INNOVATE INDONESIA

UNLOCKING GROWTH THROUGH TECHNOLOGICAL TRANSFORMATION

MARCH 2020

MINISTRY OF FINANCE
REPUBLIC OF INDONESIA

ADB

SECTION 1

A multidisciplinary study integrating evidence and expertise...

Economic analysis, review of previous studies and guidance from academic frameworks

Three surveys involving more than 1,200 firms in Indonesia

Thirteen background technical papers developed by national and international experts

Five focus group discussions involving over 50 local organizations from academia, industry, and government

Review of international policy initiatives from around the world

To assess...

SECTION 2

The critical role of technology transformation in boosting Indonesia's economic development

Indonesia's economy could gain $2.8 trillion by 2040 through technology adoption (adding 0.55 percentage points to GDP growth annually from 2020 and 2040)

Technology and innovation have historically been key drivers of structural change and economic growth

Constraints on Indonesia's growth potential:

- Slowing growth of the labor force
- Limited productivity growth
- Lower manufacturing growth rates

Which requires...

SECTION 3

An in-depth understanding of technology and sector-specific opportunities and challenges

Variety of technologies

- Photonics
- Bio
- Nano
- Advanced materials
- ICT technologies (e.g., big data, IOT, AI)
- Advanced production technologies (e.g., 3D printing)
- Other

Variety of sector-specific applications

- Energy
- Finance
- Commerce
- Manufacturing
- Agriculture
- Other

Crosscutting themes:
Gender equality, labor market, regional development, urban planning

New opportunities, including:

- In **energy**, positive spillover effects on the environment and economic activity through the use of electric motorcycles and microgeneration
- In **fintech**, improved financial inclusion and SMEs access to finance through peer-to-peer payment and lending, and equity crowdfunding
- In **e-commerce**, improved firms' market access (and increased sales and profits) through the use of online e-commerce platforms
- In **manufacturing**, productivity gains through the use of digitally enabled factory solutions
- In **urban planning**, socioeconomic development and regional disparities narrowed by expanding existing investments in digital infrastructure

As well as assessing...

SECTION 4

Indonesia's position in the technological transformation journey

The government has taken important steps to support technology transformation, including:

- New fiscal incentives (superdeductions for vocational training and R&D, tax holidays, and investment allowances)
- Large investments in digital infrastructure
- Making Indonesia 4.0
- Economic policy package on e-commerce
- New funding mechanisms to support public research

Indonesia's innovation system is, however, still in an early stage of development

- Comparatively low R&D expenditure
- Limited contribution of the business sector to innovation and R&D
- Comparatively low number of patent applications
- Relatively low education attainment levels
- Perceived regulatory barriers to private investment
- Limited technological expertise to support corporate innovation

Key national strengths:

- National policy increasingly emphasizes science and technology
- Emerging technology start-up ecosystem hosting three unicorns and one decacorn
- Indonesia is developing a critical mass of STEM graduates: the country is projected to be the 4th largest producer of STEM graduates in the G20 by 2030
- Expanding middle class
- Young population

Complemented by sectoral studies such as...

SECTION 5

A "deep dive" into Industry 4.0 in Indonesia

Opportunities identified:

- In **food and beverage**, customized healthy food and beverage products, digital tools to reduce material waste, and digital platforms to integrate sales channels
- In **automotive**, electric, hybrid, and autonomous vehicles; AI for decision-making in production processes; quality control and predictive maintenance; and the use of big data for quality verification and traceability
- In **textiles and clothing**, new products with digital features such as heartrate and distance monitoring, e-commerce platforms; and virtual 3D modeling for optimization of industrial processes
- In **electronics**, automatic domestic lighting products; security and energy-efficiency systems, health-care mobile applications; and real-time data for smart agriculture
- In **footwear**, "smart products" such as shoes with automatic size adjustment, and e-commerce platforms for direct communication with suppliers and customers

Leading to...

SECTION 6

Five pillars for policy action

- **Advanced innovation infrastructure and institutions**
- **Awareness of the business value of new technologies**
- **Technology transfer and technical support for firms**
- **Low-cost plug-and-play technology solutions for Indonesian firms**
- **A tech-savvy workforce**

To unlock...

Indonesia's technological transformation and economic growth

3D = three dimensional, AI = artificial intelligence, G20 = Group of 20, GDP = gross domestic product, ICT = information and communication technology, IOT = internet of things, R&D = research and development, SME = small and medium-sized enterprises, STEM = science, technology, engineering and mathematics.

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In this publication, "$" refers to United States dollars and "Rp" refers to Indonesia rupiahs, unless otherwise stated.
ADB recognizes "China" as the People's Republic of China, and "Korea" and "South Korea" as the Republic of Korea.

Cover design by Mike Cortes.

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FOREWORD

By the Minister of Finance, Republic of Indonesia

I welcome this flagship report as a valuable knowledge asset to support policy makers in Indonesia. We are firm in our commitment to bring Indonesia to high-income status by 2045, and the government is building the foundation toward that goal. To achieve this, we must seek investment opportunities to boost our potential for growth. The Indonesian economy is already enjoying steady growth, but meeting our aspiration for greater national prosperity requires us to enhance our economic competitiveness. To this end, innovation and new technologies are crucial as they allow industries to become more productive by enabling better use of resources, the creation of new products, and the expansion of new markets.

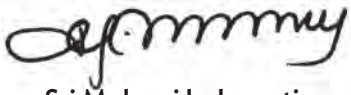
As technological developments reshape industries, restructure markets, and redefine competitive advantage, it is not immediately clear who the winners and losers will be or the role that policy makers can play in fostering inclusive growth driven by technological changes. Some degree of consensus exists about the potential large-scale impact of emerging technologies in both advanced and developing economies. However, each nation has a unique mix of economic structures and areas of specialization. Its firms participate in activities within global value chains and use technologies at varying levels of sophistication. As such, the impact of new technologies will differ in different countries and in their various economic sectors.

For policy makers, the challenge is to understand the policy responses that are required to reap the benefits of new technologies, while anticipating any associated risks. To facilitate and accelerate Indonesia's technological journey, it is crucial that we have sound information based on robust research. This enables us to understand the impact of new technologies and to devise and implement effective policies. Our policy making must be founded on solid knowledge and forecasts that help us identify where opportunities lie, and which investments can spur growth.

The Government of Indonesia has developed a number of initiatives to better equip the country to address opportunities and challenges arising from emerging technologies. We are committed to prioritize infrastructure development, particularly by improving connectivity across the country, and to accelerate the development of our digital economy. Our structural reforms focus on improving productivity and competitiveness, reinvigorating industrialization, and nurturing innovation.

This report is an important contribution to this effort. It identifies the potential impact of new technologies on the Indonesian economy and, importantly, analyzes differences across sectors, regions, and occupations, as well as opportunities to narrow the gender gap. Furthermore, the study offers insights from international policy initiatives adopted in countries around the world in their efforts to support technological transformation. Such insights are highly valuable to policy makers in Indonesia, not only to anticipate where investment can deliver value, but also to determine which sectors and workers are potentially vulnerable and may need additional support.

Particularly beneficial is the report's cataloguing of policy options, bringing together findings from across the study. Deep analytical collaboration between the Ministry of Finance and the Asian Development Bank to produce this report has been a fruitful experience. The thorough and rigorous approach taken in this formative study will support policy makers in their efforts to make sound decisions toward more inclusive and accelerated economic growth in Indonesia.



Sri Mulyani Indrawati
Minister of Finance, Republic of Indonesia

FOREWORD

By the President, Asian Development Bank

Indonesia has made remarkable development strides over the last few decades, including sustained economic growth, reduction of the poverty rate to single digits, expansion of public services, improvements in doing business, and investments in infrastructure. At the cusp of becoming an upper-middle-income country, continued progress will require increasing productivity, reducing inequality, and lowering climate costs while also navigating megatrends such as demographic changes, climate change, rapid urbanization, and technological disruptions.

Changing technologies have reoriented how we produce, consume, and live and are accelerating the cycle of creative destruction. The shelf life of new technologies continues to shorten, and the gap between innovation incubation and market commercialization is narrowing. Harnessing the benefits of new technologies promises to improve the quality of life, but only if appropriate policy responses ensure that the benefits outweigh socioeconomic risks that are still far from fully understood. As new technologies reshape our economies and societies, we need innovation policies to guide national economies toward higher productivity.

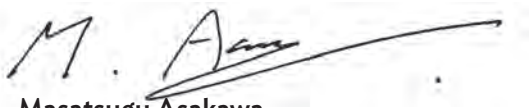
Indonesia's digital economy is projected to be worth $133 billion by 2025 and hosts one of the most vibrant e-commerce markets in the Association of Southeast Asian Nations region. Reflecting this entrepreneurial dynamism, Indonesia already hosts several unicorns, or start-up companies valued at above $1 billion, and even a decacorn, valued at above $10 billion. While, from this vantage point, Indonesia is already poised to reap the benefits of new technologies, a pertinent issue is how it can ensure that these benefits contribute to more inclusive and sustainable growth. What suite of policies will be required to deliver such desired developmental aims?

Here at the Asian Development Bank (ADB), our corporate Strategy 2030 steps up the focus on supporting our client countries as they address the development challenges emerging in Asia and the Pacific, not least by capitalizing on the benefits of global technological changes while mitigating associated risks. To help capitalize on the benefits of global technological change, ADB operations in Indonesia include support for developing human capital, accelerating investment and infrastructure development, and strengthening institutions and capacity.

We are pleased we could support the study on *Innovate Indonesia: Unlocking Growth Through Technological Transformation* in collaboration with the Ministry of Finance. We hope it will contribute to a deeper and more nuanced understanding of the economic impact that new technologies have on Indonesia, as well as related policy implications.

The process of preparing this report in itself was a journey. It not only was a humbling learning experience for the team, but it also helped nurture a network of Indonesian researchers, in government and academe, that are now well versed on the topic and available to support evidence-based policy discussion and programs going forward.

Given the fluidity of continuous and accelerating technological change, and the porous boundaries of a phenomenon with such pervasive impact, no single study of the topic at hand can claim to be conclusive. In that spirit, we hope that this country-focused analysis will be received as contributing to the broader national dialogue on developing technology and innovation policies, and as preparing the ground for future undertakings in this important area.



Masatsugu Asakawa
President, Asian Development Bank

ACKNOWLEDGMENTS

This report is the product of research collaboration over a year between national and international experts focused on developing an empirical understanding of the economic impact of new technologies on Indonesia in order to inform policy dialogue and formulation.

For their support, we thank first Sri Mulyani Indrawati, the minister of finance of the Republic of Indonesia, and Suahasil Nazara, the vice minister of finance. We also thank in the Ministry of Finance, for their helpful engagement with the analysis and their steadfast guidance in the execution of this research project, Hidayat Amir, head of the Centre for Macroeconomic Policy; Adriyanto, director of financing and non-balance transfer; Andriansyah, head of national income balance analysis; and Riznaldi Akbar, head of model development and macro data processing.

At the outset of research, the team was confronted with numerous research challenges, especially data limitations. While the number of publications pertaining to this timely topic in Indonesia grew, those offering formal empirical analysis remained few and far between. Also lacking was clarity on what constituted "new technology," what the impact of a given technology was on any particular sector, and, importantly, what it meant for a developing country. To fill this void, the research project commissioned two lines of analytical papers to provide background analysis. This report builds on these lines of inquiry, which were supplemented with the broader literature and extensive consultations with stakeholders in Indonesia.

Michele Palladino, Carlos López-Gómez, David Leal-Ayala, and Jennifer Castaneda at Policy Links, Institute for Manufacturing (IfM) at the University of Cambridge supported the drafting of the report. A team of technology experts affiliated with the institute analyzed the impact of emerging technologies on selected sectors in a global context, identified key technologies driving change in various sectors, and discussed the implications for developing countries. The team included Jaime Bonnín Roca on digitalization in manufacturing; Jagjit Singh Srai on last-mile delivery and the e-commerce retail revolution; André Cabrera Serrenho on the impact of disruptive technologies in the energy sector; Ajith Parlikad, Timea Nochta, and Li Wan on technological transformation in urban planning in the age of smart cities; and Kieran Garvey on transformation in financial services by fintech. Yuta Hirose used an innovative approach developed at IfM to structure a series of qualitative analyses with representatives from the private sector to generate a richer understanding of how private business in Indonesia viewed the emergence of new technologies, what strategies were being adopted, and the perceived opportunities and challenges.

Drawing on the global perspective, a team of experts affiliated with the Centre for Strategic and International Studies (CSIS) in Jakarta and led by Yose Rizal Damuri and Ira Setiati Titiheruw conducted a "deep dive" analysis of the economic impact of new technologies. The team included Arief Anshory Yusuf on economic growth; Haryo Aswicahyono and Dandy Rafitrandi on manufacturing; Raymond Atje, Ira Setiati Titiheruw,

and Ilma Navianti Fadhil on banking; Yose Rizal Damuri on e-commerce; Teguh Yudo Wicaksono and Carlos Mangunsong on the labor market; Medelina K. Hendytio and Lestary Jakara Barany on gender; Maxensius Tri Sambodo and V. M. Mesnan Silalahi on energy; and Komara Djaja and Paksi P. K. Walandouw on cities. We would also like to thank the many enumerators that facilitated the survey of Indonesian firms.

The research benefited from focus group discussions at key milestones that included methodological selection and reviews of empirical findings and policy recommendations. We are tremendously grateful to the participants who generously shared their insights and guidance. We thank Amalia Adininggar Widyasanti (National Development Planning Agency); Ade Fauzan (Investree); Akhis Reynold Hutabarat and Tumpak Silalahi (Bank Indonesia); Anton Gunawan and Soejahmoen (Mandiri Institute); Bob Azam, Teguh Trihono, and Windy Tanu Hidayat (Toyota Motor Manufacturing Indonesia); Dewi Setiawati and Himawan Ari Wijayanto (Industry Ministry); Eddy Manindo (Financial Services Authority); Edy Priyono (Akademika); Fitria Vidayani and Mira Tayyiba (Economic Affairs Coordinating Ministry); Mohammad Ghozie Indra Dalel and Hasiholan Tamba (PT Sarana Multi Infrastruktur); I Gusti Ketut Astawa and Septo Soepriyatno (Trade Ministry); Khairul (United Cities and Local Governments); Lany Sulaiman (Indonesian Shoes Association); Lurong Chen and Yanfei Li (Economic Research Institute for ASEAN and East Asia); Nyoman Adhiarna (Communications and Informatics Ministry); Paul Butarbutar (Indonesian Renewable Energy Society); Siti Astrid Kusumawardhani (Gojek); Turro Wongkaren (Demographic Institute, Universitas Indonesia); Vidya Simarmata (Bukalapak); Wicaksono (Palladium); and Zainal Arifin (state electricity company, PT PLN).

We would like to thank in Bank Indonesia, for giving us the opportunity to share our analysis and receive helpful feedback, Dody Budi Waluyo, Aida S. Budiman, Reza Anglingkusumo, Noor Yudanto, and Nugroho Joko Prastowo.

External peer reviewers provided comments and direction to improve the quality of our analysis and sharpen the relevance of policy recommendations, for which we thank Ariane Utomo, Dionisius Ardyanto, Djoni Hartono, Eva Huang, Febrio Kacaribu, Jonathan M. Cullen, Muhamad Purnagunawan, Mulya Amri, Parth Vaishnav, Puspa Delima Amri, Titik Anas, Tomas Harrington, and Ying Jin. For providing helpful comments and suggestions at various stages of the study, we thank Asian Development Bank (ADB) colleagues Ayako Inagaki, Azusa Sato, David Kruger, Edimon Ginting, Florian Kitt, Jane Zhang, Jason Rush, Jesus Felipe, Joris van Etten, Joven Balbosa, Poornima Jayawardana, Rana Hasan, Sameer Khatiwada, Sona Shrestha, and Thomas Abell.

The report benefited greatly from editorial support by Peter Fredenburg and design works by Mike Cortes and Alvin Tubio.

This report would not have been possible without the generous support and encouragement that the team received along the way from far too many people to name individually. That said, we would like to acknowledge and thank Mari Elka Pangestu of CSIS and Sir Mike Gregory of IfM, University of Cambridge for the guidance and the warm support they extended to the team, particularly at critical moments when we wrestled with research challenges.

We express our appreciation to Ahmed M. Saeed, Vice-President Operations 2 of ADB; Ramesh Subramaniam, director general of the ADB Southeast Asia Department; and Winfried F. Wicklein, country director of the ADB Indonesia Resident Mission, for their foresight in initiating this study as well as for their support and guidance.

Finally, special thanks go to the ADB co-team members: Priasto Aji, Cahyadi Indrananto, and Emma Allen.

Yurendra Basnett
ADB Country Economist and Task Team Leader

ABBREVIATIONS

3D	three dimensional
ADAPT	Adoption of Digital Automation Practices and Technology
ADB	Asian Development Bank
AI	artificial intelligence
ASEAN	Association of Southeast Asian Nations
FGD	focus group discussion
fintech	financial technology
G20	Group of 20
GDP	gross domestic product
GII	Global Innovation Index
ICT	information and communication technology
IOT	internet of things
IT	information technology
MADE	Manufacturing Academy of Denmark
NIS	national innovation system
OECD	Organisation for Economic Co-operation and Development
P2P	peer-to-peer
PRC	People's Republic of China
R&D	research and development
RFID	radio-frequency identification
ROK	Republic of Korea
RTO	research and technology organization
SMEs	small and medium-sized enterprises
STEM	science, technology, engineering, and math
UK	United Kingdom
US	United States
WEF	World Economic Forum
ZIM	Zentrale Innovationsprogramm Mittelstand (Central Innovation Program for SMEs)

EXECUTIVE SUMMARY

Technological transformation could add $2.8 trillion to the Indonesian economy by 2040

Indonesia is the world's fourth most populous nation and its tenth largest economy. It is by far the largest country by both measures in the Association of Southeast Asian Nations (ASEAN). It has sustained average economic growth rates above 5% since 2000 and made significant strides in reducing poverty.

Yet economic analyses point to a number of factors constraining Indonesia's growth potential, notably tepid productivity growth and slowing expansion in the labor force and manufacturing industries.

Technology has a key role to play in overcoming these constraints and boosting future growth. Internationally, advanced and developing economies alike see emerging technologies offering sustainable growth. Adopting new technologies allows industry to become more productive by enabling more efficient resource use, new product development, and entry into new markets. Indonesia is no exception in this regard, and the Government of Indonesia recognizes the role of technology and innovation in achieving economic growth targets and higher incomes.

Technology adoption could add up to $2.8 trillion to the Indonesian economy by 2040, spurring growth in gross domestic product (GDP) by an additional 0.55 percentage points annually over the next 2 decades. This was one conclusion of the present study, which explored the impact of new technologies across major economic sectors in Indonesia and identified policy options with the potential to support technological transformation (Box 1).

Building the evidence base, grounded on country context, to inform the development of policies

This study has followed a highly structured approach, integrating economic and technological expertise, quantitative and qualitative data sources, and international and local perspectives. For the study, the Indonesia Resident Mission of the Asian Development Bank and the Fiscal Policy Agency of the Ministry of Finance of the Republic of Indonesia assembled a multidisciplinary team of technology experts from the University of Cambridge and leading researchers from Indonesia's Centre for Strategic and International Studies.

Extensive consultations with local stakeholders in academia, government, and industry generated new primary data that provided a detailed understanding of the distinctive challenges and opportunities presented to Indonesian firms. In addition, 13 background technical papers employed advanced econometric tools and case studies to describe global technological trends and explore the implications for selected segments of the Indonesian economy.

Another distinctive contribution of the study is its review of recent international policy initiatives, providing practical insights into the aims, implementation approaches, and funding mechanisms adopted in the latest policy efforts to support technological transformation around the world.

BOX 1

Multidisciplinary Study Integrating Published and Survey Evidence

This publication reports the primary results of a new economic analysis and study of technology adoption in Indonesia based on the following:

- a comprehensive review of previous studies and academic frameworks,
- five focus group discussions with over 50 local organizations,
- three surveys of more than 1,200 firms,
- 13 background technical papers researched and written for the study by Indonesian and international experts, and
- a review of 16 international policy initiatives.

With the adoption of a multidisciplinary approach, the study complements existing evidence on emerging technologies with findings pursued specifically to support policy thinking in Indonesia.

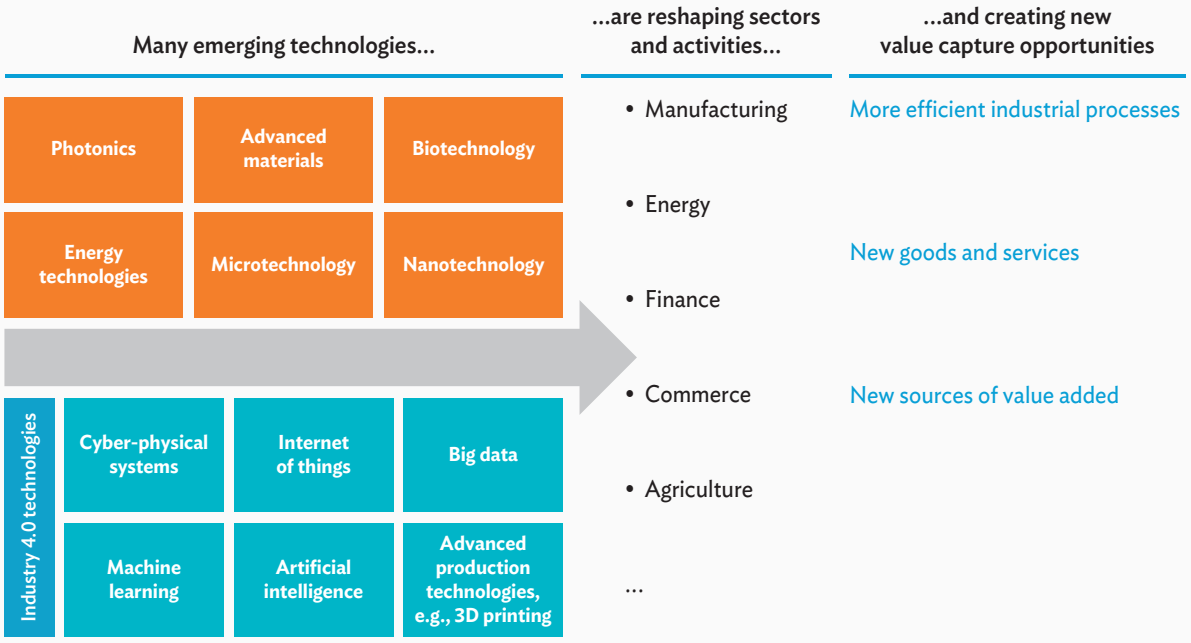
Designing appropriate policies to support Indonesia's technological transformation requires an in-depth understanding of technology and sector-specific opportunities and challenges

Many emerging technologies such as photonics, advanced materials, biotechnology, nanotechnology, and a range of information and communication technology (ICT) applications are dramatically reshaping how firms produce, compete, and innovate across sectors. However, understanding their impact on particular national economies is fraught with difficulty.

Complexity arises from many of these new technologies having multiple subdomains, each with a distinct and potentially forceful impact across sectors. This is certainly the case for a number of digital ICT technologies commonly grouped under the umbrella term "Industry 4.0," including cyber-physical systems, cloud computing, big data, artificial intelligence (AI), machine learning, and the internet of things.

Understanding the impact of each of these technologies is challenging in its own right. AI, for example, is expected to drive change across industries, with such applications as self-driving cars in manufacturing, personalized advertising in e-commerce, and automated trading in finance. Moreover, as shown in Figure 1, the new technologies driving change across sectors go beyond Industry 4.0.

Figure 1: Various New Technologies Driving Change across Economic Sectors and Activities



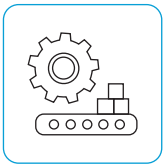
Source: Policy Links, Institute for Manufacturing, University of Cambridge.

