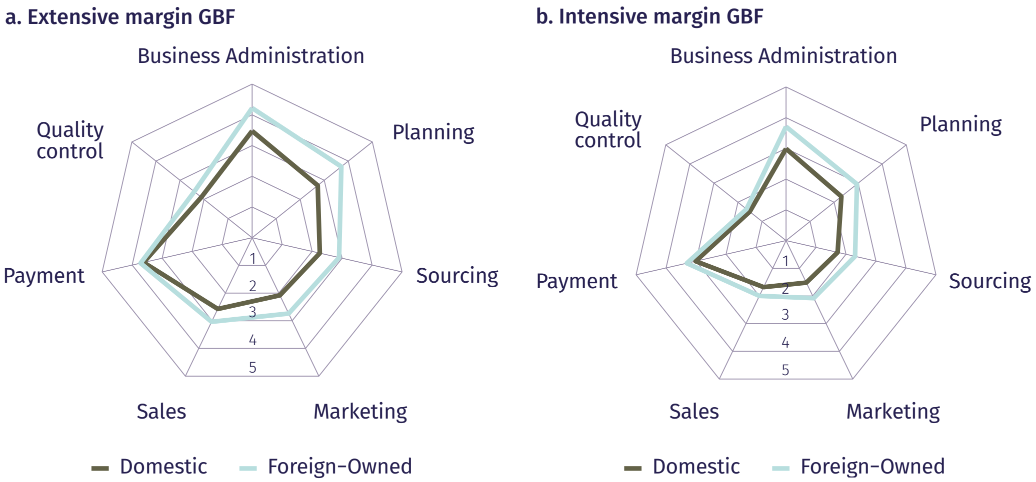


Note: Box plot shows median (horizontal line), average (dot), 25th percentile (lower hinge), 75th percentile (upper hinge), and both lowest and highest values of GBF indices by ownership. Private domestic also includes mixed ownership firms with major domestic stakeholders. Foreign-owned firms also include mixed ownership firms with major foreign stakeholders.

Source: Original figures based on TAS in Poland.

Technology adoption in payment methods and quality control is similar across ownership types, but foreign firms tend to use more advanced technologies in business administration, planning, and marketing. A breakdown of technology adoption by general business functions and ownership shows that technology adoption is very similar with regard to payment methods and quality control. However, foreign firms tend to use more advanced technologies for business administration processes, planning, and marketing than domestic firms (private and state-owned; see Figure 2.11). A general business function technology adoption index of 3 to 4 for production planning for a foreign-owned firm compared to an index value of 2 to 3 for domestic firms means that foreign firms use mobile apps and have access to special software, whereas domestic firms generally use standard software but have access to mobile apps.

FIGURE 2.11 **Detailed General Business Function Technology Adoption by Ownership**



Note: Private domestic also includes mixed ownership firms, which are majority domestic owned. Foreign-owned firms also includes majority foreign firms.
Source: Original figures based on TAS in Poland.

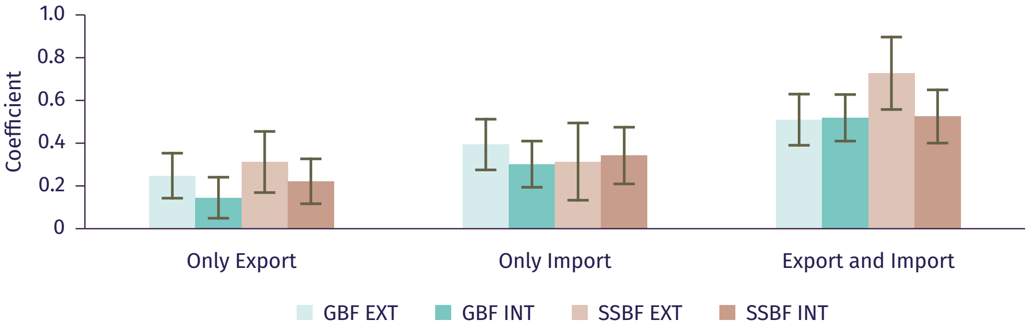
Foreign ownership is positively associated with significantly higher general business function technology adoption but does not matter for sector-specific business function technology levels. This result is not driven by firm size or the fact that the firm imports, exports, or both. Literature is not conclusive on the effect of FDI on the firm-level economic performance in hosting country. Foreign subsidiaries usually perform better than the average of the hosting economies, but sometimes the selection effect is found to be considerable.[21] One of the explanation might be that foreign-owned firms operating in Poland may learn from their owner about more advanced technologies or are made to adopt more advanced technologies upon acquisition by the foreign owner because some general business functions are centrally managed by the multinational company's headquarters or the firm sees value in using compatible general business function technologies in subsidiaries in different countries. Multinational companies may want to give customers around the world the same customer experience, so they require that sales, payment, and quality control be conducted using the same level of technological sophistication. At the same time, each subsidiary of a multinational company, and so also subsidiaries in Poland, may produce a unique product or even operate in a different sector, so headquarters may make less demand regarding sector-specific business function technology levels and firms have less to learn from other firms in the group. Whether a firm is state-owned or family-owned does not seem to matter for adoption of sector-specific technologies.

Technology adoption and trade

Trading across the border is associated with the use of more advanced technologies. Firms that export and import use more advanced technologies than those that just do one or the other, as Figure 2.12 shows. On the one hand, this may be because more advanced technologies facilitate opportunities to trade. On the other hand, exporting and importing firms may learn about the benefits of more advanced technologies through interactions with their trading partners and must keep up with their competition, thus requiring certain technology levels to be able to sell abroad. Exporting and importing thus appear complementary, as firms that do both almost double the likelihood of also having more advanced technology, regardless of general business function or sector-specific technologies.

21. For Poland: J. Hagemejer and J. Tyrowicz, *Is the effect really so large? Firm-level evidence on the role of FDI in a transition economy*, Economics of Transition 20.2 (2012): 195 – 233.

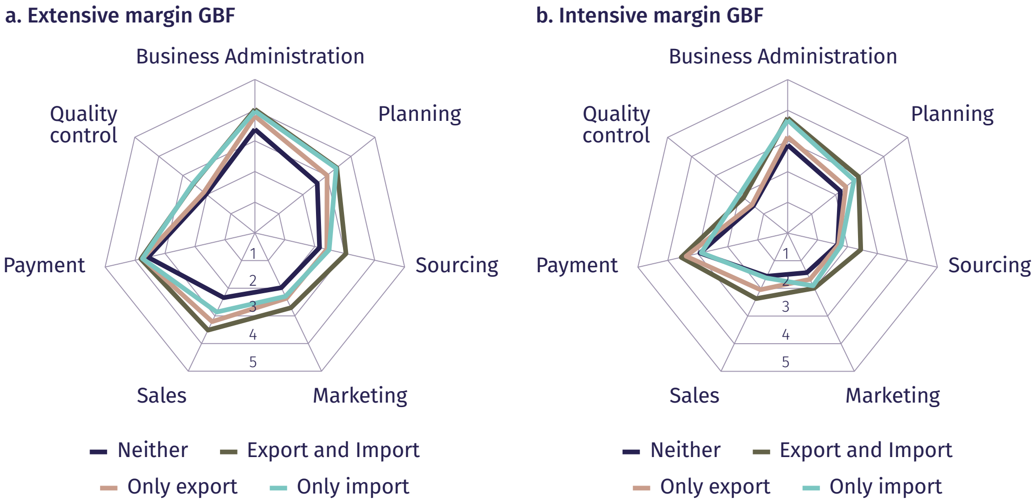
FIGURE 2.12 Technology Adoption and Trade



Note: Regression includes controls for firm age, firm size, and detailed sector, weighted by sampling weights.
Source: Original figure based on TAS in Poland.

Firms that participate in international trade use more advanced technologies than do other firms, particularly for sourcing and sales, but the differences are small. First, firms that either only export or only import use more advanced technologies than those that do neither. Second, import-only firms tend to use more sophisticated technologies than export-only firms, except for sales and payment methods, as Figure 2.13 shows. This result holds when controlling for firm size, sector, and firm age. More advanced technologies may be more important for exporting firms needing to attract customers and facilitate the export process and may also be demanded by customers.

FIGURE 2.13 Detailed General Business Function Technology Adoption by Export/Import Status

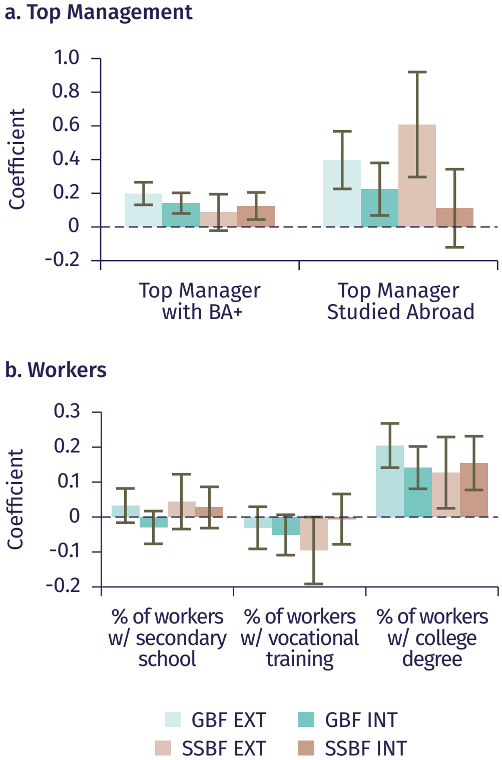


Source: Original figures based on TAS in Poland.

Technology adoption, capabilities, managerial practices, and managers' characteristics

Capabilities are crucial for technology adoption: workers' skills matter, but the capabilities of the management are even more important. Figure 2.14 shows that the share of employees with secondary school education is more important than the share of workers with vocational training, but the share of workers with at least a college degree is what really matters. Having a manager with at least a bachelor's degree is associated with significantly more advanced technology adoption, and the correlation is even stronger if the manager studied abroad for at least one month, which is likely correlated with qualities that increase chances for technology adoption.[22] The high standard deviation of the most commonly used sector-specific technology for top managers who study abroad (see the high confidence intervals on Figure 2.14), which may even turn the coefficient negative, may in comparison to the other findings suggest that top managers more likely study abroad in fields of general business functions, and therefore are more likely to push for more sophisticated technologies in those fields. At the same time, they are likely not sector-specific specialists with capacity to push for upgrading established, most commonly used, sector-specific technology.

FIGURE 2.14 Capabilities and Technology Adoption



Note: Panel (a) and (b) provide the coefficients and 95% confidence intervals from regressions. Each technology measure is regressed on a dummy for top managers' education (e.g., post-graduation and study abroad) and the percent of workers with different education levels (e.g., secondary school, vocational training, and college degree), respectively, while controlling for sector, size, and regions. All estimates are weighted by sampling weights.

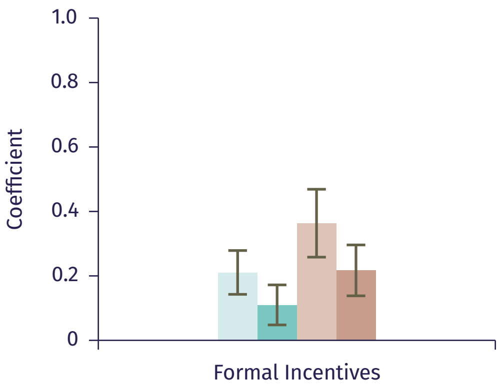
Source: Original figures based on TAS in Poland.

22. A manager who studied just one or a few months abroad may not necessarily learn about a new technology or the advantages of adopting new technology. However, we use this as a proxy for being more open-minded, daring to go out of the comfort zone, and knowing at least one foreign language. We expect that those who have gone to study abroad will be also more willing to go to conferences or trade fairs in the future, where they get more exposure to technology.

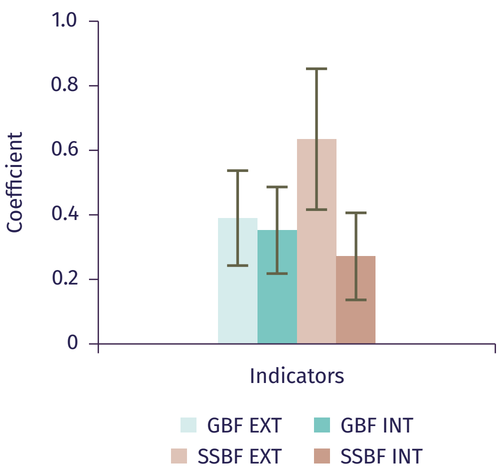
Technology adoption in general business functions rises with education, but not with vocational training. The share of workers with a college degree is what really matters for technology adoption. Having a larger share of workers with vocational training in a firm may be counterproductive, in particular when upgrading the most commonly used, sector-specific business function technology, as such workers tend to have left school at an earlier age and learned their skills on the job with a particular technology and thus have been less exposed to other, more advanced technologies. Hence, workers with vocational training may be reluctant to adopt new technologies, as they have trained on using a less advanced technology. Whether the top manager studied during the Soviet or post-Soviet era is thus irrelevant when controlling for other firm characteristics. At the same time, it may not be that a higher share of workers with college degrees raises the level of technology adopted by a firm, but that more sophisticated technology used by a firm requires that a larger share of workers has a college degree. Hence, there are two possible channels of causation.

FIGURE 2.15 Managerial Quality and Technology Adoption

a. Formal incentives



b. Performance monitoring



Note: Panel (a) and (b) provide the coefficients and 95% confidence intervals from regressions. Each technology measure is regressed on a dummy for providing formal incentives and performance indicators, respectively, while controlling for sector, size, and regions. All estimates are weighted by sampling and country weights.

Source: Original figures based on TAS in Poland.

Better management practices are positively associated with more advanced technologies. Management practices, proxied by the use of incentives and performance monitoring, increases technology adoption (Figure 2.15). Unlike with the level of education, formal incentives and performance monitoring seem to be particularly positively associated with use of a more sophisticated level of the most advanced sector-specific technology, as shown in both Figure 2.15a and 2.15b. Managerial practices matter because adoption of new technologies requires changing existing processes within a firm, which is more difficult than running a firm in a business-as-usual manner. Capturing gender differences in the context of technology adoption and managerial capabilities is difficult. The strong gender-based selection — due to discrimination or self-selection — into industries and occupations results in only 20 percent of top managerial positions being held by females. This differs significantly across sectors; for example, 95 percent of top managers in the automotive industry are males. However, it seems that gender perspective is not particularly important for technology adoption.

TABLE 2.1 Technology Adoption and Ownership

Dependent Variable	(1) GBF EXT	(2) GBF INT	(3) SSBF EXT	(4) SSBF INT
Female Top Manager	-0.022	-0.082*	-0.043	-0.117**
	(0.049)	(0.044)	(0.067)	(0.049)
State-Owned	0.514	0.220	0.197	0.379
	(0.913)	(0.829)	(1.257)	(0.918)
Foreign-Owned	0.358***	0.357***	-0.029	0.093
	(0.090)	(0.082)	(0.125)	(0.091)
Family Owned	0.037	-0.057	-0.108	0.047
	(0.086)	(0.078)	(0.118)	(0.086)
Constant	2.238***	1.777***	3.145***	2.466***
	(0.181)	(0.164)	(0.249)	(0.182)
Observations	1,053	1,053	1,053	1,053
R-squared	0.176	0.181	0.153	0.211
CONTROLS				
Sector	YES	YES	YES	YES
Size	YES	YES	YES	YES
Firm age	YES	YES	YES	YES

Standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1
Source: Original results based on TAS in Poland.

Technology adoption and jobs

Popular fears that new technologies will destroy jobs do not seem justified, since using more advanced technologies is positively and significantly associated with employment growth. Table 2.2 shows the association between employment changes in firms in the last two years (between 2018 and 2020) and the levels of technology sophistication. Those results suggest that more advanced firms also grow more, with a significant positive relationship between changes in employment and technology sophistication across different measures of levels of technology adoption. The results are also robust since the relationship still holds after controlling for the initial size of the firm, age, region, sector, ownership, and exporting status.[23] The links are correlational in nature but it's likely that firms using more sophisticated technologies are more productive and hence benefit more from upscaling. In addition, the results are more robust for the general business functions index than for the sector-specific one. It suggests that technologies more linked to management are more closely associated with employment growth and firm upscaling that technologies specific to production processes. An empirical consensus has formed that adopting more advanced technologies might be associated with a skill-biased employment growth since it causes dissapering of medium-skill jobs but at the same time might contribute to improving the quality of jobs.[24]

The adoption of more sophisticated general business function technologies seems to generate more high-skilled jobs in Poland. The change in high-skill intensity is measured as a difference in the percentages of high-skilled jobs (CEOs, managers, engineers, etc.) to total workers between 2018 and 2020. Table 2.3 shows the significant negative relationship between changes in high-skilled employment and technology sophistication across different measures of levels of technology adoption. Those results are robust for the general business functions index since the relationship still holds after controlling for firm characteristics and profitability. However, the coefficients are very small, and the model can only explain between 3 percent and 11 percent of the variation in high-skilled employment. Making strong statements based on these results would thus not be justified.

23. For sector-specific business functions these are only significant at the extensive margin.

24. D. Acemoglu and P. Restrepo, *Robots and jobs: Evidence from US labor markets*, Journal of Political Economy 128.6 (2020): 2188 – 2244.

TABLE 2.2 Technology Adoption and Changes in Employment (2018–2020)

Dependent Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Change in Employment between 2018 and 2020							
GBF EXT	0.08***	0.083***	0.097***	0.047***	0.062**			
	(0.026)	(0.024)	(0.029)	(0.018)	(0.024)			
SSBF EXT						0.039**		
GBF INT							0.028*	
							(0.017)	
SSBF INT								0.014
						(0.018)		(0.018)
Ln (Employment 2018)	-0.076***	-0.077***	-0.068***	-0.057***	-0.041***	-0.035**	-0.052***	-0.031**
	(0.019)	(0.018)	(0.017)	(0.016)	(0.015)	(0.014)	(0.015)	(0.014)
Profitability			0.000	0.000	0.000	0.000	0.000	0.000
			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Ln (value added per worker)				-0.004	0.006	-0.004	-0.002	0.003
				(0.011)	(0.016)	(0.012)	(0.011)	(0.013)
% of workers with at most bachelor's degree					0.001			
					(0.001)			
Constant	-0.012	0.065	-0.004	0.039	-0.277	-0.077	0.064	-0.070
	(0.050)	(0.070)	(0.076)	(0.172)	(0.192)	(0.160)	(0.173)	(0.167)
Observations	1,448	1,424	1,177	904	535	757	904	751
R-squared	0.082	0.140	0.150	0.093	0.141	0.084	0.081	0.061
CONTROLS								
Sector	NO	YES	YES	YES	YES	YES	YES	YES
Firm age	NO	YES	YES	YES	YES	YES	YES	YES
Export	NO	YES	YES	YES	YES	YES	YES	YES
Foreign firm	NO	YES	YES	YES	YES	YES	YES	YES
Region	NO	YES	YES	YES	YES	YES	YES	YES

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: Original results based on TAS in Poland.

TABLE 2.3 High-skilled Employment and Technology Adoption

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable	**Change in high-skilled employment (difference is high-skilled intensity between 2018 and 2020)**					
GBF INT	-0.009*	-0.010**	0.054***	0.028*		
	(0.005)	(0.005)	(0.019)	(0.017)		
SBF INT					0.017	0.014
					(0.018)	(0.018)
		(0.013)	(0.055)	(0.073)	(0.055)	(0.071)
		(0.010)	(0.047)	(0.045)	(0.046)	(0.044)
Ln (Employment 2018)	0.013***	0.014***	-0.060***	-0.052***	-0.029**	-0.031**
	(0.004)	(0.004)	(0.016)	(0.015)	(0.013)	(0.014)
Profitability			0.000	0.000	0.000	0.000
			(0.000)	(0.000)	(0.000)	(0.000)
Ln (value-added per worker)				-0.002		0.003
				(0.011)		(0.013)
Constant	-0.015*	-0.030*	0.104	0.064	0.030	-0.070
	(0.008)	(0.017)	(0.077)	(0.173)	(0.085)	(0.167)
Observations	1,448	1,424	1,177	904	983	751
R-squared	0.033	0.094	0.105	0.081	0.066	0.061
CONTROLS						
Sector	NO	YES	YES	YES	YES	YES
Firm age	NO	YES	YES	YES	YES	YES
Export	NO	YES	YES	YES	YES	YES
Foreign	NO	YES	YES	YES	YES	YES
Region	NO	YES	YES	YES	YES	YES

Robust standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1
Note: High-skilled employment is defined as workers that take up managerial, professional, or technical positions in firms.

Source: Original results based on TAS in Poland.

Exploring country-comparability: Poland and Korea

1 The Technology Adoption Survey allows comparing technology sophistication across countries, and the Republic of Korea is set to be a benchmark country for Poland. Among the ten countries where the TAS has been implemented so far, Korea is the only one comparable to Poland. Although geographically very distant, Korea is a good comparator for several reasons. First, both countries are ofen called growth miracles, and they follow very similar paths in their productivity growth. Second, Poland and Korea face similar challenges regarding an aging population, with dramatic increases anticipated in the old-age dependency ratio. Last, Korea is perceived as a global leader in innovation and technology, and Korean companies have been among key foreign investors bringing advanced technologies to Poland.

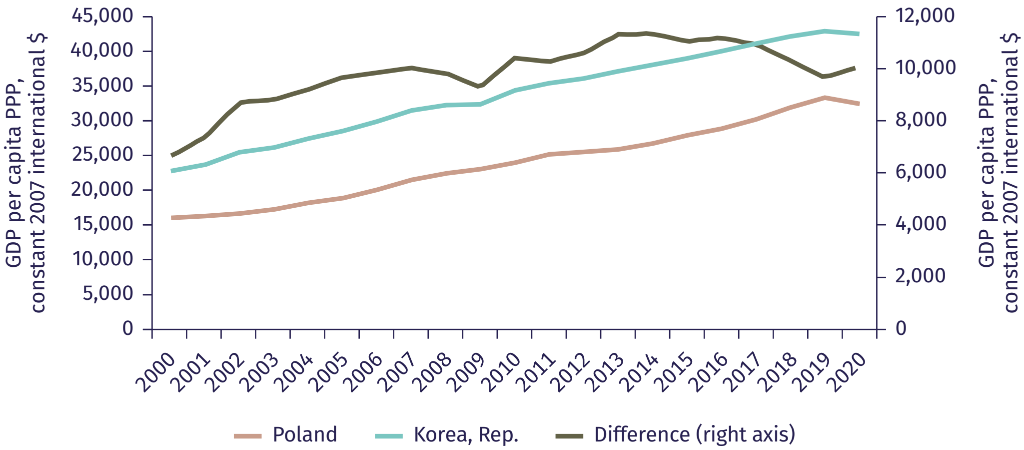
2 An average Polish firm is less technologically advanced than an average Korean firm. However, given the Korean level of economic development (GDP per capita) and its position as one of the world's leaders in innovation, the gap in technological sophistication between Poland and Korea seems small.

3 The relatively small difference in average technology sophistication between Poland and Korea results from the differences in firm sizes between countries and the service-oriented structure of the Polish economy. Not only are there relatively more large firms in Poland than in Korea, but there are hardly any differences between the level of sophistication of large firms in the two countries. In addition, it seems that, compared to Korea, fewer Polish firms use more sophisticated technology most frequently to run their businesses, but more Polish firms have access to more advanced technologies than do Korean firms. Since in Poland and Korea there is considerable heterogeneity in technology adoption across sectors, firm sizes, and ownership statuses, comparing technology sophistication between the two countries requires investigating not only firm-level advancements but also the structure of their economies.

Two growth tigers: Similarities and differences

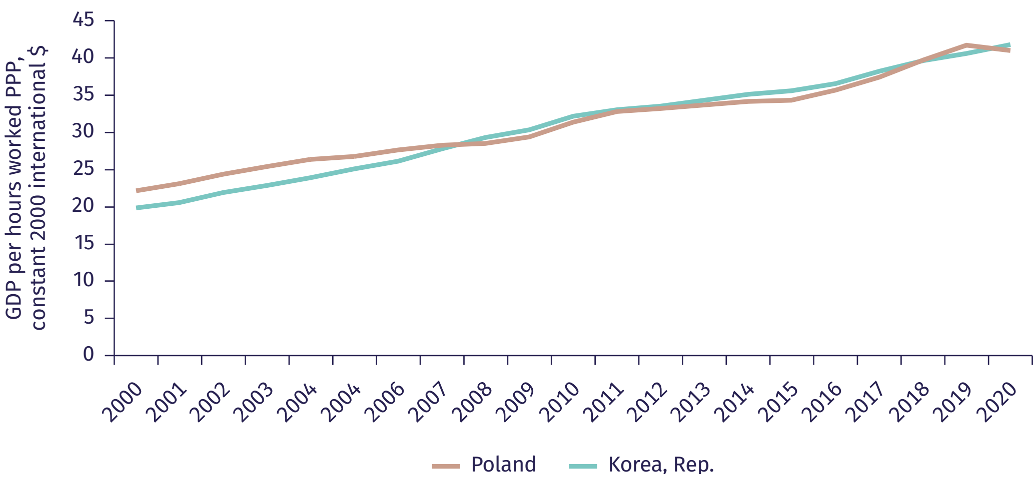
Although geographically very distant, the Republic of Korea is a good comparator for Poland in terms of technological sophistication. Both Korea and Poland are frequently called growth miracles, being among the fastest-growing economies in the world in recent decades, reaching high-income status in 1995 and 2009, respectively. Poland's GDP per capita in PPP in 2020 almost doubled since 2000, and the pace of GDP growth was even faster than for Korea: 98 percent growth in Poland, compared to 84 percent in Korea (Figure 2.16). Despite Poland's remarkable growth performance and the narrowing GDP per capita gap between the two countries, Poland's GDP per capita PPP in 2020 was still equivalent to only 76 percent of Korea's, making Korea an aspiration country for Poland. Surprisingly, when it comes to labor productivity (defined by GDP per hour worked), Poland and Korea follow very similar paths in terms not only of the pace of growth but also of levels (Figure 2.17). Given the very similar levels of productivity in both countries, it would be interesting to look beyond these aggregate values and investigate what they stand for and what they mean. This is possible with results from the detailed firm-level Technology Adoption Survey.