The task for policy makers is to disentangle this complexity and identify policy responses to help firms reap the benefits of new technologies while addressing emerging socioeconomic risks. To this end, this study looked beyond macroeconomic analysis to carefully distinguish opportunities and challenges across technology domains and economic sectors: manufacturing, finance tech, e-commerce, energy, and urban planning. It investigated technological effects on labor markets and gender equity to take into account likely socioeconomic disparities that may worsen under new technologies. Table 1 illustrates the variety of high-level opportunities and challenges arising from new technologies for Indonesia.

Indonesia has taken important steps to support technology and innovation, but its national innovation system is still at an early stage of development

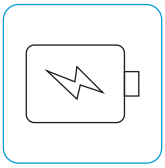
Indonesia's innovation system is a network of private companies, universities, research centers, and public institutions that generate, disseminate, and deploy new knowledge and technologies. With technology and innovation at the heart of the national policy agenda, significant steps have been taken in recent years to strengthen this national innovation system.

Table 1: Potential Implications of Technologies in Selected Sectors

	Global Technology Trends	Opportunities for Indonesia	Challenges to Exploiting Opportunities
 **Manufacturing**	• Industry 4.0 technologies leading to more connected and integrated manufacturing systems • Digital technologies enabling more efficient factories, faster product development, more efficient logistics, and new business models	• Boosting Indonesian industrial productivity by developing better products and processes and adopting improved management practices • Integrating local firms into global supply chains and export markets	• Policy makers need to ensure that digital infrastructure exists to adopt new technologies. • Policy makers need to raise awareness of digital technologies and the possibilities they offer. • Local firms require support to adopt technology and develop innovation skills.
 **Financial services**	• Mobile phone and internet penetration enabling wider access to financial services • Cloud computing minimizing upfront investment in information technology in "asset light" business models • Blockchain technology enabling smart contracts without third parties and thereby lowering the cost of contracts and payments • Artificial intelligence and machine learning enabling cheaper and more efficient financial products and services	• Financial inclusion and access to finance for small and medium-sized enterprises • Equity crowdfunding and peer-to-peer lending providing additional channels of capital flow to young businesses • New tools reducing the cost of financial products and services for users • Improved customer experience, transparency, and customization building user acceptance and adoption of financial products and services	• Policy makers need to enact effective regulation to avoid the shortcomings that may lead to financial exclusion. • Equity crowdfunding regulations must focus on consumer protection to ensure that investors understand the risks. • Regulations should guarantee that peer-to-peer lending does not create unnecessary risks for consumers. • Adequate regulation is essential to enabling the responsible development of new digital financial products.
 **E-commerce**	• Global expansion of infrastructure for information and communication technology enabling wider internet and mobile phone penetration • Wider global availability of digital content providers and internet platforms • New digital payment solutions enabling secure online transactions • Retailers adopting an omni-channel approach, integrating physical and virtual stores	• Expanding the number of consumers that Indonesian firms can reach, particularly in rural areas away from traditional retail centers • E-commerce platforms reducing physical infrastructure and capital investment requirements for new business creation • Direct contact with customers enabling more exact product and service customization for local needs, both urban and rural	• Policy makers need to anticipate disruptive impacts on displaced businesses and employees and anticipate market changes. • Legislation to protect labor rights is required for last-mile delivery personnel. • Consumer protection regulation should be extended to cover e-commerce platforms. • Safeguards against monopolies should be considered. • Privacy and cybersecurity rules and policies need updating.

continued next page

Table 1: *Continued*

	Global Technology Trends	Opportunities for Indonesia	Challenges to Exploiting Opportunities
 **Urban planning**	• Online open data sources providing useful information to understand city dynamics that are difficult to capture in traditional statistics • Geographic information systems enabling better visualization of the spatial distribution of population, jobs, buildings, and natural features • City-wide schemes for data sharing to enable better understanding of city problems and development of tailored solutions • Digital twin cities helping to optimize resource use and inform policy on planning and managing infrastructure	• Investment into digital infrastructure able to connect geographically dispersed Indonesia and rebalance regional disparities • Digital strategies differentiated for local conditions, providing, for example, digital payment systems for public transport in urban areas and, in rural areas, access to basic public services • More effective disaster and emergency response achieved by, for example, establishing a centralized national disaster response system	• Policy makers need to address barriers that may keep segments of the population digitally backward and unable to harness the benefits of digital connectivity. • Develop and implement methods of data collection that are comprehensive and accurate. • It is crucial to train planners and officials in using digital solutions to ensure successful data analysis tailored to local contexts. • The authorities need to protect personal data privacy and confidentiality.
 **Energy**	• Renewable and distributed microgenerators of electricity becoming cheaper and more readily available • Improved battery storage technology, smart meters, and smart grids enabling easier integration of distributed power generators into electricity grids	• Decarbonizing electricity supply to lower energy costs and mitigate oil dependency • Falling demand for electricity from traditional power plants even with the adoption of such green technologies as electric motorcycles • Reducing noise and improving air quality in big cities	• A national smart grid requires high financial investment, new technology adoption, and governance adaptation. • Distributed generation of renewable energy requires an appropriate regulatory framework with technology adoption incentives, investor and consumer protection, and system resilience.

Source: Summary of background analysis produced for ADB technical assistance to Indonesia on Supporting Technological Transformation (Project Number: 51343-001). Jakarta.

Newly established initiatives, institutions, and funding sources enabled by updated regulations promote research and innovation. Recently introduced fiscal incentives include a "superdeduction" tax scheme to reward vocational training and research and development (R&D), tax holidays for qualifying investments, and investment allowances for labor-intensive operations. Large investments are expanding national digital infrastructure.

Despite some progress, much remains to be done to boost Indonesia's comparatively low public and private R&D expenditure and its heretofore modest educational attainment and scientific output. National expenditure on R&D, for example, is estimated to equal only 0.08% of GDP, hardly more than a tenth of the ASEAN average (Table 2). Surveyed stakeholders pointed to perceived regulatory barriers against private innovation investment; opportunities not yet taken to improve intellectual property protection, data privacy laws, and access to finance; and short supply across Indonesia of technological expertise to support company innovation efforts.

Table 2: Science, Technology, and Innovation Indicators: Indonesia versus ASEAN

	Indonesia	ASEAN Average
R&D expenditure (% of GDP)	0.08	0.70
Private share of R&D expenditure (%)	26	46
Patent applications (resident or not, per million population)	37	348
Scientific and technical journal articles (per million population)	30	412

ASEAN = Association of Southeast Asian Nations, GDP = gross domestic product, R&D = research and development.

Notes: 2017 or latest year available. ASEAN members represented are Cambodia, Indonesia, Malaysia, the Philippines, Singapore, Thailand, and Viet Nam.

Sources: World Bank World Development Indicators; UNESCO UIS.Stat.

A number of initiatives already address some of these gaps. Notably, Making Indonesia 4.0 is a national initiative to integrate Indonesia into the Fourth Industrial Revolution through a number of innovation investments. The government estimates that Making Indonesia 4.0 will help create 10 million additional jobs, raising net exports to the equivalent of 10% of the GDP, and boosting productivity growth.

Further efforts are required to support technological transformation and unlock opportunities in Indonesia to improve productivity, growth, prosperity, and the quality of life. This requires sober analysis of the strengths and weaknesses of the national innovation system, and of its opportunities and threats, as presented in Table 3. This analysis draws from a number of secondary sources but importantly also from insights provided by local stakeholders, both private and public, when consulted in Indonesia under this study.

Industry 4.0 presents an opportunity to advance Indonesia's technological transformation

In-depth analysis of Industry 4.0 in Indonesia clearly illustrates the complexity entailed in integrating various technologies and managing their impact across sectors. Industry 4.0 has emerged in recent years as one of the most important themes in the innovation policies and R&D portfolios of countries around the world. Industry 4.0 is creating possibilities for the broader value chain of manufacturing and related activities, from planning and supply chain management to production and sales. Firms should expect changes in their business models beginning in the short term and becoming more profound over the medium and long term.

Manufacturing contributes substantially to the Indonesian economy. In 2017 manufacturers employed over 17 million workers, providing 14.1% of employment. In the same year manufacturing generated 20.2% of GDP and 42.5% of exports.

Table 3: Indonesia's National Innovation System: Strengths, Weaknesses, Opportunities, and Threats

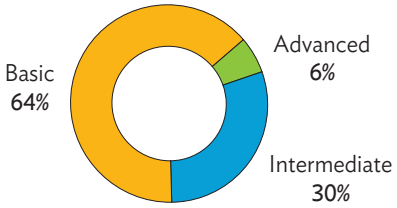
Strengths	Weaknesses
• Science and technology are receiving increasing attention in the national policy agenda. • New mechanisms have been established, including the Indonesian Science Fund, to fund public research. • Patent regulation has been updated with the aim of making research funding more efficient. • A number of technology parks, innovation centers, and incubators have been established in recent years. • Relatively high expenditure on computer software is recorded in the private sector. • Sustained economic growth is expanding the middle class and demand for consumer goods. • Recent investments have improved energy, transport, and logistics infrastructure. • Investments are developing digital infrastructure, notably the Palapa Ring national fiber-optic network. • Adoption of mobile phones is high. • Entrepreneurial activity has scored some successes, such that Indonesia hosts three unicorns—Tokopedia, Traveloka, and Bukalapak—and one decacorn, worth more than $10 billion: Gojek.	• National expenditure on R&D is only a tenth of the ASEAN average as a percentage of GDP. • Many firms do not innovate, and business R&D and patenting activity is low. • Scientific output remains small, with few scientific papers published in international journals. • Harmonization is lacking between national and subnational laws and regulations on technology. • Industry reports difficulty in finding specialized skills. • A comprehensive strategy is lacking for international research and innovation collaboration. • Regulatory barriers are perceived to hinder private investment. • Gaps and regional disparities mark fixed broadband coverage. • Technology adoption is low in industry. • Gaps are perceived in laws on intellectual property protection and data privacy, and in access to finance. • Technological assistance—for training, market research, and contract R&D—are limited across the country.
Opportunities	**Threats**
• Expanded fiscal incentives for training and R&D would promise higher exports and productive investment. • The government could commit to increased funding through various ministries for R&D and innovation. • Free trade zones could attract foreign direct investment in knowledge-intensive industries. • The number of funding schemes for micro, small, and medium-sized enterprises could be increased. • E-government, such as through one-stop services, could improve the ease of doing business. • State-owned companies could foster collaboration with universities, high schools, and ministries for research and training programs. • Indonesia's young population is set to become by 2030 the world's fourth largest producer of science, technology, engineering, and math graduates. • Its large population is an attractive market, with potential to become, for example, the largest e-commerce market in Southeast Asia.	• Low multinational investment in R&D limits prospects for developing business R&D. • Lack of expertise in cutting-edge technology could hinder its widespread adoption. • Indonesia could suffer as trade disputes threaten to slow global economic growth. • Industrial expansion could cause environmental damage if appropriate countermeasures are not implemented. • Natural hazards pose perennial risks of disruption to Indonesia's productive capacity. • Intensifying use of digital technology in businesses heightens the risk of cybercrime, requiring new approaches to ensure data security and customer protection. • Considerable diversity exists among Indonesian regions and communities, horizontally (inter-sector, inter-region) and vertically (related to income inequality)

ASEAN = Association of Southeast Asian Nations, GDP = gross national product, R&D = research and development.

Sources: ADB-BAPPENAS. 2019. *Policies to Support the Development of Indonesia's Manufacturing Sector during 2020–2024.* Manila: Asian Development Bank; Y. Damuri et al. 2018. Innovation Policy in Indonesia. In M. Ambashi, eds. *Innovation Policy in ASEAN.* Jakarta: Economic Research Institute for ASEAN and East Asia; OECD. 2016. Indonesia: Country Profile. *OECD Science, Technology and Innovation Outlook 2016.* Paris; Summary of background analysis produced for ADB technical assistance to Indonesia on Supporting Technological Transformation (Project Number: 51343-001). Jakarta.

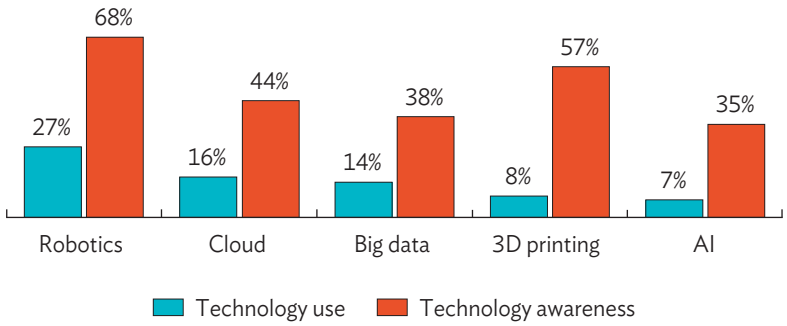
BOX 2

Industry 4.0 in Indonesia: Insights from a Manufacturing Survey



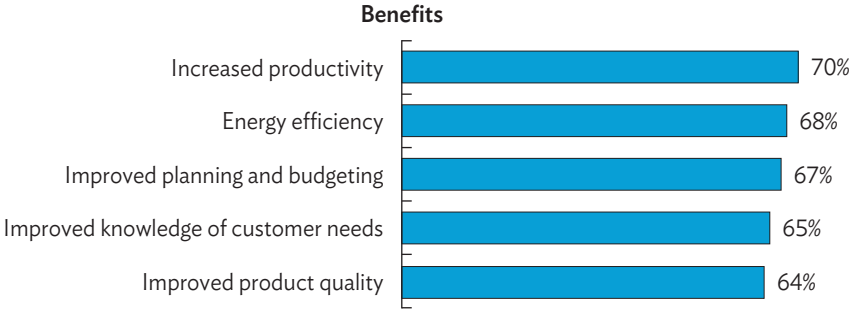
A relatively small 6% of firms have adopted new technologies and used emerging digitally enabled tools.

Nearly two-thirds of firms surveyed, or 64%, have adopted little technology and still perform many tasks with basic tools such as spreadsheets and e-mail.

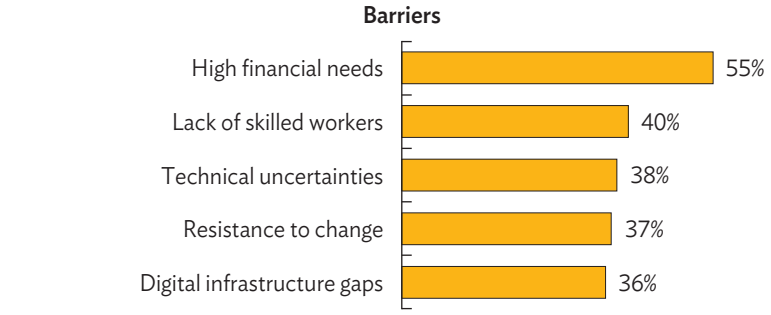


Robotics is the most commonly used Industry 4.0 technology among the surveyed firms.

Awareness of other emerging technologies is low—and especially low for less mature technologies such as AI.



Firms reported the greatest benefits of technology adoption to be enhanced productivity and energy efficiency.



Financial constraints and a lack of skilled workers are the main barriers to the adoption of new technologies.

3D = three dimensional, AI = artificial intelligence.

Note: The survey sample was 502 firms.

Source: H. Aswicahyono and D. Rafitrandi. 2019. *Disruptive Technology in Manufacturing Sector.* Background paper produced for the ADB technical assistance to Indonesia on Supporting Technological Transformation (Project Number: 51343-001). Jakarta.

Indonesian manufacturers are a diverse group with varying innovation capability and readiness to adopt new Industry 4.0 technologies. Surveys found that only 6% of firms used new technologies across their operations, 30% of them had adopted technology to an intermediate degree, and 64% had adopted only basic technology (Box 2).

The present study delved deep into Industry 4.0 in Indonesia to collect evidence on the current state of Industry 4.0 technology adoption across manufacturing firms, and to elicit industry views on the potential benefits of digitalization and barriers to achieving it. Analysis centered on five manufacturing industries—food and beverage, automotive, textiles and clothing, electronics, and footwear—which together provide 51% of all Indonesian manufacturing value added and 58% of manufacturing employment. The consulted firms cited a wide range of technological trends and drivers that they expect to see shape Indonesia's industries over the short, medium, and long term, and they foresaw a number of options to create new products and services, as well as innovative manufacturing processes and methods to interact with and deliver products to customers (Table 4). Successfully exploiting Industry 4.0 opportunities requires that Indonesian industrialists overcome high monetary costs, a lack of skilled workers, technical uncertainty, resistance to change, and digital infrastructure gaps (Box 2).

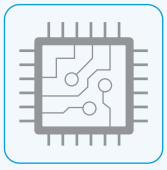
The challenges and opportunities described in this study require careful policy consideration. The aim is to complement existing knowledge in Indonesia on the topic of Industry 4.0, including evidence generated through Making Indonesia 4.0.

Table 4: Trends and Opportunities Shaping Indonesian Industry

	Short-Term Trends (<5 years)	Medium-Term Trends (5–10 years)	Long-Term Trends (>10 years)	Selected Opportunities
 **Automotive**	• Introducing electric and hybrid vehicles and corresponding infrastructure • Predictive maintenance in industrial operations using AI • IOT-connected production lines • Adopting stricter emissions standards for vehicles	• Introducing vehicles with engines powered by fuel cells, biofuel, ethanol, and flexible fuels • Higher vehicle customization to customer specifications • New sector entrants and players with strong ICT technical know-how	• Autonomous vehicle testing and adoption • Internal combustion vehicles banned • Customers shifting from car ownership to rental and/or services providing vehicles on demand • Electric cars pushing up demand for electricity nationally	• Local firms able to join value chains producing electric, hybrid, and autonomous vehicles • Local firms able to build infrastructure to charge electric vehicles • AI for process decision-making, quality control, and predictive maintenance • Big data for quality verification and traceability

continued next page

Table 4: *Continued*

	Short-Term Trends (<5 years)	Medium-Term Trends (5–10 years)	Long-Term Trends (>10 years)	Selected Opportunities
 **Electronics**	• Wider adoption of solar panel technology and smart meters • More efficient radio and wireless transmission, fiber optics, and 4G network connectivity	• Smart consumer appliances with cloud computing, IOT, and basic AI features • Higher demand for customized electronic products • New business models providing data services for smart devices	• 5G mobile communication networks • Government directives to reduce, reuse, and recycle to minimize industrial waste	• Developing mobile applications for health care and healthy lifestyles • Providing real-time data for smart agriculture adapted to Indonesia • Robotics for hospitality and food services • Automatic domestic lighting and systems for home security and energy efficiency
 **Food and beverage**	• New organic food and beverage products • More stringent environmental regulations to reduce pesticide use in food production and cut food waste from the farm through retail	• E-commerce platforms combined with big data analytics to gather consumer insights, enable targeted marketing, and bypass retail intermediaries • Increased demand for customized health products	• New finance technology services to support e-commerce platforms • Environmental and food safety standards harmonized with those in foreign markets	• Developing customized health foods and beverages for local markets • Forging digital tools to reduce food waste • Digital platforms to integrate sales channels and the use of delivery drones in urban and rural areas alike
 **Textiles, clothing, and footwear**	• Rising demand for low-cost and high-quality personalized products • Fewer intermediaries along the supply chain and more local sourcing of raw materials	• Traditional retail centers displaced by e-commerce platforms • Widespread deployment of low-cost AI, IOT, and robotics for improved quality, productivity, waste reduction, and energy efficiency	• Demand switching toward full product customization • Stricter sustainability standards and regulations coming into force in Indonesia	• New products integrating digital features for monitoring distance traveled and vital signs such as heart rate • Local firms able to develop e-commerce platforms • Virtual 3D modeling to optimize industrial processes, such as stitching models for garments

3D = three dimensional, 4G = fourth generation, 5G = fifth generation, AI = artificial intelligence, ICT = information and communication technology, IOT = internet of things.

Source: Summary of background analysis produced for ADB technical assistance to Indonesia on Supporting Technological Transformation (Project Number: 51343-001). Jakarta.

Key policy actions grouped in five pillars to support Indonesia's technological transformation and economic development

Policy recommendations for technological transformation and economic development in Indonesia rest on five policy action pillars. Each pillar rises from an area where the Indonesian context critically requires policy action to drive technological transformation.

I. Advanced Innovation Infrastructure and Institutions

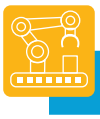
The Challenge	Policy Actions
While the government has launched a number of initiatives, Indonesia's national innovation system is still at an early stage of development. Public and private R&D and scientific outputs are comparatively low, and, despite current investment, digital infrastructure gaps persist, especially in regions outside Java. Private investors are frustrated by perceived regulatory barriers. Advanced innovation requires commensurate infrastructure and institutions to seize the opportunities that arise from new technologies and overcome the obstacles along the way to future economic growth.	➤ Address gaps in both "hard" and "soft" infrastructure and develop advanced innovation institutions. ➤ Develop digital infrastructure nationally to narrow regional disparities. ➤ Develop long-term R&D investment plans and adopt international best practices for funding research. ➤ Assess needs for new extension services and intermediate institutions such as research and technology organizations to provide technological assistance to firms. ➤ Build institutional capacity for policy delivery across regions. ➤ Ensure that regulatory frameworks are updated appropriately in response to changes brought by new technologies.

II. Awareness of the Business Value of New Technologies

The Challenge	Policy Actions
New technologies are complex and continually evolving. Industry consultations suggest that firms are not very aware of emerging technologies and their potential applications—with, for example, only 35% of survey respondents being aware of AI. Company managers' lack of awareness about the benefits of new technologies and of potentially high return on investment in them poses an important barrier to technology adoption in many firms in Indonesia.	➤ Develop industrial networks and business associations to promote linkages and knowledge exchange between firms in Indonesia and abroad. ➤ Establish mechanisms to share best practices across firms in value chains. ➤ Create sector and cross-sector technology forums in cooperation with universities, research centers, and technology vendors. ➤ Set up facilities to demonstrate technology in research centers and universities.

III. Technology Transfer and Technical Support for Firms

The Challenge	Policy Actions
Many firms lack the absorptive capacity needed to adopt the technology they need to innovate. Enabling industry-wide technology adoption in Indonesia requires specialized support mechanisms to address capacity gaps. Firms that are unable to upgrade their technological usage and practices as quickly as their competitors may suffer fierce competitive pressure. When helping firms improve their absorptive capacity, it is crucial to recognize that Indonesian firms are at different stages in their journey toward technology transformation.	➤ Develop a stratified approach combining a variety of support measures to address the diverse needs of firms at varying stages of technological sophistication. ➤ For the small group of leading firms, emphasize support in building capacity to invent and generate new technology. ➤ For the large group of intermediate followers, emphasize support that further develops absorptive capacity and the ability to innovate. ➤ For the largest group, firms that have adopted only basic technology, emphasize support to improve basic management and technology practices.



IV. Low-Cost Plug-and-Play Technology for Indonesian Firms

The Challenge	Policy Actions
Many new technologies are becoming cheaper, easier to use, and more widely accessible. Yet many Indonesian firms report that adopting new technology remains financially out of reach. For many companies, especially small and medium-sized enterprises, an unsuccessful investment in technology could greatly undermine financial performance and even jeopardize survival. The goal is therefore to facilitate access to technologies that meet the needs of these businesses but are affordable and easy to use.	➤ Take advantage of technologies that are becoming cheaper and more widely available. ➤ Identify technology solutions that address common issues faced by Indonesian firms through, for example, industrial working groups. ➤ Develop a catalogue of affordable plug-and-play technological solutions that are easy to use. ➤ For wider technology deployment, provide access to expert technical advice—such as sector-specific support offered by public and private institutions—and to funds through grants and loans.

V. A Tech-Savvy Workforce

The Challenge	Policy Actions
Exploiting the benefits of new technologies requires companies and workers to be able to understand, adopt, and adapt them to develop new products, processes, and business models. This requires new skills at all levels of the firm, from shop-floor technicians to managers and directors. Efforts to address skill gaps are under way in Indonesia, notably through expanded enrollment in technical and vocational education. However, industry surveys indicate that a lack of workers with the right skills is now preventing Indonesia from taking advantage of the opportunities offered by new technologies.	➤ Ensure a critical mass of workers trained in new technologies. ➤ Upgrade existing training centers to expand offerings in new technologies. ➤ Ensure learner access to institutions that offer advanced technical training. ➤ Provide funding to new technology training programs for small and medium-sized enterprises. ➤ Encourage foreign firms to expand their training centers, as done in the automotive industry. ➤ Tap the potential for employing skilled women. ➤ Expand funding for apprenticeships to provide on-the-job training to university students, taking advantage of the growing number of Indonesian graduates in science, technology, engineering, and math. ➤ Establish training programs in technological entrepreneurship.

INTRODUCTION

Promoting technological transformation is high on the policy agenda of many countries around the world. It is increasingly evident that a range of new technologies have the potential to reshape entire industries as we know them, with implications for productivity, competitiveness, and sustainability in both developed and emerging countries. For governments around the world, the challenge is to design policies to help reap the benefits of new technologies while addressing emerging socioeconomic challenges.

This requires an in-depth understanding of the implications of new technologies in the particular national context. Not only is the impact of technologies pervasive across sectors, but each country has a unique mix of economic structures and areas of specialization. Their firms participate in particular activities within global value chains and utilize technologies at varying levels of sophistication. As such, understanding country-specific challenges and opportunities, and informing policy making, require approaches that go beyond high-level economic extrapolation.

With these analytical challenges in mind, the Asian Development Bank (ADB) commissioned the project Supporting Technological Transformation in Indonesia to investigate the impact of new technologies across key economic sectors in Indonesia and identify policy initiatives with the potential to support the country's technological transformation. The project has incorporated contributions from experts at the University of Cambridge and Indonesia's Centre for Strategic and International Studies, under the overall guidance of the ADB Indonesia Resident Mission and the Fiscal Policy Agency of Indonesia's Ministry of Finance.

The study has followed a highly structured approach, integrating economic and technological expertise, quantitative and qualitative data sources, and international and local perspectives. On the one hand, global technology trends are analyzed, and the various types of impact across economic sectors are estimated using advanced econometric tools, surveys, and case studies. On the other hand, in-depth analysis of the challenges and opportunities of particular relevance to selected Indonesian sectors are identified in extensive industrial and expert consultations. By adopting this multidisciplinary approach, the research team has sought to strike a balance between depth and breadth.

Sources of evidence and expertise employed in this report include the following:

- **Economic analysis, review of previous studies, and guidance from academic frameworks.** This study draws from established academic frameworks to structure the analysis and guide evidence gathering. Efforts have been made to combine various types of economic and technological analysis, and to build on findings from previous studies, to more carefully consider Indonesia's economic structures.
- **Consultation with local stakeholders.** A variety of consultation activities with Indonesian stakeholders from academia, the private sector, and government were carried out to help ensure that project findings and progression remained grounded in the realities of the country. Five focus group discussions were

attended by over 50 stakeholders. Feedback on the preliminary findings of this report was also obtained from local policy stakeholders in February 2019. Furthermore, three surveys covering over 1,200 firms across manufacturing, banking, and e-commerce were conducted, as were a number of targeted interviews.

- **Review of international policy initiatives to support technological transformation.** A number of strategies, studies, and initiatives from national governments and international organizations were analyzed to inform this study. Approaches adopted in other countries cannot be reproduced regardless of context. However, the analysis of international experience provides practical insights into the missions, implementation approaches, and funding mechanisms adopted as part of the latest policy efforts aimed at supporting technological transformation around the world.
- **Thirteen background technical papers.** These papers describe key technologies driving change globally and discuss the implications for Indonesia. They include eight analytical papers developed by experts at Indonesia's Centre for Strategic and International Studies on selected topics and sectors—the whole economy, the labor market, gender, manufacturing, e-commerce, finance, energy, and urban planning—and five technology policy briefs developed by experts across the University of Cambridge on five selected sectors: manufacturing, financial services, e-commerce, urban planning, and energy.

The analysis of the evidence gathered throughout the project has led to the identification of five pillars for policy action to support Indonesia's technological transformation. These pillars represent areas where, considering Indonesia's particular context, policy action is critical to driving technological transformation in the country. Overall, the findings from this study complement the existing evidence base on the impact of new technologies in Indonesia.

The remainder of this report is structured as follows:

- **Section 1** discusses the role of technological transformation in economic development and estimates the potential impact of new technologies on Indonesia's economy over the next 20 years.
- **Section 2** discusses the variety of technologies driving change in the global economy and, based on inputs from international experts, identifies technology- and sector-specific opportunities and challenges for Indonesia.
- **Section 3** discusses Indonesia's position in the technological transformation journey. The section discusses key innovation and technology indicators; analyzes strengths, weaknesses, opportunities, and threats of Indonesia's national innovation system; and reviews key themes in the policy agenda.
- **Section 4** provides a "deep dive" into the opportunities and challenges driven by Industry 4.0 in Indonesia. This analysis helps to clearly illustrate the complexity involved in the integration of various technologies and their distinct impact across sectors in Indonesia.
- **Section 5** identifies five pillars for policy action to support Indonesia's technological transformation and unlock economic growth. These pillars represent areas where findings of the study suggest that policy action is required to address the challenges and opportunities arising from the advent of new technologies. An agenda for future action in the short, medium, and long term is presented to guide the next steps of policy design and implementation.

SECTION 1

THE CRITICAL ROLE OF TECHNOLOGICAL TRANSFORMATION IN BOOSTING INDONESIA'S ECONOMIC DEVELOPMENT

KEY POINTS

Indonesia has achieved remarkable growth rates averaging over 5% since the 2000s. This has allowed the country to make significant strides in tackling poverty and unemployment. Yet a number of factors are constraining Indonesia's growth potential: a labor force growing at lower rates than in previous decades, limited technological sophistication in Indonesian industries, and the loss of dynamism in manufacturing industries.

Technological transformation has a critical role in overcoming these constraints and unlocking Indonesia's growth potential. The findings of this study suggest that Indonesia's economy could gain an additional $2.8 trillion by 2040 through technology adoption. This is equivalent to a boost of 0.55 percentage points in gross domestic product (GDP) growth in every single year for next 2 decades.

The impact of new technologies is, however, expected to vary across regions, sectors, and skill levels. Differentiated policy responses are therefore required to avoid widening disparities.

1.1 Introduction

Indonesia's economy has grown at annual average rates of over 5% for the last 2 decades, almost twice as fast as the world economy.[1] Growth averaged 5.24% in the 2000s and 5.36% in the 2011–2018 period.[2] Significant strides have been made in poverty and unemployment reduction, both of which were reduced by over 40% in the last decade.[3]

However, recent studies have identified a number of factors constraining Indonesia's growth potential. These include a labor force growing at lower rates than in previous decades, limited technological sophistication in Indonesian industries, and a loss of dynamism in manufacturing industries.

This section discusses the role of technology transformation in unlocking Indonesia's growth potential. It reviews the role of technology development and adoption in structural change and economic growth in the historical experience. The potential impact of new technologies in Indonesia's national economy is then estimated, accounting for differences across sectors, regions, and occupations.

1.2 Constraints on Indonesia's Growth Potential

In the early 1990s, Indonesia was considered part of the "East Asian Miracle," with its economy growing at rates above 7% and a manufacturing sector expanding by over 20% per annum.[4] Indonesia achieved economic stability and developed capabilities in a number of industries. However, the Asian financial crisis of 1997 had significant effects on economic growth. While the economy is still expanding at relatively rapid rates, growth has not returned to pre-crisis levels.[5]

Recent studies have identified a number of underlying factors constraining Indonesia's economic performance. A labor force growing at lower rates than in previous decades is one of them. In the late 1970s and 1980s Indonesia's demographic bonus drove the rapid expansion of the labor force, which was responsible for most of the economic growth experienced by the country. However, the rate of new entrants into the labor market has declined in recent years, constraining its contribution to growth.[6]

1 World Bank. 2019. *GDP Growth (annual %),* World Bank national accounts data.

2 World Bank. 2019. *World Development Indicators*.

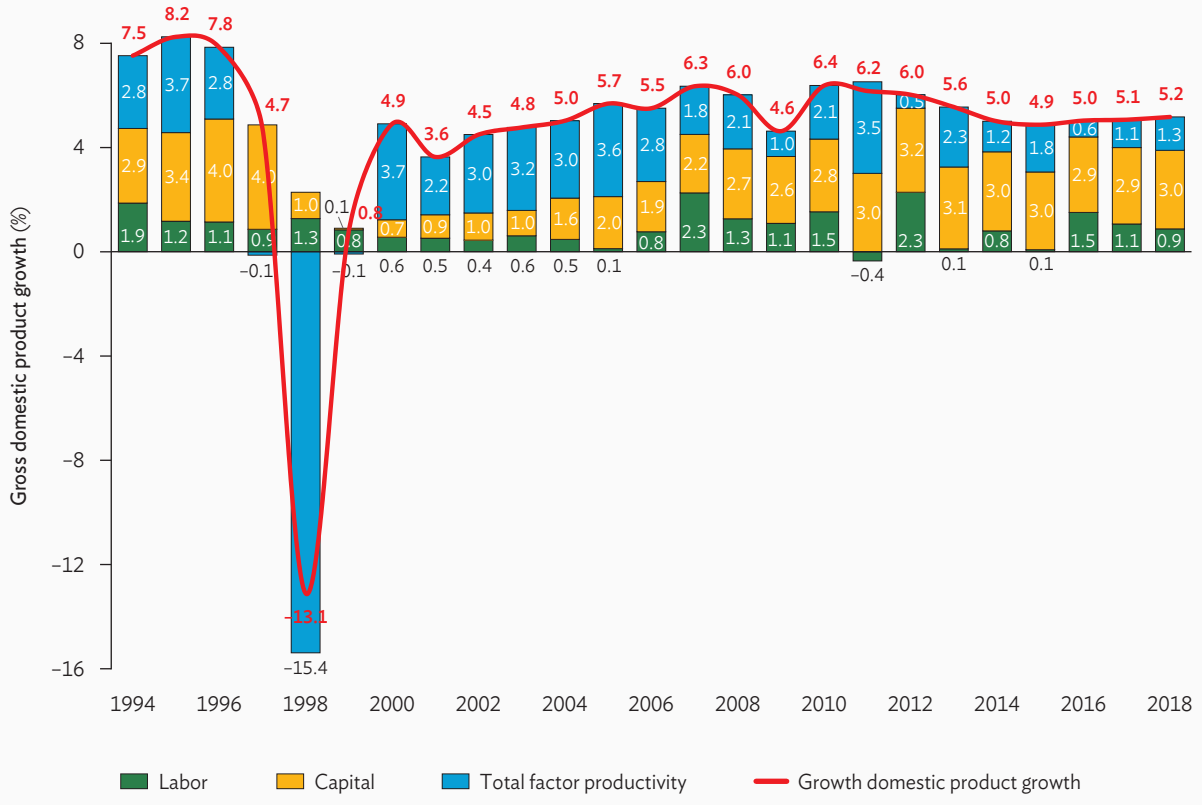
3 Statistics Indonesia.

4 World Bank. 2019. *GDP Growth (annual %),* World Bank national accounts data; T. K. Wie. 2006. *Technology and Indonesia's Industrial Competitiveness*. ADB Institute Discussion Paper No. 43. Manila: Asian Development Bank. http://hdl.handle.net/11540/3631.

5 T. K. Wie. 2006. *Technology and Indonesia's Industrial Competitiveness*. ADB Institute Discussion Paper No. 43. Manila: Asian Development Bank. http://hdl.handle.net/11540/3631.

6 ADB-BAPPENAS. 2019. *Policies to Support the Development of Indonesia's Manufacturing Sector during 2020–2024.* Manila: Asian Development Bank.

Figure 1.1: Sources of Indonesia's Economic Growth, 1994–2018



Source: Asian Productivity Organization. 2018. *APO Productivity Databook*.

Another critical factor is the limited technological sophistication of Indonesia's industries. As shown in Figure 1.1, total factor productivity, a proxy for the contribution of technological progress to growth, has decreased over recent years. The economy still depends significantly on natural resources and remains less diversified and technologically less sophisticated than in other East Asian countries (footnote 6).

Indonesia's early export boom was based on relatively few products, low wages, and access to natural resources (footnote 5). Increased international competition and failure to transition to products with higher value added have led to the deterioration of the trade balance. Low- and medium-tech exports are still dominant.[7] As a result, the current account balance has deteriorated over the last decade, reaching a deficit equal to 2.9% of GDP in 2018 (footnote 2).

[7] Ministry of Finance of Indonesia. 2019. *Thriving Indonesia: Reinforcing Strategies to Boost Productivity and Increase Competitiveness*. Jakarta.

As shown by recent analyses, current account deficits may put pressure on the exchange rate and the financial system in the long run. As a result, they may limit how fast Indonesia can grow in a sustained manner without creating domestic and external imbalances (footnote 6).

Loss of dynamism in manufacturing industries, in terms of both GDP share and productivity growth, has also been identified as a major constraint on growth. On the one hand, the reduction of manufacturing's share of GDP means that labor has been shifted toward less productive sectors. On the other, labor productivity in manufacturing has remained stagnant in recent years, signaling a loss in competitiveness and limiting the sector's contribution to overall productivity and economic growth.

Technological transformation has a critical role in unlocking Indonesia's growth potential. Technology and innovation have historically represented key drivers of structural change and economic growth. Since Indonesia can no longer rely on a rapidly expanding labor force, it is ever more pressing that its industries transition to more efficient modes of work, which requires building up both organization and technological capabilities. Increasing the sophistication of industries and the quality of exports requires the adoption of new technologies that enable firms to use resources more efficiently, develop new products, and exploit new markets. Finally, boosting the competitiveness and productivity of the manufacturing sector depends on the ability of firms to exploit opportunities being opened up by new technologies, not least new digital technologies that are becoming more widely available.

To complement the discussion about the role of technological transformation in the particular case of Indonesia, the following section reviews the evidence on the role of technology on economic development, drawing from both academic discussions and historical experience.

1.3 The Role of Technological Transformation in Economic Development

The importance of technology in economic development is well established in academia and policy.[8] In development economics, the "catch-up" argument is based on the assumption that developing countries can grow faster by introducing technologies already developed in more advanced countries. Empirical studies based on the catch-up concept emphasize the interdependence of technology and context-specific factors in explaining growth outcomes.[9]

[8] X. Cirera and W. F. Maloney. 2017. *The Innovation Paradox: Developing-Country Capabilities and the Unrealized Promise of Technological Catch-Up*. World Bank; C. Cherif and F. Hasanov. 2019. *The Return of the Policy That Shall Not Be Named: Principles of Industrial Policy*. IMF Policy Working Paper. Institute for Capacity Development; J. Fagerberg and M. Srholec. 2009. Innovation Systems, Technology and Development: Unpacking Relationships. In B. Lundvall et al., eds. *Handbook of Innovation Systems and Developing Countries: Building Domestic Capabilities in a Global Context*. Cheltenham, UK: Edward Elgar Publishing.

[9] J. Fagerberg. 1995. Convergence or Divergence? The Impact of Technology on Why Growth Rates Differ. *Journal of Evolutionary Economics.* 5. pp. 269–284.

More recent studies exploring the relationships between technological progress and long-run growth have been influenced by evolutionary economic approaches inspired by Joseph Schumpeter.[10] From an evolutionary perspective, reaching the status of an advanced economy is possible only through innovation.

A stream of the evolutionary literature has focused on the systemic nature of innovation, highlighting how the institutional framework shapes interactions between innovation actors and the flow of technological know-how between them.[11] This report draws from this systems approach to identify contextual factors constraining the technological transformation of Indonesia and policy options for addressing them.

History also provides insights into the key role of technology in development. A number of studies characterized, for example, the economic development of industrial latecomers such as Germany and Japan as one of technological catch-up.[12] The four Asian tigers—Hong Kong, China; the Republic of Korea; Singapore; and Taipei,China—constitute another emblematic case often used by researchers to describe the role of technological transformation in achieving economic growth and better standards of living.[13]

The approach followed by the Asian tigers has been explained in terms of three key strategies: (i) intervention to create new capabilities in technologically sophisticated tradable industries, (ii) export orientation, and (iii) the promotion of domestic competition.

Historical experiences such as the ones described above highlight the critical importance of technology for economic development. As a country climbs the development ladder, productivity gains from low-cost labor, the reallocation of resources from less to more competitive sectors, and the adoption of foreign technology tend to decrease. Real wages rise, and developing countries need to find new sources of competitiveness to sustain productivity increases (footnote 13). Technological transformation also has positive effects on the integration of firms into global value chains. In those countries that have managed to technologically upgrade and diversify, firms tend to leverage knowledge flows to build export capacity and are supported by enabling and forward-looking government policies.[14]

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10 F. Castellacci. 2007. Evolutionary and New Growth Theories. Are They Converging? *Journal of Economic Surveys.* 21(3). pp. 585–627.

11 J. Fagerberg and B. Verspagen. 2002. Technology-Gaps, Innovation-Diffusion and Transformation: An Evolutionary Interpretation. *Journal of Evolutionary Economics.* 31. p. 1294.

12 J. Fagerberg and M. Srholec. 2009. *Innovation Systems.* Cheltenham, UK: Edward Elgar Publishing.

13 C. Cherif and F. Hasanov. 2019. *The Return of the Policy That Shall Not Be Named: Principles of Industrial Policy.* IMF Working Paper. WP/19/74. Washington, DC: International Monetary Fund.

14 R. Lema, R. Rabellotti, and P. G. Sampath. 2018. Innovation Trajectories in Developing Countries: Co-evolution of Global Value Chains and Innovation Systems. *European Journal of Development Research*. 30. pp. 345–363.

1.4 Potential Impact of New Technologies: International Evidence

While the importance of technology in economic development is widely accepted in the literature, estimating the impact of particular technologies in national economies is fraught with challenges. Technologies, sectors, and innovation activities are becoming increasingly complex and interdependent (Section 2). As a result, the emerging picture is characterized by a high degree of uncertainty.

Studies on the impact of technological change on employment are a case in point. Academics, consultancies, and international organizations around the world have produced studies revealing a significant effect of new technologies on employment. Predictions are, however, far from forming a consensus. In fact, a number of studies have been criticized for presenting an overly simplistic view of the tasks carried out by workers and for not accounting for variations in economic and institutional contexts across countries.

As an illustration of complexity and uncertainty in estimating the impacts of technology, a review of international studies reveals a great deal of variation in predictions of the impact of automation on jobs (Figure 1.2). Figures go from the creation of over 100 million jobs[15] to the loss of over 200 million.[16] The variation in predictions is down to differences in definitions, assumptions, and methodological approaches.

Following a pattern seen before in history, alarms about the power of new technologies to replace jobs echoed worldwide over the last decade. More recently, however, a more balanced story has been emerging, which suggests that, while new technologies might have a profound effect on the global economy, they will bring opportunities and challenges alike.[17]

1.5 Estimating the Potential Impact of New Technologies on Indonesia's Development

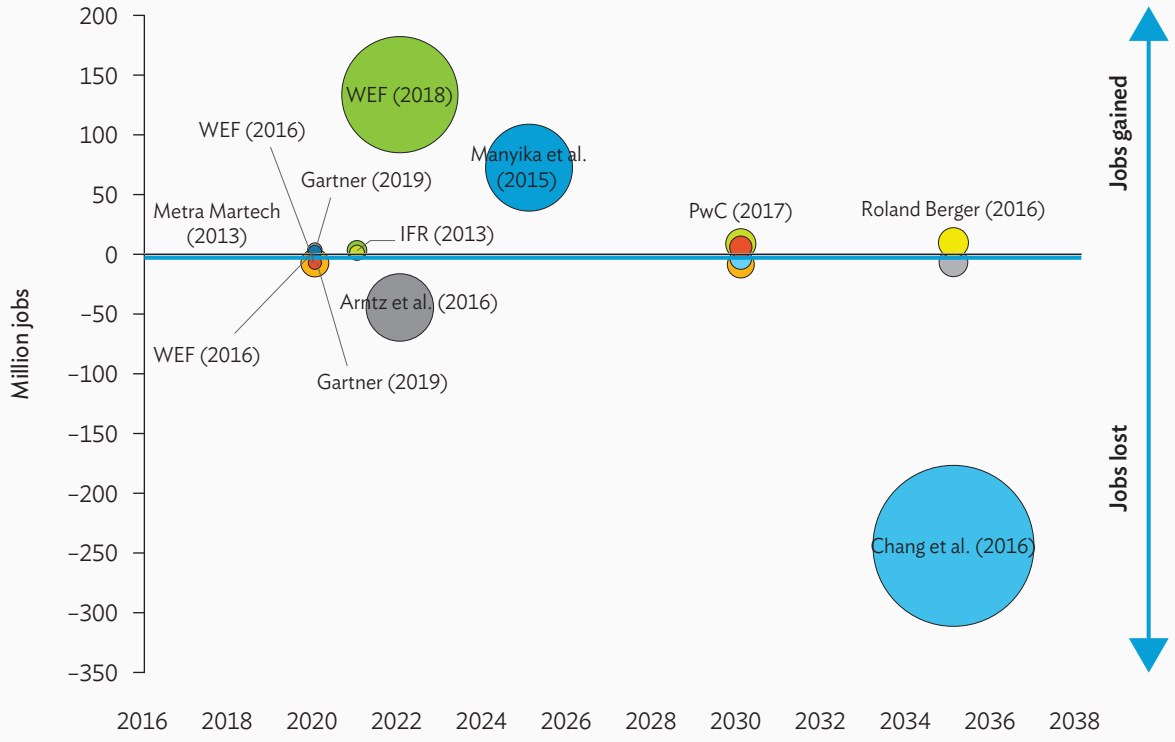
As illustrated above, estimates about the impact of particular technologies on national economies are likely to depend on the particular methodology adopted. Given the complexity involved, results should be taken as indicators of the rate of change and useful to highlight relationships between variables, rather than as precise estimations of impact.

15 World Economic Forum. 2018. *The Future of Jobs Report 2018*.

16 J. Chang, G. Rynhart, and P. Huynh. 2016. *ASEAN in Transformation: The Future of Jobs at Risk of Automation*. Geneva: International Labour Organization.

17 M. Muro, R. Maxim, and J. Whiton. 2019. *Automation and Artificial Intelligence.* Washington, DC: Brookings Institution.

Figure 1.2: Lack of Consensus in Predictions of the Impact of Automation on Jobs Worldwide



Sources: International Federation of Robotics. 2013. *Positive Impact of Industrial Robots on Employment*. London: Metra Martech; Metra Martech. 2013. *Positive Impact of Industrial Robots on Employment.* International Federation of Robotics; J. Manyika et al. 2015. *A Labor Market That Works Connecting Talent with Opportunity in the Digital Age*. McKinsey Global Institute; M. Arntz, T. Gregory, and U. Zierahn. 2016. The Risk of Automation for Jobs in OECD Countries: A Comparative Analysis. *OECD Social, Employment, and Migration Working Papers.* No. 189. Paris: OECD Publishing; J. Chang, G. Rynhart, and P. Huynh. 2016. *ASEAN in Transformation: The Future of Jobs at Risk of Automation*. Geneva: International Labour Organization; Roland Berger. 2016. *The Industrie 4.0 Transition Quantified*. World Economic Forum. 2016. *The Future of Jobs Employment, Skills and Workforce Strategy for the Fourth Industrial Revolution*; PwC. 2017. *Will Robots Steal Our Jobs? The Potential Impact of Automation on the UK and Other Major Economies*; Gartner. 2019. *Future-Proof Your Talent Strategy: How Artificial Intelligence Is Evolving the Workforce*; World Economic Forum. 2018. *The Future of Jobs Report 2018*. Geneva.