FIGURE 2.16 **GDP Per Capita, 2000–2020**



Source: World Development Indicators.

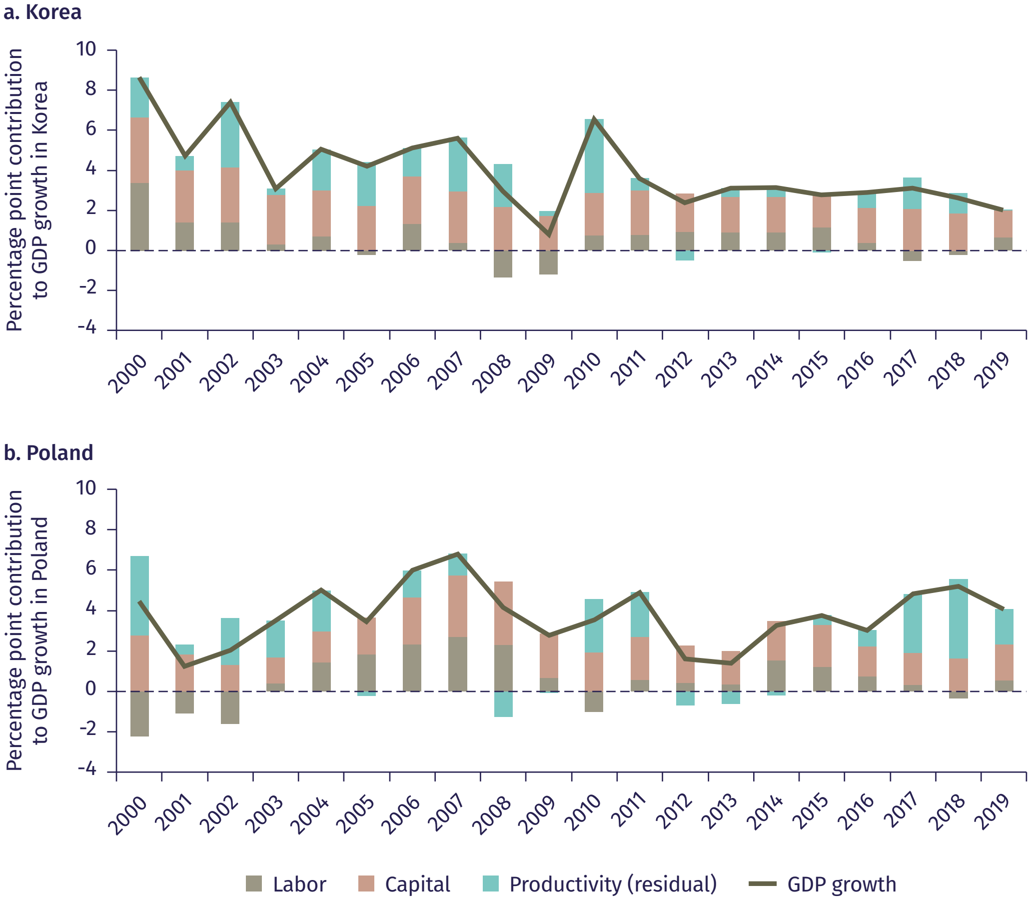
FIGURE 2.17 **GDP Per Hour Worked, 2000–2020**



Source: OECD (2022).

Regardless of outstanding growth performance, due to their aging populations, both Korea and Poland will soon face significant challenges keeping up their pace of development, but these challenges may be counteracted with investments in productivity. The growth of Poland's economy since 2000 was driven mainly by capital accumulation (52 percent contribution to GDP growth) and by improving production efficiency (33 percent), with the remaining 15 percent associated with an increase in the size of the labor force (Figure 2.18). The growth of the Korean economy at the same time was also driven majorly by capital accumulation (54 percent), followed by improving production efficiency (31 percent) and an increase in the size of the labor force (15 percent).

FIGURE 2.18 Contributions to GDP Growth (2000–2019)

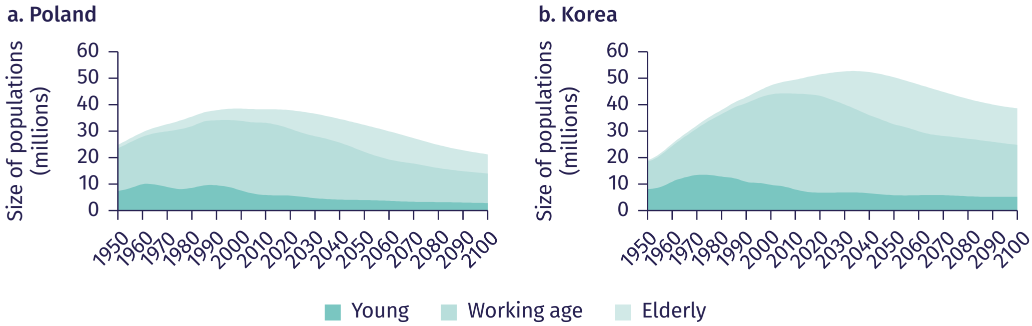


Note: The presented values are a rough estimation of actual GDP growth constituent parts. Contributions to GDP growth are calculated by weighting the growth of the input by their respective share in income, the labor income share for labor inputs, and (1—labor income share) for capital inputs. The productivity is a residual of GDP growth minus the input contributions (labor and capital) and not the production function estimation result.

Source: Elaboration based on the Conference Board Total Economy Database (Conference Board 2021).

According to projections, both countries will face a significant demographic challenge: in 2050, for every 100 people of working age (15 – 64 years), Poland will have 56 people aged over 64 years, and Korea even more (66 people) (Figure 2.19). Given the dramatically increased dependency ratio and uncertainty of migration, the remaining two engines of growth, capital and productivity, must be strengthened. Due to diminishing returns (for example, from education and capital), however, it will not be possible to maintain equally strong physical and human capital growth. Therefore, improving productivity through structural competitiveness, innovation activity, institutional environments, and increasing technology sophistication is critical in both countries in the years to come.

FIGURE 2.19 Actual and Projected Populations



Source: UN World Population Prospects (2017).

Despite the similarities, significant differences exist between Poland and Korea, including not only the GDP per capita but also the size of the economy, the size of the population, and thus the size of the labor force. Differences between the two countries go beyond the gap in the standard measure of a country's economic development (GDP per capita) and consist primarily of structural differences. First, Poland is by far the smaller country, with a population of 38 million, three-fourths the population of Korea (Figure 2.19). However, with a working population of 25 million, the Polish economy has about 250,000 non-micro establishments (five or more employees), which translates to ten businesses for every thousand people in Poland and more than 6.5 businesses for every thousand in the working-age population (GUS 2022).[25] Korea has about 338,000 non-micro establishments, representing more than 40 percent more businesses than the total in Poland, but this amounts to about 6.5 businesses for every thousand people in Korea and more than nine businesses for every thousand in the

25. According to the Polish National Official Register of National Economy Entities (REGON).

working-age population (Korea Statistics 2018). These statistics can signify either stronger entrepreneurial activity in Poland or larger business fragmentation in Korea compared to Poland (Korea has more micro firms). In addition, Korea is also perceived as a global leader in innovation and technology. All of these factors strongly determine the country's level of technological sophistication.

Since considerable heterogeneity in technology adoption exists across sectors, firm sizes, and ownership statuses, comparing technology sophistication between countries requires investigating not only firm-level advancements but also the structure of the economy. Nationally aggregated level of technology sophistication results from a within-firm technology sophistication and firm structure of the economy.[26] First, firms in more advanced economies are not only more sophisticated technologically, there are simply more of them. A key economic challenge in this area for less advanced countries is not only that average firm sophistication is significantly more distant from the technological frontier but also, relative to the population, there are fewer firms. Second, since firm size is positively correlated with technological sophistication, the larger an economy's establishments, the higher the average level of sophistication. Third, firms participating in the global market use, on average, more technologically advanced methods to run their businesses; thus the more exporters in an economy, the higher the country-level technological sophistication. Last, developed countries have a large service sector share in their GDP and a declining share of agriculture and manufacturing. Given technological heterogeneity across sectors, structural change is also an important determinant for average technology sophistication. All these features must be considered while comparing countries and trying to successfully identify the key challenges to facilitating technological upgrades that can lead firms to upscale and create better jobs.

In terms of technological sophistication, structural characteristics such as firm size and advancement in structural change seem to favor Poland over Korea. Given the GDP per capita, Poland is a less advanced country than Korea (Figure 2.16). However, some features of the Polish economy indicate that the average level of technology sophistication may not be very different from Korea's.[27]

26. X. Cirera, D. Comin, M. Cruz, *Bridging the Technological Divide: Technology Adoption by Firms in Developing Countries* (Washington, DC: World Bank, 2022).

27. This paragraph is based on the survey data and explains the results of the Technology Adoption Survey. Even though surveys are representative for a population of firms with more than five employees in Poland and Korea, data might not identically represent the structure of firms observed in the economy.

First, the percentage of medium (20 – 99 employees) and large firms (100+ employees)[28] in Poland is larger than in Korea (Table 2.4). Moreover, Poland has a little higher number of establishments for every thousand people than Korea, which is partially driven by market fragmentation in Korea, not a desirable feature in the context of technological sophistication. Second, relatively more Polish enterprises participate in the global market compared to Korea. Third, Korea has a significantly larger share of agriculture firms (8 percent) than Poland (about 1 percent) and a relatively more minor service sector (less than 50 percent of Korean firms are service firms, while 77 percent of Polish establishments are service firms). Last, the share of foreign-owned enterprises is larger in Poland (5.5 percent compared to 2 percent in Korea). Hence, the difference between aggregated levels of technology sophistication between Poland and Korea results not only from the firm-level technology advancements but also from country-specific characteristics.[29]

TABLE 2.4 Firm Structure in the Survey

a. Poland

	Firm share by sector (%)			
	Total	**Agriculture**	**Manufacturing**	**Services**
Total	1.2	21.4	77.4	
Size classes				
Small (5–19)	78.9	82.5	69.5	81.4
Medium (20–99)	17.3	15.9	22.1	16.0
Large (100+)	3.8	1.6	8.4	2.6
Ownership classes				
Private domestic (PDE)	93.8	90.9	92.3	94.1
State-owned (SOE)	0.7	3.3	0.1	0.8
Foreign-owned (FOE)	5.5	5.8	7.0	5.2
International trade				
Exporters	20.5	10.5	43.8	14.3

28. The stratification in the TAS was based on three firm-size categories: small (5 – 19 employees), medium (20 – 99 employees), and large (100+ employees). However, due to different classification methodology used in European countries, the Polish survey was stratified on a more disaggregated level of six firm-size categories: (i) 5 – 9, (ii) 10 – 19, (iii) 20 – 59, (iv) 60 – 99, (v) 100 – 249, and (vi) 250+ employees. When presenting cross-country results, however, the firm-size classification relies on three categories.

29. In terms of firm-size enabling higher technology sophistication, Korea is not an aspirational country for Poland. Western countries, especially Germany, have a more favorable structure; see Chapter 3.

b. Korea

	Firm share by sector (%)			
	Total	Agriculture	Manufacturing	Services
Total	8.3	42.0	49.7	
Size classes				
Small (5–19)	82.5	70.7	76.8	85.1
Medium (20–99)	15.1	28.5	20.0	12.9
Large (100+)	2.4	0.7	3.2	2.0
Ownership classes				
Private domestic (PDE)	96.3	97.2	92.3	89.5
State-owned (SOE)	1.7	1.6	2.0	6.1
Foreign-owned (FOE)	2.0	1.3	5.7	4.4
International trade				
Exporters	19.1	8.0	39.5	10.0

Note: Percentages sum to 100 within sectors for every category (firm size, ownership, and international trade). Foreign-owned and state-owned enterprises are firms with majority foreign or state ownership, respectively. The stratification in the TAS was based on three firm-size categories: small (5 – 19 employees), medium (20 – 99 employees), and large (100+ employees). However, due to different classification methodology used in European countries, the Polish survey was stratified on a more disaggregated level of six firm size categories: (i) 5 – 9, (ii) 10 – 19, (iii) 20 – 59, (iv) 60 – 99, (v) 100 – 249, and (vi) 250+ employees. For comparability, however, the tables present structures adjusted to the Korean stratification.
Source: Sample details from TAS in Poland.

Technology adoption: Where does Poland stand compared to Korea?

The average Polish firm is less technologically advanced than the average Korean firm. The country-level technology sophistication on the intensive margin for general business functions amounts to 2.60 in Korea compared to 2.18 in Poland. However, the difference in technology sophistication between countries is not equally distributed across business functions (Figure 2.20). Poland is more advanced compared to Korea in terms of payment methods and less advanced for the remaining six business functions. The gap in technology sophistication between an average Polish firm and an average Korean firm is widest for business administration and planning, meaning that average Polish firms employ computers with

FIGURE 2.20 General Business Functions in Poland and Korea

Note: The radar plots the average GBF index on the intensive margin across business functions for Poland and Korea, weighted by sample weights.
Source: Original figure based on TAS in Poland.

standard software to run day-to-day administrative and planning processes, while Korean firms use more sophisticated digital platforms for the same processes. When it comes to sourcing and procurement, Korean firms move past manual processes and rely mostly on computer software in this area. However, given the Korean level of economic development and its position as one of the world's leaders in innovation, one might expect a larger gap in technological sophistication between Poland and Korea.

The relatively small difference in average technology sophistication between Poland and Korea is mainly driven by the firm sizes in both countries and the service-oriented structure of the Polish economy. A couple of features drive the relatively small gap in technology sophistication between Poland and Korea. First, not only does Poland have relatively more large firms than Korea, but hardly any differences exist between the level of sophistication for large firms in the two countries (Table 2.5), especially for general business functions. Second, probably due to Poland's accession to the European Union and the country's cultural and geographical proximity to Western economies, Poland offers attractive conditions for foreign direct investments, and hence the percentage of foreign-owned firms is higher in Poland than in Korea.[30]

TABLE 2.5 Technology Sophistication Across Firm Sizes in Poland and Korea

INTENSIVE MARGIN – the most frequently used technology

	Average Business Functions (ABF)			General Business Functions (GBF)			Sector-Specific Functions (SBF)		
	Small (5–19)	Medium (20–99)	Large (100+)	Small (5–19)	Medium (20–99)	Large (100+)	Small (5–19)	Medium (20–99)	Large (100+)
Korea	2.23	2.62	3.06	2.28	2.68	3.07	2.09	2.26	2.87
Poland	2.03	2.41	2.96	2.07	2.47	3.05	1.92	2.24	2.71
GAP	0.20	0.21	0.10	0.21	0.21	0.02	0.17	0.02	0.16

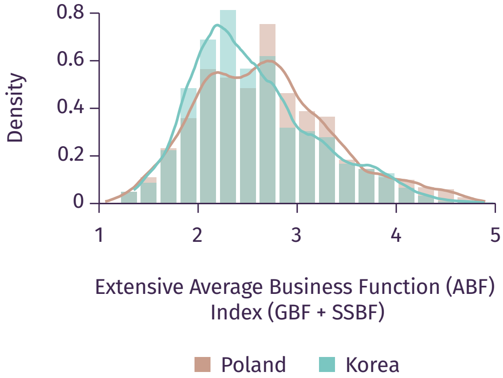
Note: The table shows the average values of the technology sophistication indices on the intensive margin: for general business functions, sector-specific business functions, and the average for both, weighted by sample weights. The Average Business Functions Index (ABF) is the average level of technology sophistication of the firm across all business functions, including general business functions (GBF) and sector business functions (SBF).

Source: Original results based on TAS in Poland.

30. Actually, since 2013, when the two countries signed a strategic partnership, Korean firms (Samsung, LG, SK IE Technology) have been investing heavily in Poland, and Korea is now the largest Asian investor in Poland, with a cumulative value of Korean FDI reaching EUR 3.1 billion as of 2020 (National Bank of Poland 2022).

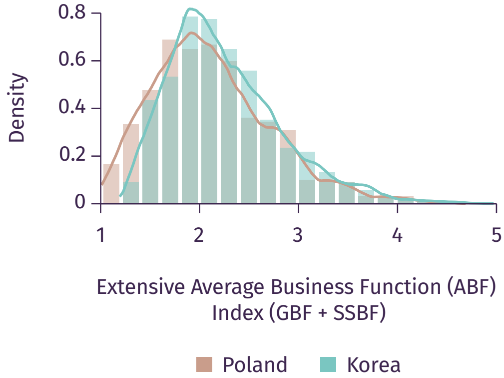
This, in turn, may influence the aggregate level of technological sophistication. Interestingly, the difference between the two countries on the intensive margin does not translate into the difference on the extensive margin (Figure 2.21 and Figure 2.22). It seems that, in comparison to Korea, fewer Polish firms use more sophisticated technology most frequently to run business (Figure 2.22), but more Polish firms have access to more advanced technologies than so Korean firms (Figure 2.21). One possibility is that Polish enterprises are undergoing technological change, and even though they are not using some technologies most frequently, they have already been adopted. There might be also some managerial practice differences or general attitudes toward change that make the gap between the intensive and the extensive margin in Korean firms smaller than in Poland.

FIGURE 2.21 Distribution of Average Business Functions Index on the Extensive Margin Across Firms in Poland and Korea



Source: Original figures based on TAS in Poland.

FIGURE 2.22 Distribution of Average Business Functions Index on the Intensive Margin Across Firms in Poland and Korea



Source: Original figures based on TAS in Poland.

What does enable and inhibit technology adoption?

Designing effective instruments to foster technology adoption requires addressing the barriers that entrepreneurs report themselves and, most importantly, the barriers supported by data. Use of the Technology Adoption Survey allows verifying if theoretical and empirical literature findings on enablers and inhibitors of technology upgrading are also found in the Polish entrepreneurial environment (see Box 2.2). Moreover, it allows comparson of obstacles reported by firms against their actual financial situation and level of technology sophistication. Given the considerable variation in technology adoption across sectors, firm sizes, and business functions, one expects the barriers to adoption to also be heterogeneous, increasing the difficulty of designing appropriate policy responses.

BOX 2.2 Literature review: what are the barriers and enablers to technology adoption?

Extensive theoretical and empirical literature describes the barriers and drivers of firm-level technology adoption. Cirera, Comin, and Cruz (2022) builds on the literature review to provide the justification for the questions and answers chosen in the Technology Adoption Survey. Thanks to the firm-level data, the perceived obstacles and motivations described by the entrepreneurs are then tested with factual information. Complementing the review described in Cirera, Comin, and Cruz (2022), there is a systematic review provided by Stornelli et al. (2021) that focuses on the barriers and enablers along with the adoption of more advanced technologies, hence in countries comparable with Poland.

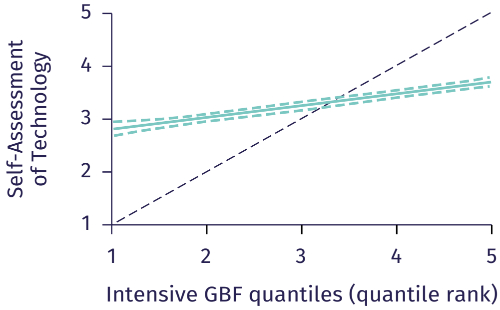
The important factor in the technology uptake process is the skill of the workforce (recent Mercenier and Voyvoda,2021; EIB, 2022), a factor rarely mentioned by Polish entrepreneurs. Moreover, firms that have invested in digital transformation also tend to implement better management practices. These findings are in line with the results from previous studies highlighting the importance of management practices for technology adoption and firm performance (Bloom et al., 2019; EIB, 2020). The human factor seems to be significant in technology adoption in other ways as well. This factor includes employee resistance such as a threat to established competencies (Sjödin et al.,2018, present insight from the automotive industry), or skills development issues causing several months of installation delays (Swamidass and Winch, 2002, analyzing US and UK companies). Alternatively, some authors also describe employee resistance as fear of job losses in unionized firms (Baldwin and Lin, 2002, covering Canadian companies; Small and Yasin, 2000, for the US; Borges and Tan, 2017, for Brazil). The gaps in skills are also recognized in the literature as a common obstacle to technology uptake: for example, design skills challenges for additive manufacturing or lack of Big Data analysis skills for Industrial Internet of Things (IIoT) (see Ford and Despeisse, 2016, analyzing global companies; Kiel et al., 2017, for German companies).

Literature shows that policy and regulation barriers may also impact the adoption. The obstacles include gaps in the regulatory system and government initiatives, which fail to incentivize industry standards and the diffusion of knowledge on technology applications and costs (Dwivedi et al., 2017, describe Indian companies). Some studies highlight lack of safety, material properties, production methods, or design standards (Harrington et al., 2017; Wagner and Walton, 2016). Several studies analyze the lack of government capabilities in form of inconsistent adoption policies, especially for additive manufacturing readiness which in turn results in the lack of awareness of technology applications and capabilities (Durach et al., 2017; Samford et al., 2017; Meier et al., 2019).

According to the European Manufacturing Survey (more than 2,000 European firms), high investment requirements and a corresponding lack of financial resources remain the core barriers to technology adoption (EC, 2017). Moreover, about half of all firms indicate difficulties in assessing the performance and the potential business return of novel technologies and/or a lack of skilled personnel. Finally, market uncertainty and turbulences play a major role. The majority of studies indicating economic barriers to technology adoption highlight the significantly high cost of capital coupled with the liquidity constraints (Stornelli, 2021; Arvanitis and Hollenstein, 2001; Harrington et al., 2017; Müller et al., 2018). According to Muller et al. (2018), two-thirds of the sampled SMEs mention high investments in machine parks and IT infrastructure, as well as costs for IT personnel and technical training as the main obstacles to adoption. Also, the interviewees perceive Industry 4.0 as costly in the short term, whereas its expected benefits require time to unfold.

Firms in need of technological upgrading might be the most reluctant to adopt new technologies due to overconfidence and self-assessment bias. Most Polish firms cannot correctly indicate their level of technological development. Figure 2.23 plots the relationship between self-assessed (X-axis) and actual (Y-axis) position in the distribution (quantile rank) of technology sophistication for firms in Poland.[31] The 45-degree line shows the accurate assessment, where both self-assessed and actual values coincide. If the blue line lies above the 45-degree line, it suggests that firms are overconfident in evaluating their level of sophistication; if below, it may imply self-doubt. Two main conclusions can be drawn from this figure. First, most firms tend to position themselves above the median (around 3) and at relatively similar levels of technology adoption, regardless of the actual technological development. Only 13 percent of Polish firms indicate that their level of sophistication might be below the median. Second, the gap between the self-assessed and the true level of sophistication is largest for firms in the lowest quantiles of the distribution: the less advanced a company is, the more it overestimates its level of technology sophistication. When it comes to international comparisons (Figure 2.24), Polish firms seem to be more down-to-earth and hence closer to appropriately indicating their level of technological development. On the one hand, this humbling approach might be motivating. On the other hand, a lack of confidence

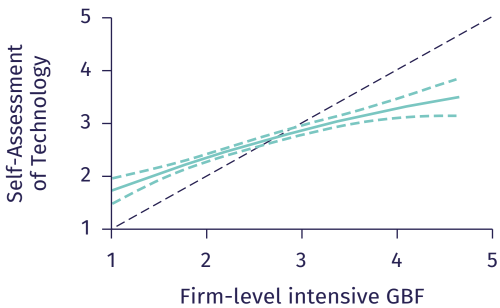
FIGURE 2.23 Association Between Self-Assessment and Technology Adoption in Relation to Other Firms in Poland



Note: The turquoise line shows the quadratic prediction for self-assessment of technology sophistication with a 95% confidence interval. Firm quantile rank in the intensive GBF index (firm location in the distribution of intensive GBF index in Poland) is regressed on firms' self-assessment with respect to other firms in Poland.

Source: Original figure based on TAS in Poland.

FIGURE 2.24 Association Between Self-Assessment and Technology Adoption in Relation to the World's Most Advanced Firms



Note: The turquoise line shows the quadratic prediction for self-assessment of technology sophistication with a 95% confidence interval. Firm-level intensive GBF index is regressed on firms' self-assessment with respect to the world's most advanced firms. Since the world distribution of the intensive GBF index is unknown, the firm-level GBF index is used for the regression (plotting actual versus perceived firm-level intensive GBF index).