In the framework of this study, the potential impact of new technologies on growth in Indonesia's economy during the period 2020–2040 was estimated.[18] The impact was computed using a general equilibrium model where the effects of new technology were estimated through sector-specific labor-productivity shocks. The analysis focused in particular on the effect of digitalization, robotization, and artificial intelligence technologies.

[18] A. Yusuf. 2019. *The Effect of New (Disruptive) Technology on Indonesian Economy: An Economy-Wide Assessment.* Background paper produced for ADB technical assistance to Indonesia on Supporting Technological Transformation (Project Number: 51343-001). Jakarta.

The findings of the statistical simulation suggest that, by adopting new technologies, improvements in productivity could drive additional accumulated growth of 11% of GDP during the period 2020–2040. This represents an increase in the average annual GDP growth rate from 5.2% without technology adoption to 5.7% with adoption, as presented in Table 1.1. In other words, the model shows that technological transformation could enable the Indonesian economy to gain an estimated $2.8 trillion by 2040.[19]

Table 1.1: Simulated Impact on Indonesia's National and Regional Economic Growth Rates

	National	Sumatra	Java	Kalimantan	Sulawesi	Bali NT	Papua Maluku
Baseline scenario, annual GDP growth (%)							
2020–2030	5.20	4.60	5.85	3.81	4.72	4.79	3.42
2030–2040	5.20	4.38	5.88	3.84	4.53	4.83	3.56
2020–2040	5.20	4.49	5.87	3.83	4.63	4.81	3.49
With new technology adoption, annual GDP growth (%)							
2020–2030	5.73	5.00	6.48	4.15	5.14	5.22	3.72
2030–2040	5.77	4.64	6.65	4.12	4.83	5.20	3.80
2020–2040	5.75	4.82	6.57	4.14	4.99	5.21	3.76
Growth gain difference (percentage points)							
2020–2030	0.53	0.40	0.63	0.35	0.42	0.43	0.30
2030–2040	0.57	0.26	0.77	0.28	0.30	0.37	0.24
2020–2040	0.55	0.33	0.70	0.31	0.36	0.40	0.27

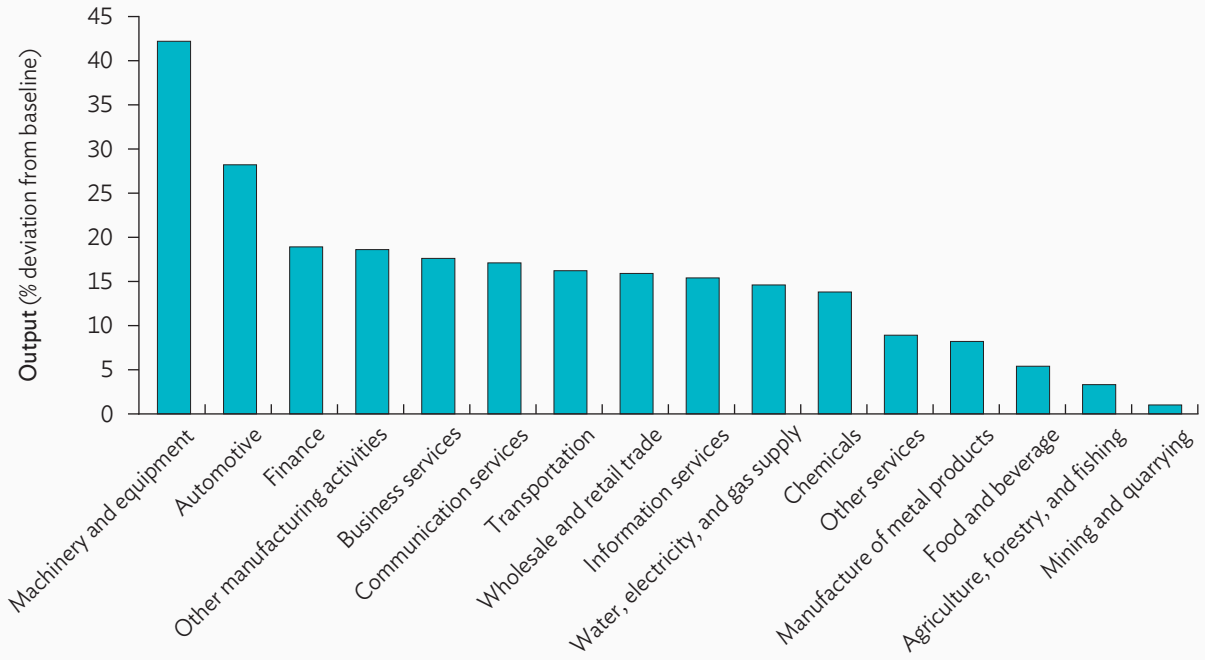
NT = Nusa Tenggara.

Source: A. Yusuf. 2019. *The Effect of New (Disruptive) Technology on Indonesian Economy: An Economy-Wide Assessment*. Background paper produced for ADB technical assistance to Indonesia on Supporting Technological Transformation (Project Number: 51343-001). Jakarta.

The effects forecasted across regions are, however, uneven. The gains in economic growth are projected to be concentrated in Java, while Papua and Maluku, the most disadvantaged regions, would obtain the smallest growth gains. This indicates that, though the adoption of new technologies could drive significant economic growth, it is likely to demand appropriate policy countermeasures to avoid widening interregional disparities.

[19] Estimates based on values in Table 2.1 and A. Yusuf. 2019. *The Effect of New (Disruptive) Technology on Indonesian Economy: An Economy-Wide Assessment*. Background paper produced for ADB technical assistance to Indonesia on Supporting Technological Transformation (Project Number: 51343-001). Jakarta; Indonesia's GDP estimate by International Monetary Fund. 2019. *World Economic Outlook Database*, April.

Figure 1.3: Expected Impact of New Technology Adoption on Sectoral Output in 2040



Source: A. Yusuf. 2019. *The Effect of New (Disruptive) Technology on Indonesian Economy: An Economy-Wide Assessment*. Background paper produced for ADB technical assistance to Indonesia on Supporting Technological Transformation (Project Number: 51343-001). Jakarta.

Variations in impact are also expected across sectors. Productivity shocks and output expansions are predicted to be largest in the machinery and equipment and automotive industries, and lowest in the mining industry, agriculture, and the food and beverage industry. By 2040 machinery industry output could be 42% above its baseline if new technologies are adopted, while the motor vehicle industry could expand by 28%. The third largest expansion is expected in the financial sector, up 19% from the baseline (Figure 1.3).

Cross-sectoral differences in the projected impacts of technology adoption on productivity and production are also reflected in heterogeneous impacts on employment. In comparison with the baseline without technology adoption, the largest gains in employment are projected to occur in machinery and equipment at 19%, business services 9.6%, and automotive 9.3%. The sectors expected to show levels of employment below their baseline are mining industry at –15.9%, food and beverage –7.2%, other services –3.6%, agriculture –1.3%, and the manufacture of metal products –1%. These negative numbers do not necessarily mean job losses; they indicate lower increases in employment in comparison with a scenario where new technologies were not adopted in these sectors. Two likely explanations were identified for the differentiated impacts on employment projected across sectors. The first is that labor-intensive sectors are more likely to show a negative balance on jobs, and the second is that sectors that are more technologically sophisticated are more likely to show a positive balance on jobs, even if they are labor intensive.

Differentiated impacts on wages were estimated, depending on the tasks performed by employees. It is expected that new technologies will increase demand for employees that perform nonroutine tasks and thus drive an increase in their wages. In contrast, occupations that involve heavily routine manual tasks are expected to face declines in both demand and wages.[20]

The impact of new technologies on gender disparities in the labor market is expected to be heterogeneous. An analysis conducted as part of this project suggests a mixed picture depending on the sector and type of job.[21] Labor-intensive industries, such as food and beverage, services, and retail, tend to have a relatively high share of women in the labor force. Yet, in these industries technology adoption is slow, and so the impact of new technologies on women workers in terms of job creation, job replacement, or job reduction was not found to be significant. Nonetheless, as already discussed, it is likely that in the long term these low-technology sectors will increase the use of labor-saving technologies, having negative effects on jobs and wages. In advanced technology companies, by contrast, women seem to be better off, and technology adoption may contribute to narrowing the gender pay gap and opening new job opportunities for women.

1.6 Conclusions

Technological transformation plays a critical role in unlocking Indonesia's growth potential. The adoption of new technologies can enable Indonesian firms to transition to more efficient modes of work. It also allows firms to use resources more efficiently, develop new products, and exploit new markets.

However, the impact of new technologies is likely to be uneven. Though there is uncertainty about the precise effect that new technologies might have on the economy, less sophisticated sectors, less advantaged regions, and lower-skilled workers are less well positioned to reap the benefits. In this context, policy has a crucial role to play, not only in promoting technology adoption but also in addressing disparities that might be accentuated.

The findings presented in this section highlight the importance of understanding the differentiated impacts of new technologies on particular sectors. Section 2 complements the national-level analysis presented here by exploring the opportunities and challenges for the adoption of new technologies in selected sectors in Indonesia.

[20] T. Y. Wicaksono and C. Mangunsong. Forthcoming. *Disruptive Technology, Skills, and Tasks: Implications for Employment in Indonesia*. Background paper produced for ADB technical assistance to Indonesia on Supporting Technological Transformation (Project Number: 51343-001). Jakarta.

[21] M. K. Hendytio and L. J. Barany. Forthcoming. *Impact of Disruptive Technology on Indonesian Women Workers*. Background paper produced for ADB technical assistance to Indonesia on Supporting Technological Transformation (Project Number: 51343-001). Jakarta.

SECTION 2

TECHNOLOGY AND SECTOR-SPECIFIC OPPORTUNITIES AND CHALLENGES FOR INDONESIA

KEY POINTS

A range of emerging technologies is expected to drive change in industries and services, and create new opportunities for businesses and improve people's lives. Examples of these technologies include photonics, advanced materials, biotechnology, nanotechnology, and digital information and communication technologies (ICT) such as machine learning and artificial intelligence.

To understand the differentiated impacts of new technologies on selected sectors, inputs from international experts were used to identify the particular opportunities and challenges for Indonesia.

New opportunities for Indonesia arising from new technologies include the following examples:

- in energy, positive spillover effects in the environment and economic activity through the use of electric motorcycles and microgeneration;
- in finance tech, improved financial inclusion and access to finance for small and medium-sized enterprises (SMEs) through peer-to-peer payment and lending, and equity crowdfunding;
- in e-commerce, improved market access, and increased sales and profits, through the use of online e-commerce platforms;
- in manufacturing, productivity gains through the use of digitally enabled factory solutions; and
- in urban planning, socioeconomic development and reduced regional disparities by expanding existing investments in digital infrastructure.

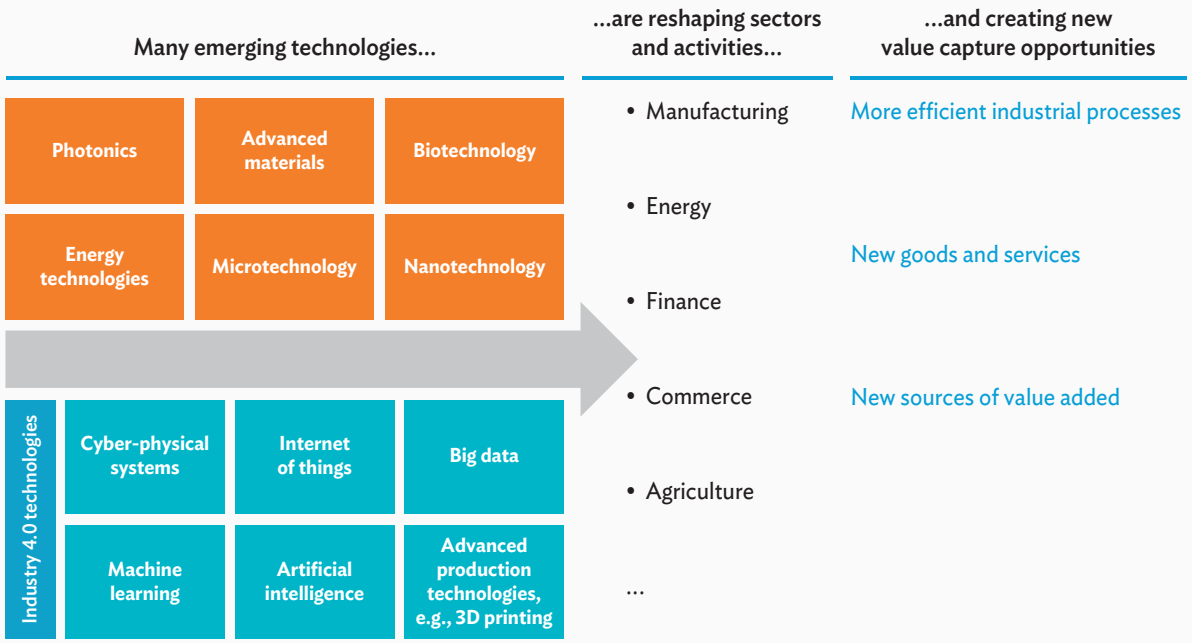
To exploit these opportunities, a number of challenges in infrastructure, regulation, skills, and finance will need to be addressed.

2.1 Introduction

Rapid developments in a number of technology domains are receiving significant attention in the policy agenda of countries around the world. Indonesia is no exception. Technologies such as photonics, biotechnology, nanotechnology, advanced ICT, advanced materials, and novel production technologies such as 3D printing have the potential to drive fundamental change in global industries.

It is important to consider, however, that Indonesia has a unique mix of economic structures and areas of specialization, while local firms participate in particular activities within local and global value chains and utilize technologies at varying levels of sophistication. As such, the impact of new technologies will be different for different technological applications and sectors (Figure 2.1).

Figure 2.1: Various New Technologies Driving Change Across Economic Sectors and Activities



Source: Policy Links, Institute for Manufacturing, University of Cambridge.

Based on inputs from international experts, this section discusses the variety of opportunities and challenges that new technologies could drive in Indonesia's economy. The focus of the analysis is mostly on manufacturing, finance, e-commerce, energy, and urban planning.[22]

[22] Sectors were selected by ADB in consultation with relevant stakeholders and considering key priorities in the national policy agenda. While recognizing that neither the selected sectors nor the focus technologies are exhaustive, this section highlights the various impacts arising from new technologies that could affect Indonesia.

2.2 Diversity of Emerging Technologies

There is considerable consensus internationally on the broad categories of emerging technologies with the potential to dramatically reshape different industries. They include photonics, biotechnology, nanotechnology, advanced materials, and digital ICT such as machine learning and artificial intelligence (AI), which have received increased policy attention in recent years (Figure 2.2).[23]

Many of these families of technologies have a variety of subdomains. For example, a number of digital ICTs are commonly grouped under the umbrella term "Industry 4.0" to depict their particular application to manufacturing.[24] They include cyber-physical systems, cloud computing, big data, AI, machine learning, and the internet of things (IOT). However, each of these technologies could have a significant impact in its own right across a number of industries within and beyond manufacturing.[25] AI, for example, is expected to drive change across manufacturing industries such as automotive, in applications such as autonomous driving, but also in activities as diverse as e-commerce, in applications such as highly customized advertising, and in finance, in applications such as automated trading.

Investigating the impact of each technology would be challenging in its own right. However, it is their combination—which is enabling completely new types of functionality and levels of performance not yet fully understood—that makes any attempt to predict their effect particularly difficult.[26] For example, artificial intelligence is being combined with cyber-physical systems and big data to create new applications such as predictive maintenance and advanced production planning, which could have an impact across a number of industries. Technology combination, therefore, means not only that expertise is required from across academic disciplines but also that studies on individual technologies provide only a limited picture. As a result, appropriately studying the potential impact of all these technologies is a highly complex task, requiring the integration of both sector- and technology-focused studies to gain a full picture of the potential impact on the national economy. In other words, some technologies may combine to produce new units of analysis with very wide parameters.

[23] UNIDO. 2017. *Emerging Trends in Global Advanced Manufacturing: Challenges, Opportunities and Policy Responses*. Vienna: United Nations Industrial Development Organization; OECD. 2017. *The Next Production Revolution: Implications for Governments and Business*. Paris: OECD Publishing.

[24] The term "Industry 4.0" is short for the Fourth Industrial Revolution, which follows the First Industrial Revolution, in which production was mechanized through the use of steam power; the Second Industrial Revolution, in which mass production was developed through the use of electric power; and the Third Digital Revolution, in which computers and ICT were used to enhance the automation of manufacturing.

[25] Acatech. 2013. *Recommendations for Implementing the Strategic Initiative INDUSTRIE 4*. Report for the ForschungUnion "Industry 4.0" strategic working group for New High Strategy.

[26] E. O'Sullivan and C. López-Gómez. 2017. Manufacturing R&D Policies for the Next Production Revolution: An International Review of Emerging Research Priorities and Policy Approaches. In OECD. 2017. *The Next Production Revolution: Implications for Governments and Business*. Paris: OECD Publishing.

Figure 2.2: Several Emerging Technologies Driving Change in National Economies

Photonics	Scanning, sensing, and imaging; information, communication, and networks; screens and displays; advanced lighting; photonic energy systems; and laser systems
Biotechnology	Biopharma, tissue engineering and regenerative medicine, synthetic biology, and bio-inspired manufacturing using self-assembly
Nanotechnology	Carbon nanotubes, nanocomposite structural materials, nanoelectronics, nanotechnology-based coatings, nanoparticles, and nano-tagging
Advanced materials	Advanced composites and metamaterials
Environmental and energy technologies	Resource recovery and reuse, renewable feedstocks, electricity storage, fuel cells, renewable energy, nuclear fission and fusion, and advanced vehicles
Microtechnology	Micro-tooling for replication manufacturing and micro-systems in machine tools and products
INDUSTRY 4.0 TECHNOLOGIES	
Cyber-physical systems	Systems formed of electronic hardware including sensors and actuators, and software including computer interfaces and control algorithms, designed to sense and interact with the physical world, including human users.
Internet of things	Networks of physical objects such as electronic devices and other equipment, vehicles, and buildings containing electronic hardware, software, and sensors connected to the internet.
Big data	Data sets whose size is beyond the capability of typical database software tools to capture, store, manage, and analyze. Big data can be analyzed to reveal patterns, trends, and associations that would not be evident using small data samples.
Artificial intelligence	Artificial intelligence refers to the ability exhibited by machines or computer systems to perform some tasks that are normally considered to require human knowledge, learning, and understanding.
Machine learning	Machine learning is considered to be an enabler of artificial intelligence. In its most basic form, machine learning refers to the use of algorithms to analyze data, learn from it, and then make decisions about specific tasks.
Advanced production technologies, including 3D printing	3D printing, or additive manufacturing, encompasses multiple techniques used to build solid parts by adding material in layers. This stands in contrast to typical manufacturing processes in which material is removed or reformed.

Source: Policy Links, Institute for Manufacturing, University of Cambridge.

2.3 Variety of Technological Applications across Sectors, Value Chains, and Firms

Different types of technology are likely to drive different types of change across sectors. Advanced robotics and automation technologies, for example, are likely to have a more direct impact in discrete sectors that integrate a large number of components, such as automotive and electronics, than in process sectors that use continuous production methods, such as food and pharmaceuticals. This is also the case for digital ICT. Cloud computing, blockchain, and AI, for example, are driving change in a number of areas of financial technology innovation, including equity crowdfunding, peer-to-peer (P2P) lending, and regulatory innovation initiatives. In e-commerce, however, major changes driven by digital ICT have to do with the development of digital platform businesses and the power asymmetries they create.

Variation can also be expected within the value chain of any given sector. For example, in car production, technologies are having different impacts in different car subsystems. Developments in new battery technologies, for example, have important implications for the suppliers of automotive powertrain and electronic components. Meanwhile, developments in advanced composite materials are likely to be more significant for suppliers of metallic components and raw materials used in the body of the car.

Adding to the complexity is the fact that traditional sectoral boundaries and the dynamics of innovation are being redefined. ICT and electronics capabilities traditionally outside the automotive industry, for example, are becoming an integral part of emerging value networks as cars become increasingly connected, autonomous, and personalized. New high-end cars require around 150 million lines of software code to function, compared with roughly 12 million lines of code in a typical smartphone and 50 million in the Large Hadron Collider.[27] Meanwhile, the share of the cost of electronics in the cost of producing an average car has risen steadily in recent decades to around 30%, and is expected to increase to 50% by 2030.[28] As such, nonautomotive companies are now a critical driver of innovation in the industry.

A number of other factors fundamentally affect the potential impact of any given technology across sectors. One is the sector's regulatory regime. In highly regulated industries such as aerospace and pharmaceuticals, changing processes and products using new technologies can be particularly complex, time-consuming, and expensive.

Another factor is the length of the supply chain. In some cases, the impact of technologies can be fully realized only when they have been adopted by firms across the supply chain. Because complexity increases with the number of processes and firm boundaries involved, this can take longer in sectors that depend on several suppliers and more complex infrastructure. Achieving the full benefits of digital integration, for instance, may take longer in sectors involving more upstream and downstream processes, such as electronics and aerospace, than in those that are more vertically integrated and have shorter supply chains, such as chemicals and pharmaceuticals.

[27] Statista.

[28] US International Trade Commission.

Finally, current rates of technology adoption by firms also have an influence.[29] Leading firms that commonly engage in innovation are expected to be affected and react differently to the challenges and opportunities deriving from new technologies than firms with no well-established innovation practices. As such, indications are needed on the current technology-use intensity at the firm level.

2.4 Technology and Sector-Specific Opportunities and Challenges: Selected Examples

The following subsections illustrate, from a global perspective, the variety of opportunities and challenges being driven by a range of technological trends around five key sectors summarized in Table 2.1: financial services, e-commerce, energy, urban planning, and manufacturing. Technology trends refer to the key technologies driving change in the sector at the global level and their current applications. Similarly, opportunities describe the potential benefits arising from the practical use of these technologies, and challenges note the potential barriers to technology deployment. Where possible, the implications for Indonesia are briefly illustrated to provide local insights.

The evidence shown here has been drawn from the background papers developed by technology experts at the University of Cambridge as part of this project and are primarily based on reviews of relevant literature, including academic sources, as well as documents produced by governments, international organizations, research centers, industrial organizations, and international consultancy firms.

2.4.1 | Digitalization of Manufacturing

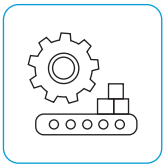
Global Technology Trends

The global manufacturing landscape is shaped by the convergence of digital ICTs such as cyber-physical systems, cloud computing, big data, AI, machine learning, and the IOT, which offer potential to more effectively connect and integrate manufacturing systems.[30] This convergence process is commonly referred to as Industry 4.0, or the Fourth Industrial Revolution. These families of digital ICT are enabling manufacturers to make factories more efficient, develop new products faster, make logistics operations more efficient, and adopt new and disruptive business models. At the same time, digital ICT is allowing firms to respond to customer and society demands for greater personalization, better safety, and improved energy and resource efficiency.

[29] A key trend facilitating the widespread adoption of new technologies across sectors is their recent price reduction. For example, industrial sensors have become smaller, more powerful, and less expensive. According to one estimate, their average cost is projected to reach $0.38 by 2020, down from $1.30 in 2004. As a result, such new technologies are becoming more affordable and accessible for firms of all sizes. Source: Goldman Sachs, BI Intelligence Estimates. 2016. The Average Cost of IOT Sensors Is Falling.

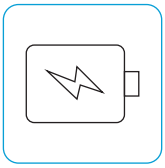
[30] This section is based on J. Bonnín Roca. 2019. *The Digital Transformation of Manufacturing*. Background paper produced for the ADB technical assistance to Indonesia on Supporting Technological Transformation (Project Number: 51343-001). Jakarta.

Table 2.1: Potential Implications of Technologies in Selected Sectors

	Global Technology Trends	Opportunities for Indonesia	Challenges to Exploiting Opportunities
 **Manufacturing**	• Industry 4.0 technologies leading to more connected and integrated manufacturing systems • Digital technologies enabling more efficient factories, faster product development, more efficient logistics, and new business models	• Boosting Indonesian industrial productivity by developing better products and processes and adopting improved management practices • Integrating local firms into global supply chains and export markets	• Policy makers need to ensure that digital infrastructure exists to adopt new technologies. • Policy makers need to raise awareness of digital technologies and the possibilities they offer. • Local firms require support to adopt technology and develop innovation skills.
 **Financial services**	• Mobile phone and internet penetration enabling wider access to financial services • Cloud computing minimizing upfront investment in information technology in "asset light" business models • Blockchain technology enabling smart contracts without third parties and thereby lowering the cost of contracts and payments • Artificial intelligence and machine learning enabling cheaper and more efficient financial products and services	• Financial inclusion and access to finance for small and medium-sized enterprises • Equity crowdfunding and peer-to-peer lending providing additional channels of capital flow to young businesses • New tools reducing the cost of financial products and services for users • Improved customer experience, transparency, and customization building user acceptance and adoption of financial products and services	• Policy makers need to enact effective regulation to avoid the shortcomings that may lead to financial exclusion. • Equity crowdfunding regulations must focus on consumer protection to ensure that investors understand the risks. • Regulations must guarantee that peer-to-peer lending does not create unnecessary risks for consumers. • Adequate regulation is essential to enabling the responsible development of new digital financial products.
 **E-commerce**	• Global expansion of infrastructure for information and communication technology enabling wider internet and mobile phone penetration • Wider global availability of digital content providers and internet platforms • New digital payment solutions enabling secure online transactions • Retailers adopting an omni-channel approach, integrating physical and virtual stores	• Expanding the number of consumers that Indonesian firms can reach, particularly in rural areas away from traditional retail centers • E-commerce platforms reducing physical infrastructure and capital investment requirements for new business creation • Direct contact with customers enabling more exact product and service customization for local needs, both urban and rural	• Policy makers need to anticipate disruptive impacts on displaced businesses and employees and anticipate market changes. • Legislation to protect labor rights is required for last-mile delivery personnel. • Consumer protection regulation must be extended to cover e-commerce platforms. • Safeguards against monopolies should be considered. • Privacy and cybersecurity rules and policies need updating.

continued next page

Table 2.1: *Continued*

	Global Technology Trends	Opportunities for Indonesia	Challenges to Exploiting Opportunities
 **Urban planning**	• Online open data sources providing useful information to understand city dynamics that are difficult to capture in traditional statistics • Geographic information systems enabling better visualization of the spatial distribution of population, jobs, buildings, and natural features • City-wide schemes for data sharing to enable better understanding of city problems and development of tailored solutions • Digital twin cities helping to optimize resource use and inform policy on planning and managing infrastructure	• Investment into digital infrastructure able to connect geographically dispersed Indonesia and rebalance regional disparities • Digital strategies differentiated for local conditions, providing, for example, digital payment systems for public transport in urban areas and, in rural area, access to basic public services • More effective disaster and emergency response achieved by, for example, establishing a centralized national disaster response system	• Policy makers need to address barriers that may keep segments of the population digitally backward and unable to harness the benefits of digital connectivity. • They need to develop and implement methods of data collection that are comprehensive and accurate. • It is crucial to train planners and officials in using digital solutions to ensure successful data analysis tailored to local contexts. • The authorities need to protect personal data privacy and confidentiality.
 **Energy**	• Renewable and distributed microgenerators of electricity becoming cheaper and more readily available • Improved battery storage technology, smart meters, and smart grids enabling easier integration of distributed power generators into electricity grids	• Decarbonizing electricity supply to lower energy costs and mitigate oil dependency • Falling demand for electricity from traditional power plants even with the adoption of such green technologies as electric motorcycles • Reducing noise and improving air quality in big cities	• A national smart grid requires high financial investment, new technology adoption, and governance adaptation. • Distributed generation of renewable energy requires an appropriate regulatory framework with technology adoption incentives, investor and consumer protection, and system resilience.

Source: Summary of background analysis produced for ADB technical assistance to Indonesia on Supporting Technological Transformation (Project Number: 51343-001). Jakarta.

Opportunities for Indonesia

The diversity and complexity of Industry 4.0 technologies open up many opportunities at the firm level for value creation, novel business models, and emerging market structures, thus also creating opportunities to foster economic growth and competitiveness across the whole economy. In particular, in a country such as Indonesia, where some capabilities are missing in traditional manufacturing, the digitalization of manufacturing may provide the chance to adapt emerging technologies to their particular needs, which often differ from the needs of nations at the technological frontier. The adoption of emerging technologies in manufacturing may enable new entrants into the market who may decide to serve different market segments as a way to reach economies of scale, potentially increasing price competition.[31]

[31] C. Weller, R. Kleer, and F. T. Piller. 2015. Economic Implications of 3D Printing: Market Structure Models in Light of Additive Manufacturing Revisited. *International Journal of Production Economics*. 164. pp. 43–56.

Macroeconomic data suggest that Indonesian productivity is lower than that of its regional competitors, and digital ICT could help to accelerate the improvement of management practices.[32]

Challenges to Exploiting Opportunities

The impact of digitalization is expected to be crosscutting, and specific implications can vary widely from sector to sector. However, in Indonesia, where the penetration of ICT is lower than in other members of the Association of Southeast Asian Nations (ASEAN),[33] investments in digital infrastructure may be needed to close any ICT infrastructure gaps and ensure the full exploitation of new technologies. Indonesia faces various policy challenges, notably raising awareness of what digital technologies are and the possibilities they offer, supporting technology adoption by SMEs, and promoting research and development (R&D). A big challenge arising from the digitalization of manufacturing concerns workforce development.[34] To implement complex, interdisciplinary technology environments, a new generation of highly skilled workers is needed with expertise in computer and data sciences, mechanical and electrical engineering, and other science, technology, engineering, and math (STEM) disciplines. Workers with low skills will probably need to be retrained to learn how to work in the new technological environment. This problem might be exacerbated in SMEs, which usually have less capital than larger companies to devote to retraining labor. Government efforts related to the digitalization of manufacturing should involve investment in more than just traditional mechanisms for research and innovation, such as tax credits and R&D funding. Significant resources should be allocated to addressing market failures related to the increasing need for the coordination of a diverse pool of stakeholders or the creation of reliable ICT infrastructure.

2.4.2 | Transformation of Financial Services by Fintech

Global Technology Trends

The financial services industry is undergoing dramatic structural change driven by emerging technologies that are enabling new financial products and services. Such transformation is often referred to as "fintech." A number of key technologies are contributing to advances in the financial sector. Mobile phone and internet technologies are enabling wider access to financial services, often offered through apps in smartphones. Cloud computing provides access to online computing storage and servers for processing and storing data, enabling fintech firms to build and scale up or down services quickly to meet customer demand. Blockchain or distributed ledger technology allows, among other things, the creation of smart contracts, software programs that automatically execute complex instructions when certain conditions are met.[35] AI and machine learning enable the analysis of data to model some aspects of the world using computers and models that learn from data, allowing financial service providers to use a vast amount of often new types of data to provide their products and services more efficiently and cheaply.

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[32] N. Bloom, A. Mahajan, D. McKenzie, and J. Roberts. 2010. Why Do Firms in Developing Countries Have Low Productivity? *American Economic Review.* 100. pp. 619–623.

[33] McKinsey. 2016. *Unlocking Indonesia's Digital Opportunity*. Jakarta; L. Puspitasari and K. Ishii. 2016. Digital Divides and Mobile Internet in Indonesia: Impact of Smartphones. *Telematics and Informatics.* 33. pp. 472–483.

[34] N. E. Waldeck. 2000. *Advanced Manufacturing Technologies and Workforce Development*. London and New York: Taylor & Francis.

[35] M. Rauchs et al. 2017. *Global Blockchain Benchmarking Report*. Cambridge Centre for Alternative Finance, University of Cambridge.

These technologies have a variety of impacts and applications on business areas, models, and products related to financial services: digital payments through mobile money and P2P transfers, or business-to-business payments; P2P lending, either consumer or business; the creation of cybersecurity markets; equity crowdfunding and micro-savings; and micro-insurance.

Opportunities for Indonesia

Opportunities to improve financial inclusion for consumers and access to finance for SMEs exist in Indonesia. For example, equity crowdfunding could provide an important additional channel of capital to young SMEs that lack access to sufficient capital. On the other hand, since 2017 the P2P lending market has grown rapidly in Indonesia, particularly after the introduction of regulations for this sector by the Financial Services Authority, or Otoritas Jasa Keuangan.[36] As of January 2018, it was estimated that over a quarter of a million people had taken out loans via fintech firms offering P2P lending, with some 30 P2P firms lending $193.8 million.[37]

Challenges to Exploiting Opportunities

Widespread diffusion of technologies and digital infrastructure are needed to fully exploit the advantages of fintech services. In Indonesia, for example, internet penetration is 50%, or 132.7 million people, and as long as it continues to increase more people will be able to access fintech services. Mobile penetration, which is essential for many fintech services, is estimated at 1.4 mobile devices per person, but not every individual has access to a mobile device. Unique mobile user penetration is 67%, or 177.9 million people, meaning that a third of the population still lacks an individual mobile account.[38] Surveys conducted in this study show that traditional banks perceive high development costs and a lack of skilled workers to be among the main constraints on fintech technology adoption. Fintech companies, on the other hand, consider inadequate telecommunication and internet infrastructure, especially in regions outside Java, and a shortage of IT workers, to be the main constraints on their development.[39] Further, regulations need to ensure that technology-enabled financial innovation is managed effectively, in order to reap the potential benefits while avoiding some of the pitfalls that may worsen financial exclusion. In this respect, in August 2018 the Financial Services Authority introduced law changes involving a new regulatory sandbox that will create an opportunity for the financial regulator to increasingly engage with the domestic fintech sector and identify areas in the existing regulatory framework that can be improved.[40]

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36 Otoritas Jasa Keuangan. 2017. *Issues Regulation on IT-Based Lending Services*. Jakarta.

37 Reuters. 2018. *Indonesia's Fintech Lending Boom Exploits Shortfall in Bank Loans*. 30 January.

38 WeAreSocial. 2018. *Digital in Southeast Asia*.

39 R. Atje, I. Setiati, and I. N. Fadhil. 2019. *Disruptive Technology in Indonesia's Banking Sector*. Background paper produced for the ADB technical assistance to Indonesia on Supporting Technological Transformation (Project Number: 51343-001). Jakarta.

40 Columbia Business School. 2018. *POJK 13/POJK.02/2018 Digital Financial Innovation in the Financial Services Sector*.

2.4.3 | E-Commerce Retail Revolution

Global Technology Trends

The development of e-commerce retailing has been transformative because wide access to the internet and mobile phone platforms provide consumers with ready access to this new channel in both industrialized and emerging markets.[41] The development of digital ICT is providing numerous options for consumers, delivery organizations, retailers, service providers, and product manufacturers. Consumers are seeking fulfillment options that support enhanced product variety, speed of delivery, convenience, and traceability. Delivery organizations are also transforming, with specialist logistics providers such as Ocado in the United Kingdom emerging as e-tailers in their own right while also supporting traditional retailers. Conventional retail has experienced the greatest impact from e-commerce. Digital platform businesses such as Amazon, Uber, and Airbnb have substantially displaced traditional models and, in some cases, largely replaced the established retail formats, such as video shops for digital media, or made significant competitive inroads, as in urban road transport. Traditional retailers have responded with omni-channel models to compete with digital platform businesses. However, digital platform businesses are also diversifying, using their customer base to offer platforms that operate across sectors.[42]

Opportunities for Indonesia

Through its impact on business, consumers, workers, infrastructure, and the environment, the e-commerce phenomenon presents huge opportunities for economic development. Gojek in Indonesia and neighboring counties, and Grab in Singapore and Malaysia, are examples of successful taxi services that have expanded quickly using digital platforms to provide a broader suite of services. They demonstrate the power of e-commerce digital platforms when combined with effective low-cost delivery models. Further, a survey conducted for this study on a sample of 600 firms in three big cities in Indonesia—Jakarta, Bandung, and Surabaya—found that the vast majority of companies benefited from using online platforms to sell their products. Since joining e-commerce platforms, companies have experienced increases in sales and profits, as well as the number of consumers they can reach, though large companies perceived more benefits than did SMEs.[43]

Challenges to Exploiting Opportunities

E-commerce operates in a digital ecosystem that is highly dependent on ICT infrastructure: IT hardware and software, telecom companies that provide enabling infrastructure for the internet, and digital solutions that facilitate payments and contribute to the digitalization of the wider economy. The wider ecosystem includes digital content providers and internet platforms. Therefore, ensuring further development of

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41 This section is based on J. S. Srai. 2019. *Last Mile Delivery: E-Commerce Retail Revolution.* Jakarta. Background paper produced for the ADB technical assistance to Indonesia on Supporting Technological Transformation (Project Number: 51343-001).

42 The arrival of global online retailers such as Amazon in traditional markets often signals major disruption in the retail landscape, coupled with enhanced customer expectations. For traditional retail chains, developing an e-commerce channel has been a key element of their survival strategy.

43 Y. R. Damuri. 2019. *E-Commerce in Indonesia: The Rise of Online Commerce and its Impact on Firms' Performance and Consumers.* Background paper produced for the ADB technical assistance to Indonesia on Supporting Technological Transformation (Project Number: 51343-001). Jakarta.

ICT infrastructure and improving access to technology such as the internet and mobile phones are necessary to further develop e-commerce retailing in Indonesia.[44] E-commerce creates major challenges to existing policy and regulatory controls. For example, given the displacing impact on conventional retail, e-commerce can spark resistance from established retailers. In this respect, policy responses should anticipate impacts and support the transition for affected businesses and employees. To guarantee employment safeguards, service providers should be encouraged to provide equitable returns to their delivery agents. Policy makers should establish consumer protection where service quality falls below acceptable standards. Safeguards against monopolistic effects should be considered, as the rapid growth of digital platforms may create an overly dominant position. Digital infrastructure highlights the importance of robust policies for resilience and measures to manage cybersecurity and data management, including the observance of privacy and security rules. Finally, the tax implications of new business models should be addressed by regulatory frameworks (Box 2.1).

2.4.4 | Technological Transformation of Urban Planning in the Age of "Smart Cities"

Global Technology Trends

The potential of using emerging digital ICT and data-driven solutions to reform planning theory and practice is culminating in a worldwide discourse around "smart cities"—referring to a wide range of policy initiatives and corporate projects around the world that aim to utilize the power of data and digital tools for city planning, management, and operation. Several smart technologies are relevant to the smart city discourse. For example, online open data sources and associated data analytics have the advantage of providing new sources of information that can complement conventional data sources such as census data and administrative or geographical surveys. Geographic information system data visualization and integration have been widely used as an interoperable framework for gathering, managing, and analyzing geospatial data. City-scale data-sharing schemes include open data-sharing portals where citizens, business owners, researchers, and property developers can access data sets to help them understand and develop solutions for city problems.[45]

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[44] This study also identified the following constraints to the further development of e-commerce in Indonesia:
- Logistics: Given Indonesia's topography with over 17,500 islands, reliable sea and air transportation is needed to connect most of the islands, in addition to land transportation. However, direct lines of air transportation are limited to big cities such as Jakarta and Surabaya on Java, or Makassar on Sulawesi, which act as hubs. A parcel sent from a smaller city first needs to be flown to a hub city before being sent to the final destinations. Moreover, ocean transportation can also be costly.
- Financial support: E-commerce depends upon financial services for payment and financing. In Indonesia, access to finance remains relatively low, despite many initiatives to improve financial inclusion.
- Business and consumer behavior: There is reluctance among business and consumers to use e-commerce. Most businesses believe that e-commerce has no benefits. In addition, there is a lack of trust in virtual systems, which hinders retailers' use of online technology.

Source as in footnote 43.

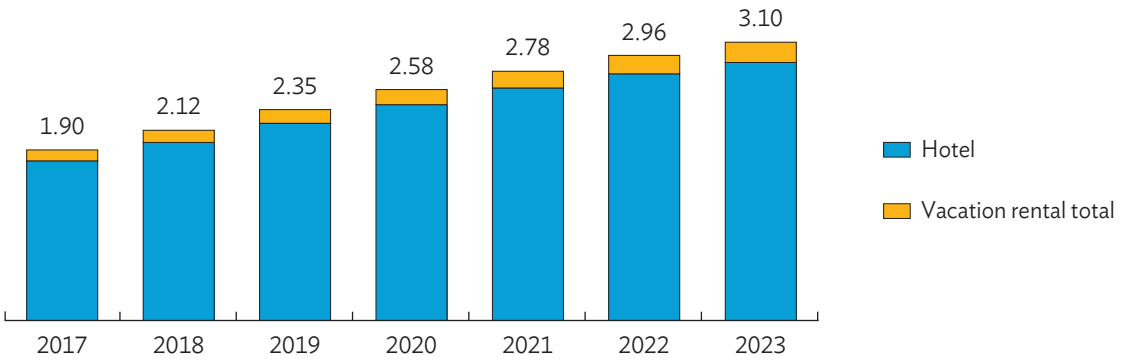
[45] An example is the London Datastore in the United Kingdom.

BOX 2.1

Tax Implications from Online Hotel Booking in Indonesia

Governments around the world may need to consider the tax implications of new business models arising from the e-commerce retail revolution, such as the hotel booking system. In Indonesia, online hotel booking is a growing market, projected to generate $3.10 billion in revenue by 2023.

Revenue from Online Hotel Booking in Indonesia ($ billion)



Source: Statista.

The online hotel booking market comprises two segments:

- Hotels and professionally run guesthouses can be booked directly through the provider's website, a tour operator, or an online travel agency. Examples include Hotels.com, Trivago, and Booking.com.
- Vacation rentals are private accommodation, including private holiday homes and houses, that are arranged and booked online through portals such as HomeAway, and short-term rentals of private rooms or flats through portals such as Airbnb, Airyrooms, RedDoorz, ZEN Room, and Oyo.

An increasing amount of revenue generated by online booking providers can have positive impacts for government tax revenues. However, compliance with tax payment regulations must be ensured. One mechanism is to obtain hotel booking transaction data. In this case, the government may consider requiring the online hotel booking provider to share or connect its database with the government so that property owners' compliance can be ensured. According to Law No. 28 of 2009 on Local Tax and Retribution, however, only property owners with more than 10 dormitory rooms are obliged to pay taxes, so taxes cannot be collected from numerous property owners who rent homes with fewer than 10 rooms.

There is an opportunity to use PMK No. 210/PMK.010/2018 as the basis to require online hotel booking providers to connect or share transaction data in order to make tax payment compliance more effective, including locally. However, efforts could also be made to enlarge the scope of Law No. 28 of 2009 to include property owners who rent homes with fewer than 10 rooms.

Source: ADB technical note on *Online Hotel Booking System* for the ADB project Tax Revenue Administration Modernization and Policy Improvement in Local Governments.

Opportunities for Indonesia

The digital revolution and smart city initiatives provide the momentum to reform existing urban planning practice in countries such as Indonesia to better fit the local context, and to develop context-informed solutions to local problems. The Government of Indonesia has expressed an interest in smart city solutions, launching 25 smart city pilot projects in 2017 and aiming to expand the number of participating cities to 100 by 2019.[46] Analysis conducted as background for this report shows that, in Indonesia, digital ICT has already changed the way the government is delivering services to citizens and the business community. The adoption of digital technology changes how residents and businesses can interact with local governments, for example to obtain business licenses, making it more efficient.[47] Furthermore, in Indonesia investments in digital infrastructure such as the Palapa Ring national fiber-optic network may become strong catalysts for local socioeconomic development, particularly in rural areas, by promoting digital connectivity. For such investment to achieve these aims, however, a comprehensive solution package should follow, addressing the barriers that prevent digitally deprived people living in underdeveloped areas from harnessing the benefits of digital connectivity through, for example, education programs and the establishment of community centers with access to computers and the internet. Moreover, given development disparities between urban and rural areas in Indonesia, digital strategies may be differentiated among different locations to fit the local context.

Challenges to Exploiting Opportunities

Smart city initiatives could potentially become strong policy instruments to rebalance regional disparity in countries such as Indonesia. Digital strategies may be differentiated among different locations to fit the local context, given development disparities between urban and rural areas in Indonesia. However, data-driven solutions processed with the help of digital technologies are only as good as the data they use. High urbanization rates pose significant issues for collecting accurate and good-quality data that can be acted upon. Thus, it is crucial to develop and implement data collection methods and technologies that substantially reduce the time required for data collection. Furthermore, training for planners and public officers in digital solutions will be needed to ensure that data analysis and sharing are effectively used for policy making and economic development. Finally, harnessing the benefits of emerging digital technologies implies finding a role for public sector planning in processes of policy making, implementation, and monitoring where they are deployed. This could involve the development of legal and regulatory frameworks for the use of digital technologies in city planning, management, and monitoring, as well as governing their newly created digital interfaces.

[46] R. Dwinanda. 2017. Ministry Launches 100 Smart City Movement. *Republika*. 23 May.

[47] K. Djaja and P. Walandouw. 2019. *Impact of Digital Technology on Urban Life*. Background paper produced for the ADB technical assistance to Indonesia on Supporting Technological Transformation (Project Number: 51343-001). Jakarta.

2.4.5 | Impact of New Technologies on the Energy Sector

Global Technology Trends

Digitalization and electrification are the core disruptive transformations influencing the energy sector. Key technologies reshaping energy generation, distribution, and use include renewable power, battery storage, electric vehicles, autonomous vehicles, smart meters, and smart grids.[48] These technologies may bring gains in productivity and efficiency, which may offer new business opportunities, mitigation of environmental impacts, and improved social well-being. Batteries' ability to store electricity from the power grid or intermittent sources could make electric devices more autonomous and intermittent renewable sources more reliable. Vehicles that are either fully electric or hybrid could reduce air pollution and oil dependency. Driverless autonomous vehicles could create new business models in which transport services replace vehicle ownership. Smart meters could, by showing instantaneous consumption, change people's behavior in ways that reduce energy demand. Smart grids that control and condition electricity production, distribution, and consumption will improve grid efficiency, reliability, and flexibility. Yet, the deployment of disruptive technologies redefines practices and equipment, requiring changes in infrastructure and energy use and having a systemic impact on the energy sector.

Opportunities for Indonesia

New technologies offer opportunities for Indonesia. Although the deployment of disruptive technologies will increase electricity demand, new technologies could mitigate this effect. This is particularly important for Indonesia, where growth in electricity generation has lagged electricity demand, despite generation doubling over the past decade. In this respect, some disruptive technologies—such as electric motorcycles combined with microgeneration from intermittent renewable energy sources—may contribute to a transformation of the energy sector by reducing electricity demand pressure, with spillover effects on the environment and economic activity. Electric motorcycles could facilitate the transition to an electricity grid with a higher share of renewables and thus help Indonesia to exploit its undeveloped potential for geothermal energy and natural gas, thereby reducing its dependence on imported oil.

Challenges to Exploiting Opportunities

The deployment of disruptive technologies depends on reliable access to electricity, and most technologies increase electricity demand. The Indonesian energy sector has been under continuing transformation in recent decades.[49] However, new disruptive technologies, climate change, and political and economic developments will require further transformations in energy supply infrastructure. In addition, promoting infrastructure to develop the smart grid can provide more opportunities for renewable energy to fit in the system.[50] In this respect, a reliable electricity grid and a power sector capable of meeting fast-growing

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[48] This section is based on A. Serrenho. 2019. *The Impact of Disruptive Technologies on the Energy Sector*. Background paper produced for the ADB technical assistance to Indonesia on Supporting Technological Transformation (Project Number: 51343-001). Jakarta.

[49] Since the early 1970s, energy production in Indonesia has increased sixfold and energy demand fourfold. Source: International Energy Agency. 2018. *Energy Statistics*.