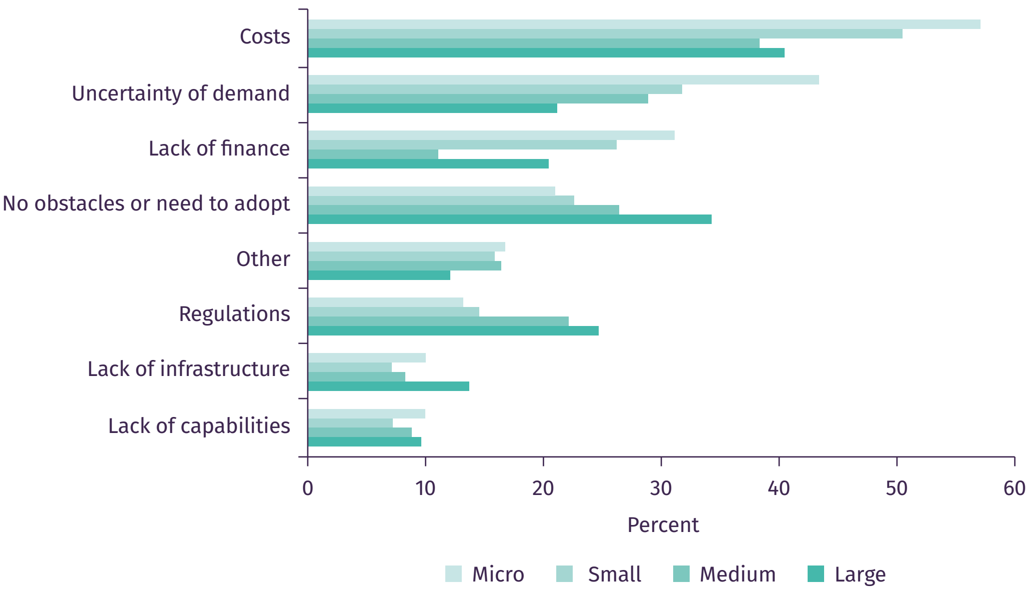
Source: Original figure based on TAS in Poland.

31. Firms answered the following question: "In a scale from 1 to 10, where 10 means that the establishment is using the most advanced production processes available in its sector, where do you think this establishment stands with respect to 1) other firms in Poland, 2) most advanced firms in the world." For comparability, the values were later rescaled (divided by two), to fit a 1 to 5 scale. The question was asked before any questions regarding the technology adoption to prevent any bias in the self-assessment from potential framing.

may inhibit the decision to start competing in international markets and export. Above all, if firms' judgments are truly biased, those judgments challenge justification for demand-driven instruments to foster technology adoption, since the underlying assumption that companies can correctly identify their needs may be flawed. Moreover, it also indicates that the obstacles and enablers to adoption reported by firms should be approached with caution.

Firms consider themselves financially constrained or assume that returns from technology upgrading are not sufficient to cover their costs. On average, around 60 percent of firms in Poland list finance-related barriers (costs and lack of finance) as the main obstacles to adopting new equipment, machines, software, or processes to improve the firm's performance (Figure 2.25). Regardless of company size, costs remain the most significant barrier to technology adoption, although the percentage of firms reporting this as an obstacle varies: around two-thirds for firms employing fewer than 50 people and about 40 percent for larger establishments. These results for Poland differ significantly from those of other countries included in the Technology Adoption Survey.[32]

FIGURE 2.25 Perceived Obstacles for Technology Adoption by Firm Size in Poland

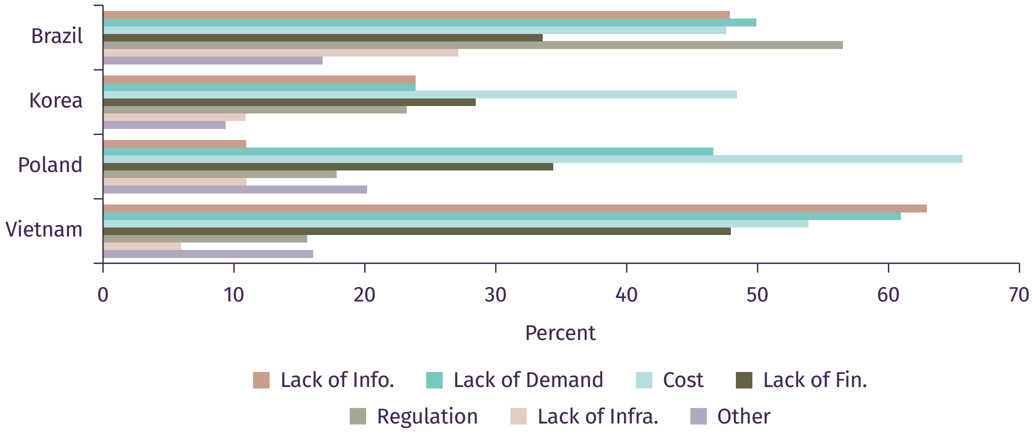


Note: Every firm could name the top three main obstacles to technology adoption; answers weighted by sample weights.
Source: Original figure based on TAS in Poland.

32. X. Cirera, D. Comin, M. Cruz, *Bridging the Technological Divide: Technology Adoption by Firms in Developing Countries* (Washington, DC: World Bank, 2022).

First, the variation across firm sizes is substantially larger for Poland, suggesting that differences between small and large Polish firms are more significant than in other countries. Second, the percentage of firms reporting costs as the main obstacle is highest in Poland compared to other countries. Interestingly, finance seems to play a more important role for entrepreneurs in Poland, not only compared to other countries, but also more than the literature suggests. It's highly unlikely that Polish companies face tighter financial constraints than Vietnamese or Brazilian firms. Therefore, the actual barriers preventing firm-level technology upgrading in Poland seem to be overestimated costs and undervalued adoption benefits.

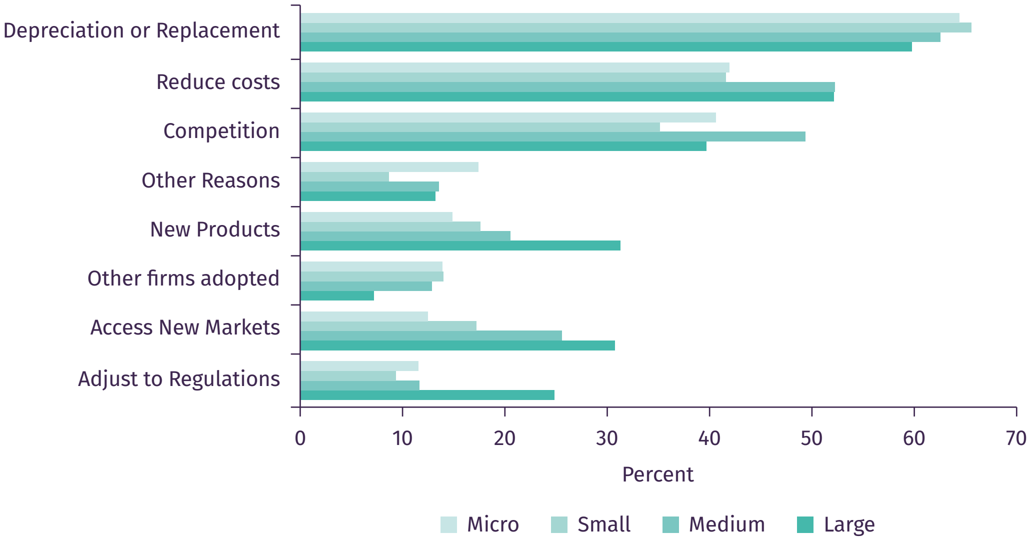
FIGURE 2.26 Perceived Obstacles for Technology Adoption across Brazil, Korea, Poland, and Vietnam



Note: Every firm could name the top three main obstacles to technology adoption; answers weighted by sample and country weights.
Source: Original figure based on TAS in Poland.

Even though the vast majority of Polish firms do not use the frontier technologies, many claim they do not need upgrading and seem confident in their capabilities. On average, every fourth company in Poland and one-third of large Polish firms report not needing technology adoption or seeing no obstacles to upgrading. Moreover, even though the survey was collected during the COVID-19 pandemic, the international comparison suggests that high uncertainty has little impact on obstacles to technology upgrades perceived by Polish entrepreneurs, and finances remain the most reported obstacle. Also, Polish firms perceive themselves as well-informed and skillful, since only around 10 percent report a lack of capabilities as a barrier to technology adoption. Apparently, capabilities are significantly less of a problem for Polish entrepreneurs than they are in Korea, Vietnam, or Brazil, which may imply that Polish firms do not recognize capabilities as an important and integral part of technology upgrading.

FIGURE 2.27 Reasons for Technology Adoption by Firm Size in Poland



Note: Every firm could name the top three main drivers and motivations to technology adoption; answers weighted by sample weights.
Source: Original figure based on TAS in Poland.

FIGURE 2.28 Reasons for Technology Adoption across Brazil, Korea, Poland, and Vietnam

Note: Every firm could name the top three main drivers and motivations to technology adoption; answers weighted by sample and country weights.

Source: Original figure based on TAS in Poland.

BOX 2.3 In-depth interviews: what firms say about the barriers and enablers to technology adoption?

Entrepreneurs emphasize that the costs of technologies are always analyzed in the first place before recognizing potential benefits from their adoption. Such an attitude oftentimes leads to resistance in moving to the next decision steps after an initial reaction to costs. An incomplete approach to analyzing technological decisions results from the fact that they are conducted in the same way as everyday business processes related to the production and sale of products and services, where short-term perspective and cost orientation are predominant. Notably, the cost-orientation takes place both in relation to technologies with a high absolute price (e.g., industrial robots) and low (e.g., office software). Building awareness of companies regarding the benefits of technology adoption, including the ability to conduct feasibility studies, is thus key to streamlining technology decisions.

Enterprises prefer technologies that can be adopted in a modular manner and that do not generate high recurring costs, especially for firms with constrained access to finance. SMEs have limited organizational and financial capacity to adopt new technologies and therefore aim to minimize technological risks. Uncertainty related to the involvement of significant human and financial resources in the process of technology implementation, which may turn out to be unproductive, poses a threat to smaller enterprises. Therefore, they are more likely to carry out 10 smaller technological implementations than one or two large ones. Due to limited managerial capabilities, planning such investments is easier in the case of technologies with a known upfront cost, as opposed to solutions with the need to recurring variable costs. A constant upfront cost also makes it easier to obtain financing as the role of future uncertainty is reduced.

The main impetus for the adoption of technologies is the requirements set by business partners. Both suppliers and recipients are driving companies to adopt new technologies through direct and indirect means. The direct method involves the need to maintain compliance with new technologies used by business partners - for example, when one of them implements the ERP system and starts to accept orders only in one specific electronic format. An indirect way involves inquiries from business partners about the use of respective technologies in order to probe the possibility of continuing or expanding cooperation. The combination of both methods of influence are technological audits carried out by recipients of products from the manufacturing sector, the recommendations of which are voluntary to be implemented, but non-compliance may lead to termination of cooperation. The pressure to make technological adjustments is greater on the part of foreign companies, especially in the environmental and climate areas.

Source: A series of 3 individual in-depth interviews (IDIs) with managers from enterprises at various levels of technology advancement, size and sector, conducted in June 2022.

Compared to other countries, Polish firms appear to be less concerned about their competitors and to see the adoption of new technology as due to depreciation rather than being a way to modernize. Eighty percent of Polish enterprises adopt new technology because are forced to replace an old one. This is the most common reason for technology adoption reported by Polish companies, much more so than in other countries. In Vietnam and Brazil, competition is what most often motivates companies to improve their technology, while in Korea it is an attempt to reduce costs. This is in blatant contradiction to Poland, where companies see technology adoption as excessive spending rather than a way to cut costs. Since responses vary by firm size and country, firms operating in different sectors and countries, the complementary report "Sectoral Approach to the Drivers of Productivity Growth in Poland. A Firm-Level Perspective on Technology Adoption and Firm Capabilities." investigates in detail the differences in perceived obstacles and reasons to adopt by sectors.

III

SECTORAL PERSPECTIVE IN THE ANALYSIS OF TECHNOLOGY SOPHISTICATION

1 Sectors in Poland differ in technology sophistication in both general business and sector-specific functions. To a large extent, however, those differences are driven by the sectors' structural differences, such as number of large firms, share of exporters, and number foreign-owned enterprises. Moreover, firms in different sectors face different economic conditions and are exposed to a different balance of regulatory, environmental, and geopolitical risks and challenges. The complementary report "Sectoral approach to the drivers of productivity growth in Poland. A firm-level perspective on technology adoption and firm capabilities." presents a comprehensive sectoral analysis. Understanding those sectoral differences, especially as they affect use of sector-specific technologies, is of the utmost importance, because productivity improvements historically have been driven primarily by capital-intensive investment, which often involves sector-specific technologies.

2 Technology sophistication regarding general business functions is highest in the motor vehicles, pharmaceuticals, and financial services sectors, while agriculture and food processing, more than the country average, use basic technologies for day-to-day business activities. Firms in the automotive and pharmaceuticals sectors have higher than the average levels of technology sophistication in payments and business administration, which translates into a higher level of technological advancement in general.

3 The sophistication of sector-specific technologies in Poland is generally low to moderate, with the pharmaceuticals and agriculture sectors leading the sectoral ranking. Surprisingly, even though the automotive sector uses on average more advanced methods for general business functions, this is not the case for sector-specific technologies. Similarly, firms in agriculture are below average in their sophistication of general business functions, but display higher than average sophistication in their use of sector-specific business technologies.

This chapter briefly describes the findings of the Technology Adoption Survey on Poland's sector-specific business technologies (SBFs), which captured more distinctly the sectoral perspective in the analysis of technology sophistication. A comprehensive sectoral analysis that includes the structural characteristics of Polish sectors and cross-country comparison with other countries (e.g., the Czech Republic, Germany, and the Republic of Korea), as well as detailed Technology Adoption Survey results for general and sector-specific business functions, is presented in the complementary report entitled "Sectoral approach to the drivers of productivity growth in Poland. A firm-level perspective on technology adoption and firm capabilities". This chapter briefly reviews these findings. Since structural characteristics such as firm size and sectoral FDI share are highly significant for technology sophistication (see Chapter 2), this chapter first delivers a short summary of the structural characteristics of the sectors included in the Technology Adoption Survey: agriculture, food processing, wearing apparel, automotive, pharmaceuticals, wholesale and retail trade, financial services, and land transport. It then presents the key results from the Technology Adoption Survey that focus on sector-specific technologies. (Due to space limitations, these technologies are described in detail only in the complementary report; see the technology ladders for SBFs in the Appendix, Figure A1.6.) In the context of sector-specific technologies, it is worth noting that the level of sophistication differs between sectors. To illustrate, the SBF technology index level is 3 in financial services, indicating more advanced technologies are used than in, for example, agriculture. However, comparing technology trends across sectors is beyond the scope of this report; rather, we closely follow the methodology described in "Bridging the Technological Divide: Technology Adoption by Firms in Developing Countries".[33] Moreover, when comparing general and sector-specific business technologies, one should take into account that sector-specific technologies are more capital intensive and significantly more costly to implement. Given that large increases in labor productivity come mainly from improving the capital-to-labor ratio, to secure productivity improvements, capital-intensive investments in sector-specific technologies are substantially more important than technology adoption in the general business functions area.

33. . X. Cirera, D. Comin, M. Cruz, *Bridging the Technological Divide: Technology Adoption by Firms in Developing Countries* (Washington, DC: World Bank, 2022).

Overview of the sectors covered in Poland's TAS

Agriculture

Polish agriculture is dominated by small, non-exporting companies, more so than Korea, and Polish farms remain fragmented and are less productive than those in Western Europe. Over the last decades, Polish agriculture has been losing importance, but it still generates around 2 percent of gross value added (GVA) and about 10 percent of employment (down from 20 percent in 2000). Hence, agriculture is still one of the largest employers in the country, and its share in the national GVA is also significant compared to that of other developed countries. Since Poland joined the EU, Polish farms have also become larger and more technologically advanced. On the other hand, modernization and asset concentration have not gone as far there as in Western countries, nor has the sector delivered corresponding productivity gains. As a result, Polish farms remain significantly less productive than those in Western Europe. Most farm production reaches the national market only: just 10 percent of agriculture companies export their goods. Polish farms continue to rely on low to moderate advancement technologies to run their general and sector-specific business functions. The complexity of technologies used in general business activities is below the country's mean, but the sophistication of Poland's sector-specific processes in agriculture is generally above that observed in Korea. At the same time, the differences between extensive and intensive margins in Polish agriculture's sector-specific functions are not large, which indicates that, once implemented, the technologies are indeed used.

Food processing

In Poland's food processing, small non-exporting firms dominate to a significantly higher degree than in Korea, and Polish food manufacturing is losing its role in the Polish economy. Although food processing remains one of the largest sectors in the Polish economy, the last decade saw a drop in the sector's role both in the Polish GVA and in the employment structure. Food processing is responsible for around 14 percent of manufacturing GVA and 17 percent of manufacturing jobs. The scarcity of mergers and acquisitions taking place in the sector over the last decade resulted in continuation of a fragmented sectoral structure, with firms specializing in rather low-value-added food manufacturing. As a result, Polish food processing is characterized by one of the lowest levels of labor productivity in the EU. Although between 2015 and 2019, food processing labor productivity in Poland increased by around 20 percent, the level of product and business process modernization remains low compared to the manufacturing average. Most products reach the national market only, and just 15.4 percent of food processing companies export their goods. Firms in the sector continue to rely on low to moderate advancement technologies to run their general and sector-specific business functions. The sophistication level of general business functions is below the country's mean, and sector-specific activities advancement is below the levels observed in Korea. Moreover, a gap exists between technology adoption (extensive margin) and frequency of use (intensive margin). Such a gap may signal that although the firms put some effort into securing input testing capabilities in their establishments, barriers to using such solutions remain.

Wearing apparel

Poland's wearing apparel sector is dominated by small firms engaged in exporting activities to a larger degree than are their Korean counterparts, but the sector's role in the Polish economy continues to fall. The apparel sector is small in value and is losing its GVA share in Polish manufacturing faster than any other sector. In 2020 it accounted for around 3 percent of the manufacturing's GVA and only 0.5 percent of the total value of economic activities performed in Poland. The relative decline in the sector's importance can also be seen in its employment levels, which have almost halved since 2005. The relatively lower cost competitiveness of Polish apparel, compared to that manufactured in countries such as China, India, or Turkey, forced many of the sector's enterprises to close. Moreover, the absence of high-value-added apparel-producing firms reduced the sector's labor productivity to among the lowest in the EU. On the other hand, over 45 percent of the sector's production is exported, over 30 percentage points more than is recorded in Korea. At the same time, firms in the wearing apparel subsector use unsophisticated processes to perform general and sector-specific business functions, using means generally below the level of technological sophistication of average Polish and Korean firms. More advanced solutions are rarely adopted in Poland's wearing apparel sector, perhaps one of the reasons why basic technologies are most frequently used.

Automotive

The manufacturing of motor vehicles has evolved into one of the key industries in Poland, dominated by medium and large exporting enterprises, even more so than in Korea. In 2019, the automotive sector contributed around 8.2 percent to the total manufacturing GVA and provided over 7 percent of manufacturing jobs. Polish foreign trade in motor vehicles is characterized by a positive trade balance, making the country one of the Central Eastern European leaders in manufacturing cars, car parts, and components. Most of the production reaches foreign markets, with 75 percent of motor vehicle companies exporting their goods. The sector is characterized by low labor productivity compared to other EU states, however, mainly due to specialization in relatively low GVA activities, such as vehicle assembling and automobile parts production. Technological sophistication in running general business operations in the Polish motor vehicles sector significantly exceeds the Polish economy-wide average, but sector-specific business functions remain unsophisticated and generally below levels observed in Korea. When firms adopt more advanced technologies, they are not frequently used. Instead, firms turn to more basic solutions, which may signal that the sector struggles with technological know-how.

Pharmaceuticals

Poland's pharmaceuticals are dominated by medium and large exporting companies, more so than in Korea, but the Polish pharmaceutical sector remains less productive than that of Western Europe. The sector's contributions to the Polish GVA are small, and its role has been decreasing. In 2020, the GVA from pharmaceutical activities constituted 1.7 percent of the manufacturing GVA, with the sector employing less than 1 percent of the Polish manufacturing workforce. Although 65 percent of Polish pharmaceutical enterprises export their products, Poland has a marginal role in global drug exports. Despite the sector's labor productivity being high compared to other industries, it remains low compared to other EU countries, a factor related to Poland's specialization in producing generic rather than innovative drugs. At the same time, the Polish pharmaceutical products sector exhibits significantly more advanced general and sector-specific business processes than the Polish economy-wide average or the levels recorded in Korea. Across all business functions, Polish pharmaceutical companies adopt advanced technological solutions and tend to use them in their daily operations.

Wholesale and retail trade

The Polish wholesale and retail sector is dominated by small non-exporting companies, at rates comparable to that observed in Korea, with Polish firms remaining fragmented and less productive than in most EU states. Polish wholesale and retail trade has been experiencing continuous growth and has evolved to become one of the most important sectors in the country. In 2020 it was responsible for over 18 percent of GVA and around 16.5 percent of all jobs in Poland (approximately 25 percent of service jobs). On the other hand, despite some consolidation trends, the wholesale and retail sector remains highly fragmented and shows a low level of innovation, even though internet sales are rising in the country. As a result, sector labor productivity is low compared to that of most EU states. Most of the sector's products reach the national market only, with just 20 percent of wholesale and retail companies exporting their goods. Wholesale and retail firms employ low to mid-level advancement technologies to perform general and sector-specific business functions. In both cases, the sophistication of implemented solutions is slightly below the country mean and on levels similar to those observed in Korea. Although Polish wholesale and retail firms have access to more advanced solutions, they do not exploit their full potential, suggesting that know-how barriers may exist in the sector.

Financial services

The Polish financial sector comprises predominantly small- and medium-sized companies, unlike in Korea, where small firms dominate. The sector is small in Poland compared to more developed European economies, mainly due to its short history. On the other hand, the last decade saw a significant increase in its gross value-added while recording an employment drop, which signals substantial productivity gains in the sector. In 2019, the GVA from financial and insurance activities constituted 4.5 percent of the country's total GVA (compared to 3.3 percent in 2010) and 2.5 percent of employment (4 percent of services employment). The Polish financial services sector differs significantly from those observed in the developed European markets, where the insurance subsector usually has a larger share in the structure of assets of the entire financial sector. On the country level, financial and insurance activities lead in service industry innovation and the pace of technological transformation. In fact, Polish banking innovation is one of the most advanced in the world. Unsurprisingly, financial services thus show more technologically advanced general business processes than the economy-wide average. On the other hand, the sector-specific business functions used most frequently remain technologically unadvanced compared to the solutions that financial firms could access. Poland's results, however, do not differ significantly from those recorded in Korea.

Land transport

Polish land transport is dominated by small companies, more so than Korea's, and despite having an important role in the Polish economy, its labor productivity remains at the tail of the EU. Transport services constitute a critical part of the production and supply chain for many other sectors, and their role in the Polish economy continues to grow. Despite experiencing a drop in value related to the disruptions caused by the COVID-19 pandemic, the transportation and storage sector's GVA has been consistently increasing, almost doubling in value between 2000 and 2019. Currently, transportation and storage activities generate around 7 percent of Poland's GVA and provide approximately 11 percent of its services' employment. Since 2008, the share of Polish carriers in the European freight industry has more than doubled, making Poland a European leader in this category, but the sector's labor productivity has stayed at one of the lowest levels in Europe. This relates to Poland's specialization in low-value transports and its lack of large headquarters functions, additionally hindered by relatively low purchasing power, resulting in low service fees. Although the beginnings of technological transformation are visible in the sector, the level of technology adoption remains low. Firms in the land transport sector employ low- to mid-level advancement technologies to perform typical business and sector-specific functions. They do not differ much from the national average but lag behind Korea. When Polish land transport firms have access to somewhat more advanced solutions, they do not exploit their full potential, perhaps due to know-how barriers.

What do we know about technology sophistication across sectors in Poland?

The technological advancement of general business functions is highest in motor vehicles, pharmaceuticals, and financial services, while agriculture and food processing use more basic technologies than the country average for day-to-day business activities. Business administration and payments functions are the most developed among the general business functions, with businesses most frequently using computers with specialized installed software (or digital platforms) and online banking. The most advanced functions do not differ much across sectors, but the motor vehicle and pharmaceutical sectors stand out in this category, showing both higher than average levels of technological sophistication in payments and business administration, as well as higher levels of technological advancement in general. Those differences are driven by structural characteristics (see Appendix, Table A1.3), however, and when controlling for those, no significant differences emerge between sectors. Moreover, Polish companies struggle to adapt technologies supporting quality control, sales, sourcing, and marketing activities. Again, pharmaceutical firms lead, recording a particular advantage in quality control, but also exceeding the country mean in marketing and sourcing activities. Agriculture, food processing, and wearing apparel firms are some of the biggest laggards in these categories.