[50] M. T. Sambodo and M. Silalahi. 2019. *Implications of Disruptive Technology to the Energy Sector in Indonesia: From a Fossil-Based Economy to Low Carbon Development.* Background paper produced for the ADB technical assistance to Indonesia on Supporting Technological Transformation (Project Number: 51343-001). Jakarta.

demand for electricity will enable the deployment of new technologies. Indonesia is the fourth most populous country in the world, and its population is projected to increase in the coming years. Electricity demand is likely to increase more than energy production. Further efforts should be made to avoid power shortages and unreliable access to the power grid caused by a mismatch between electricity generation and demand. Further, Indonesia has substantial reserves in a variety of energy resources, notably geothermal energy and natural gas, that have not been fully exploited. Regulations will play an important role in maximizing synergies between transport electrification and variable renewable sources.

2.5 Conclusions

Understanding the potential impact of emerging technologies in national economies is a key concern for nations around the world, including Indonesia. Because of the crosscutting effect of new technologies and the increasing complexity of modern industrial systems, detailed insights into sector-specific opportunities are required to understand country-specific opportunities and challenges.

Based on inputs from international experts, this section provided insights into global technology trends and identified sector-specific opportunities and challenges for Indonesia. To assess how well Indonesia is positioned to exploit these opportunities, Section 3 analyzes the national innovation system—the network of public and private institutions that enable the generation, diffusion, and deployment of knowledge and technologies. Section 4 then presents a “deep dive” into Industry 4.0 to better understand opportunities for Indonesia by incorporating findings from extensive consultations with industrial stakeholders in the country.

SECTION 3

INDONESIA'S POSITION IN THE TECHNOLOGICAL TRANSFORMATION JOURNEY

KEY POINTS

Indonesia has taken important steps to strengthen its national innovation system in recent years. The importance of technology and innovation is widely recognized in the national policy agenda. Ongoing government initiatives to support technological transformation include new fiscal incentives, large investments in digital infrastructure, and new funding mechanisms to support public research. Making Indonesia 4.0 is a national initiative that recognizes the critical importance of technology for the future of Indonesia.

However, Indonesia's innovation system is still at an early stage of development. Indonesia underperforms the ASEAN average in terms of R&D expenditure, contributions from businesses to innovation and R&D, patent applications, and scientific publications. Higher-education attainment is low compared with its peers in the Group of 20 (G20), and technological expertise to support firms' innovation efforts is limited.

Opportunities nevertheless exist to leverage key national strengths to foster Indonesia's technological transformation. The national policy agenda places increasing emphasis on science and technology; the emerging technology start-up ecosystem has already produced three unicorns and one decacorn, valued at over $10 billion; and Indonesia is developing a critical mass of STEM graduates, with the country projected to be the fourth largest producer of STEM graduates in the G20 by 2030. Finally, the population is young, and the middle class is growing.

3.1 Introduction

Indonesia has taken important steps to strengthen its national innovation system (NIS) in recent years. New initiatives, institutions, and funding sources have recently been established to promote research and innovation. Despite recent progress, however, the country's NIS is still at an early stage of development.

To assess how well Indonesia is positioned to exploit opportunities arising from new technologies, this section provides an overview of its NIS. In particular, the section reviews key innovation indicators related to the generation, diffusion, and use of new knowledge in the economy. Key themes and priorities in the policy agenda are also reviewed. Finally, the strengths, weaknesses, opportunities, and challenges of Indonesia's NIS are summarized.

3.2 Indonesia's National Innovation System and Its Performance

The NIS is defined as the network of public and private actors and institutions that influence the processes through which knowledge and technologies are generated, diffused, and used.[51]

International innovation benchmarks indicate that, though Indonesia's innovation performance has improved in recent years, it remains comparatively low in both regional and global terms. For example, the Global Innovation Index (GII), a widely referenced innovation ranking, situates Indonesia in the lower tier of ASEAN countries and ranks it 87th out of 127 nations.[52] Indonesia is considered a "nascent" country by a recent World Economic Forum (WEF) report[53] which reviews countries' readiness to shape and benefit from the changing nature of production in the future.[54] Similarly, Indonesia underperforms in other international rankings compared to its regional ASEAN peers, as shown in Table 3.1.

3.2.1 | Research and Innovation

Research in Indonesia is conducted primarily by national research centers and, increasingly, by universities.[55] The central government allocates and distributes funds for R&D to ministries, research centers, and public universities by direct and usually noncompetitive funding.[56]

51 C. Freeman. 1987. *Technology and Economic Performance: Lessons from Japan*. London: Pinter.

52 Global Innovation Index. 2017. *Innovation Feeding the World*. Ithaca: Fontainebleau and Geneva.

53 World Economic Forum. 2018. *Readiness for the Future of Production Report 2018*. Geneva.

54 In the context of this study, the WEF defines "nascent" countries as those with "a limited production base today that exhibit a low level of readiness for the future through weak performance across the drivers of production component."

55 Investment Coordinating Board. 2017. *Making Indonesia 4.0: Indonesia's Strategy to Enter the 4th Generation of Industry Revolution.* Jakarta.

56 Y. Damuri et al. 2018. Innovation Policy in Indonesia. In M. Ambashi, eds. *Innovation Policy in ASEAN.* Jakarta: Economic Research Institute for ASEAN and East Asia. pp. 96–127.

Table 3.1: Indonesia's Position in Selected Innovation and Digitalization Rankings

Country	Global Innovation Index (127 countries)	Readiness for the Future of Production Assessment (100 countries)		Networked Readiness Index (139 countries)	Digitization Index (100 countries)
		Structure of Production	Drivers of Production		
Brunei Darussalam	71	N/A	N/A	N/A	N/A
Cambodia	101	81	91	109	N/A
Indonesia	87	38	59	73	71
Malaysia	37	20	22	31	29
Philippines	73	28	66	77	68
Singapore	7	11	2	1	7
Thailand	51	12	35	62	66
Viet Nam	47	48	53	79	81

N/A = data not available.

Notes: The Global Innovation Index provides detailed metrics about the innovation performance of 127 economies around the world. Its 81 indicators explore a broad vision of innovation, including political environment, education, infrastructure, and business sophistication. The World Economic Forum's Networked Readiness Index 2016 measures how well an economy is using information and communication technologies to boost competitiveness and well-being. The Digitization Index is a composite index that measures the degree of digitization in 99 economies around the world. It classifies information into three broad categories: supply conditions, demand conditions, and institutional environment. Data not available for the Lao People's Democratic Republic and Myanmar.

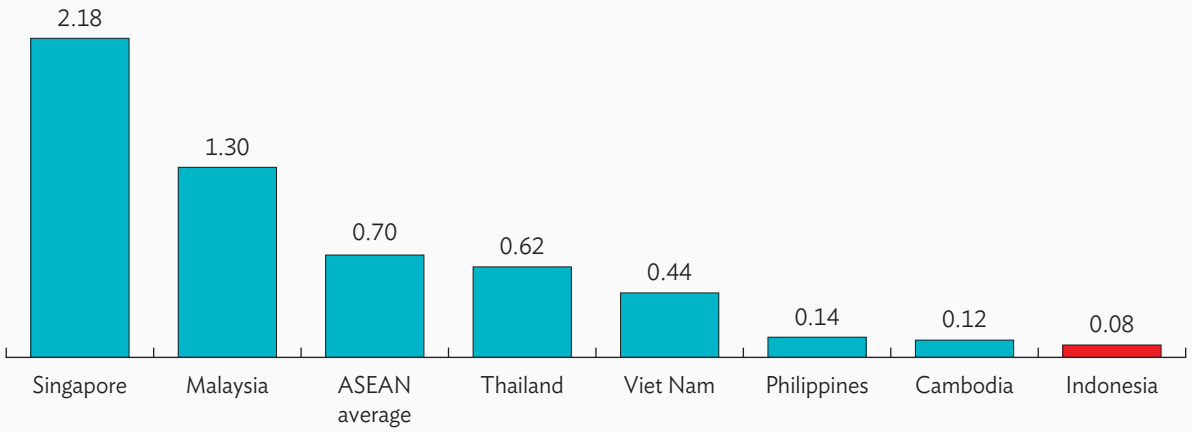
Sources: WEF. 2016. *The Global Information Technology Report 2016*. Geneva; BBVA Research. 2017. *The Digitization Index (DiGiX)*. Working paper; Cornell University, INSEAD, and WIPO. 2017. *The Global Innovation Index 2017: Innovation Feeding the World*. Ithaca: Fontainebleau and Geneva; WEF. 2018. *Readiness for the Future of Production Report 2018*. Geneva.

According to the latest available estimate, Indonesia's expenditure in R&D equals only 0.08% of its GDP. This proportion is low compared with its regional peers, at only one-tenth of the ASEAN average (Figure 3.1) and one-thirtieth of the average of Organisation for Economic Co-operation and Development (OECD) members.[57]

The high involvement of the public sector in R&D is reflected in R&D performance: 39% of the gross domestic expenditure on R&D is by the government, executed through its public research centers, and 35% is performed by higher-education institutions. Only 26% of the national R&D is performed by private businesses. In other ASEAN countries, businesses perform a higher share of national R&D: 64% in Viet Nam, 73% in Thailand, and 61% in Singapore (Figure 3.2).

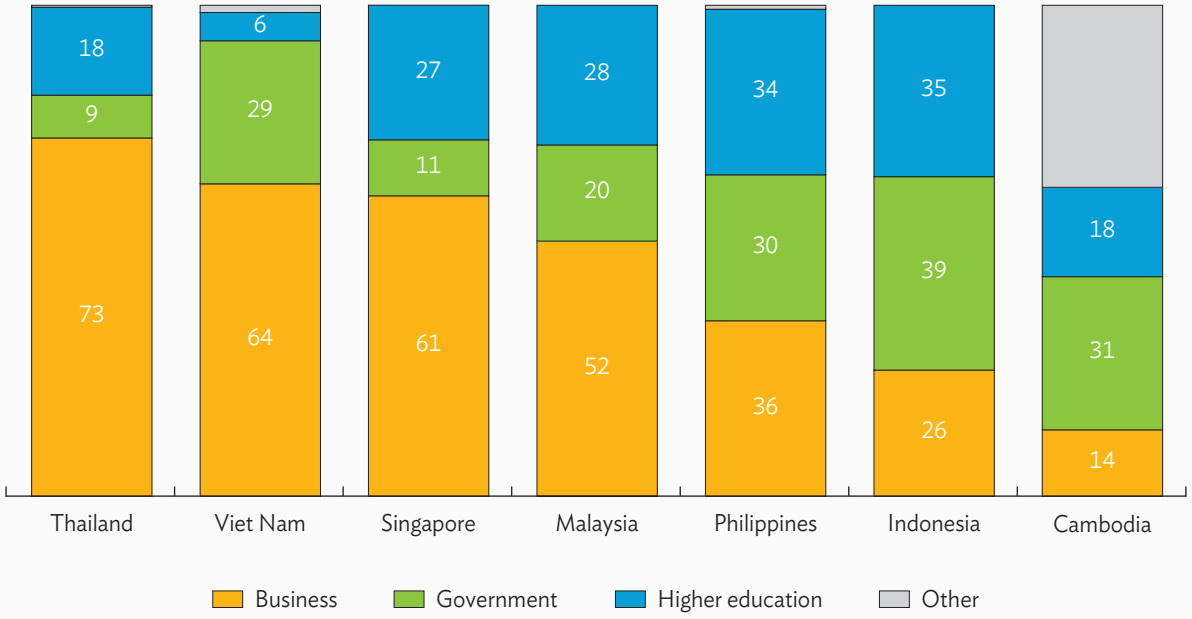
[57] OECD. 2019. *OECD Data*.

Figure 3.1: Research and Development Expenditure in ASEAN, 2017 or Latest Available (% of GDP)



ASEAN = Association of Southeast Asian Nations, GDP = gross domestic product.
Sources: World Bank. 2019. *World Development Indicators*; UNESCO. 2019. *UIS.Stat*.

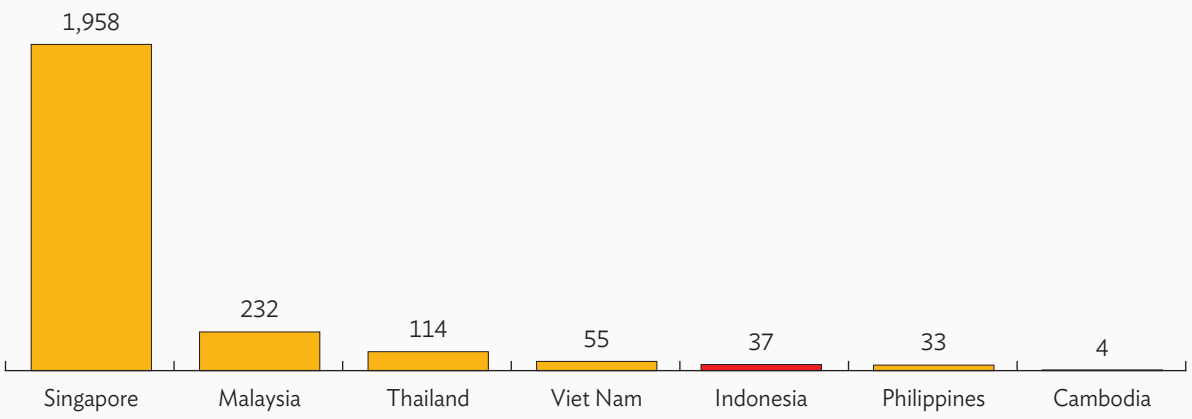
Figure 3.2: Research and Development by Sector Performance, 2017 or Latest Available (% of GDE)



GDE = gross domestic expenditure.
Sources: World Bank. 2019. *World Development Indicators*; UNESCO. 2019. *UIS.Stat*.

In advanced countries and other emerging countries, the contribution of business to R&D typically exceeds 50% of gross domestic expenditure (footnote 57). Nonetheless, the Indonesian private sector shows some advantages in terms of its ability to innovate. According to the GII, Indonesia ranks 18 in 100 countries in the component "companies embracing disruptive ideas" and 30th in "company investment in emerging technologies" (footnote 53).

Figure 3.3: Patent Applications by Residents and Nonresidents in ASEAN, 2017 or Latest Available
(per million population)



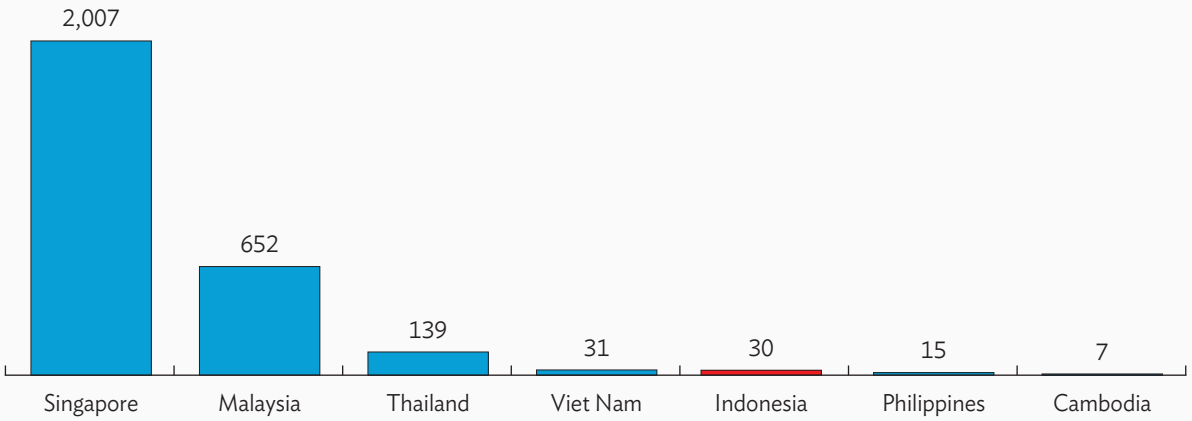
ASEAN = Association of Southeast Asian Nations.
Sources: World Bank. 2019. *World Development Indicators*; UNESCO. 2019. *UIS.Stat*.

Lower investment in R&D yields lower knowledge output. Indonesia ranks 83 in 100 countries by the number of patent applications per million population, with 37 patent applications in 2017 (Figure 3.3). According to the GII, it ranks 97th in the number of scientific and technical publications (Figure 3.4).

Finally, with respect to the human capital involved in knowledge generation, the latest available estimate is 171 researchers per million inhabitants, 89 of them full-time, in Indonesian institutions and enterprises. Of them, 55% were in higher-education institutions, 27% in government, and 18% in private business.[58] Indonesia ranks six in eight ASEAN countries covered in the "human capital and research" component of the GII.

[58] UNESCO. 2019. *Indonesia. Science, Technology and Innovation*. Paris.

Figure 3.4: Articles Published in Scientific and Technical Journals in ASEAN, 2017 or Latest Available (per million population)



ASEAN = Association of Southeast Asian Nations.

Sources: World Bank. 2019. *World Development Indicators*; UNESCO. 2019. *UIS.Stat*.

3.2.2 | Technology Diffusion

In terms of activities that support the diffusion of new technologies and know-how within Indonesia's national innovation system, including network linkages, data from WEF and the OECD suggest strong integration of the local scientific community into international networks and a high number of university–industry collaborations.[59] In addition, Indonesia ranks 24 in 100 countries in the "state of cluster development" component of the WEF index on readiness for the future of production.[60]

The successful diffusion of certain technologies requires the implementation of appropriate physical infrastructure and framework conditions. This is true, for instance, for the expansion of digitally enabled services and products in Indonesia, facilitated by recent growth of the nation's ICT infrastructure, including broadband and mobile phone networks.

Increased access to internet and mobile phones has enabled the development of e-commerce and fintech in Indonesia. In particular, e-commerce businesses have experienced dramatic development in recent years.

[59] Average response to the question: *In your country, to what extent do businesses and universities collaborate on research and development (R&D)?* World Economic Forum. 2017. *Executive Opinion Survey 2016–2017*; OECD. 2016. Indonesia: Country Profile; OECD. 2016. *OECD Science, Technology and Innovation Outlook 2016*. Paris.

[60] Cluster development is indicated by how widespread and developed clusters are, with clusters defined as geographic concentrations of firms, suppliers, and producers of related products and services, along with specialized institutions in a particular field. Source: WEF. 2018. *Readiness for the Future of Production Report 2018*. Geneva.

The total value of e-commerce transactions grew from $0.27 billion in 2012 to $8.59 billion in 2018, and it is estimated to reach $10.37 billion by the end of 2019. With a population of 264 million, Indonesia has the potential to become the largest e-commerce market in Southeast Asia (footnote 43).

Box 3.1 illustrates key features of Indonesia's growing digital start-up ecosystem, where e-commerce and transport start-ups dominate deals and investment values. Box 3.2 relates the case of Gojek, a successful service provider on demand offering transportation, logistics, payment, and food delivery. Box 3.3 presents some recent government initiatives to support e-commerce and fintech.

BOX 3.1

Indonesia's Digital Start-Up Ecosystem

A start-up ecosystem comprises entrepreneurs, their ideas and skills, mentoring support, capital, infrastructure, the institutional framework, and other intertwined resources that contribute to the creation and development of new companies.

While the Indonesian start-up ecosystem is still young, it is growing rapidly. In the first half of 2017 it reached nearly $3 billion, duplicating the amount achieved in the whole of 2016. E-commerce and transport categories dominate deals, at 46%, and investment value, at 96%, with the largest funding rounds led by companies such as Gojek, Traveloka, and Tokopedia. However, fintech and health care are emerging as top investment categories.

In 2017, investors in the People's Republic of China became heavily involved in Indonesia's start-up environment, providing approximately 95% of investment by value. In 2018, according to the World Bank's *Doing Business* index, Indonesia scored 81.2 out of 100 in the component "starting a business," ranked 134 in 190 countries. However, Indonesia's competitiveness has increased significantly in recent years. In its IMD World Competitiveness ranking among 63 economies, Indonesia rose from 43 in 2018 to 32 in 2019.[a]

Despite these significant improvements, Indonesia's start-up ecosystem could benefit from lower barriers to doing business. Some opportunity areas identified by investors are talent attraction and development, fiscal incentives, funding and exit options, and start-up facilitation through the regulatory framework and infrastructure development.

Initiatives already addressing these opportunity areas include the following:

- The NextICorn (Next Indonesian Unicorn) International Convention is a joint initiative by Indonesia's ICT Ministry, Indonesian Venture Capital and Startups Association, and Ernst & Young, which connects digital start-ups with venture capital investors.
- The Digital Talent Scholarship Program in 2019 is a training program aiming to improve the upskilling of human resources in areas such as artificial intelligence, big data, cloud computing, cybersecurity, the internet of things, and machine learning. Among its private partners in Indonesia are Cisco, 30 universities, and 23 polytechnics.

[a] The IMD World Competitiveness ranking measures four dimensions: economic performance, government efficiency, business efficiency, and infrastructure.

Sources: Google-A.T. Kearney. 2017. *Indonesia Venture Capital Outlook*; IMD. 2019. *IMD World Competitiveness Ranking 2019. One Year Change*; Ministry of Communication and Information. 2019. Press release; World Bank. 2019. *Doing Business. Starting a Business.*

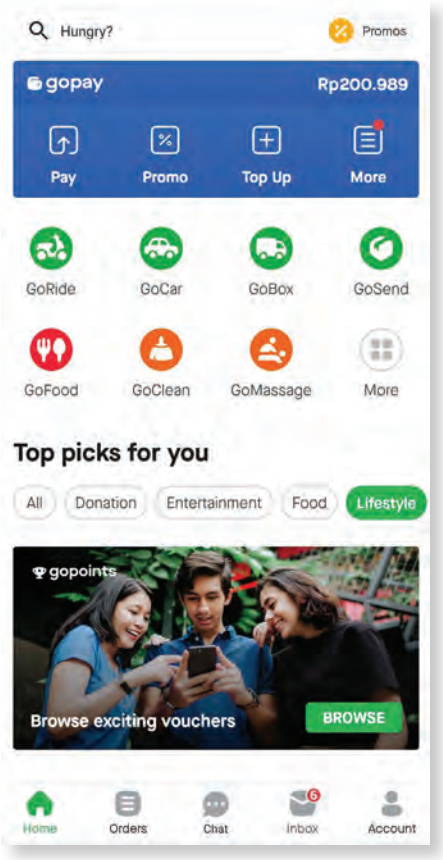
BOX 3.2

The Case of Gojek

Gojek is a provider of services on demand offering mostly transportation, logistics, payment, and food delivery. It is Indonesia's first decacorn—a company valued at over $10 billion—and the only Southeast Asian company featured in the 2017 edition of Fortune's *50 Companies That Changed the World*.

Gojek began operations in 2010, providing phone-based motorcycle transportation. In 2015, the company launched its app and soon after it evolved into a platform offering a multitude of services, notably delivering food, other goods, and services.

The company has over 125 million users, more than 2 million driver partners, more than 200,000 food vendors, and more than 30,000 other service providers. Its success in Indonesia has spurred significant expansion in neighboring countries in Southeast and South Asia, notably Bangladesh, Singapore, Thailand, and Viet Nam.



Sources: J. S. Srai. 2019. *The E-Commerce Retail Revolution*. Background paper produced for the ADB technical assistance to Indonesia on Supporting Technological Transformation (Project Number: 51343-001). Jakarta; K. Djaja and P. Walandouw. 2019. *The Impact of Digital Technology on Urban Life*. Background paper produced for the ADB technical assistance to Indonesia on Supporting Technological Transformation (Project Number: 51343-001). Jakarta; R. Rahman. 2019. Gojek Officially Launches Operations in Thailand. *Jakarta Post*. 28 February.

BOX 3.3

Recent Government Initiatives to Support E-Commerce and Fintech

Recognizing the potential benefits arising from e-commerce, the Government of Indonesia launched in November 2016 the E-Commerce Roadmap as part of its Economic Policy Package XIV. The roadmap proposes a policy and regulatory framework to support e-commerce development. However, Indonesia still faces challenges that may hinder the development of e-commerce in the country, including the state of national digital infrastructure, logistics, and financial support (Section 2).[a]

As with e-commerce, the future expansion and improvement of telecommunications and broadband infrastructure are considered key challenges to ensure the development and adoption of new digital products and services in the fintech sector.[b]

continued next page

BOX 3.3

(continued)

The Government of Indonesia has shown a strong commitment to supporting this sector by adopting the *Bali Fintech Agenda*.[c] Launched at the 2018 Annual Meetings of the International Monetary Fund and the World Bank Group, the agenda provides 12 pillars that countries can adopt to develop fintech:

- embracing the promise of new fintech technologies to enhance financial service provision;
- reinforcing competition and commitment to open, free, and contestable markets;
- fostering fintech to promote financial inclusion and develop financial markets;
- monitoring developments closely to deepen understanding of evolving financial systems;
- adapting regulatory frameworks and supervisory practices for the orderly development and stability of the financial system;
- safeguarding the integrity of financial systems and modernizing legal frameworks to provide an enabling legal landscape;
- ensuring the stability of domestic monetary and financial systems;
- developing robust financial data infrastructure to sustain fintech benefits;
- encouraging international cooperation and information-sharing; and
- enhancing collective surveillance of the international monetary and financial system.

[a] Y. R. Damuri. 2019. *E-Commerce in Indonesia: The Rise of Online Commerce and its Impact on Firms' Performance and Consumers.* Background paper produced for the ADB technical assistance to Indonesia on Supporting Technological Transformation (Project Number: 51343-001). Jakarta.

[b] R. Atje, I. Setiati, and I. N. Fadhil. 2019. *Disruptive Technology in Indonesia's Banking Sector*. Background paper produced for the ADB technical assistance to Indonesia on Supporting Technological Transformation (Project Number: 51343-001). Jakarta.

[c] International Monetary Fund. 2018. *The Bali Fintech Agenda*. Washington, DC.

Beyond e-commerce and fintech, the need to expand and strengthen national ICT infrastructure is widely recognized as an opportunity area to improve Indonesia's knowledge diffusion capability.[61] Figure 3.5 shows that opportunities still exist to increase the penetration of key enabling digital technologies when compared with other ASEAN countries. This could include, for example, extending internet access, as currently only half of the Indonesian population has access to the internet, and increasing broadband subscriptions.

Recognizing the importance of strengthening digital infrastructure across the country to foster economic development, the Government of Indonesia has launched efforts to address this issue through the construction of digital networks such as 4G and 5G, optical fiber, data centers, and cloud servers.

[61] OECD. 2016. *Indonesia: Country profile*. Paris; WEF. 2018. *Readiness for the Future of Production Report 2018.* Geneva.

Figure 3.5: Digital Technology Penetration Indicators in ASEAN, 2018

	INTERNET USERS	MOBILE CONNECTIONS	ACTIVE MOBILE SOCIAL USERS	FIXED BROADBAND SUBSCRIPTIONS (per 100 people)
LAO PDR	35% 2.4 million	91% 6.3 million	32% 2.2 million	0.40
BRUNEI DARUSSALAM	95% 410,000	124% 534,400	81% 350,000	9.61
VIET NAM	67% 64.0 million	153% 146.5 million	52% 50.0 million	11.80
CAMBODIA	50% 7.0 million	181% 29.2 million	39% 6.3 million	0.81
SINGAPORE	84% 4.8 million	150% 8.6 million	75% 4.3 million	25.76
PHILIPPINES	63% 67.0 million	115% 121.4 million	59% 62.0 million	3.24
INDONESIA	50% 132.7 million	157% 416.7 million	45% 120.0 million	2.29
MALAYSIA	79% 25.1 million	133% 42.3 million	69% 22.0 million	8.50
MYANMAR	34% 18.0 million	101% 54.0 million	30% 16.0 million	0.76
THAILAND	83% 57.0 million	135% 93.6 million	67% 46.0 million	11.89

ASEAN = Association of Southeast Asian Nations, Lao PDR = Lao People's Democratic Republic.

Note: Penetration figures refer to the total population, regardless of age.

Sources: We Are Social. 2019. *Digital in 2018 in Southeast Asia*; World Bank. 2019. *World Development Indicators*.

Recent initiatives in this area include the implementation of the Palapa Ring national fiber-optic network and a new communication satellite that will provide access to fast internet throughout Indonesia.[62]

3.2.3 | Technology Deployment

Technology adoption by Indonesian firms remains comparatively low. According to a survey conducted by the International Labour Organization in 4,000 enterprises across ASEAN, two key barriers to upgrading technology are high fixed capital costs and the lack of a skilled workforce.[63] The largest share of Indonesia's manufacturing structure, or 49.6%, is in low-technology sectors. Medium-technology sectors are 16.2% of the industrial structure, and medium-high and high-technology sectors are 31.7%. However, analysis conducted by ADB shows that the share of manufacturing value added in high-technology sectors has increased fourfold since 2000 (footnote 6). In addition, the country ranks 10 in 100 countries in the GII for the component "government procurement of advanced technology products" (footnote 61).

Human capital is a key enabler of knowledge-deployment activities, in particular the availability of science, technology, engineering, and mathematics (STEM) graduates. Indonesia ranks 47th internationally in the number of graduates in science and engineering, 30th in digital skills, and 24th in its capacity to attract and retain talent.[64] In ASEAN, the country ranks sixth in eight countries in the "human capital and research" component of the GII.

The share of population with tertiary education in the 25–34 age group is still relatively low, at 16.1%, which is below tertiary education attainment in other G20 countries or the OECD.

Indonesia is, however, projected to be among the highest producers of STEM graduates in the world because of rapid expansion in its tertiary education system and population. As shown in Figure 3.7, Indonesia is expected to produce 3.7% of global STEM graduates in 2030. Access to this pool of local skills presents an opportunity for the country's future development and innovation capacity.

It should be noted, however, that an increasing number of STEM graduates will not automatically translate into greater R&D in the country. This is because STEM graduates can undertake several tasks in the production system, such as being an engineer working in a production facility, a mathematician working in finance, or a teacher. There is indeed scope for government policies to manage these local scientific and engineering capabilities.

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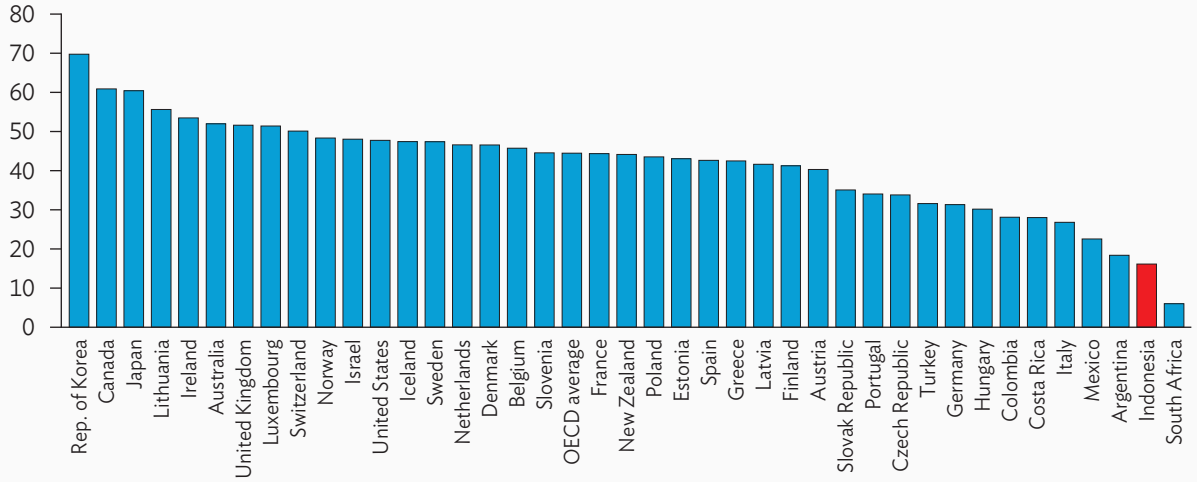
62 Ministry of Finance of the Republic of Indonesia.

63 International Labour Organization. 2016. ASEAN in Transformation: The Future of Jobs at Risk of Automation. *Bureau for Employers' Activities Working Paper.* No. 10. Bangkok.

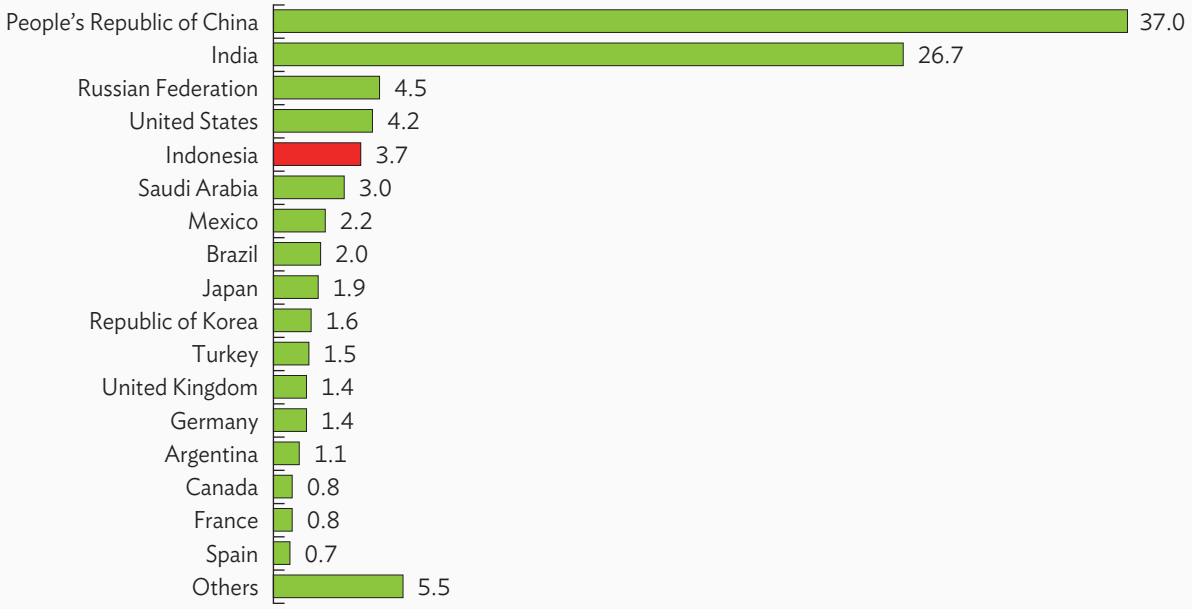
64 International Labour Organization. 2016. ASEAN in Transformation: The Future of Jobs at Risk of Automation. *Bureau for Employers' Activities Working Paper.* No. 10. Bangkok; WEF. 2018. *Readiness for the Future of Production Report 2018.* Geneva.

Figure 3.6: Population with Tertiary Education in the OECD and Other Selected Countries, 2017
(25–34 year-olds; % in same age group)



OECD = Organisation for Economic Co-operation and Development.
Source: OECD. 2019. *OECD Data*.

Figure 3.7: Projected Share of Graduates with STEM Degrees across OECD and G20 Countries in 2030



OECD = Organisation for Economic Co-operation and Development, STEM = science, technology, engineering, and math.
Source: OECD. 2015. *Education Indicators in Focus n. 13*.

Given the importance of human capital to addressing the challenges of economic development, the Government of Indonesia has recently implemented an education policy framework to support human quality enhancement. The framework includes five aspects: access to education, especially to higher education; the quality of teachers and facilities; synergy connecting educational programs and agencies; the vocational education network; and incentives, both fiscal incentives and tax exemption for R&D (footnote 62).

3.3 Key Themes in the Policy Agenda

The Ministry of Research, Technology, and Higher Education is the main authority responsible for science, technology, and innovation policy in Indonesia, with the State Ministry of National Development Planning responsible for the development of medium- and long-term plans for science and technology.[65] Besides coordinating the implementation of science and technology policy, the former ministry plays a key role in funding research.[66] It oversees 3,226 public and private universities, 24 science and technology parks, and 6 research centers: the Nuclear Energy Agency, National Nuclear Energy Agency, Agency for the Assessment and Application of Technology, National Standardization Agency of Indonesia, National Institute of Aeronautics and Space, and Indonesian Institute of Science.[67] These research centers are 100% funded by public sources.[68] The Ministry of Industry is also involved in the design and implementation of science, technology, and innovation policy. Local governments, such as the city government of Bandung, the capital of West Java Province, also play important roles in shaping the innovation environment (footnote 56).

Indonesian innovation policy is framed under the National Long-Term Development Plan, 2005–2025, which is divided into four separate medium-term plans, each with a life span of 5 years (footnote 68). The key sectors promoted in these plans are ICT, energy, food, manufacturing, transport, and health and health care.[69] Moreover, national development plans are placing green growth and sustainability at the center of their strategies.

While Indonesia's expenditure on R&D is relatively low, the government has implemented several systemic initiatives to increase and improve research funding:[70]

- New funding instruments are increasingly in use, including competitive grants, debt financing, and risk-sharing mechanisms, as well as a number of tax incentives.
- The National Research Agenda, 2015–2019, according to the OECD, "marks a new step in the lasting efforts to foster industry–science cooperation on research and increase private investment in public research."

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65 Center for Research and Development Strategy and Japan Science and Technology Agency. 2005. *Current Status on Science and Technology in ASEAN Countries.* Tokyo; Ministry of Research, Technology, and Higher Education. *Profile.*

66 Center for Research and Development Strategy and Japan Science and Technology Agency. 2005. *Current Status on Science and Technology in ASEAN Countries.* Tokyo.

67 Ministry of Research, Technology, and Higher Education. *Profile*; 2017. *Laporan Tahunan 2017*; 2015. *Statistics.*

68 Indonesia-Investments. 2019. *Government Development Plans of Indonesia*. Jakarta; World Bank and OECD. 2013. *Indonesia: The Innovation Policy Platform*. Washington, DC.

69 World Bank and OECD. 2013. *Indonesia: The Innovation Policy Platform*. Washington, DC.

70 This section is mainly based on OECD. 2016. *Indonesia: Country Profile*.

- The Indonesian Science Fund was established as an autonomous body under the Indonesian Academy of Sciences, established in 2016 to supply funding to the Indonesian science and technology research community. As an independent body, it provides advice to the government and society on the acquisition, development, and application of science and technology.
- A regulation approved in 2015 introduces the possibility of rewarding researchers with patent royalties.
- The Roadmap for a Regional Innovation System aims to strengthen competitiveness and the capability to address basic needs.
- The Ministry of Planning has created an excellence scholarship program to allocate scholarships in the priority areas energy, food, and health.
- Toward making public procurement arrangements more flexible and accessible, the Electronic Procurement Agency was established, to provide an electronic procurement system.

Examples of measures for specific sectors and technology areas include the following:

- As Indonesia has become a key player in international food and farm markets, the government is promoting research in synthetic biology for the generation of new crop and grass varieties.
- The Indonesian Institute of Sciences has increased research activities on drought- and flood-tolerant rice varieties.
- A new program, Agrifarm Training, provides seed capital and training for the development of technology-based businesses.
- A center of innovation was established to develop energy generators that combine various sources of alternative energy.
- The Indonesian Science Fund was established in March 2016 to supply funding to the Indonesian science and technology research community.
- The International Center for Interdisciplinary and Advanced Research was built in 2013 to increase the capacity for interdisciplinary research.
- A roadmap was designed for the pharmaceutical and e-commerce industries in 2016 (footnote 6).

To boost economic growth, the Government of Indonesia launched in April 2018 Making Indonesia 4.0, a masterplan developed by the Ministry of Industry with the aim of revitalizing Indonesia's manufacturing industry and readying it for the opportunities and challenges in the Fourth Industrial Revolution (Box 3.4). In addition, several tax incentives managed by the Ministry of Finance are currently available to boost exports and investments in manufacturing (Box 3.5).

However, some challenges remain. There have been suggestions that, in addition to funds, industry expects assistance in providing guidance for technology users, joint R&D activities, training for technical personnel, and managerial training, among other things (footnote 56).

BOX 3.4

Making Indonesia 4.0

In order to integrate Indonesia into the Fourth Industrial Revolution, the Ministry of Industry has developed Making Indonesia 4.0 as a roadmap. This initiative covers a range of technologies, including AI, the internet of things, robotics, and 3D printing. Other ministries and agencies involved in the implementation of Making Indonesia 4.0 are the Ministry of State-Owned Enterprises; Ministry of Manpower; Ministry of Education and Culture; Ministry of Research, Technology, and Higher Education; and Investment Coordinating Board.

Five industries are central to the initiative: food and beverage, textiles and apparel, automotive, chemicals, and electronics. Making Indonesia 4.0 includes 10 cross-sector strategies: (i) improvement of the flow of goods and inputs, (ii) redesign of industrial zones, (iii) adaptation to sustainability standards, (iv) strengthening SMEs, (v) the development of national digital infrastructure, (vi) attraction of foreign direct investment, (vii) improvement of human capital, (viii) development of an innovation ecosystem, (ix) improvement of the incentives for innovation and technology adoption, and (x) harmonization of rules and policies.

Making Indonesia 4.0: 10 National Priorities

1 Reform material flow

- Enhance domestic upstream material production; e.g., 50% of petrochemicals are imported

2 Redesign industrial zones

- Build a single nationwide industry zoning roadmap; resolve zoning inconsistency challenges

3 Embrace sustainability

- Grab opportunities under global sustainability trend; e.g., electronic vehicles, biofuel, renewables

4 Empower SMEs

- Empower 3.7 million SMEs with technologies; e.g., build SME e-commerce, technology bank

5 Build nationwide digital infrastructure

- Advance network and digital platforms; e.g., 4G to 5G, fiber speed 1 Gbps, data center and cloud

6 Attract foreign investments

- Engage top global manufacturers with attractive offers and accelerate technology transfer

7 Upgrade human capital

- Redesign education curriculum for the Fourth Industrial Revolution era
- Create professional talent mobility program

8 Establish innovation ecosystem

- Enhance R&D centers under the government, the private sector, and universities

9 Incentivize technology investment

- Introduce tax exemptions and subsidies for technology adoption and support funding

10 Reoptimize regulations and policies

- Build more coherent policies and regulations through collaboration across ministries

4G = fourth generation, 5G = fifth generation, Gbps = gigabits per second, R&D = research and development, SMEs = small and medium-sized enterprises.

Sources: Ministry of Industry of Indonesia. 2018. *Indonesia's Fourth Industrial Revolution—Making Indonesia 4.0.* Jakarta; ADB-BAPPENAS. 2019. *Policies to Support the Development of Indonesia's Manufacturing Sector during 2020–2024.* Manila: Asian Development Bank.

BOX 3.5

Fiscal Incentives for the Manufacturing Industry

In recent years, the Ministry of Finance has enacted tax incentives focused on boosting exports, encouraging new investments, and enhancing competitiveness.

New tax incentives recently approved include the following:

- mini tax holiday for investment of less than Rp500 billion,
- super deduction for vocational training and R&D, and
- investment allowance for labor-intensive investment.

This new package of tax incentives will add to the existing fiscal incentives:

- **Tax holiday**, granted to corporate tax payers that are classified as pioneer industries—because they offer high economic integration, create high value added, introduce new technology, and have a strategic role in the national economy—and invest at least Rp100 billion.
- **Tax allowance**, granted to domestic corporate tax payers that are located in priority regions and are classified as high-priority industries because they support economic diversification and strengthen the national industry structure, compete in the international market, have high absorption of workers, and support technology transfer. Incentives include an investment allowance of 30%, accelerated depreciation and amortization, a dividend tax rate of 10% to foreign tax payers, and loss carried forward for longer than 5 years, to a maximum 10 years.
- **Value-added tax exemptions** on imports and/or transfers of taxable goods categorized as strategic goods, and exemption on machinery and factory equipment, assembled or separated, not including spare parts.
- **Customs exemptions** that include import duty exemption on the import of machines, goods, and materials, and import duty paid by the government on the import of goods and materials.

In addition to the tax incentives above are the following:

- **Spatial incentives:** special economic zones, industrial parks, free trade zones, bonded areas, and bonded logistics centers.
- **Tax incentives for exports:** special assignment for exports and a bonded zone.

Source: R. Kurniawan. 2019. *Fiscal Incentives for Manufacturing Sectors*. Fiscal Policy Agency, Ministry of Finance. Presentation at the seminar Structural Transformation Through Manufacturing Sector Development for High and Sustainable Economic Growth at Bank Indonesia, Jakarta, 12 August 2019.

3.4 Analysis of Strengths, Weaknesses, Opportunities, and Threats Affecting Indonesia's National Innovation System

Certain conditions are necessary for the Indonesian innovation system to be efficient and successful in the medium and long term and to continue making significant contributions to productivity, growth, prosperity, and the quality of life. Determining these conditions requires an analysis of current strengths and weaknesses, and of the opportunities and challenges in a changing global context.

Table 3.2 presents an analysis of strengths, weaknesses, opportunities, and threats affecting Indonesia's national innovation system. It summarizes some of the key points discussed in the previous subsections and complements the discussion with insights from stakeholders consulted in focus group discussions convened in Indonesia.

Table 3.2: Indonesia's National Innovation System: Strengths, Weaknesses, Opportunities, and Threats

Strengths	Weaknesses
• Science and technology are receiving increasing attention in the national policy agenda. • New mechanisms have been established, including the Indonesian Science Fund, to fund public research. • Patent regulation has been updated with the aim of making research funding more efficient. • A number of technology parks, innovation centers, and incubators have been established in recent years. • Relatively high expenditure on computer software is recorded in the private sector. • Sustained economic growth is expanding the middle class and demand for consumer goods. • Recent investments have improved energy, transport, and logistics infrastructure. • Investments are developing digital infrastructure, notably the Palapa Ring national fiber-optic network. • Adoption of mobile phones is high. • Entrepreneurial activity has scored some successes, such that Indonesia hosts three unicorns—Tokopedia, Traveloka, and Bukalapak—and one decacorn, worth more than $10 billion: Gojek.	• National expenditure on R&D is only a tenth of the ASEAN average as a percentage of GDP. • Many firms do not innovate, and business R&D and patenting activity is low. • Scientific output remains small, with few scientific papers published in international journals. • Harmonization is lacking between national and subnational laws and regulations on technology. • Industry reports difficulty in finding specialized skills. • A comprehensive strategy is lacking for international research and innovation collaboration. • Regulatory barriers are perceived to hinder private investment. • Gaps and regional disparities mark fixed broadband coverage. • Technology adoption is low in industry. • Gaps are perceived in laws on intellectual property protection and data privacy, and in access to finance. • Technological assistance—for training, market research, and contract R&D—are limited across the country.

continued next page

Table 3.2: *Continued*

Opportunities	Threats
• Expanded fiscal incentives for training and R&D would promise higher exports and productive investment. • The government could commit to increased funding through various ministries for R&D and innovation. • Free trade zones could attract foreign direct investment in knowledge-intensive industries. • The number of funding schemes for micro, small, and medium-sized enterprises could be increased. • E-government, such as through one-stop services, could improve the ease of doing business. • State-owned companies could foster collaboration with universities, high schools, and ministries for research and training programs. • Indonesia's young population is set to become by 2030 the world's fourth largest producer of science, technology, engineering, and math graduates. • Its large population is an attractive market, with potential to become, for example, the largest e-commerce market in the Southeast Asia.	• Low multinational investment in R&D limits prospects for developing business R&D. • Lack of expertise in cutting-edge technology could hinder its widespread adoption. • Indonesia could suffer as trade disputes threaten to slow global economic growth. • Industrial expansion could cause environmental damage if appropriate countermeasures are not implemented. • Natural hazards pose perennial risks of disruption to Indonesia's productive capacity. • Intensifying use of digital technology in businesses heightens the risk of cybercrime, requiring new approaches to ensure data security and customer protection. • Considerable diversity exists among Indonesian regions and communities, horizontally (inter-sector, inter-region) and vertically (related to income inequality).