In Poland, the sophistication of sector-specific technologies is generally low to moderate, with the pharmaceuticals and agriculture sectors leading in the sectoral ranking. Polish firms operating in the wearing apparel, trade, and automotive sectors most often use unsophisticated technologies. Even though the vast majority of agriculture firms are small, the level of sophistication of sector-specific technologies is significantly higher than in other sectors in Poland. This might be driven by the strict food regulations imposed by the European Union, which might also explain why the difference between the extensive and the intensive margin in agriculture is the smallest among all Polish sectors. Polish farms in almost all but one sector-specific functions are also more sophisticated than farms in Korea, which, again, might be driven by EU membership. Similarly, the pharmaceuticals sector is the most advanced in Poland, both on the extensive and the intensive margin. In wearing apparel, basic technologies are frequently used both in Poland and Korea, and more advanced solutions are rarely adopted. It might be that the wearing apparel industry is subject to barriers preventing technology adoption or experiences problems on the supply side, meaning that technology providers are inefficient. Interestingly, both automotive and financial services sectors have relatively low technology sophistication on the intensive margin. However, the differences between the extensive and the intensive margins for both sectors are significantly higher than for other sectors (even three times larger). In the automotive sector, it might be that customers require certain advanced technologies from Polish firms, but due to production composition these technologies are not the most frequently used.

The perceived barriers to technology adoption in the sectors analyzed by the TAS most frequently relate to costs and lack of finance, lack of demand, and uncertainty, although pharmaceutical, motor vehicle, and financial firms also voice substantial concerns over the regulatory environment. Financial matters are considered a primary obstacle for over 60 percent of the Polish firms, followed by over 40 percent of firms expressing concern about lack or uncertainty of demand, which might have been exacerbated by data collection during the COVID-19 pandemic. Enterprises in the food processing and wearing apparel sectors indicate that financial and demand matters have above-average adverse effect on their propensity to adopt technologies. On the other hand, motor vehicles and pharmaceutical enterprises are relatively less concerned about access to finance and demand uncertainty; they more frequently voice concern about the regulatory environment. These sectors have, on average, greater numbers of larger establishments than do other sectors and are apparently less concerned about the financial aspects of doing business.

Currently, all sectors analyzed in the TAS face a series of challenges, predominantly related to cost pressures and changing regulations. At the same time, many sectors are subject to an insufficient labor supply, which makes it difficult for them to find qualified workers. In the short term, by putting a strain on profitability, rising production costs (related, for example, to rising prices for fuels or the increasing minimal wage) may discourage increases in production or service provision, negatively impacting the sectors' development. Moreover, all sectors will be subject to changing EU regulation related to delivery of the European Green Deal, and many are not yet prepared to respond to these requirements.

IV

POLICIES SUPPORTING TECHNOLOGY ADOPTION

1 **Up to half of the budget for private sector development in 2021–2027 allows investments in technology adoption, totaling to €16.7 billion.** The need for firms to adopt supporting technology is recognized in strategic documents at the European, national, and regional levels. However, the vast majority of instruments contributing to this objective are broad, technology-agnostic, and follow a demand-driven approach, contrary to more granular approach to advance technology creation. The demand-driven approach assumes that firms are aware of their needs; thus, targeting of support programs is limited, and applicants are expected to identify their needs themselves. As a result, technology adoption is supported mostly through returnable instruments aimed at general improvement in SME competitiveness. Only with regard to sustainable technologies do targeted instruments consider the specifications of particular green solutions.

2 **Complementary factors, such as managerial skills and digital readiness, are supported separately from programs aimed at advanced technology adoption.** Only one-third of all instruments to support technology adoption allow financing to upgrade skills, improve managerial capabilities, or enhance digital readiness. Instruments aimed at developing firm capabilities are offered predominantly at the regional level and delivered by providers registered in the Development Services Database. Public support for firm-level digitization is concentrated in a dozen instruments with multiple digital objectives. As for nondigital technologies, interventions promoting digitization are technology-agnostic, although with greater use of nonrefundable support.

3 **Recent interventions supporting technology adoption resulted in increasing the scale of firms' operations, with modest improvement in productivity.** Rigorous evaluations indicate that the development impact was stronger among young, smaller firms than among more mature enterprises, and benefits for manufacturing firms on average exceeded the gains for service firms. Outcomes were limited by duplication of programs with overlapping objectives offered by various institutions, as well as by gaps in design and implementation practices. Awareness-rising activities were fragmented and yielded modest results in terms of broadening information dissemination among a wide range of companies about the need for technology upgrading: the majority of program beneficiaries between 2014 and 2020 were firms that had participated in support programs in the previous financial perspectives. In recent years, interventions aimed at addressing some of the above shortcomings were piloted, including a network of one-stop-shops promoting digital technologies and using needs assessments in instruments to support SMEs' managerial capabilities and restructuring.

This chapter examines the portfolio of public interventions for enhancing technology adoption in Poland. The analysis of the supply side in combination with the findings from the Technology Adoption Survey (demand-side analysis) gives public authorities a view into where and how mechanisms for technology adoption can be strengthened. This chapter builds on and extends the recent World Bank (2020) project Return on Investment of Public Support to SMEs and Innovation in Poland. First, we present a brief overview of Poland's firm-level support ecosystem to better understand the country's policy priorities. Second, the policy mix analysis compares whether the current set of support instruments aligns with the technology needs of firms identified in the Technology Adoption Survey and seeks to identify potential gaps and overlaps. In addition to the characteristics mapped in World Bank (2020) for all technology-related instruments from 2014 to 2020, whether EU or nationally funded, the instruments from the ongoing 2021 – 2027 perspective were mapped, and the strategic and organizational components of the ecosystem were reviewed. Third, the analysis provides insights into whether resources in the current financing perspective are appropriately allocated to the themes and forms of support expected to yield the highest productivity gains.

The analysis predominantly examines the supply of public interventions related to technology-specific policies, initiatives for raising awareness on technological upgrading, and support for developing complementary factors, such as firm capabilities. The above policy areas emerged as the main challenges in the Technology Adoption Survey. They were subjected to a detailed analysis covering all policies related to the support of technology diffusion and uptake. Insights from the supply-side analysis provide information on where and how future public support for technology adoption can be channeled to increase its impact and to help Polish enterprises increase their productivity. Based on evaluation of the literature, we have also identified good practices in past initiatives that managing authorities and implementing bodies could leverage in upcoming interventions.

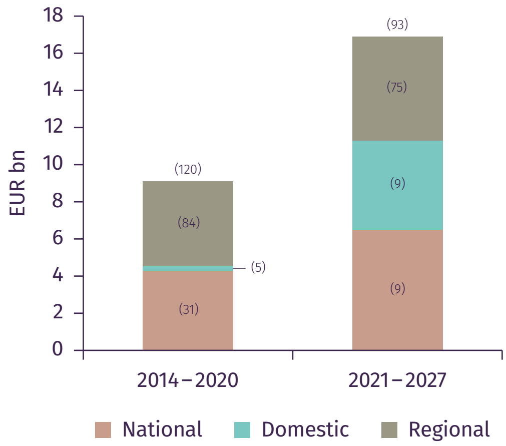
Policies and programs supporting technology adoption

The European Union (EU) programs (co-financed by domestic resources) provide almost 90 percent of the funding for private sector development policies in Poland, including interventions aimed at advancing technology adoption and strengthening complementary factors. EU funding is implemented through the Multiannual Financial Framework (MFF), a seven-year policy cycle in which national and regional priorities are negotiated with the European Commission. As part of the MFF, various groups of beneficiaries, including individuals, firms, and public institutions, are supported through interventions financed from multiple EU-wide funds. Instruments for enhancing private sector development are predominantly cofinanced by the European Regional Development Fund, the subject of this analysis. The current MFF extends from 2021 to 2027; however, implementation of support instruments in the current policy cycle had not started as of May 2022. EU-cofinanced programs are complemented by domestic instruments fully financed from national budgets. Challenges related to the firm-level technology adoption are reflected in national and regional operational programs (Ops) that determine strategic categories of interventions. The technology adoption issue is also reflected in the institutional set-up of the national firm-support ecosystem, but with limited coordination between various institutions. The policy context of the interventions is discussed in more detail in the Appendix.

Distribution of interventions

Technology adoption is financially supported almost exclusively through broad instruments following a demand-driven approach, despite awareness and knowledge of gaps in strategic documents. The demand-driven approach assumes firms are aware of their needs and thus that support programs should be flexible and not impose specific types of support on applicants. The demand-driven approach was initially introduced to guide public investments in business support services in the 2014 – 2020 period. In the current financial period, however, this approach has been extended to most categories of firm-level support. It stands in contrast both to strategic documents (see Appendix) and findings from the Technology Adoption Survey, which show that many firms may not effectively assess their managerial practices and level of technological advancement. Financial support is complemented by other forms of support, such as access to information and technology demonstration services offered by Digital Innovation Hubs or Innovation Centers; however, they account for less than 10 percent of the total support value to private sector development.

FIGURE 4.1 Maximum Value of Public instruments Allowing for Support on Technology Adoption 2014 – 2020 vs. 2021 – 2027 (Number of Instruments in Parenthesis)



Note: National and regional programs are cofinanced by EU sources; domestic programs are financed only from domestic budgets.

Source: World Bank Staff analysis; ERDF and domestic programs only.

TABLE 4.1 Key parameters of the FENG Priority 1: Support for Entrepreneurs programs

Total value	€4,385 million
Implementation period	2022–2027
Support components	Obligatory: • Research and development works • R&D infrastructure Optional: • Implementation of R&D works • Internationalization activities • Services related to protection of intellectual property • Upgrade of managerial capabilities and employees training • Digitization of enterprise, including adoption of digital technologies • Greening of business models, including eco-design, life-cycle assessment, etc.
Managing authority	Ministry of Development Funds and Regional Policy
Implementing body	Polish Agency for Enterprise Development
Public cofinancing rate	For SMEs, up to 75%; for large firms, up to 50%

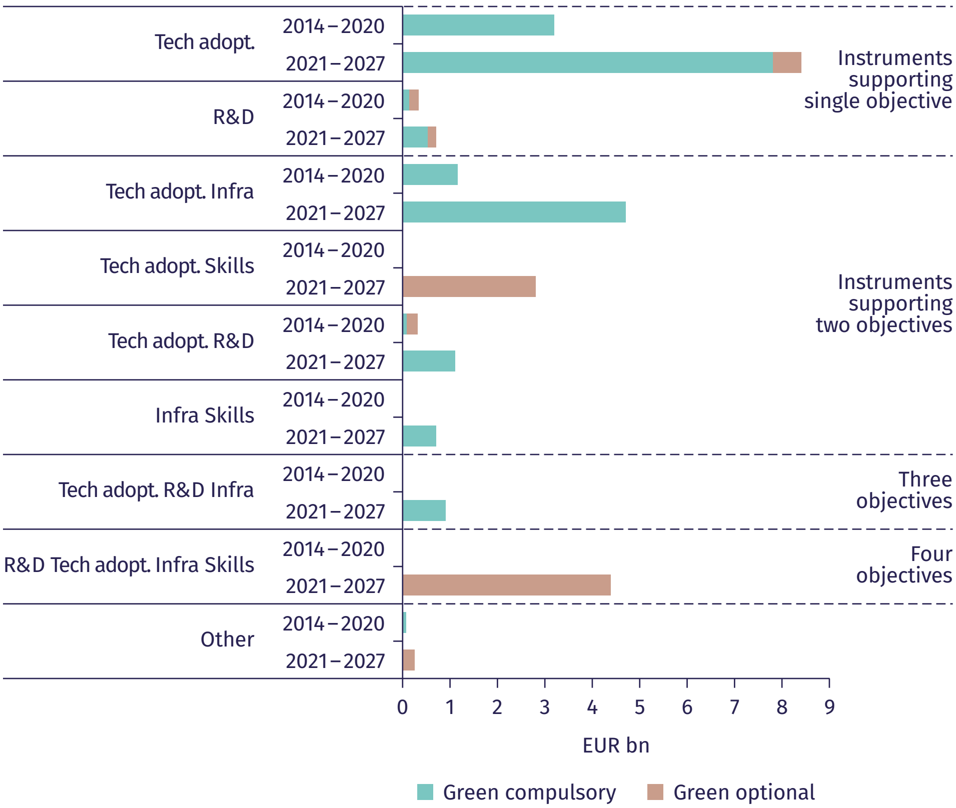
Source: Documentation of the European Funds for Smart Economy operational program.

In 2021–2027, over two-thirds of technology adoption funds at the national level will be provided through a single instrument with a mandatory R&D component. The Support for Entrepreneurs (Wsparcie dla Przedsiebiorcow) instrument is assigned €4.4 billion, including eight support components (Table 4.1). Two of these, R&D works and R&D infrastructure, relate to technology creation, and the instrument makes firms' use of one of the two obligatory, while the remaining modules are optional. Applicants determine the exact mix of components they will choose. The program is open both to SMEs and large firms, with additional criteria for the latter. Eight other EU-funded programs support technology adoption at the national level: six are dedicated to adoption of sustainable technologies, and two target sector-specific technologies for advanced manufacturing. Similarly, seven out of nine domestic instruments (funded from domestic budgets) support adoption only of sustainable technologies. The mix of instruments supporting green technologies is provided in Box 4.1.

BOX 4.1 Support for adoption of green technologies

While the overall funding for firm-level support through EU resources remained largely unchanged between the previous (2014–2020) and current (2021–2027) operational periods, support for adoption of green technologies significantly increased. Support provided by direct green instruments has been categorized into four types of activities: technology adoption, R&D, infrastructure, and skills. In both financial perspectives, the biggest share of budget specifically aims to support green technology adoption or a combination of green technology adoption and green infrastructure. The total value of potential public support for adoption of green technologies increased from €5.1 billion to €13.0 billion; however, the funds may not necessarily be spent on green aims, as the funding increase is mainly driven by introduction of a new "optional" green objective to instruments that support many other policy areas (Figure B4.1.1).

FIGURE B4.1.1 Value of Green Support Instruments per Green Objective, 2014–2020 vs. 2021–2027



Source: World Bank analysis, ERDF and domestic programs only.

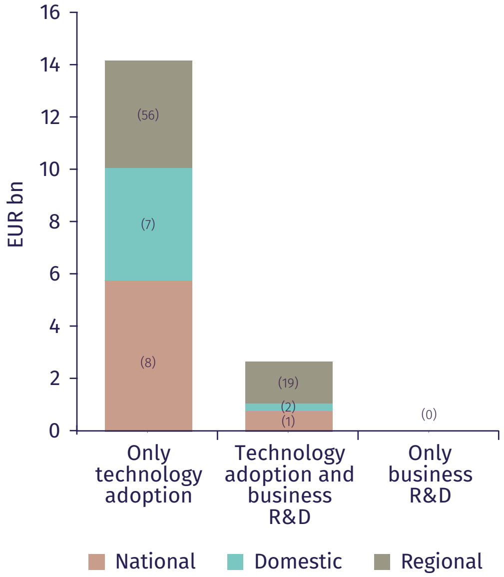
Instruments supporting adoption of green technologies are more targeted than are interventions aimed at increasing general technology upgrading. Support of complementary factors is rarely provided. Catalogues of eligible costs in green-specific instruments limit the types of technology adoption that can be supported. Moreover, the criteria for selecting green instruments require not only indicating what technologies will comply with the catalogue of supported investments, but also showing how their adoption will contribute to decreasing a firm's negative climate or environmental impact. For instruments supporting general technology adoption, less than 10 percent of funds are allocated to instruments that support building skills along with investing in technology adoption.[a] Specifically, in both the current and past financial perspectives, no single instrument supports both adopting green technologies and enhancing skills.

a. Additional funding for investments to strengthen human capital, including developing green skills, is offered in support instruments addressed to individuals and financed by the European Social Fund. Because the companies are not direct recipients of support under the ESF cofinanced programs, they remain outside the scope of this analysis.

Source: World Bank (2022), *Poland — Green Growth Country Economic Memorandum* (forthcoming).

At the regional level for the 2021 – 2027 programming period, support for adopting and for creating technologies is sometimes bundled in the same instruments, with a returnable component envisioned for technology adoption and a nonreturnable component for technology creation. This division aligns with best practices and reflects that uncertainty about results related to technology adoption is significantly lower than for research and development.[34] Technology adoption, unlike its creation, does not usually lead to positive external results for other enterprises. For the above reasons, use of returnable public investments in technology adoption is justified. In 2021 – 2027, support for technology adoption and creation is in most cases combined in a single instrument. Among 75 regional instruments allowing financing for investments in technology adoption, 19 also allow financing to cover expenses related to creating technology (Figure 4.2). In such instruments, technology adoption is supported by loans and credits, while R&D is supported through grants. When this document was being finalized, documentation of operational programs had not been completed; therefore the value of budget of repayable and nonrepayable components is not known. Technology adoption itself, without the necessary R&D component, is not supported in more developed regions, e.g., Dolnoslaskie, Mazowieckie, and Wielkopolskie, or in national programs.[35]

FIGURE 4.2 Public instruments Supporting Technology Adoption on the Regional Level, 2021 – 2027 (Number of Instruments in Parenthesis)



Source: World Bank Staff analysis; ERDF and domestic programs only.

Except for the green focus, most instruments for advancing firms' technological sophistication are technology-agnostic. Multiple regional instruments state as their objective advancing adoption and use of "modern" or "advanced" technologies, but that approach is reflected neither in eligibility nor in selection criteria. The defining criteria for supporting technology adoption is the introduction of

34. X. Cirera, J. Frias, J. Hill, and Y Li, *A Practitioner's Guide to Innovation Policy: Instruments to Build Firm Capabilities and Accelerate Technological Catch-Up in Developing Countries* (Washington, DC: World Bank, 2020).

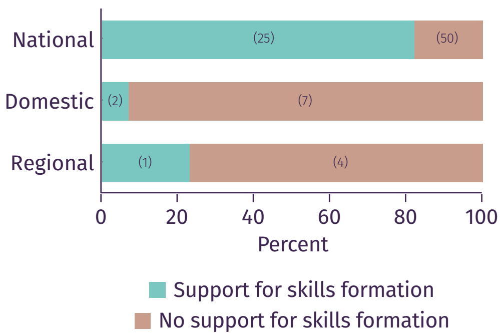
35. Ministry of Development Funds and Regional Policy, *Projekt Umowy Partnerstwa dla Realizacji Polityki Spojnosci 2021 – 2027 w Polsce* (Warsaw: Ministry of Development Funds and Regional Policy, 2021).

"firm-level innovation" — defined as a process, product, or organizational innovation — into the project.[36] Based on learning from the past financial period, it might be expected that communication concerning these programs will reflect stated objectives and encourage enterprises to apply for support to adopt relatively sophisticated sector-specific technologies, despite the possibility of also financing projects to adopt general business function technologies. Two national instruments have narrow technological scope and support only advanced manufacturing technologies that can lead to developing Industry 4.0 capabilities. Of the 75 regional interventions, 21 include preferences for digital solutions in the selection process, with no further differentiation between types of digital technologies.

Policies and programs supporting complementary factors

Managerial capabilities and skills upgrading

FIGURE 4.3 Value Share of Instruments Allowing Support for Skills Upgrades in Total Instruments Supporting Technology Adoption, 2021–2027 (Number of Instruments in Parenthesis)



Source: World Bank Staff analysis; ERDF and domestic programs only.

Evidence from the TAS and scientific literature on the crucial role of managerial capabilities in technology adoption is not reflected in supply-side policies, as only one-third of all instruments to support technology adoption allow financing for skills upgrading. On the national level, no instrument other than the multi-objective Support for Entrepreneurs intervention envisages financing for both skills upgrading and technology adoption. Among regional programs, all programs that allow skills upgrading along with technology adoption focus on sustainable technologies. The capacity-building component supported in regional instruments must align closely with the primary project objective related to business R&D or non-R&D innovation (adoption of new processes, products, and organizational improvements). Thus, programs supporting the introduction of general business functions technologies are scarce.

36. M. Polder, M. Mohnen, G. van Leeuwen, and W. Raymond, "Product, Process and Organizational Innovation: Drivers, Complementarity and Productivity Effects," *SSRN Electronic Journal* (2010).

In half of the regions, upgrades to managerial capabilities and to employees' skills are financed under separate instruments, channeled through the Development Services Database. Eight of 16 regional programs for 2021 – 2027 envisage separate instruments to support development of firm capabilities, all of which deliver the support through the database. The Development Services Database (BUR) gathers information on providers of business advisory and training services to facilitate search and comparison of services for entrepreneurs, based on the key assumption that firms are aware of their needs and can select the best business services for them based on the information the database provides. The BUR is also intended to maintain quality of services by certifying providers and publishing satisfaction evaluation results about individual providers. The database is operated by PARP separately from instruments covering costs of services for enterprises, which are implemented as part of national and regional operational programs. Enterprises can freely choose from 12 types of development services, including support in strengthening managerial and organizational capabilities, technical advisory services, and financial assistance. Experience from the first few years of system implementation, including channeling over €0.4 billion of support to approximately 50,000 beneficiaries, reveal areas for improvement related to quality of providers, role division, and prices of services, while shortening the time between application and service delivery is seen as one of the tool's main advantages.[37] The demand-driven approach using the BUR remains the primary approach for supporting firm capabilities in the current financial period.

BOX 4.2 Pilot programs for building firm capabilities

Parallel to BUR, two pilot programs implemented by PARP tested alternative modalities for supporting skills formation in SMEs. The SME Manager Academy (Akademia Menedzera MSP) and Innovation Manager Academy (Akademia Menedzera Innowacji) differ from the BUR approach to strengthening firm capabilities by adding support to firms in determining their needs. In both pilot instruments, SMEs receive assistance from consultants in selecting packages of development services, a significant departure from the demand-driven assumption that governs the main body of support. The differences between the two pilots are described in Table B4.2.1.

37. Danae, Ewaluacja *Wpływ Bazy Usług Rozwojowych na Jakość i Rynek Usług Rozwojowych oraz Ocena Podmiotowych Systemów Finansowania — Etap II* (Warsaw: Polish Agency for Enterprise Development, 2020).

TABLE B4.2.1 Summary of pilot initiatives for SME skills formation

	SME Manager Academy	Innovation Manager Academy
Objective	To boost managerial competence and adaptation abilities of SMEs by offering them training and advisory services in managing the company, including human capital management.	To equip managers (mid- and high-level) and key personnel with the competence (skills) needed to manage innovation in their companies.
Beneficiaries	SMEs, in particular their managers.	Firm of all sizes, in particular mid- and high-level management.
Content of program	Phase 1 (analytical phase): assessment of firm's growth potential and managerial skills by an external expert and selection of suitable development services. Phase 2 (development phase): application for and implementation of services prescribed by the expert in phase 1.	Services available from PARP's experts (Innovation Health Check Analysis + 60 hours of external advisory/coaching services for micro-companies and 120 hours for small/medium/large companies).
Governance	Ministry of Development Funds and Regional Policy as managing authority, PARP as intermediary body, 5 operators in Poland as implementing institution.	Ministry of Development Funds and Regional Policy as managing authority, PARP as implementing institution.
Program value	€30 million	€7 million
Public cofinancing rate	Grants cofinancing 50 to 80% of initial service costs.	Grants cofinancing 50 to 80% of initial service costs (depending on number or participants and size of the company).

Source: World Bank staff analysis.

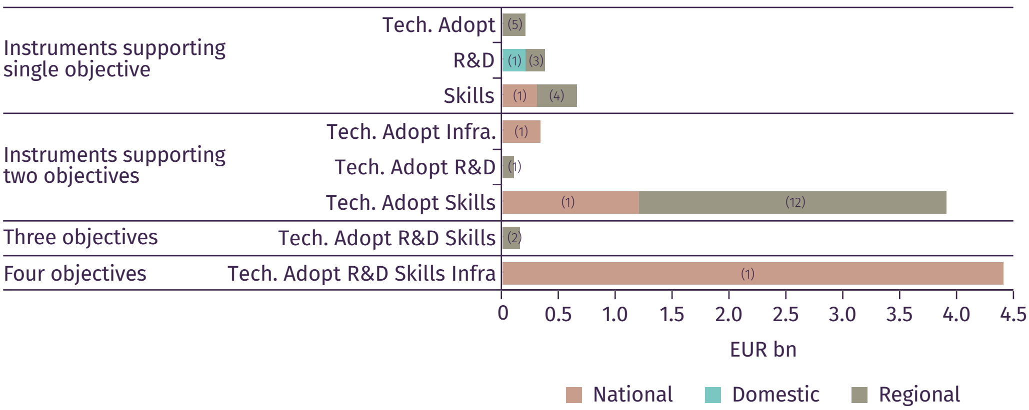
Initial results of pilots of both instruments suggest the positive impact of providing advisory services to businesses that are determining their development needs, but supply-side constraints limit the programs' scale-up potential. Beneficiaries of both programs declare high satisfaction with their participation and the great usefulness of the services received.[a] Upfront diagnostics led not only to services better tailored to enterprises' needs, but also helped increase companies' awareness of development challenges. The challenge was to find and coordinate an appropriate number of consultants to support companies in diagnosing their needs. When such programs are scaled up, the problem of limited availability of high-quality consultants is expected to intensify. Although learning generated from pilots justifies broadening the offer of modalities tested in the pilot programs, the quality of evidence is limited by the perfunctory monitoring and evaluation systems and lack of follow-up data collected on beneficiaries.

a. Information gathered during functional analysis interviews with representatives of an agency responsible for implementation of both pilot programs.

Digital readiness

The public support for firm-level digitization is concentrated in a dozen instruments with multiple digital objectives. Out of 138 interventions for private enterprises, 32 instruments specifically aim to enhance digitization of private enterprises (Figure 4.4). The cumulative value of these programs in the current financial period equals €9.8 billion, half of which is concentrated in the horizontal program Support for Entrepreneurs at the national level, described in detail in Table 4.1. In twelve regions, digital objectives are explicitly stated in general programs supporting firm-level competitiveness. Most of these programs support not only multiple digital objectives, but also other types of firm outcomes, such as greening, internationalization, or skills development.

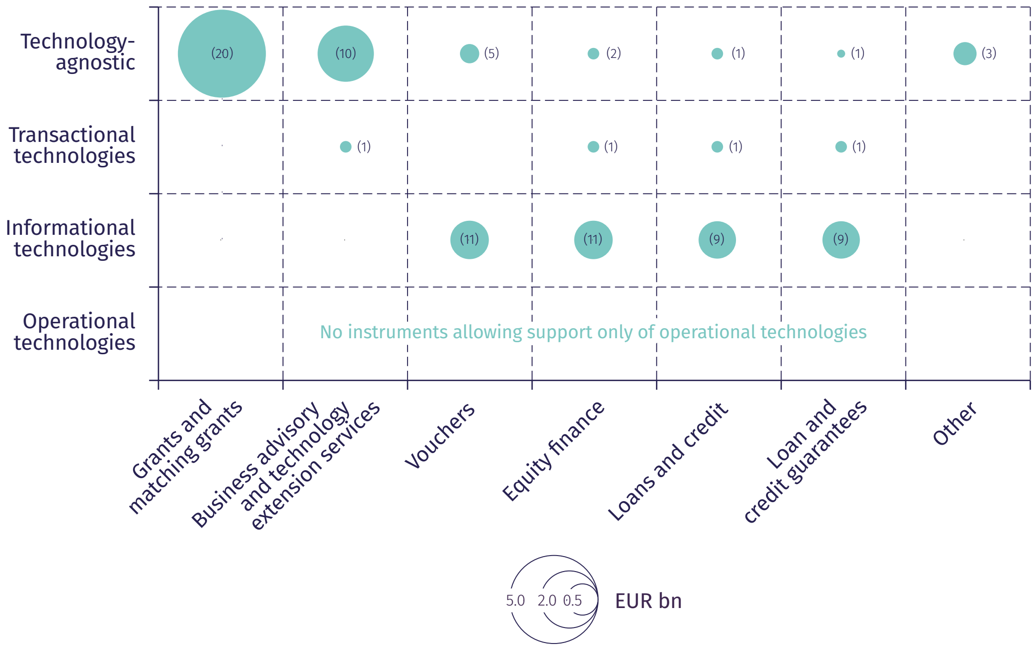
FIGURE 4.4 **Value of Firm-Level Public Support Instruments for Digitization per Digital Objective, 2021–2027 (Number of Instruments in Parenthesis)**



Source: World Bank staff analysis; ERDF and domestic programs only.

Similar to nondigital technologies, interventions promoting digitization are predominantly technology-agnostic, although with a higher use of nonrefundable support. Eight out of ten cents envisaged to support private sector digitization is technology agnostic, with the remaining part targeting support to operational technologies (e.g., machine learning and artificial intelligence). Only one instrument offers dedicated support for transactional technologies (Figure 4.5). Out of numerous instruments with the stated objective of enhancing adoption of Industry 4.0 and other advancing manufacturing technologies, all offer technology-agnostic support. Over 55 percent of all public investments to support firm digitization in 2021–2027 are distributed through grants, followed by 18 percent of the budget financing business advisory and technology extension services, both of which support all types of digital technologies.

FIGURE 4.5 Value of Firm-Level Public Support Instruments for Digitization per Type of Technology and Form of Support, 2021–2027 (Number of Instruments in Parenthesis)



Note: The count of instruments is higher than the total number of instruments supporting firm-digitization, as a single instrument could support multiple technology types and forms for support. In the case of instruments offering multiple forms of support, value has been divided equally between each form of support.

Transactional technologies = Solutions for matching supply and demand, such as platforms and distributed ledger technologies (e.g., Amazon, Spotify, Uber).

Informational technologies = Computing and data storage solutions, including cloud computing, big data analysis, and machine learning (e.g., Facebook, Google, SAP).

Operational technologies = Solutions for reducing labor costs through automation and robotization (e.g., ABB, Fanuc, Siemens).

Source: World Bank Staff analysis; ERDF and domestic programs only.

Digitization of enterprises is additionally indirectly supported through investments in public digital infrastructure and digital skills creation among individuals. Under the NextGenerationEU (NGEU) intervention, €3.6 billion will be invested in a complex digitization of the economy and society.[38] Support will be provided for easing barriers in supply-side drivers of technology adoption, such as strengthening access to ultra-fast broadband, improving the quality of digital public services, and improving the regulatory framework for robotization. Participation of private enterprises, in partnership with public institutions, is envisaged in selected NGEU instruments.

38. Calculation based on the analysis of the National Recovery and Resilience Plan, after social consultations in April 2021, following the approach of in the World Bank publication *Europe 4.0 — Addressing the Digital Dilemma* (2021).

Awareness raising

Despite recognition of limited awareness among Polish SMEs of strategic documents addressing the benefits of and conditions necessary to adopt technology, elaborated initiatives to overcome these informational barriers have only recently begun to be implemented. Incomplete information about technology, such as knowledge on how to use it, uncertainty about its returns, and unpredictability about its effectiveness under different conditions, are well-known constraints to technology adoption. Communication about instruments aimed at supporting technology adoption and strengthening complementary factors was generic; focused on administration aspects of interventions specific to EU cofinanced programs in Poland; and disseminated predominantly through public implementing bodies and consulting firms and service providers financed under public interventions. More personalized communication methods, such as mobile or digital technologies, remain limited and underused. However, since 2019 two new initiatives have been launched to strengthen information transmission channels: the pilot of the Digital Innovation Hubs (see Box 4.3) and the establishment of the Future Industry Platform.

BOX 4.3 Pilot of the Digital Innovation Hub network

The Digital Innovation Hubs network supports firms in adopting Industry 4.0 technologies by addressing informational barriers and market failures related to information asymmetry and coordination. DIHs are intended to be local orchestrators leveraging tech offerings from private and public entities by providing complementary awareness raising, education, and ecosystem activities. The DIH network allowed specialization of individual hubs by facilitating exchange of customers with the objective of promoting and providing (i) easily accessible sets of tech-agnostic services to help build readiness for tech adoption, and (ii) technology extension services. Its creation was supported by the European Commission, as a part of the Digital Europe Program, a centrally managed €9.2 billion funding program focused on bringing digital technology to businesses, citizens, and public administrations.[a] From 2022 onwards, financing for DIHs will be provided directly by the European Commission; as of May 2022, selection of European DIHs is ongoing.

Five DIHs in Poland were piloted by the Ministry of Economic Development and Technology in 2019–2021. The pilot assigned €7 million to build operational capacity before applying for the European funding. Results showed numerous challenges that, with other issues, decreased the hubs' activities on raising awareness. The piloting proved to be a useful testing ground to understand how DIHs might work. DIHs assumed that advanced technological aspects are of greatest value to SMEs and operated in a narrow range of advanced technologies. Thus they did not serve as one-stop-shops for comprehensive digital transformation. Moreover, as the pilot DIHs were composed predominantly of technology-focused institutions, hubs had limited experience working with SMEs at early stages of technology adoption.

a. European Commission, Digital Europe Programme 2021–2027: EU Budget for the Future (Brussels: European Commission, 2021).

Source: World Bank Staff analysis as a part of the Supporting a Sustainable and Resilient Recovery from COVID-19 in Poland project.

The Future Industry Platform (FPPP), a nonprofit foundation supervised by the Ministry of Development and Technology, was created in 2019 to raise awareness among Polish firms of the benefits of adopting Industry 4.0 technologies and to strengthen the capacity of the DIH network. However, its activities remained limited due to organizational challenges. From the very beginning of the foundation's activity, it directly promoted technology adoption and engaged with managers through webinars, trainings, and conferences, albeit on a relatively limited scale.[39] To enhance dissemination of knowledge about the benefits of adopting technologies and about available public support, the FPPP could engage both directly with a larger set of firms and fine-tune its activities toward DIHs. In the former case, the Foundation could perform mass awareness raising campaigns about the business potential of technology upgrading and offer direct training for managers. In the latter case, the FPPP might provide technical assistance and capacity building for DIHs, interact with firms and redirect them toward appropriate partners supporting technology adoption, and manage a pool of experts shared across the network.

Lessons learned from past interventions

Based on over 15 years of experience implementing instruments to support technology adoption in Poland, numerous factors determining its effectiveness were identified. Polish firm-level support ecosystem is subject to numerous evaluations. In 2007 – 2022, over 550 external assessments and evaluations of instruments supporting enterprises were conducted following requests from authorities managing their delivery.[40] Additionally, interventions and policies aimed at enhancing firm growth and productivity upgrading were analyzed by academic researchers and international organizations, including the World Bank.[41] This section provides an overview of key lessons from past interventions that might enhance impact or create obstacles in the design and implementation of support programs aimed at technology adoption. Particular attention is paid to documented best practices not envisaged to be introduced in the current financial period.[42]

39. Fundacja Platforma Przemysłu Przyszłości, *Sprawozdanie z działalności za rok 2020* (Radom: Fundacja Platforma Przemysłu Przyszłości, 2021).

40. Ministry of Development Funds and Regional Policy, *Baza Badań Ewaluacyjnych — stan na 27 maja 2022 roku* (Warsaw: Ministry of Development Funds and Regional Policy, 2022).

41. In 2015 – 2021, the World Bank concluded seven projects that included analysis of public support instruments for firm-level productivity growth in Poland.

42. As of May 2022, the implementation of operational programs for the financial perspective 2021 – 2027 had not begun but is in an advanced stage of preparation. Therefore, some best practices described below could be applied in the final version of the programs.

Technology adoption was supported by generic instruments, with limited targeting of or adaptation to the heterogeneity of diffusion processes, contrary to sophisticated interventions aimed at enhancing technology creation. Adoption of technologies in 2014 – 2020 was financed through general programs supporting firm development that covered multiple objectives: technology adoption was the predominant focus of only 23 instruments. At the same time, business R&D was addressed in 115 instruments, most of which had narrowly defined objectives.[43] For example, instruments financing projects were at various stages of technological readiness and firms were of different maturity or active in particular sectors, and a wide array of targeted interventions supported complementary factors (such as business-science collaboration, technology transfer, or commercialization of scientific research). The above distinction in approaches toward supporting adoption and creating technologies is also prevalent in the current financial perspective, except for adoption of green technologies, which are supported by programs that allow costs covering specific equipment (e.g., low-carbon energy sources, recycling, or smart monitoring). Results of the survey show the need to integrate characteristics of firms and particular types of technology into support instruments.

No instrument for technology adoption had an obligatory needs assessment component. Following the demand-driven intervention model, firms are assumed to be aware of their development needs and able to independently determine what projects that address their needs are eligible for public support. Regulations of support programs require applicants to provide business justification for every single project envisaged for support. In practice, however, it is often advisers, commissioned by enterprises, who prepare the applications with only generic justification for the need for support.[44] The use of a needs assessment was piloted by the Polish Agency for Enterprise Development in private sector development instruments aimed at supporting objectives other than technology adoption. Succession in Family Firms (Sukcesja w Firmach Rodzinnych) supported firms in preparing and executing transition plans, while Early Warning Europe Poland assisted enterprises endangered by bankruptcy to

43. World Bank, *Return on Investment of Public Support to SMEs and Innovation in Poland — Portfolio Mapping Technical Note* (Washington, DC: World Bank, 2020).

44. This was indicated by evidence generated from interviews with enterprises and institutions engaged in managing and implementing public support programs as part of the World Bank project Supporting a Sustainable and Resilient Recovery from COVID-19 in Poland.

restructure. Two additional instruments — SME Manager Academy (Akademia Menedzera MSP) and Innovation Manager Academy (Akademia Menedzera Innowacji) — strengthened managements through tailored training. In all of these pilot programs, needs assessment were performed by a centrally managed network of consultants who were encouraged to exchange knowledge and were offered trainings to increase their capabilities on the job. Standardization of assessment of firm needs resulted in high-quality needs assessments that were useful in constructing an appropriate support package.

Results of impact evaluations suggest that beneficiaries of firm-level support instruments increase the scale of their operations, with mixed evidence on productivity growth. The impact evaluation so far has generated little information on technology adoption, focusing almost exclusively on analyzing the impact of support on traditional performance measures reported in financial statements. Nevertheless, results indicate the varied impact of public interventions according to the company's characteristics and modality of support (Table 4.2). Several consistent conclusions emerged from impact evaluations carried out with different methods, including various programs and timeframes. First, public interventions generate high additionality of private investments, but at the same time the effect of substitution is visible: applicants, before submitting applications, usually limit their investment outlays to collect funds for their own contribution. Second, beneficiaries of programs supporting technology adoption significantly increased revenue and employment compared to non-beneficiaries, with little impact on productivity and investments unrelated to supported projects. Third, the increase in scale of operations resulting from public support was bigger in younger and smaller firms than in more mature and larger enterprises. A similar differentiation of the effects of support was observed during the analysis of private sector development programs in 2007 – 2013.[45] Results of qualitative research show the existence of a deadweight effect, indicated in the results of quantitative research in which over half of beneficiaries declared that they would implement a project without public support, but on a smaller scale and later. As a multitude of firm-level support programs exist in Poland, many enterprises are beneficiaries of more than one intervention, creating challenges in evaluating their impact relevant to establishing an appropriate identification strategy.

45. World Bank, *Return on Investment of Public support to SMEs and Innovation in Poland — Effectiveness/ROI Analysis Technical Note* (Washington, DC: World Bank, 2020).

TABLE 4.2 Summary of selected impact evaluations studies of multiprogram, firm-level technology upgrading instruments

Study name	Programs covered	Timeframe	Methodology	Results
Bluehill (2022)	All interventions from the thematic objective 3 (support for SME competitiveness) in Opolskie Regional OP	2014–2020	Regression Discontinuity Design (RDD)	• Public support for R&D resulted in increased revenue with few new patents or other IP generation. • BSIs services are effective in supporting firms in introducing firm-level innovation.
Idea, PAG Uniconsult, Imapp (2021)	All interventions from the thematic objective 1 (innovativeness) from the national-level Smart Growth OP and from 16 regional OPs	2014–2019	Dynamic stochastic general equilibrium models (DSGE) and cluster analysis	• Support for R&D projects leads to increase in investment outlays, but limited IP output. • Impact of instruments including a capacity-building component is higher than interventions limited to financial support. • Impacts are higher among younger and smaller firms.
World Bank (2020)	Over 70 direct and 50+ indirect support instruments from national OPs and 16 regional OPs	2007–2013	Difference-in-difference (DID) with Propensity Score Matching (PSM)	• Positive impact of support instruments was achieved on increasing scale of operations, not productivity. • Strongest impact was achieved on young and micro and small firms, as well as in the manufacturing sector. • Support for firm competitiveness and business R&D turned out to be cost-effective in creating jobs.
Evalu, STOS, WiseEuropa (2020)	All interventions from the thematic objective 3 (support for SME competitiveness) in 16 regional OPs	2014–2018	DID with PSM and RDD	• Slightly positive impact was seen on productivity of some programs. • High additionality was achieved: US$1 of public support generated US$3.2 of additional private investments.

Note: BSI = business support institutions; CAPI = Computer Assisted Personal Interviewing; DID = difference in difference; IDI = individual in-depth interviews; IP = intellectual property; RDD = regression discontinuity design; PSM = propensity score matching.

Research sources were as follows:

Bluehill (2022). Efekty wsparcia konkurencyjności, innowacyjności I internacjonalizacji MŚP i rozwój potencjału jednostek naukowo-badawczych w województwie opolskim w perspektywie 2014–2020.

Idea, PAG Uniconsult, Imapp. (2021). Wpływ wsparcia działalności badawczo-rozwojowej w polityce spójności 2014–2020 na konkurencyjność i innowacyjność gospodarki — I etap: badanie w trakcie wdrażania.

World Bank (2020). Return on Investment in Public Support to SMEs and Innovation in Poland.

Evalu, STOS, WiseEuropa (2020). Ewaluacja regionalnej pomocy inwestycyjnej w zakresie celu tematycznego 3 w obszarze wzmacniania konkurencyjności mikroprzedsiębiorstw oraz MŚP w ramach regionalnych programów operacyjnych na lata 2014–2020.

Source: World Bank Staff analysis.

Most of the support for private sector development goes to recurring beneficiaries. Over 80 percent of beneficiaries of the Smart Growth Operational Program received public support from other programs in the past.[46] The dominance of recurring beneficiaries in the structure of enterprises receiving support is also visible at the regional level, although to a lesser degree.[47] This is likely because most programs' promotional and informational campaigns are carried out by institutions involved in their implementation, with communication channels that mainly reach enterprises already familiar with the public support system, or include passive activities, such as displaying acknowledgment of EU funding.[48] Instruments financed from the European Social Fund targeting individuals could be a source of good practices in communications to promote programs to enterprises.[49] Information campaigns in mass media or intensified promotion through digital channels may contribute to increased awareness among SMEs about possible support for adopting technology. Inefficiencies in disseminating knowledge about support programs correspond to survey responses indicating that a large group of enterprises are unaware of public support programs.

The technological loans instrument has successfully mobilized private capital for technology adoption across heterogeneous groups of firms. Through technological loans, the National Economy Bank (BGK) provided subsidies for partial repayment of loans acquired by enterprises from commercial banks to finance expenditures for technology adoption.[50] Eligible costs related to expenditures for purchasing and implementing a new external technology or implementing internally developed new technology expected to lead on its basis to new or significantly improved goods, processes, or services. In seven rounds, almost 900 SMEs received support with the cumulative value of €702 million and the program

46. Borowczak, et al., *Ewaluacja pierwszych efektów wsparcia PO IR w zakresie prac B+R oraz wdrażania wyników prac B+R realizowanych w przedsiębiorstwach* (Warsaw: Polish Agency for Enterprise Development, 2020).

47. Urząd Marszałkowski Województwa Śląskiego, *Ewaluacja dotycząca wsparcia sektora przedsiębiorstw w RPO WSL 2014 – 2020* (Katowice: Urząd Marszałkowski Województwa Śląskiego, 2021).

48. EGO (Evaluation for Government Organisations), *Metaewaluacja wyników dotychczasowych badań ewaluacyjnych i innych (wniosków i rekomendacji) dotyczących informacji i promocji Funduszy Europejskich i poszczególnych programów operacyjnych (Warsaw: Evaluation for Government Organisations, 2013); Ministry of Regional Development and Infondo, Analiza efektywności funkcjonowania sieci Punktów Informacyjnych Funduszy Europejskich w latach 2017 – 2019.* (Warsaw: Ministry of Development Funds and Regional Policy, 2021).

49. Danae, *Badanie rozpoznawalności i wiedzy o Funduszach Europejskich w społeczeństwie polskim: Edycja 2020* (Warsaw: Ministry of Development Funds and Regional Policy, 2020).

50. The instrument was implemented under the Submeasure 3.2.2 of the Operational Programme Smart Growth on the national level; *Szczegółowy Opis Osi Priorytetowych Programu Inteligentny Rozwój 2014 – 2020* (Warsaw: Ministry of Development Funds and Regional Policy, 2022).

enjoyed very high interest among applicants. The effort was made possible (i) by providing commercial banks with a clear incentive to build awareness about the instrument, and (ii) by organizing ongoing calls for applications.[51] The technological loan could also serve as a best practice for showing evidence of learning during implementation, as the instrument was several times adapted to reflect feedback from beneficiaries.

Overlap in returnable support for technology adoption between national and regional levels decreased the effectiveness of support. Support instruments for firms show considerable fragmentation, which increases the risk of duplication of support between national and regional agencies and leads to situations where most objectives are covered by many instruments. In 2014 – 2020, private sector development was the aim of 297 support instruments, compared to 156 in 2021 – 2027, with over half of the support value concentrated in a dozen interventions.[52] Coordination takes into account the largest of the interventions. For example, implementation of technology loans on the national level is planned to be continued, and the institutions managing regional programs are aware of these plans, at least in some voivodeships, as no similar instruments are planned.[53] However, it's crucial to pay close attention to duplication and overlaps with lesser-known instruments. In the previous financial perspective, duplication or overlap of support resulted in competition between regional and national instruments with the same objectives and target groups.[54] National instruments enjoyed a greater uptake among entrepreneurs due to shorter and simpler administrative procedures and slightly more favorable financing conditions, hindering disbursement of funds by the marshals' offices.

Relations between the regions and the National Economy Bank (BGK), despite initial difficulties, turned out to be effective in implementing the financial instruments included in the regional operational programs. The National Economy Bank acts as a manager of funds for the financial instruments to support

51. PAG Uniconsult, *Analiza porównawcza instrumentów w ramach działania 3.2 PO IR* (Warsaw: Ministry of Investments and Development, 2018).

52. The number of instruments is expected to increase with time. As of May 2022, implementation of interventions envisaged for the 2021 – 2027 financial perspective had not yet started, but between October 2019 and May 2022, the number of firm-level support instruments increased from 182 to 297.

53. PAG Uniconsult, Imapp, *Ewaluacja wyników wdrażania zwrotnych instrumentów finansowych realizowanych w ramach RPO WM 2014 – 2020 wraz z analizą ex-ante dla perspektywy finansowej 2021 – 2027* (Kraków: Urząd Marszałkowski Województwa Małopolskiego, 2020).

54. World Bank, *Return on Investment of Public Support to SMEs and Innovation in Poland — Functional Review Technical Note* (Washington, DC: World Bank, 2020).

technology adoption implemented in 15 out of 16 voivodships. Initially, cooperation between the Bank and marshals' offices faced challenges due to lack of agreement on scale of differentiation of financial instruments between regions — they all covered similar objectives and were addressed to homogeneous target groups, but differed in support parameters, which created operational difficulties for the Bank. To ensure smooth implementation of instruments and to streamline exchange of information between institutions engaged in the process, the Bank developed a dedicated IT platform that addressed initial difficulties. Therefore, it is worth considering the use of BGK's existing capabilities and the principles of cooperation between the marshal's offices and BGK to distribute financial instruments, without the need to establish new regional institutions for growth funds. Participation of national development banks would also help raise awareness about support programs, as enterprises across the country are increasingly familiar with the business profile of both National Economy Bank (BGK) and Polish Development Fund (PFR).[55] This is because BGK strengthened 16 regional branches in 2018 – 2019 and PFR distributed support under anti-COVID packages to over 1.5 million enterprises.[56] Procedures established between the marshals' offices and the Bank could also be useful for managing returnable funds from the previous financial perspectives that could be reused by the regions.[57]

Functionality of firm-level support instruments is unequal and differs significantly between the design and implementation areas. Areas with strong performance often result from requirements under European regulations, which precisely define certain design and implementation areas. In areas with more discretion for managing and implementing institutions, distance from international best practices varies.[58] While most interventions have a comprehensively identified catalogue of products and outputs, the lists of activities or outcomes could be more detailed. Instruments are designed in consultative processes, but their design is often generic, resulting from high-level European policies with limited adaptation to local contexts. Insufficient coordination between institutions in the firm support ecosystem results in redundancies in both design and implementation, with numerous cases of direct competition between similar instruments

55. Bank Gospodarstwa Krajowego, *Sprawozdanie Zarządu z Działalności Grupy Kapitałowej Banku Gospodarstwa Krajowego w 2020 roku* (Warsaw: Bank Gospodarstwa Krajowego, 2021).

56. Polski Fundusz Rozwoju, *Skonsolidowany Raport Roczny Grupy Kapitałowej PFR* (Kraków: Polski Fundusz Rozwoju, 2022).

57. Polski Fundusz Rozwoju, *Skonsolidowany Raport Roczny Grupy Kapitałowej PFR* (Kraków: Polski Fundusz Rozwoju, 2022).

58. World Bank, *Return on Investment of Public Support to SMEs and Innovation in Poland — Functional Review Technical Note* (Washington, DC: World Bank, 2020).

offered by national and regional authorities. Administration of ongoing calls and projects was high quality overall, with the biggest space for improvement in process digitization and development of human resources at the managing and implementing authorities. Monitoring and evaluation systems could also be strengthened to improve evidence production on impacts to improve ongoing learning and future program design.

V

POLICY RECOMMENDATIONS

Technology sophistication among Polish firms could be strengthened by reforms in five key areas: building awareness, supporting technology adoption, supporting firm capabilities, reducing barriers to scaling up, and coordinating and using data. Table 5.1 summarizes the recommendations based on the report's findings, with information on priorities and key stakeholders. The highest priority is assigned to reforms directly related to designing and implementing EU co-financed investments in public support instruments for the 2021 – 2027 financial perspective, as implementation has not yet started. The recommendations also build on previous World Bank projects, including Return on Investment of Public Support to SMEs and Innovation (2020) and Supporting Resilience and Recovery of Polish Enterprises (2021).

TABLE 5.1 Recommended policy actions

Area	Recommendation	Priority	Key stakeholders
Building awareness	Include needs assessment component in instruments supporting technology adoption	High	MFiPR, PARP, marshals' offices
	Enhance capabilities of the Future Industry Platform in raising awareness of technology adoption	High	MRiT, FPPP
	Revise approach to building awareness of technology adoption	Medium	MFiPR, MRiT, PARP
	Leverage Digital Innovation Hubs to serve as a one-stop-shop provider of information on technology adoption	Medium	MRiT, DIH, FPPP
Support for technology adoption	Facilitate widespread adoption of off-the-shelf general business function technologies at the core of private sector development	High	MFiPR, MRiT, PARP
	Target public interventions to firms with the highest potential for technological catch-up	High	MFiPR, PARP
	Increase linkages between SMEs and SOEs, including large firms and internationalized tradable sectors	High	MFiPR, MRiT, PARP
	Align instruments supporting adoption of green technologies to readiness of firms in respective sectors	High	MFiPR, MRiT, PARP

TABLE 5.1 Recommended policy actions (continued)

Area	Recommendation	Priority	Key stakeholders
Support for technology adoption	Account for heterogeneity of factors in decisions on technology adoption in support instruments	Medium	MFiPR, MRiT, PARP
	Maintain supply of public support for adoption of operational technologies	Medium	MFiPR, MRiT, BGK, PFR
Support for firm capabilities	Broaden support supplementary capabilities in instruments for financing technology adoption	High	PARP, marshals' offices
Reducing barriers to scaling up	Remove regulatory barriers to scale-up that firms face	Medium	MRiT, MS
	Improve the efficiency of resource allocation in manufacturing	Medium / Low	MRiT, MS
Policy coordination and use of firm-level data	Strengthen monitoring and evaluation systems	Medium	MRiT, MFiPR, PARP, marshals' offices
	Enhance coordination of policies for enhancing technology adoption	Medium	marshals' offices, MoED, MFiPR
	Improve access to statistical data on technology adoption by firms	Medium / Low	Statistics Poland

Note: BGK = National Economy Bank; DIH = Digital Innovation Hub; FPPP = Future Industry Platform; MFiPR = Ministry of Development Funds and Regional Policy; MRiT = Ministry of Economic Development and Technology; MS = Ministry of Justice; PARP = Polish Agency for Enterprise Development; PFR = Polish Development Fund.

Source: World Bank Staff analysis.

Building awareness

Include obligatory technology needs assessments in instruments supporting technology adoption. The Technology Adoption Survey in Poland, similarly to a vast literature from other countries, shows that firms are unaware of the gaps in their technology and organization.[59] Thus, the survey justifies providing support to firms to help them determine their technological needs before they are offered financial incentives to adopt the technology or build supplemental capabilities themselves. Professional assessment of technological needs could increase alignment of projects supported from public resources with areas of firm operation with the highest potential for productivity improvement, which would eventually drive the

59. X. Cirera, D. Comin, M. Cruz, K. M. Lee, and A. S. Martins-Neto, *Firm-Level Technology Adoption in the State of Ceara in Brazil*, World Bank Policy Research Working Paper 9568 (World Bank, Washington, DC, 2021).

development impact.[60] Past experience with publicly financed technology audits in Poland indicate the need to invest in developing high quality and standardized audits and assessments for critical areas related to technology adoption and firm capabilities.[61] While initial audits might benefit from automation through the use of online tools, a follow-up analysis requires creating a group of high-quality technology experts. Lessons learned from instruments that included mandatory needs assessment in other policy areas (not related directly to technology adoption) indicate that valuable audits are performed by a centrally managed network of consultants in an environment conducive to exchange of best practices, transfer of clients, and continuous improvement. Additional learning on delivery of needs assessment advisory services could also be sourced from the Early Warning Europe and Succession in Family Firms programs managed recently by PARP. Their history also shows that scaling up programs with mandatory needs assessment should be gradual, except for use of the online tool, to maintain the quality of the audits.

Enhance capabilities of the Future Industry Platform related to raising awareness of the benefits of adopting all types of technologies. Within three years of its inception, the platform has achieved a level of development that allows it to effectively reach many enterprises with information about the availability of Industry 4.0 solutions. This has been possible thanks to the use of various engagement methods, including webinars, group and individual trainings, and cooperation with business associations, as well as to the expanded community of technological experts and organizational capabilities within the FPPP. The Foundation has also coordinated with the Digital Innovation Hubs network to supply business support institutions with relevant knowledge. This gives the FPPP a proper position to further promote technology adoption among broader audiences by extending outreach to other types of technologies than Industry 4.0 and addressing broad technological needs of SMEs. For this purpose, the Platform would need to further develop its capabilities to allow it to effectively manage and implement a broad informational campaign using mass media. The Platform could also leverage lessons learned about innovative methods for addressing informational barriers among SMEs from implementation of instruments with similar objectives, e.g., the Early Warning Europe and the New Opportunity Strategy (Polityka Nowej Szansy).

60. X. Cirera, J. Frias, J. Hill, and Y. Li, A *Practitioner's Guide to Innovation Policy: Instruments to Build Firm Capabilities and Accelerate Technological Catch-Up in Developing Countries* (Washington, DC: World Bank, 2020).

61. Program managers interviewed by the World Bank indicated that when an assessment of company needs for technology was required, the quality of the assessments was low and consultants sold the same generic write-up to multiple companies.

BOX 5.1 Examples of diagnostic tools

Numerous methodologies for assessing firms' level of technological advancement are currently being implemented, including the Self-Assessment of Digital Maturity (Samoocena dojrzalosci cyfrowej) offered on the Future Industry Platform website. However, methodologies differ in their ability to generate useful insights into enterprises' technological needs, and most are also limited to or predominantly focused on digital solutions. Effective diagnostic tools should address information barriers and overconfidence regarding technological capabilities. Best practice examples of diagnostic tools for identifying firm-level technological needs are presented below.

Belgium's **Digital Wallonia**, a regional public authority managing the digital transformation agenda, performs analysis of digital maturity in two steps. First, a firm completes an online self-assessment questionnaire focused on business processes, which incorporates sales, human resources, and operations perspectives. The self-assessment also includes a sectoral component, allowing retail, construction, and manufacturing firms to offer insights on specific business processes related to their activities. Second, firms are offered tools to analyze in depth their readiness to adopt particular types of technologies, such as cashless payment or additive manufacturing. Results of the assessments can be used to access support instruments offered by the Digital Wallonia.

In Estonia/Latvia, the **Diginno Tool** can be used to assess the digital maturity of managers and employees separately, using two dedicated components. The methodology uses ten business processes (ranging from financial management and controlling to customer acquisition and retention) to set up targets and monitoring plans. Apart from the maturity assessment itself, the tool generates a set of tailored recommendations for action, indicating possible ways to obtain implementation support.

Through Australia's **Tasmania Technology Checkup**, the Tasmanian regional government offers a technology maturity assessment tool in the form of an interactive discussion with an AI-powered chatbot. This delivery method may facilitate the use of the tool by individuals with lower digital competencies, who are among the target groups of technology upgrading programs. The Technology Checkup uses other types of data in addition to user-supplied information, and it automatically analyzes the quality, readability, and positioning of firm websites and social media outreach.

Source: World Bank staff analysis of program documentation.

Improve information sharing to build awareness about business benefits and enablers of technology adoption. The Technology Adoption Survey showed that enterprises across all sectors and size groups have incomplete information about how to use technologies and about the technologies' effectiveness, which drives uncertainty about returns from adoption and use. Limited awareness of key technology factors is a well-known inhibitor of technology upgrading. The survey results indicate that the main reason for a technological switch results from the replacement of dysfunctional or depreciated equipment rather than from a willingness to reap additional benefits from technology upgrading. Entrepreneurs' and managers' general overconfidence in their technological advancement strengthens justification to address market failures related to information asymmetries. Information constraints could be addressed in two ways. First, increase individual learning, leveraging digital means, such hotlines, webinars, or online chats, to spread information about available technologies and their benefits. Second, use interventions that support social learning, including activities conducive to word-of-mouth dissemination of technological knowledge among peers. Awareness raising interventions are expected to have higher impacts on technology use with high network effects where adoption is shown to be driven by the number of known adopters.[62]

BOX 5.2 Examples of online one-stop-shop information platforms

Internet platforms could effectively complement on-site one-shop-shops by lowering informational barriers faced by lagging firms and by addressing coordination problems. The quality of content presented will be critical to its success: to be relevant to entrepreneurs and SME managers, a platform must be up-to-date, technically sound, and understandable for audiences with various levels of prior knowledge. The scope of content could range from case studies of successful implementation of digital tools through how-to guides to training modules. The knowledge must be accompanied by actionable services to incentivize firms to take action. Examples include a matchmaking service with technology providers or contacts with experts from the DIH network.

Examples of online one-stop-shops for addressing informational constraints are presented below.

New Zealand's **Digital Boost** website offers free-to-access video tutorials on various aspects of transferring business operations online, with supplemental learning materials and tutorial one-on-one sessions with professional consultants. Service provision is centralized with one organization—The Mind Lab—a top graduate education institute in the country. The platform is operated by the Ministry of Business, Innovation, and Employment.

In Spain, **Accelera Pyme** is an internet platform with effective tools for assessing firms' technological maturity and for selecting training courses to advance digitization of enterprises at various levels of advancement. Based on the results of assessment and training, the platform forwards enterprises to a network of over 20 physical offices specializing in providing specific advisory services, with costs cofinanced from the state budget. The Accelera Pyme is part of the SME Digitization Plan 2021–2025 managed by the Ministry of Economic Affairs and Digital Transformation.

France's **France Num** offers an educational platform for SMEs with digital learning courses that provide practical knowledge on adopting and scaling use of digital technologies and connects with a scheme of preferential credits for acquiring necessary equipment. The financial product addresses basic technological needs with loans up to €50,000 from six commercial banks. It aims to support technological upgrades for 50,000 enterprises by 2023.

Source: World Bank staff analysis of program documentation.

Strengthen the functioning of the Digital Innovation Hub network as a one-stop-shop information point for addressing the broad range of enterprises' technological needs. The primary objective of DIHs is to address informational barriers preventing firms from adopting and creating digital technologies. The network's mandate could be broadened to include raising awareness about

62. G. Saloner and A. Shepard, "Adoption of Technologies with Network Effects: An Empirical Examination of the Adoption of Automated Teller Machines," RAND *Journal of Economics* 26 (3; 1995).

potential benefits of adopting nondigital technologies as well, after adjusting the offer to meet the needs of less digitally advanced companies. Hubs could provide basic information, assess the need for nondigital technologies, and connect enterprises with appropriate business support institutions, including organizations outside the DIH network, such as regional technological parks, development agencies, local business support institutions, or technology providers. DIHs are the institutions best positioned to perform this task given their combination of technical capabilities and mandate for initiating direct contact with SMEs. While many aspects of the Digital Innovation Hubs are still being developed, including the model for initiating contact with companies, lessons from pilots show that the hubs have started providing relevant services in a relatively short time. However, the quality of their operations varies, indicating the need for standardization. Addressing the needs of SMEs at lower levels of technological sophistication would, in particular, require introducing a replicable approach toward technological maturity assessment and streamlining procedures for transferring companies between DIHs and support service (especially nondigital ones) providers outside the DIH network.

Support for technology adoption

Introduce support for a widespread adoption of off-the-shelf general business function technologies, including less advanced technologies. The TAS results show that firms still often rely on the most basic technologies to conduct some of their everyday operations. But even simple technology upgrades offer a high potential for productivity improvement: improving technology sophistication of the bottom 25 percent of companies to the level of a median company would increase labor productivity in the economy by 1 percent. This requires wide adoption of unsophisticated, already widely used technologies that require relatively low capabilities for adoption. Additionally, many advanced technologies present a business rationale for adoption only for firms that have achieved an appropriately high scale of operations: they are uneconomical for micro or small companies. For these reasons, policies supporting technology adoption should include objectives related not only to diffusion of frontier technologies, but also to incremental, gradual upgrades, while still supporting standardized technology audits and online marketplaces with a wide range of certified off-the-shelf solutions (open source where possible).

Do not focus only on high-growth firms: promote horizontal ecosystem approaches. Episodes of firms' dynamic growth are temporary, rare, and difficult to predict.[63] As 95 percent of enterprises in Poland are micro and small firms, it is of key importance to guarantee the availability of technologies and support services adapted to their needs. Promote a horizontal ecosystem approach rather than predominantly targeting high performers. Despite technological differences, solutions used in various business functions require similar conditions for adoption.[64] For this reason, combine technological readiness already present in firms for particular business functions to leverage adoption in other business functions; e.g., use high sophistication of payment technologies to stimulate upgrades in quality control, marketing, and sales. During the COVID-19 pandemic, many firms quickly escalated their use of e-commerce solutions thanks to previous familiarity with payment technologies.[65] Explore similar concentrations when designing support instruments to maximize their impact.

Increase linkages between SMEs and SOEs, including both large and international firms, through supplier development programs in tradable sectors. Enterprises must generate a financial surplus to cover the fixed and variable costs of adopting technologies. Thus, opportunities for scaling up demand, in both domestic and foreign markets, provide incentives for firms to make the technological switch. The relationship between participation in international trade and technology adoption is well-evidenced both in the Technology Adoption Survey and in the literature.[66] While not all enterprises offer tradable products or services, many of them have potential for increasing participation in national or international value chains. For example, the Czech Republic, Slovakia, and Hungary, despite having economic structures similar to Poland's, have trade-to-GDP ratios several percentage points higher.[67] Effective instruments supporting internationalization, such as supplier development programs and country-focused trainings, successfully incentivize firms to start exporting.[68] The Technology

63. G. A. Grover, D. Medvedev, and E. Olafsen, *High-Growth Firms: Facts, Fiction, and Policy Options for Emerging Economies* (Washington, DC: World Bank, 2019).

64. D. R. King, J. Covin, and W. H. Hegarty, Complementary Resources and Exploitation of Technological Innovations," *Journal of Management* 29 (4; 2003).

65. C. Ungerer, A. Portugal, M. Molinuveo, and N. Rovo, *Recommendations to Leverage E-commerce during the COVID-19 Crisis*, Trade and COVID-19 Guidance Note (World Bank Group, Washington, DC, 2020).

66. D. Andrews, C. Criscuolo, and P. N. Gal, *The Global Productivity Slowdown, Technology Divergence and Public Policy: A Firm Level Perspective* (Washington, DC: Brookings Institution, 2016).

67. M. Szczurek and M. Tomaszewski, *Poland Diagnostic Paper: Assessing Progress and Challenges in Developing a Sustainable Market Economy* (European Bank for Reconstruction and Development, London, 2018).

68. INTRA Interreg Europe, *Good Practice on SME Internationalization* (Lille: INTRA Interreg Europe, 2019).

BOX 5.3 Examples of technology support for laggards

Because early adopters and laggards differ in technical, organizational, and knowledge capabilities, initiatives aimed at supporting adoption of less advanced technologies should be distinct from instruments stimulating diffusion of frontier solutions. Instruments that successfully drive adoption of less advanced technologies can overcome constraints due to firm capabilities and weak incentives through modular support adapted to gaps in firm technology adoption readiness.

Examples of support instruments effective at driving technology upgrading of less capable SMEs are discussed below.

The United Kingdom's **Digital Manufacturing on a Shoestring** provides a technology extension program that allows SMEs to test affordable, easy-to-implement technologies as small-scale digital solutions that will not disrupt their core business operations but will provide immediate benefits. It focuses on manufacturing enterprises and follows a three-step process with dedicated experts delivering ongoing support. First, digital needs of SMEs are analyzed to determine their three most pressing business areas for potential improvement. Second, an appropriate technical solution is designed to address those needs using only easily approachable building blocks; a precisely defined purchase specification is then suggested. Third, appropriate providers are identified through the Shoestring portal, which aggregates quality technology suppliers. The program is operated by the Institute for Manufacturing at Cambridge University and has supported over 300 SMEs as of Q1 2022.

In Ireland, the **Trading Online Voucher** program uses vouchers to incentivize SMEs to start offering products and services online. It is a competitive process in which micro firms can receive up to €2,500 to cover expenditures related to building e-commerce capabilities, including developing websites, applications, or digital payment infrastructure. The support is conditional on participation in centrally managed informational sessions that aim to equip beneficiaries with the capabilities necessary for successful adoption of e-commerce technologies. Successful applicants could apply for a second voucher to further develop the solutions financed from the initial grant.

Singapore's **Technical Advisory Programme** provides firms with advisory services from a certified group of technological experts to prepare a technology upgrading strategy, including the knowledge and competence necessary for successful adoption and use of new solutions. Beneficiaries of the program could receive four hours of support per month for up to two years from various consultants selected based on needs identified on an ongoing basis. While in the program, SMEs can test different technological solutions and discuss R&D opportunities with researchers. After successfully completing the upgrade, enterprises are offered preferential access to financial instruments, including equipment and complementary costs, at A*STAR, the national agency for science, technology and research.

Source: World Bank staff analysis of program documentation.

Adoption Survey showed that large enterprises are on average more technologically advanced. Thus, stimulating connections between SMEs and large firms has the potential for cross-firm learning, through standards, requirements, and provision of knowledge from the larger to the smaller organization.[69] Consider aggregating SMEs in purchasing groups to facilitate connection of multiple SMEs

69. M. Kuwayama, Y. Ueki, and M. Tsuji, *Information Technology for Development of Small and Medium-Sized Exporters in Latin America and Asia* (New York: United Nations Development Programme, 2005).

with larger firms. Domestic demand could also be stimulated by public procurement, which is shown to drive technology adoption.[70]

Align instruments supporting adoption of green technologies to readiness of firms in their respective sectors. Risks related to adaptation to the requirements of the EU climate policy, including the Fit for 55 package, were indicated as a widespread challenge. Results presented in the second part of the TAS report: "Sectoral Approach to the Drivers of Productivity Growth in Poland. A Firm-Level Perspective on Technology Adoption and Firm Capabilities", evidence transition to low-carbon business models as one of the key challenges for enterprises across all economic sectors. Both in the survey and in the individual in-depth interviews, companies identified technological adaptation, together with green business processes (including emissions tracking, energy efficiency, and the circular economy), as their main mitigation measures. However, the level of technological advancement differs between sectors, as some have a high share of large firms and exporters, and others are more fragmented and focused on the internal market. Characteristics of sector-specific sustainable technologies also differ. For example, deployment of low-carbon energy sources is conditional on knowledge allowing firms to adjust production processes, whereas reducing the emissions of products or services requires searching for new partners across the value chain. Better reflecting this heterogeneity in instrument design would increase uptake of support among target groups and accelerate adoption of technologies necessary to align with climate objectives.

Account for the heterogeneity in the adoption paths of various technologies to maximize impact on adoption of various technologies simultaneously. No one-size-fits-all approach to supporting technology adoption exists, as neither technologies nor the factors behind firms' technology decisions are homogeneous. Results of the TAS show that diffusion of technologies among Polish firms is highly heterogeneous, with different paths of adoption and use. Policies for enhancing technology adoption should account for this. For example, adoption of most transactional technologies (e.g., digital platforms) does not require extensive firm capabilities, unlike informational technologies (e.g., management support systems or machine learning and artificial intelligence), the use of which is highly dependent on, and limited by, organizational factors.[71] Similarly, adop-

70. D. Atkin, A. Khandelwal, and A. Osman, "Exporting and Firm Performance: Evidence from a Randomized Experiment," *Quarterly Journal of Economics* 132 (2; 2017).

71. World Bank, *Europe 4.0 Addressing the Digital Dilemma* (Washington, DC: World Bank, 2020).

tion of some technologies may be concentrated in selected sectors. Approaches accounting for that heterogeneity would enable firms to adopt multiple technologies at once. Productivity increases are up to three times higher when firms deploy technologies in combination.[72] For this reason, it is crucial to understand the specific determinants related to each technology type and to use this evidence to design policies facilitating simultaneous adoption of multiple technologies.

Maintain the supply of public support for adoption of operational technologies. Regulations of the EU budget require that at least 35 percent of ESIF investments in 2021 – 2027 per Member State support climate objectives, with an 25 percent additional contribution to digitization.[73] This framework resulted in limited support for adoption of technologies that do not fit into these categories, mostly operational technologies introduced for purposes other than reducing environmental impact. This group includes processing, fabrication, assembly, or material technologies crucial for increasing manufacturing firms' productivity. The broader European regulations related to public support allow investment in firm-level adoption of non-green and non-digital technologies if they are following the do-no-significant-harm principle that safeguards environmental standards. Instruments supporting adoption of non-green and non-digital technology could be financed from national sources (domestic programs) to supplement the EU cofinanced programs and avoid modifications of green and digital shares of operational programs agreed with the EC.

Support for firm capabilities

Broaden the scope of nonreturnable support for supplementary capabilities in programs supporting adoption of digital technologies. Results of the Technology Adoption Survey confirm evidence in the literature that successful technology adoption is conditional on complementary investments in managerial and digital skills and new product development.[74] Investments in advisory services to promote organizational changes are effective in accelerating the pace of technology upgrading by addressing nonpecuniary challenges such as risk

72. T. Abdrazakova and S. Salihudin, "COVID-19 and Technology Adoption in Small and Medium-Sized Enterprises: The Impact and the Way Forward," World Economic Forum White Paper (World Economic Forum, Geneva, 2022).

73. Regulation (EU) 2021/1060 of the European Parliament and of the Council of 24 June 2021.

74. D. Atkin, A. Chaudhry, A. Khandelwal, and E. Verhoogen, "Organizational Barriers to Technology Adoption: Evidence from Soccer-Ball Producers in Pakistan," *Quarterly Journal of Economics* 132 (3; 2017).

aversion, change-holding behavior, or lack of skills. Thus, introducing a nonreturnable component for complementary capabilities to programs by offering returnable support for investments in technology acquisition would enhance creation of capabilities necessary for taking advantage of opportunities to adopt new solutions. Support for building supplementary capabilities should not be limited to key managers, but should also include acquisition and development of talent, as a workforce with adequate skills and in-firm incentives for using newly adopted technologies are key to promoting productivity.[75]

Reducing barriers to scaling up

Remove regulatory barriers to firm scale-up. The level of technology adoption, and related productivity performance, can increase by improving the level of technological advancement of existing companies ("within" component) or through growth of firms and a change in the structure of the economy ("between" component). Results from the Technology Adoption Survey supply evidence on obstacles to resource allocation in the private sector that could primarily hinder changes in sectoral structure between firms.[76] The results illustrate existence of weak external incentives for adopting technologies, like anticompetitive regulations or subdued demand. Enterprises must generate a financial surplus to cover costs of technology adoption, which is why some productive technologies will not be implemented by smaller enterprises. Thus, opportunities for scaling up demand provide incentives to firms to make a technological switch. Overall, regulatory barriers to competition in Poland are higher than the OECD average, with a high degree of public ownership and an excessive administrative burden on business.[77] Liberalization of competition regulation has the potential to drive the pace of technology adoption by providing market incentives to adopt and accumulate it.[78] Demand stimulus programs could additionally alleviate lack of appropriate demand, which was cited in the TAS as a key barrier holding enterprises back from adopting technologies.

75. J. Mokyr, *The Lever of Riches: Technological Creativity and Economic Progress* (Evanston: Northwestern University Press, 1990).

76. World Bank, *Paths of Productivity Growth in Poland: A Firm-Level Perspective* (Washington, DC: World Bank, 2021).

77. OECD, 2018 *Product Market Regulation Country Note — Poland* (Paris: OECD, 2019).

78. A. Rabah, D. Vianney, F. R. Yuting, and C. M. Rosotto, "Liberalization, Technology Adoption, and Stock Returns: Evidence from Telecom," World Bank Policy Research Working Papers 9561 (World Bank, Washington, DC, 2021).

Improve efficiency of resource allocation in manufacturing. Following the recent study on drivers of productivity among Polish enterprises, results from the Technology Adoption Survey provide additional evidence on the barriers in flow of capital and labor between firms.[79] Business dynamism is especially reduced in the manufacturing sector, which directly affects incentives for adopting and using technologies. When highly productive or technologically advanced firms encounter larger barriers to increasing their market share and low-productivity firms remain on the market longer, the business need to upgrade is limited. In markets with regulations that limit allocation of resources, technology adoption is slower.[80] While anticompetitive barriers should be addressed across the economy, the manufacturing sector requires particular attention, as it faces sector-specific challenges that significantly hold back allocative efficiency.

Policy coordination and use of firm-level data

Strengthen monitoring and evaluation procedures to inform continuous learning. The M&E systems of support instruments are predominantly driven by the objective of maintaining legal compliance with EU regulations. For this reason, M&E focuses on collecting information on activities and outputs of support instruments, with limited insight into medium- and long-term impact on beneficiaries. Even pilot programs intended to test the effectiveness of novel interventions lacked follow-up data collection from beneficiaries, which decreases applicability of pilot results. Good M&E systems are based on an explicit theory of change that identifies crucial inputs, activities, outputs, results, and assumptions to be monitored, and they gather actionable data in a timely and systematic way so a plan for adjustments that depends on the results found can be followed. Adaptation of technology-related programs is particularly important, due to the heterogeneity of factors driving their adoption and the fast pace of technological development.[81] M&E systems should be accompanied by a structured learning process that documents implementation insights and decisions made to adapt to new circumstances.

79. World Bank, *Paths of Productivity Growth in Poland: A Firm-Level Perspective* (Washington, DC: World Bank, 2021).

80. D. Andrews and F. Cingano, "Public Policy and Resource Allocation: Evidence from Firms in OECD Countries," *Economic Policy* 29 (78; 2014).

81. OECD, *Regulatory Effectiveness in the Era of Digitalization* (Paris: OECD, 2020).

Establish functional coordination mechanisms for policies on technology adoption and enhancement of supplementary capabilities undertaken by various institutions. Firm-level instruments for technology adoption are managed by two ministries and sixteen marshals' offices, and implementation is further dispersed among numerous institutions. Programs are financed from different sources and governed by partially differing regulatory frameworks. Despite such fragmented policy making, no functional body conducts ongoing coordination of the various initiatives and analyzes their fit within broader policies for private sector development.[82] Creation of a coordination body, with strong analytical capabilities and clear political support, would help avoid overlap of instruments, identify gaps, and allow evidence-based adjustment of support instruments. Previous World Bank Reports (World Bank 2020, 2022) indicate the need to create an Innovation, Technology, and Productivity Excellence Center. A government-level body is required for successful coordination, as currently organizations have narrow areas of responsibility (e.g., PARP focuses on technology adoption, while NCBR focuses on its creation) or scopes of activity (e.g., FPPP operates on an operational rather than a policy-making level and focuses predominantly on digital technologies).

Improve access to statistical information on firm performance. The authors of this report are grateful to Statistics Poland for making the arrangements necessary for external researchers to perform calculations directly on individual administrative data in the agency's headquarters. This significantly improved the project and allowed it to generate additional insights from the analyses. Lessons learned through this cooperation show areas for future improvement. The decentralization of the Statistics Poland lengthens the decision-making processes and hinders coordination of activities. These effects were visible in this project, as firm-level administrative information used for calculations is stewarded by the Statistical Office in Szczecin, while its use is authorized by the HQ office in Warsaw. Preparation of standards in procedures related to validation of compliance with statistical confidentiality regulations would streamline such work. Moreover, facilitation of combining information from different datasets would facilitate research activities. Given such a possibility, additional evidence on the relation between the level of technological advancement and firm performance could be generated.

82. World Bank, *Return on Investment of Public Support to SMEs and Innovation in Poland* (Washington, DC: World Bank, 2020).

APPENDIX

TABLE A.1 Descriptive statistics

		Sample
Employment	Mean	26.74
	Standard deviation	(100.43)
	P10	5
	P50	9
	P90	43
Firm age	Mean	17.5
Foreign-owned	Percent	21
Share in sales	Agriculture	3
	Food Processing	11
	Wearing Apparel	2
	Automotive	3
	Pharmaceuticals	12
	Wholesale and Retail	17
	Financial Services	9
	Land Transport	5
	Health Services	4
	Other Manufacturing	18
	Other Services	17

Note: Estimates are weighted by sample weights.
Source: TAS survey statistics.

TABLE A.2 Sample distribution across

Region	Size	Agriculture	Food Processing	Apparel	Automotive	Pharma-ceutical	Other Man-ufacturing	Wholesale and Retail	Financial Services	Land Trans-portation	Health Services	Other Services	Total Region
South	5–9	4	8	5	3	4	25	28	3	12	2	39	291
	10–19	3	5	4	3	5	10	3	3	2	3	4	
	20–49	3	4	4	3	3	6	2	3	2	3	2	
	50–99	3	3	3	3	1	2	2	3	2	3	2	
	100–249	2	3	3	3	2	2	2	3	2	3	2	
	250+	1	3	3	3	1	2	2	2	2	3	2	
North-West	5–9	7	6	5	3	1	19	16	3	11	3	31	257
	10–19	5	4	4	3	0	7	4	3	2	2	3	
	20–49	4	5	4	3	1	6	2	3	2	3	2	
	50–99	3	3	3	3	2	2	2	3	2	3	2	
	100–249	3	3	3	2	1	2	2	3	2	3	2	
	250+	3	3	1	3	3	2	2	2	2	3	2	
South-West	5–9	4	5	4	3	2	8	5	3	2	2	6	161
	10–19	4	3	3	2	0	2	2	3	2	2	2	
	20–49	3	3	3	2	1	1	2	4	2	2	2	
	50–99	3	2	2	2	0	3	2	3	2	2	2	
	100–249	2	2	3	3	0	2	2	0	2	3	2	
	250+	1	2	0	3	5	2	2	1	2	3	2	
North	5-9	5	5	5	3	3	15	7	4	6	2	17	206
	10-19	4	4	4	2	0	5	2	3	2	2	3	
	20-49	3	4	4	3	0	4	2	3	2	3	2	
	50-99	3	3	3	2	2	2	2	4	2	3	2	
	100-249	4	3	3	2	2	2	2	1	2	3	2	
	250+	0	3	1	2	1	2	2	1	2	3	2	
Central	5–9	4	4	8	3	3	9	5	4	4	2	5	175
	10–19	3	4	5	2	0	2	2	3	2	4	2	
	20–49	3	3	4	3	1	2	2	4	2	2	2	
	50–99	2	3	3	2	2	2	2	2	2	2	2	
	100–249	2	3	3	3	1	2	2	2	2	3	2	
	250+	0	2	2	2	1	2	2	0	2	3	2	
East	5–9	4	5	4	3	1	9	5	3	5	2	6	171
	10–19	3	4	3	2	1	2	2	4	2	2	2	
	20–49	3	4	3	3	2	2	2	3	2	3	2	
	50–99	3	3	3	1	0	2	2	3	2	2	2	
	100–249	1	3	3	2	2	3	2	2	2	3	2	
	250+	0	2	2	3	1	1	2	1	2	3	3	
Mazovia	5–9	3	6	5	3	5	16	20	2	10	2	30	239
	10–19	3	4	4	2	1	4	3	2	2	3	3	
	20–49	4	4	4	3	5	3	2	3	2	2	2	
	50–99	3	2	3	2	2	2	2	2	2	3	2	
	100–249	2	2	3	2	2	2	2	2	2	3	2	
	250+	0	3	1	3	3	2	2	3	2	2	2	
Total		120	150	140	108	73	200	160	109	120	110	210	1500

Source: TAS survey statistics.

TABLE A.3 Detailed firm structure in sectors with sector-specific technologies

Poland

		Firm share by sector (%)							
		Agriculture	Food Pro-cessing	Apparel	Auto-motive	Pharma-ceuticals	Wholesale & Retail	Financial Services	Land Transport
Size classes	Small (5–19)	82.5	67.4	84.3	29.5	22.8	84.6	51.2	79.1
	Medium (20–99)	15.9	25.6	13.1	39.9	38.8	12.7	41.0	18.9
	Large (100+)	1.6	7.0	2.7	30.6	38.5	2.7	7.8	2.0
Ownership classes	Private domestic (PDE)	90.9	96.4	97.9	80.4	81.3	91.9	96.9	96.6
	State-owned (SOE)	3.3	0.4	0.1	1.0	2.3	0.0	0.0	0.9
	Foreign-owned (FOE)	5.8	3.2	2.0	18.6	16.4	8.1	3.1	2.5
International trade	Exporters	10.5	15.4	45.7	75.0	66.5	20.1	0.8	20.1

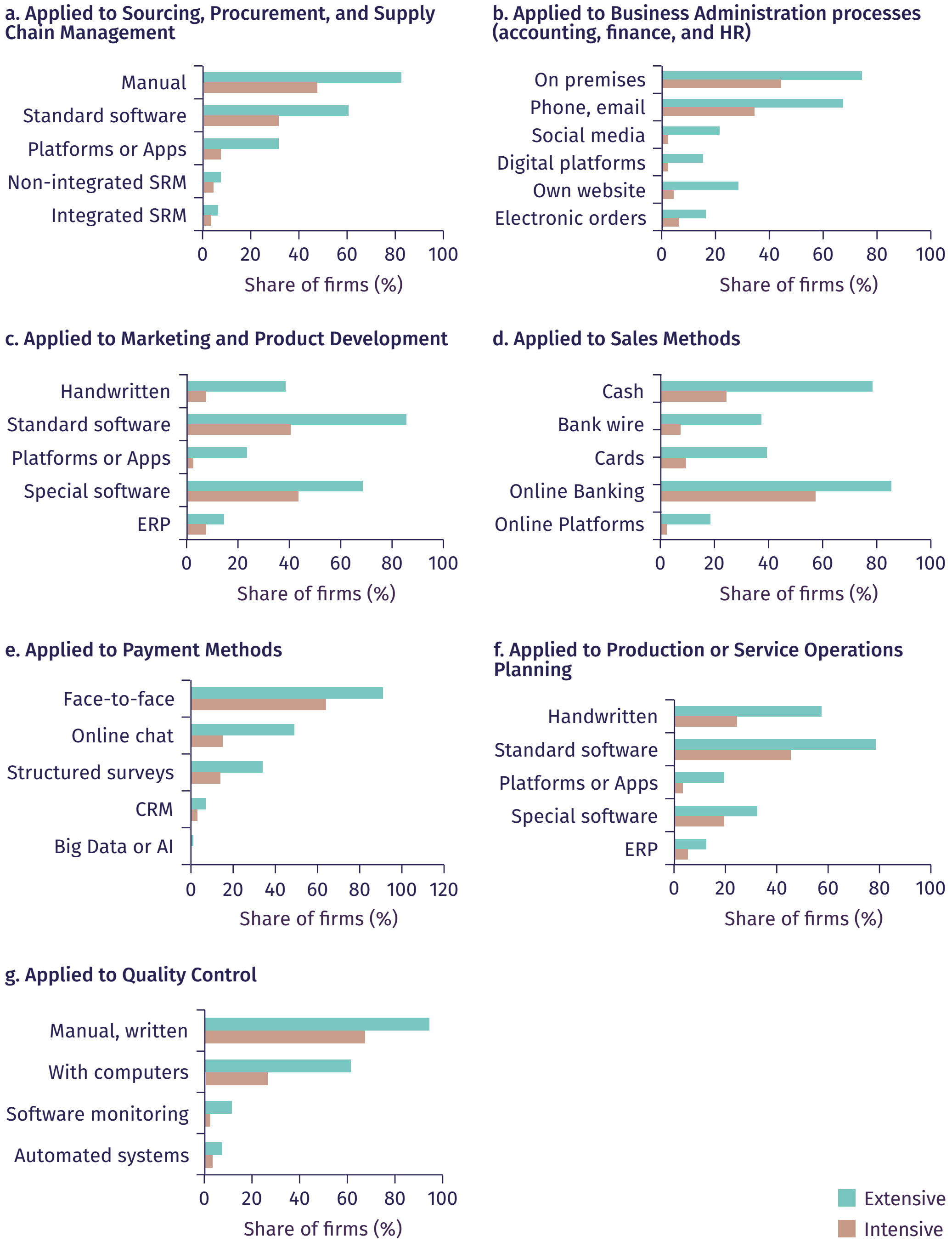
Korea

		Firm share by sector (%)							
		Agriculture	Food Pro-cessing	Apparel	Auto-motive	Pharma-ceuticals	Wholesale & Retail	Financial Services	Land Transport
Size classes	Small (5–19)	70.7	63.7	89.1	44.2	51.7	89.1	90.7	54.8
	Medium (20–99)	28.5	27.7	10.0	34.4	39.5	9.9	8.6	35.3
	Large (100+)	0.7	8.6	0.9	21.4	8.8	1.0	0.7	9.8
Ownership classes	Private domestic (PDE)	91.5	96.5	100.0	96.9	99.3	98.2	97.1	91.8
	State-owned (SOE)	0.0	3.5	0.0	3.1	0.7	1.8	2.9	0.0
	Foreign-owned (FOE)	8.5	0.0	0.0	0.0	0.0	0.0	0.0	8.2
International trade	Exporters	8.0	39.9	13.3	24.9	40.2	21.2	0.2	2.3

Note: Percentages sum to 100 within sectors for every category (firm size, ownership, and international trade). Foreign-owned and state-owned enterprises are firms with majority foreign or state ownership, respectively. The stratification in the TAS was based on three firm size categories: small (5–19 employees), medium (20–99 employees), and large (100+ employees). However, due to different classification methodologies used in European countries, the Polish survey was stratified on a more disaggregated level by six firm size categories: (i) 5–9, (ii) 10–19, (iii) 20–59, (iv) 60–99, (v) 100–249 and (vi) 250+ employees. Yet, for comparability, the tables present structures adjusted to the Korean stratification.

Source: TAS survey statistics.

FIGURE A.1 **Share of Firms Using Technologies**



Note: Firms can use multiple technologies to perform certain task (extensive margin) so the percentages sum up to 100 only for intensive margin (one technology is used most often).
Source: Original figure based on TAS in Poland.

FIGURE A.2 **General Business Functions distribution: Intensive margin**

Note: The radar graph plots the values of general business functions in the 90th percentile, 50th percentile (median), and 10th percentile (distribution across business functions, not across firms).

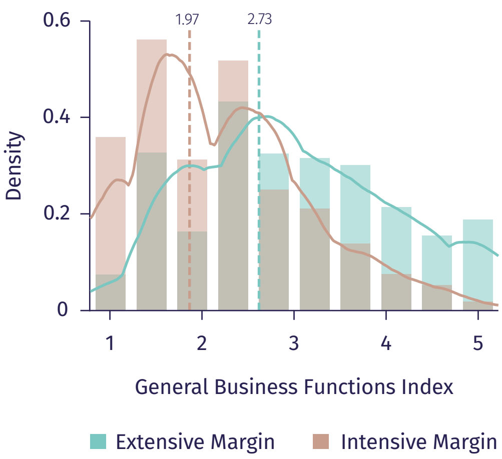
Source: Original figure based on TAS in Poland.

FIGURE A.3 **General Business Functions: Firm-level intensive margin**

Note: The radar graph plots the median values of general business functions for the firms with the GBF intensive index: (1) above the 90th percentile, (2) in the 50th percentile (median), and (3) below the 10th percentile.

Source: Original figure based on TAS in Poland.

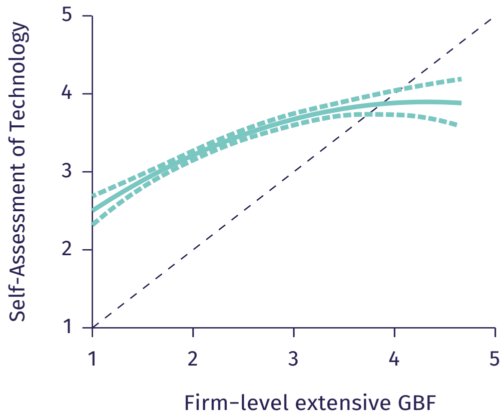
FIGURE A.4 **Distribution of Sector-Specific Technologies Index across Firms**



Note: Solid lines represent Kernel densities. Vertical dashed lines show the averages. Values are weighted with sample weights.

Source: Original figure based on TAS in Poland.

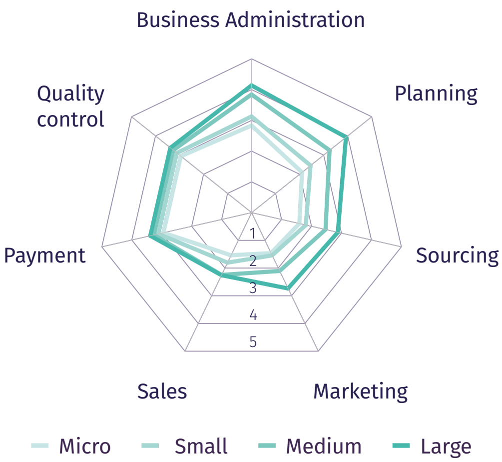
FIGURE A.5 **Association between Self-Assessment and Technology Adoption in Relation toother Firms in the Country**



Note: Turquoise line shows the quadratic fit with 95% confidence interval. Firm-level intensive GBF index is regressed on firms' self-assessment with respect to relation to other firms in the country.

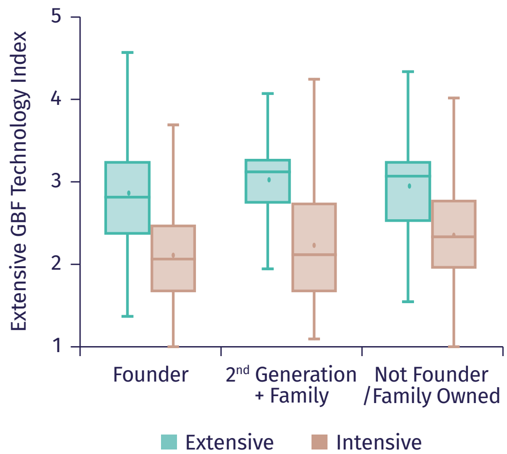
Source: Original figure based on TAS in Poland.

FIGURE A.6 Technology Adoption by Specific General Business Function



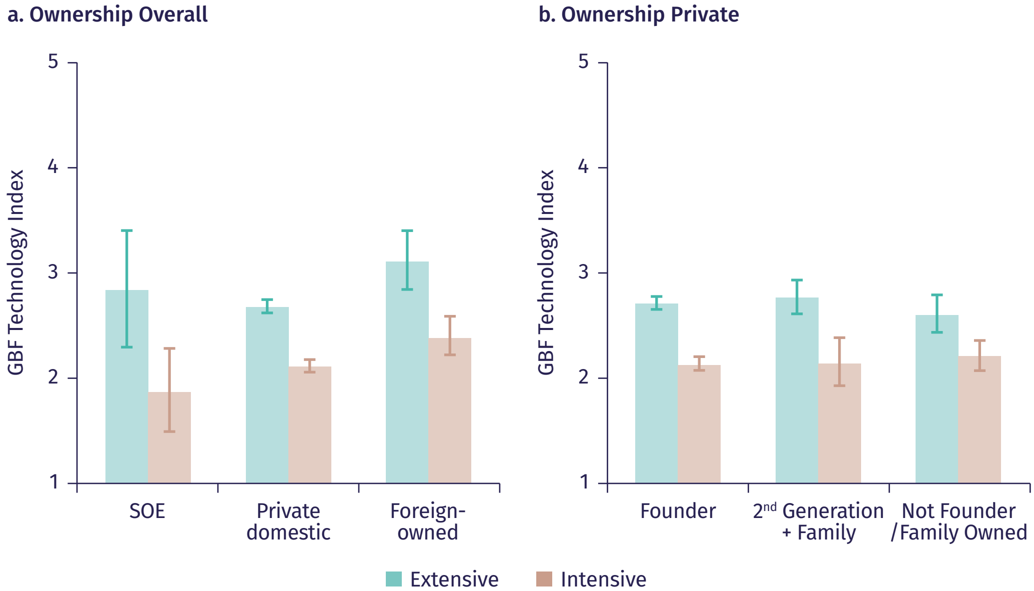
Note: Each line represents the index average across firms for each business function.
Source: Original figure based on TAS in Poland.

FIGURE A.7 General Business Function Technology Adoption by Family Ownership



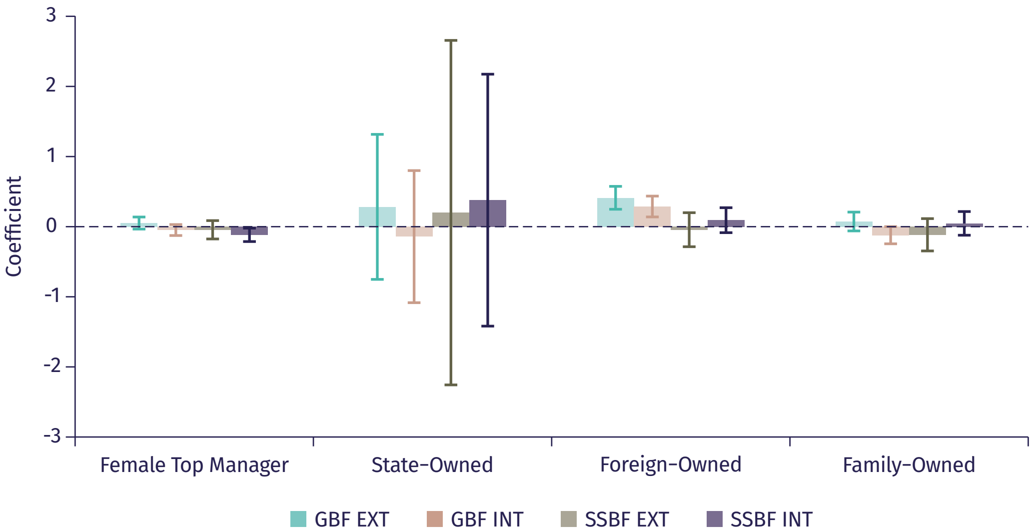
Note: Box plot of general business function index by family ownership.
Source: Original figure based on TAS in Poland.

FIGURE A.8 Technology Adoption and Ownership Controlling for Firm Characteristics



Source: Original figure based on TAS in Poland.
Note: The figure shows the predicted values of GBFs index by overall ownership and private owner types (non-state-owned) with confidence intervals from the regressions controlling for: region and sector and size and the respective other ownership categorization. All estimates are weighted by sampling weights.

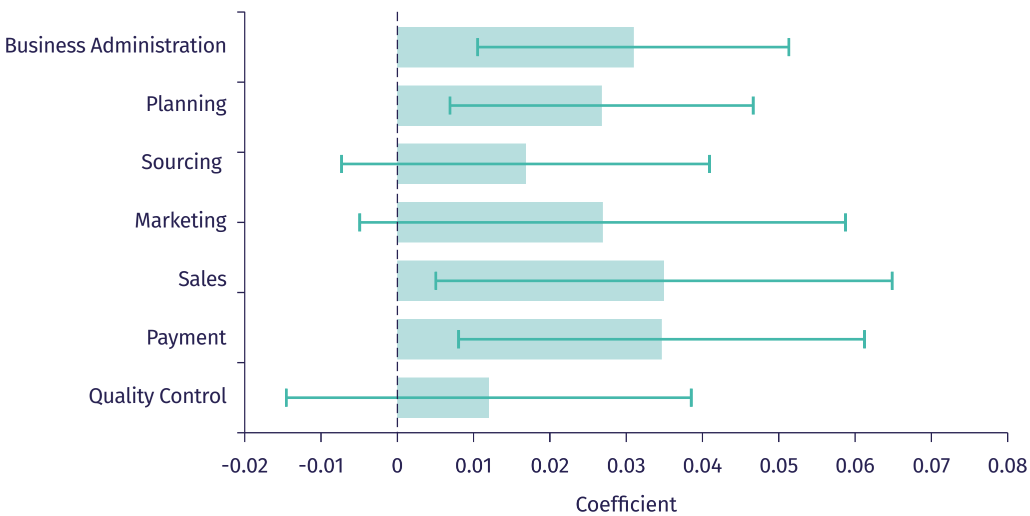
FIGURE A.9 Technology Adoption and Firm Ownership



Source: Original figure based on TAS in Poland.

Note: Figure provides the coefficients and 95% confidence intervals from regressions, while controlling for sector, size, and regions. All estimates are weighted by sampling weights.

FIGURE A.10 Specific General Business Function and Employment Growth



Source: Original figure based on TAS in Poland.

Note: The figure provides the coefficients and 95% confidence intervals from regressions. Job growth is regressed on each specific general business function at the intensive margin, while controlling for sector, size, and regions.

Policy context

European Union (EU) programs (co-financed by domestic resources) provide over 90 percent of the funding for private sector development policies in Poland through the Multiannual Financial Framework. Hence, the EU strategies and regulations determine most of the investment priorities and intervention areas related to firm-level technology adoption.[83] The priorities of the EU Multiannual Financial Framework (MFF) for 2021–2027 include five high-level policy objectives, two of which are directly related to promoting technology upgrading by firms (Table A.4). It is noteworthy that a separate category of intervention is provided for adopting green technologies, which were identified as a challenge area in almost all sectors in which the Technology Adoption Survey was conducted (see sectoral chapters). The main European strategy related to private sector development — A European Industrial Strategy — makes support to technology-driven digital and green business models the core principle in SME support.[84]

TABLE A.4 Priorities for the 2021–2027 Multiannual Financial Framework (MFF)

Priority	Main beneficiary groups	Main funds envisaged for its implementation
1. A more competitive and smarter Europe	Enterprises	European Regional Development Fund
2. A greener, low-carbon transition toward a net zero carbon economy	Enterprises	European Regional Development Fund Just Transition Fund Cohesion Fund
3. A more connected Europe by enhancing mobility	Public authorities	Cohesion Fund
4. A more social and inclusive Europe	Individuals	European Social Fund+
5. Europe closer to citizens by fostering the sustainable and integrated development	Public authorities & individuals	Interreg

Note: On top of the Multiannual Financial Framework, in years 2021–2023 the EU Member States will receive payments from the NextGenerationEU (NGEU) Programme for Post-COVID Recovery. The NGEU is envisioned to finance reforms and investments listed in the National Recovery and Resilience Plans — a governmental strategy for restoring the economy after the crisis related to the coronavirus pandemic — which do not include provision of support individual enterprises. For this reason, the NGEU financing is excluded from scope of this analysis.
Source: World Bank staff analysis.

The priorities of the MFF are implemented in Poland through operational programs (OPs) at the national and regional level. For 2021–2027, at the national level enterprises will be predominantly supported under the European Funds for Smart Economy (FENG) OP. FENG will offer

83. World Bank, *Return on Investment of Public Support to SMEs and Innovation in Poland* (Washington, DC: World Bank, 2020).
84. European Commission, *A New Industrial Strategy for Europe* (European Commission, COM(2020) 102 final, 2020).

three flexible instruments: one aimed at supporting the creation of new technologies by firms (firm-level R&D), a second aimed at enhancing cooperation of enterprises with the academic sector, and the third supporting firms in aligning with the climate needs.[85] Most direct support for adopting existing technologies will be provided through the third area, with modest investments offered in the remaining interventions. On the regional level, to a varying degree, all 16 regional operational programs include instruments supporting technology adoption by firms. The landscape of support instruments adopting technologies among firms is complemented by interventions entirely financed by national funds, but their value is limited. Table 14 summarizes the types of support depending on the governance level.

The challenges related to the firm-level technology adoption are reflected in the national and regional strategic documents. The 2030 Productivity Strategy, a document presenting policy framework for private sector development, indicates that the key barrier to the transformation of the Polish enterprise sector is its low awareness of global technology trends and lack of knowledge on the practical aspects of adopting new technologies. Consequently, willingness to adopt new and scale the use of already adopted technologies is limited.[86] The Strategy identifies awareness-raising activities and advisory services as a necessary step to enable Polish enterprises to advance technological transformation of SMEs. Also, regional development strategies highlight challenges related to increasing technological sophistication of enterprises among the main barriers in increasing SMEs competitiveness.[87]

The technology adoption angle is also reflected in institutional set-up of the national firm-support ecosystem, but with limited coordination between various institutions. The Polish Agency for Enterprise Development (PARP) and the National Development Bank (BGK) are primarily responsible for stimulating technology adoption in the private sector. The objectives of PARP include s*upporting (...) use of new technologies in business activities by SMEs, while BGK mission encompasses addressing financial gap on the market in (...) mobilization capital for economic development through support for adoption of innovation SMEs,* both of which are directly aligned with technology adoption. PARP is responsible for implementing EU cofinanced programs (mostly grants), while BGK offers returnable financing supported by the state budget. Additionally, regional implementing agencies are responsible for implementing instruments allowing investments in technology adoption in respective voivodships. Despite clear designation of institutions supporting firm-level technology adoption, exchange of information between them could

85. Ministry of Development Funds and Regional Policy, *Program Fundusze Europejskie dla Nowoczesnej Gospodarki 2021–2027 (projekt)*, Załącznik do uchwały nr 165/2021 Rady Ministrów z dnia 6 grudnia 2021 r. (Warsaw: Ministry of Development Funds and Regional Policy, 2020).

86. Ministry of Economic Development and Technology, *Strategia Produktywności 2030* (Warsaw: Ministry of Economic Development and Technology, 2021).

87. T. Kudlacz, *Analiza Pięciu Strategii Regionalnych Województw Polski Zachodniej i Problemów Stykowych Pomiędzy Województwami Polski Zachodniej z Innymi Regionami* (Kraków: Uniwersytet Ekonomiczny w Krakowie, 2015).

TABLE A.5 Types of policies and instruments supporting firms, including firm-level technology adoption, in Poland[a]

	Level of governance		
	National	**Regional**	**Domestic**
Management authority	Central government ministries	Regional government executive branch (marshals' offices)	Central government ministries
Policy cycles	Seven years, following the policy cycle of the EU budget (MFF)		Various, depending on individual policies
Sources of financing	Predominantly (>75%) the EU budget		100% state budget
Priority setting	European Commission		National government
Audit and control			
Number of OPs in 2021–2027 MFF	Five covering individual objectives, FENG for firms	Sixteen (1 per region) covering all objectives simultaneously[b]	N/A
Total value of support for firms (EURbn)	11.9	12.3	4.9
Maximum value of support for firm-level technology adoption (EURbn)[c]	6.5	5.6	4.7
Degree of support for firm-level technology adoption	Moderate — direct support only for green technology adoption. Otherwise, the support focused on creation of new technologies and technology adoption can be a complementary element	High — support focused on general growth of SME competitiveness, including technology adoption	Moderate — support focuses on creation of new technologies; support for adoption only for green technologies

a. Data on 2021–2027 programs presented in this section were sourced from program documentation from February 2022. Implementation of the firm-level support instruments under the new financial perspective has not yet started at the time of publication of this report. Thus, documentation related to interventions related to this area may have changed.

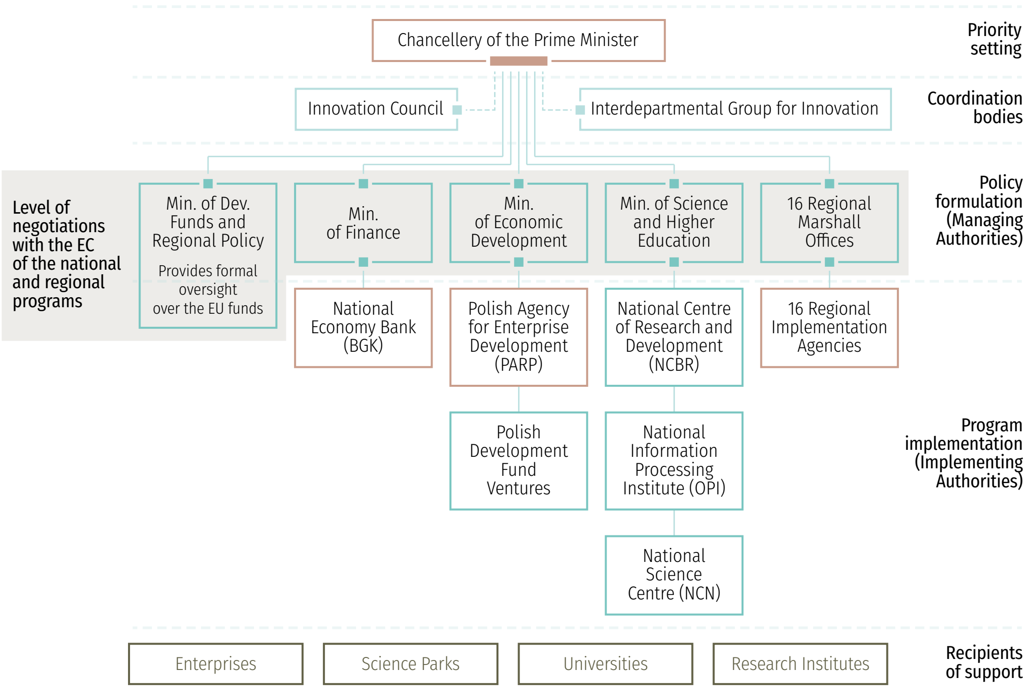
b. Regional Operational Programs cover numerous policy areas — ranging from the provision of social services and protection of cultural heritage to supporting growth of SME competitiveness and creation of innovation. On the national level, respective operational programs address closely interconnected policy areas — FENG include activities predominantly targeting private enterprises.

c. Maximum value of support for firm-level technology adoption was calculated on the basis of the portfolio mapping, where individual instruments were classified against various criteria (including eligible types of projects) based on program documentation. For national instruments, support for technology adoption was identified in the following instruments: European Funds for a Modern Economy (FENG) Priority Axis 2 and 3, European Funds for Eastern Poland (FEPW) 2.1.1 and 2.1.2, European Funds for Infrastructure, Climate, and Environment (FEIKS): Priority Axis 1, 2, and 3, and European Funds for Digital Development (FERC) Priority Axis 1.

Source: World Bank Staff analysis.

be improved, as high-level coordination bodies exist only for research & development activities (Figure 46). The ex-ante assessment, a formal alignment of instruments with EU-wide regulations at the beginning of seven-year-long financial period, together with ongoing monitoring committees, are the main mechanisms of coordination; however, their mandate is limited predominantly to exchange of operational information to support implementing interventions planned in the OPs at the beginning of the financial cycle.

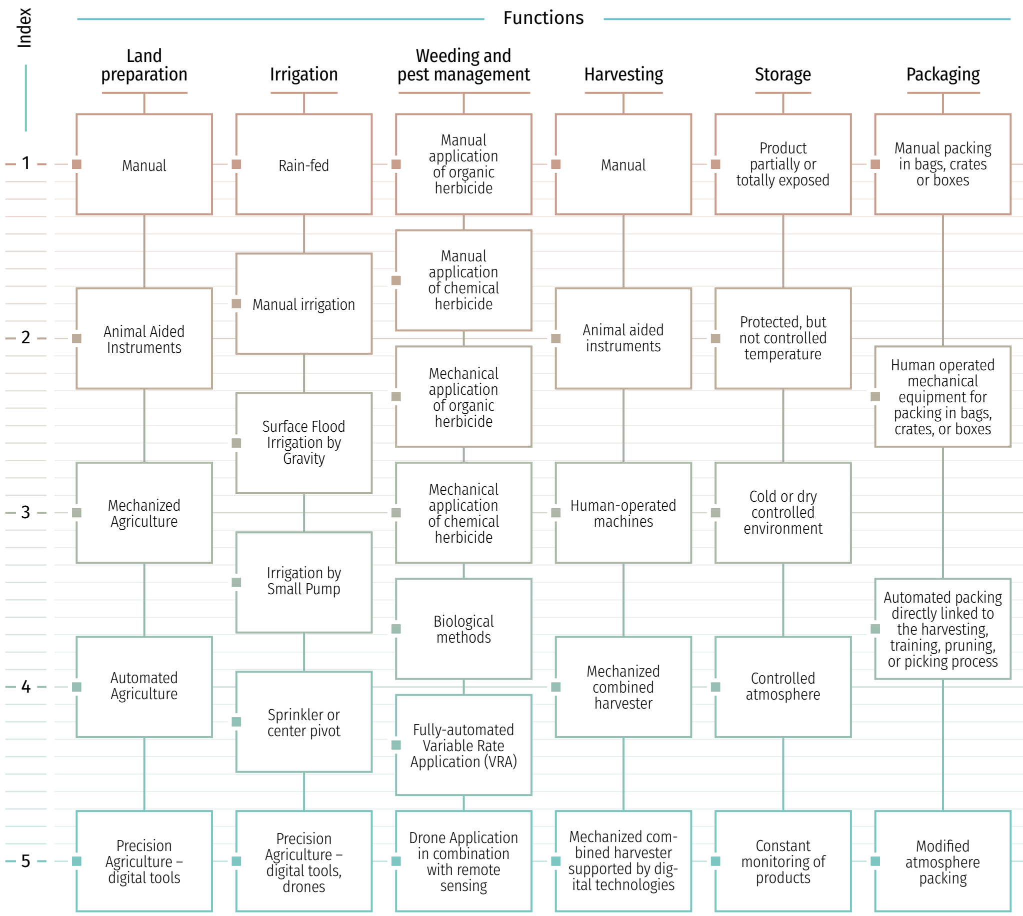
FIGURE A.11 Division of Roles in Policy Making Regarding Private Sector Development in Poland



Note: Names of institutions primary engaged in support of firm-level technology adoption are in brown frames.
Source: World Bank Staff analysis.

FIGURE A.12 Sector-Specific Business Technologies

a. Agriculture



b. Food processing

Functions

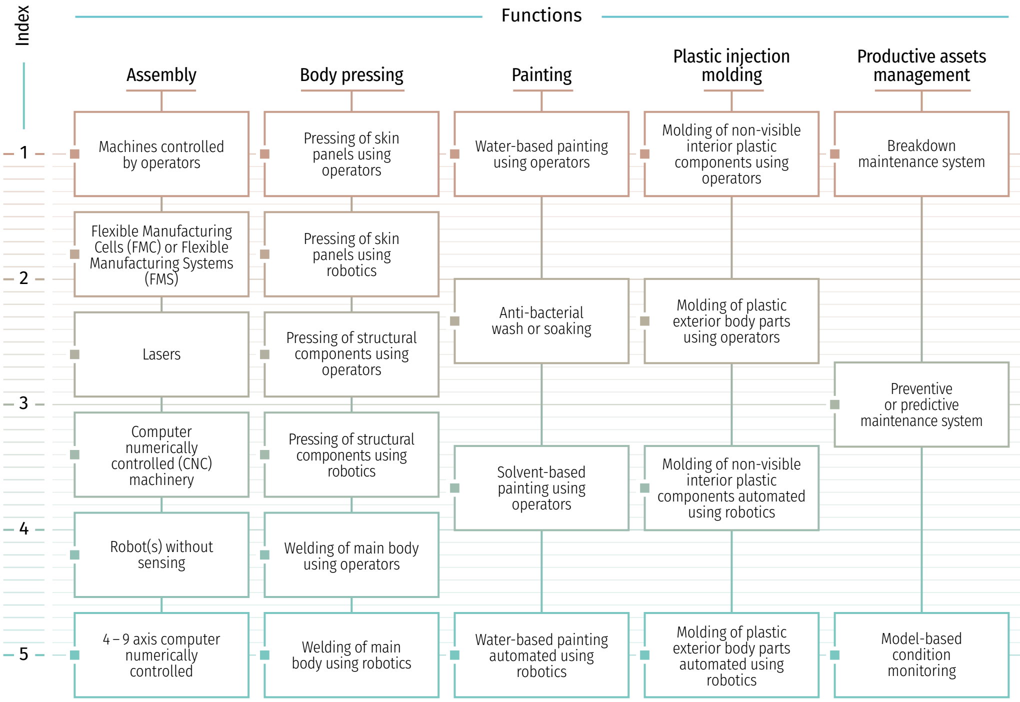
Index	Input testing	Mixing/blending /cooking	Anti-bacterial	Packaging	Food storage
1	Sensory (visual, smell, color, etc.)	Manual process	Minimal-processing preservation methods	Manual packing in bags, bottles or boxes	Minimal protection, some exposure to outside elements
2	Review of supplier testing on Certificate of Analysis	Mechanical equipment requiring human force to operate	Anti-bacterial wash or soaking	Human operated mechanical equipment for packaging in bags, bottles or boxes	Ambient conditions in closed building
3–4	Non-computer--controlled testing kits	Power equipment requiring routine human interaction	Thermal Processing Technologies	Automated process with minimal human interaction	Some climate control in secured building
5	Computer testing such as chromatography or spectroscopy	Power equipment con-trolled by computers or robotics, with minimal human interaction	Other advanced methods such as High-pressure processing (HPP) and Pulsed electric field (PEF)	Fully Automated with Robotics	Fully automated climate and security-controlled building

c. Wearing apparel

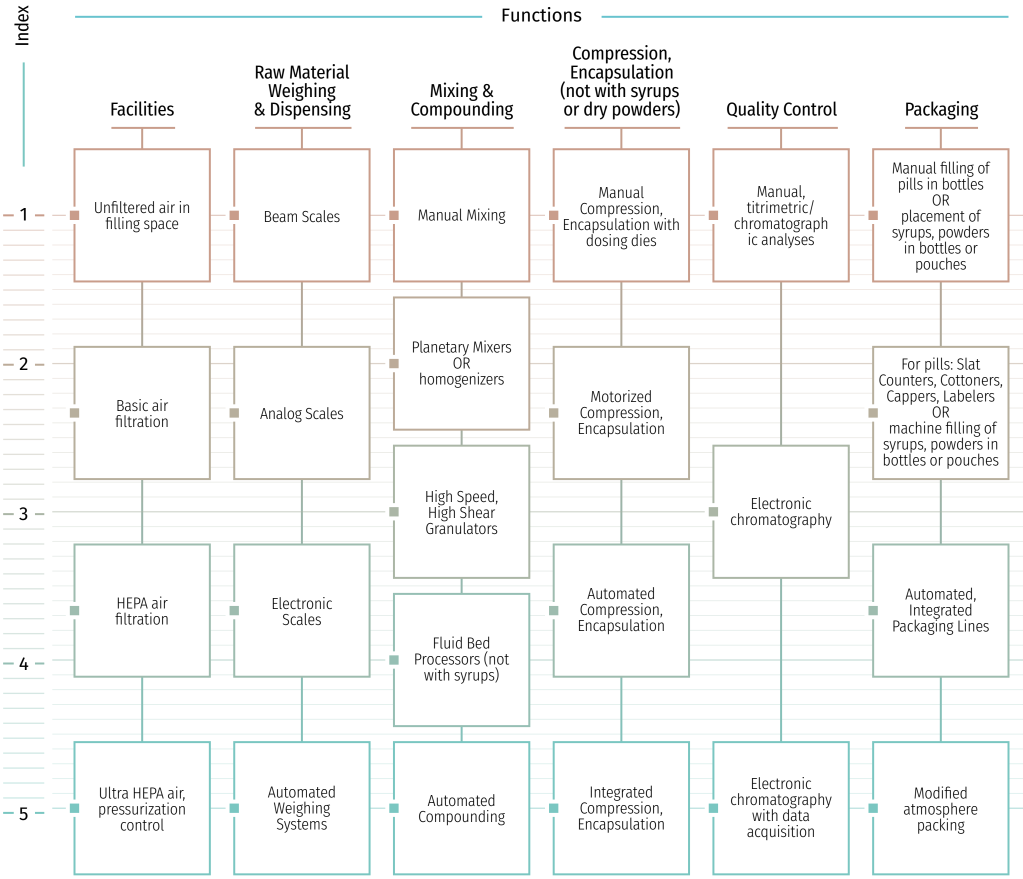
Functions

Index	Design	Cutting	Sewing	Ironing
1	Manual design and hand drawing	Manual cutting	Manually sewing	Basic manual ironing
2		Cutting machine manually operated	Sewing machine manually operated	Electric high-pressure steam iron
3	Digital or semi-digital design using specialized 2D drawing software	Semi-Automatic cutting machine (straight knife, round knife, die cutting machine)	Semi-automated sewing machines	Tunnel finisher
4		Automatic or Computerized cutting machine (no Laser: water jet, knife, other)	Automated sewing machines	Form finishing machine
5	Computer Aided Design (CAD), 3D design, virtual prototyping,	Automatic or Computerized cutting machine (Laser)	3D Knitting	High tech pressing machine

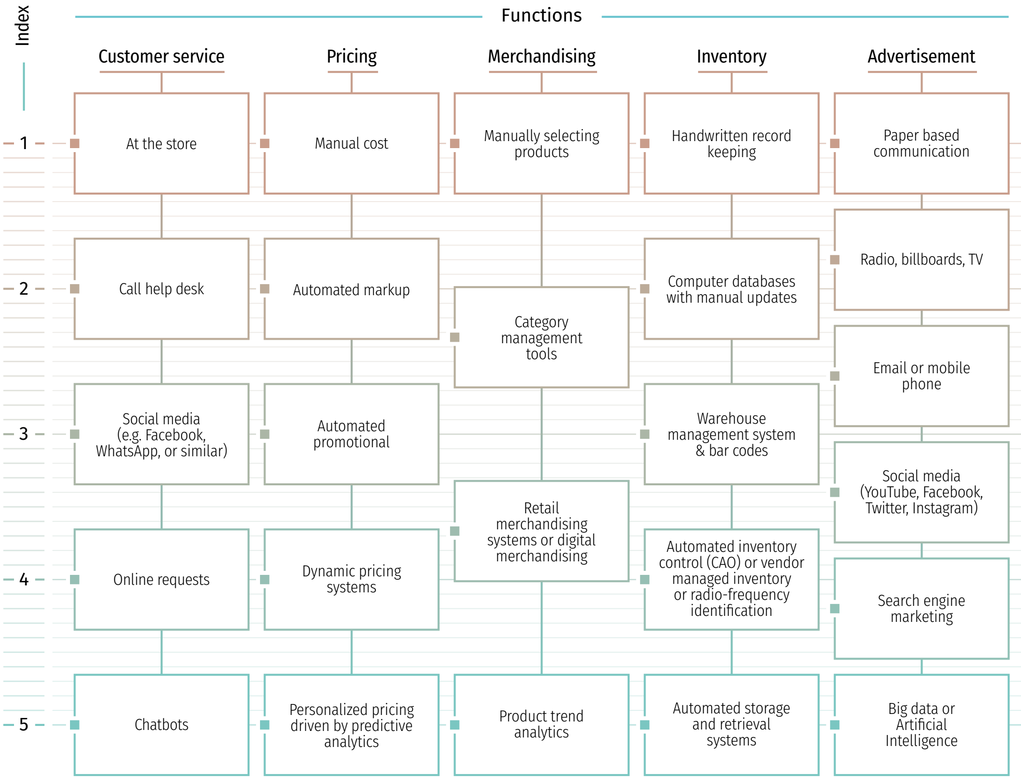
d. Motor Vehicles



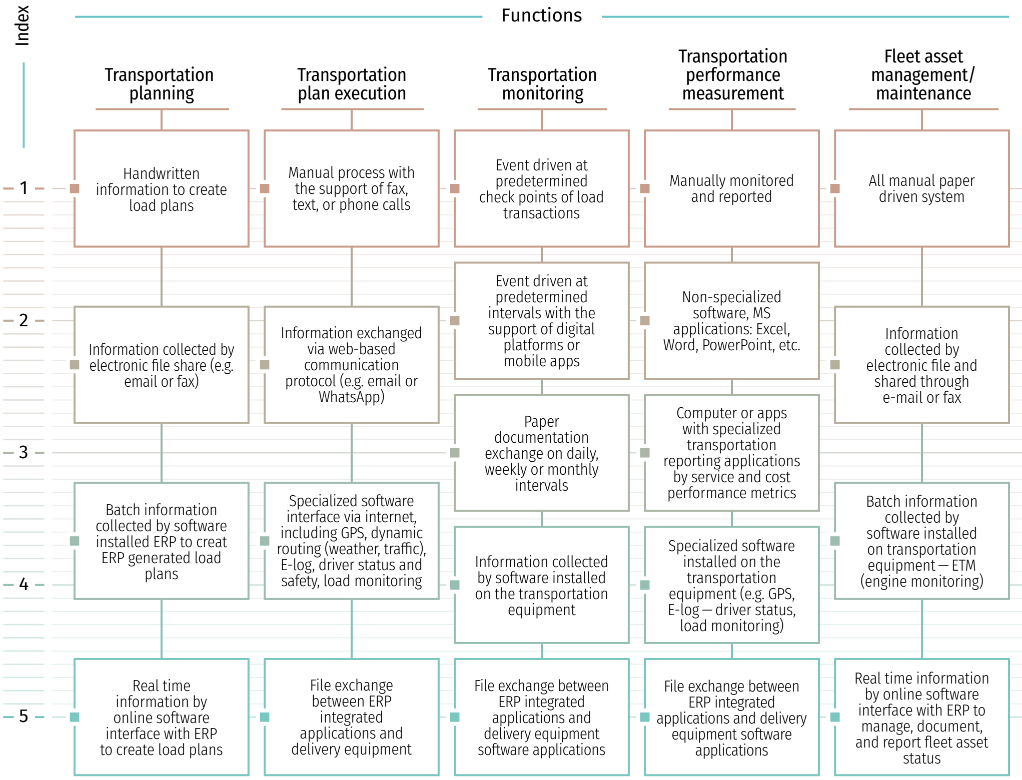
e. Pharmaceuticals



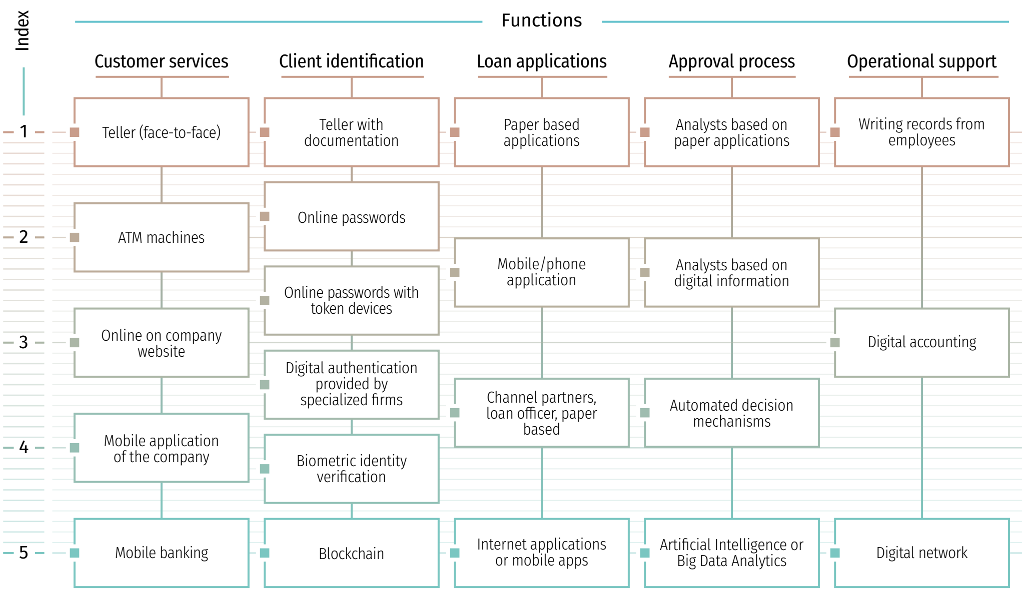
f. Trade


Index
Functions
Customer service
Pricing
Merchandising
Inventory
Advertisement
1
2
3
4
5
At the store
Manual cost
Manually selecting products
Handwritten record keeping
Paper based communication
Radio, billboards, TV
Call help desk
Automated markup
Category management tools
Computer databases with manual updates
Email or mobile phone
Social media (e.g. Facebook, WhatsApp, or similar)
Automated promotional
Warehouse management system & bar codes
Social media (YouTube, Facebook, Twitter, Instagram)
Retail merchandising systems or digital merchandising
Online requests
Dynamic pricing systems
Automated inventory control (CAO) or vendor managed inventory or radio-frequency identification
Search engine marketing
Chatbots
Personalized pricing driven by predictive analytics
Product trend analytics
Automated storage and retrieval systems
Big data or Artificial Intelligence

g. Land Transportation



h. Financial Services



Source: Adapted from Cirera, Comin, and Cruz (2022).
Note: X. Cirera, D. Comin, M. Cruz, *Bridging the Technological Divide: Technology Adoption by Firms in Developing Countries* (Washington, DC: World Bank, 2022).