ASEAN = Association of Southeast Asian Nations, GDP = gross national product, R&D = research and development.

Sources: ADB-BAPPENAS. 2019. *Policies to Support the Development of Indonesia's Manufacturing Sector during 2020–2024.* Manila: Asian Development Bank; Y. Damuri et al. 2018. Innovation Policy in Indonesia. In M. Ambashi, eds. *Innovation Policy in ASEAN.* Jakarta: Economic Research Institute for ASEAN and East Asia; OECD. 2016. Indonesia: Country Profile. *OECD Science, Technology and Innovation Outlook 2016*. Paris; Summary of background analysis produced for ADB technical assistance to Indonesia on Supporting Technological Transformation (Project Number: 51343-001). Jakarta.

3.5 Conclusions

Technology and innovation have received increasing attention in Indonesia's national policy agenda. Public efforts include more funding for public research and various incentives to promote private investment in R&D. The initiative Making Indonesia 4.0 exemplifies national recognition of the importance of technology and innovation for the future in Indonesia.

However, to reap the benefits of technological transformation, a number of challenges need to be addressed. Indonesia is still a nascent country in terms of its technology and innovation readiness. The institutional framework needs to be strengthened, and further improvements to physical and digital infrastructure are required. Investment in human capital development is also required, and the growing supply of graduates needs to be matched by opportunities in the labor market.

SECTION 4

A "DEEP DIVE" INTO INDUSTRY 4.0 IN INDONESIA

KEY POINTS

This section provides an in-depth analysis of Industry 4.0 in Indonesia based on primary evidence collected through industry stakeholder consultations involving a manufacturing survey of 502 firms and three focus group discussions with over 20 local companies.

The majority of consulted firms, or 64%, report low technology adoption, performing many activities with basic tools such as spreadsheets and e-mail. Only a relatively small 6% of firms report advanced technology adoption, using emerging digitally enabled tools. Industry 4.0 technology adoption remains relatively low for all technologies covered in the survey: 27% for robotics, 16% for cloud computing, 14% for big data, 8% for 3D printing, and 7% for AI.

A number of opportunities exist for Indonesian firms to create new innovative products, services, manufacturing processes, and delivery methods to interact with customers. They could enable in turn improvements in productivity, energy efficiency, planning and budgeting, knowledge of customer needs, and product quality.

However, barriers to technology adoption include financial constraints, lack of skilled workers, technical uncertainties, resistance to change, and digital infrastructure gaps.

4.1 Introduction

Estimating the potential impact of emerging technologies in national economies is a challenging task, requiring in-depth insights into technologies, sectors, and innovation activities that are becoming more complex, distributed, and interdependent, as discussed in Section 3. Disentangling this complexity consequently requires evidence beyond high-level macroeconomic data to carefully distinguish opportunities and challenges across selected technology domains and economic sectors. Toward meeting this requirement, this section provides in-depth analysis of Industry 4.0 in Indonesia that illustrates the complexity involved in understanding the integration of various technologies and the impact they are having across sectors.

Industry 4.0, shorthand for the Fourth Industrial Revolution, has emerged in recent years as one of the most important themes in innovation policies and R&D portfolios in countries around the world. This technological trend is opening possibilities for the broader manufacturing value chain, with activities ranging from production to supply chain management, planning, and sales. Firms expect profound changes in their business models in the short, medium, and long term.

Industrial digitalization is relevant in the context of Indonesia's technological transformation as it offers the potential to further increase the already significant contribution of manufacturing to the national economy. In 2017, manufacturing firms employed over 17 million workers, 14.1% of all employment in the economy, and provided 20.2% of Indonesia's GDP and 42.5% of its exports.[71]

The analysis shown here is aimed at complementing the existing knowledge base, such as the evidence provided by *Making Indonesia 4.0,*[72] by collecting primary data on opportunities and challenges arising from the digital transformation of manufacturing specific to the Indonesian context, as perceived by local firms in selected industries. The Industry 4.0 "deep dive" is based on extensive stakeholder consultation that involved an industrial survey of 502 local firms complemented by three focus group discussions with over 20 firms in automotive, electronics, food and beverage, textiles and clothing, and footwear. This evidence joins findings from previous sections to provide a foundation to identify the priority policy themes required to support the technological transformation of Indonesian firms.

4.2 Relevance of Industry 4.0 for Indonesia

Industry 4.0 can be explained as a process of profound transformation in the way that firms think, learn, conceive, distribute, and produce goods and services, powered by the development and availability of a new generation of digital technologies with increasingly competitive prices.

[71] World Bank. 2019. *World Development Indicators*; World Bank. 2019. *World Integrated Trade Solution.* Washington, DC; Badan Pusat Statistik. 2019. Labor Survey.

[72] Ministry of Industry of Indonesia. 2018. Indonesia's Fourth Industrial Revolution—Making Indonesia 4.0. Jakarta.

National Industry 4.0 strategies around the world have resulted in increased attention and effort being paid to the development and adoption of a range of digital technologies, notably the internet of things, big data, and cloud computing, but also advanced robotics, AI, visualization technologies, and 3D printing.

These families of technologies offer the promise of manufacturing industries better able to respond to evolving customer and user demand, such as for greater personalization, better safety, and improved energy and resource efficiency. In particular, the combination of emerging digital technologies offers the potential to more effectively connect and integrate manufacturing systems. Innovation in the digitalization of manufacturing is anticipated to allow more rapid development of new products, more efficient logistics, and more customized products and services, thereby becoming a key element for national competitiveness in global supply chains where Indonesian firms take part.

In this regard, Industry 4.0 is opening possibilities not only for particular processes or products, but also for the broader value chain of manufacturing activities, including manufacturing-related producer services. This means digital applications can be used to drive change, not only in physical transformation processes, but also in the wider set of manufacturing activities involved in modern industrial networks, from design and R&D to logistics, marketing, and after-sale service. In this respect, transformations in manufacturing driven by new technologies are key drivers of change in the service sector. The interface between manufacturing and services is thus blurring, and product-related services are becoming an ever more important component of the service sector.[73]

The digitalization of manufacturing is relevant to Indonesia's technological transformation as it offers the potential to further increase the already significant contribution of the manufacturing sector to Indonesia's economy (Figure 4.1).

Based on their contribution to manufacturing value added and employment, five manufacturing industries stand out from the rest: food and beverage, automotive, textiles and clothing, electronics, and footwear (Figure 4.2). Distinctive features of these sectors, shown in Table 4.1, show why they all are clear targets for Industry 4.0 efforts in Indonesia, to boost their already prominent role in Indonesian production.[74] From a broader perspective, other main features of Indonesia's manufacturing include the following:

- Medium-high and high-technology sectors represent a relatively high 31.7% share of total manufacturing value added.[75]
- The manufacturing sector is mostly small firms, with 91.2% of them classified as microenterprises employing 1–4 employees and contributing 4.6% of total employment in the sector. On the other hand, large enterprises employing more than 100 employees generate 80% of Indonesia's total manufacturing value added.[76]

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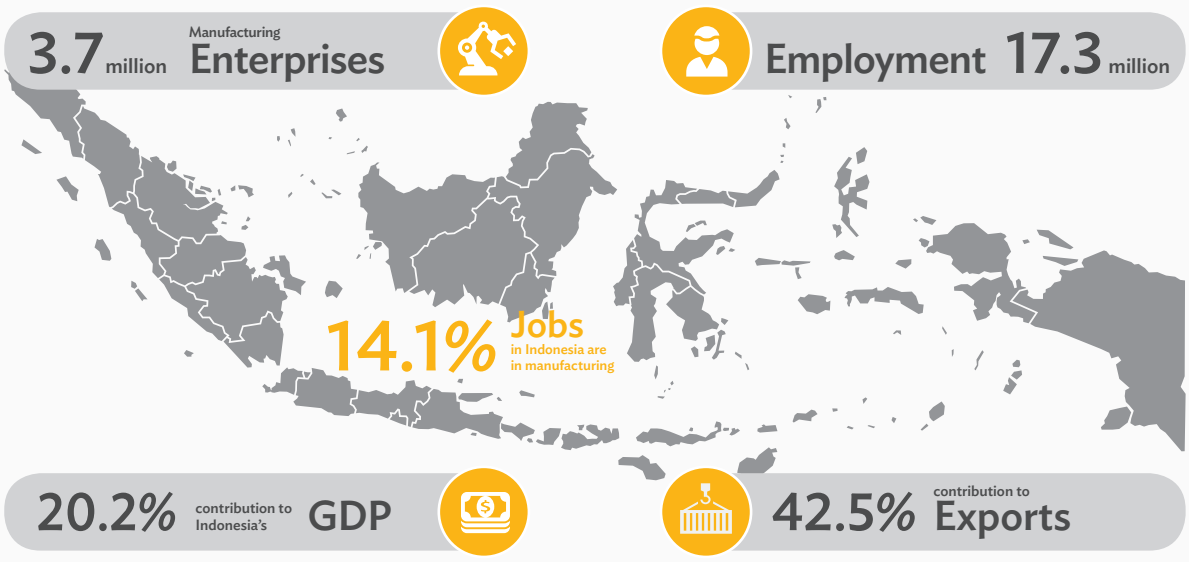
[73] For a recent review of available evidence, see a recent report commissioned by the Government of the United Kingdom: J. Hauge and E. O'Sullivan. 2019. *Inside the Black Box of Manufacturing: Conceptualising and Counting Manufacturing in the Economy*. Centre for Science, Technology & Innovation Policy, University of Cambridge.

[74] Based on focus group discussion with private sector representatives for the ADB technical assistance to Indonesia on Supporting Technological Transformation (Project Number: 51343-001). Jakarta.

[75] The sector clarification is based on the United Nations' 2008 International Standard Industrial Classification of All Economic Activities. https://unstats.un.org/unsd/publication/seriesM/seriesm_4rev4e.pdf.

[76] All data from Badan Pusat Statistik. 2015. *Survey of Micro and Small Manufacturing; Survey of Medium and Large Manufacturing.*

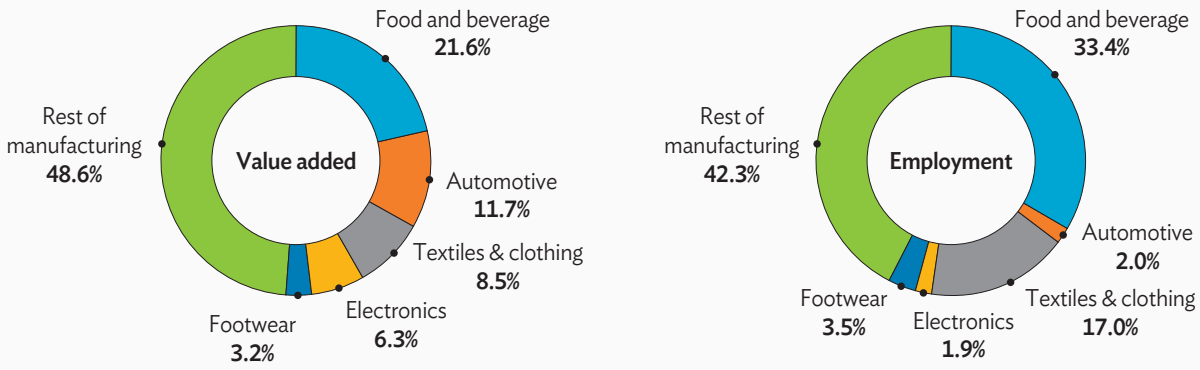
Figure 4.1: Contribution of Manufacturing to Indonesia's Economy, 2017



Note: Data are from 2017 or the latest available.

Sources: Badan Pusat Statistik. 2019. *Survey of Micro and Small Manufacturing; Survey of Medium and Large Manufacturing; Labour Force Survey*; World Bank. 2019. *World Development Indicators*; *World Integrated Trade Solutions*.

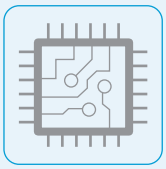
Figure 4.2: Contribution of Selected Sectors to Manufacturing Value Added and Employment



Note: Data are to 2015.

Source: Background analysis produced for ADB technical assistance to Indonesia on Supporting Technological Transformation (Project Number: 51343-001). Jakarta.

Table 4.1: Distinctive Features of Selected Indonesian Manufacturing Industries

Sectors	Qualitative Features
 Food and beverage	• The sector is composed of SMEs but dominated by a small number of large companies. • Main exports are snacks, special beverages, sauces, condiments, pickles, processed fruit and vegetables, and shellfish. • The domestic availability of numerous agricultural commodities is a big factor in favor of the industry. • Food processing remains highly dependent on imported raw materials, despite increasing reliance on the domestic market.
 Automotive	• Indonesia's automotive sector is the second largest in ASEAN in terms of production. • Major multinational companies have established plants in the country, making the industry highly dependent on foreign direct investment. • Domestic market demand for automotive is expected to growing rapidly in tandem with the middle class. • The domestic production of components with high value added remains low, and the sector still depends on imports of components and parts.
 Textiles and clothing	• Indonesia is one of the 10 largest textile-producing countries in the world. • Rising competition from other ASEAN countries and inflows of illegal textile imports are challenging the domestic textile industry. • Aging machinery and equipment are undermining productivity and efficiency, particularly in traditional and small-scale players in the sector. • Gas and electricity prices are among the highest in textile-producing countries, making the sector less competitive.
 Electronics	• The sector specializes mostly in the production of consumer electronics, where televisions capture the largest share of domestic sales. • Multinational corporations with facilities in Indonesia dominate the higher-end digital electronics market segment, notably for liquid crystal display televisions, air-conditioners, and refrigerators, often through joint ventures with local manufacturers. • Indonesia's rapidly growing middle class is expected to foster demand for electronic products. • High import duties for raw materials and zero tariffs for finished goods from other ASEAN countries are challenging the sector.
 Footwear	• Indonesia is the world's fifth largest footwear exporter, with the United States and the European Union being the largest markets for Indonesian footwear exports. • Footwear exports consist mostly of finished leather products, representing around half of total footwear exports. • The Indonesian footwear industry is still highly dependent on foreign brands, and the upstream footwear industry is still limited. • The large domestic market and the rise of the middle class provide opportunities for further developing the sector.

ASEAN = Association of Southeast Asian Nations, SMEs = small and medium-sized enterprises.

Note: Data are to 2015.

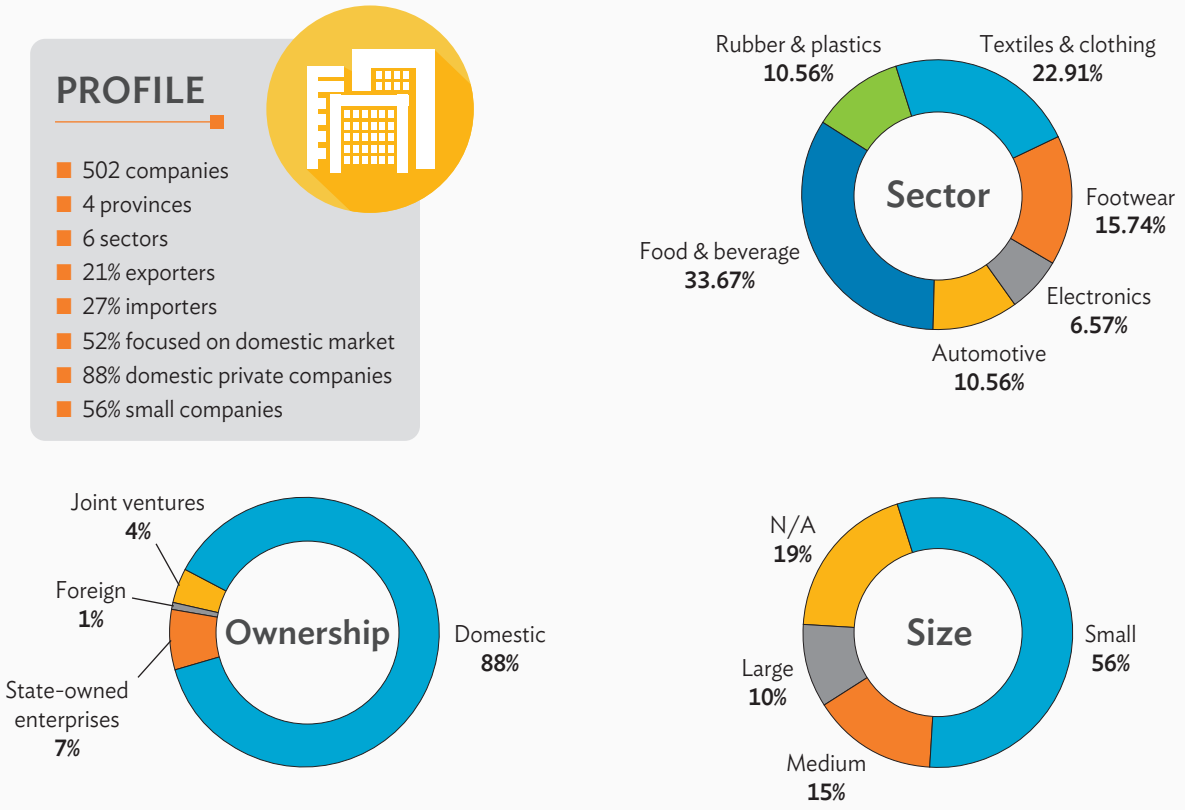
Source: Background analysis produced for ADB technical assistance to Indonesia on Supporting Technological Transformation (Project Number: 51343-001). Jakarta.

From an Industry 4.0 perspective, a key challenge is therefore to understand the different needs of distinct types of enterprises, from micro to large, in medium-high and high-technology sectors and beyond, to foster the technological transformation of the entire manufacturing sector. In particular, Industry 4.0 efforts should cover those industries where new technology applications can have the greatest impact.

4.3 Industry 4.0 in Indonesia: Insights from a Manufacturing Survey

A survey to assess the impacts of Industry 4.0 technologies on manufacturing firms in Indonesia was conducted as part of this study. The survey consulted 502 local firms to explore how artificial intelligence, robotics and automation, 3D printing, cloud computing, and big data are affecting the following selected sectors: textiles and clothing, electronics, footwear, automotive, food and beverage, and rubber and plastic. Key features of consulted firms are shown in Figure 4.3.

Figure 4.3: Manufacturing Survey Respondents' Profile



N/A = not applicable.

Source: H. Aswicahyono and D. Rafitrandi. 2019. *Disruptive Technology in Manufacturing Sector*. Background paper produced for the ADB technical assistance to Indonesia on Supporting Technological Transformation (Project Number: 51343-001). Jakarta.

The survey explored four main topics at the firm level:

- level of technological adoption,
- awareness and use of Industry 4.0 technologies,
- perceived benefits of technological adoption, and
- perceived barriers to technological adoption.

Technological adoption was relatively low (Figure 4.4):

- A relatively small 6% of firms report advanced technology adoption, using emerging digitally enabled tools.
- Around 30% of firms report intermediate technology adoption, using some advanced technologies, such as SAP and Oracle, in specific operations such as enterprise resource planning, customer relationship management, computer-aided manufacturing, and collaborative supply chain management.
- A 64% majority of surveyed firms have low technology adoption, performing many activities with basic tools such as spreadsheets and e-mail.

Awareness and use of Industry 4.0 technologies can be summarized as follows:

- Although reported awareness of robotics is relatively high at 68%, knowledge of newer emerging technologies is relatively low, particularly for less mature tools such as big data, at 38%, and AI, at 35%.
- In terms of usage, robotics is the most commonly used Industry 4.0 technology among the surveyed firms, at 27%. However, usage remains low for all technologies consulted, with cloud computing at 16%, big data 14%, 3D printing 8%, and AI 7%.
- AI, robotics, and 3D printing are used mostly in production and assembling, while cloud and big data are used mostly in finance.
- Most companies obtain information regarding Industry 4.0 technologies from in-house research. Additionally, large companies receive information from their parent company.
- The highest awareness is found in large companies, but company size does not reflect technological adoption.

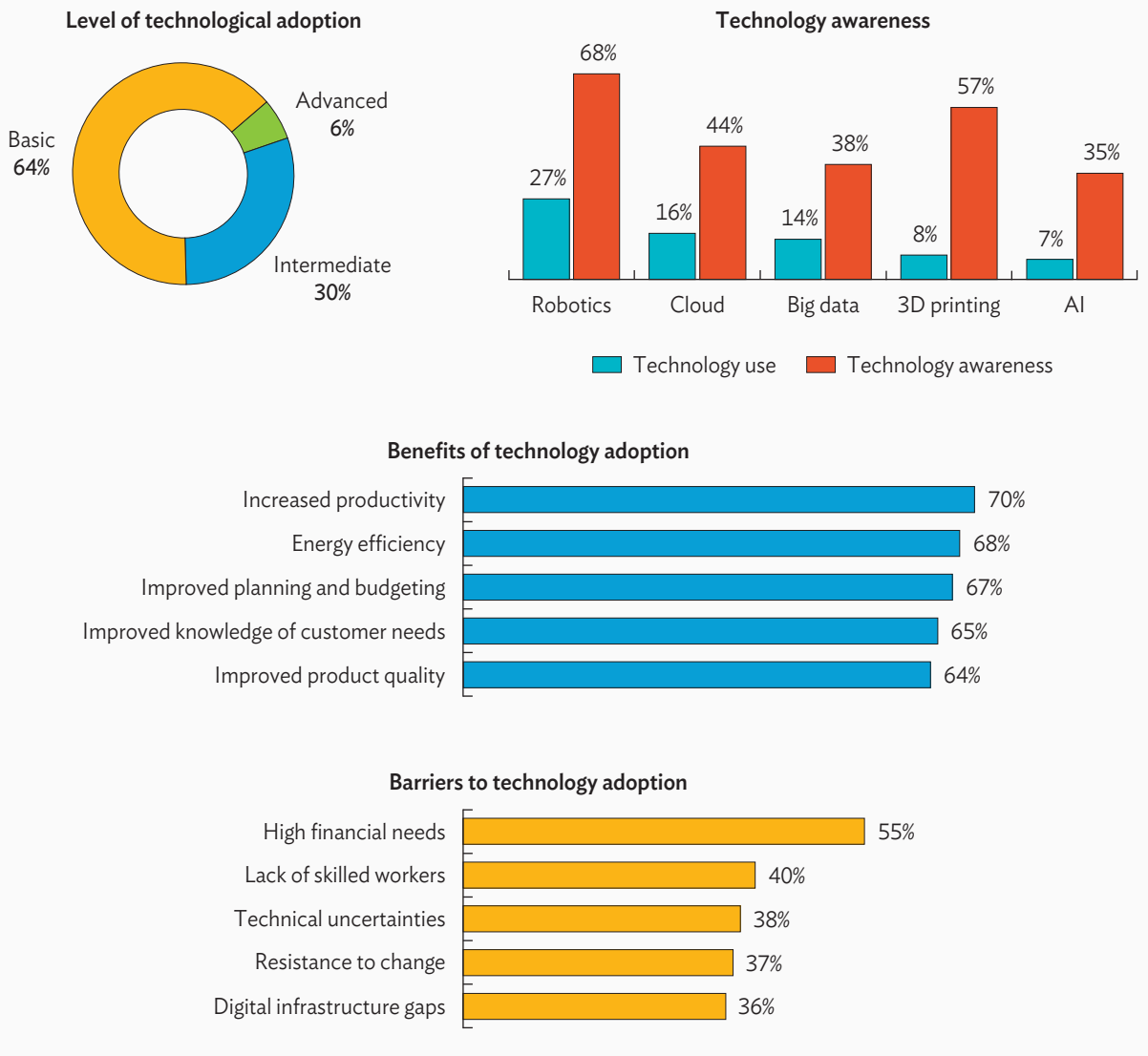
Perceived benefits of technological adoption are as follows:

- The highest benefit from technology adoption reported by consulted firms was increased productivity gains, at 70%, followed by energy efficiency at 67.5%, improved planning and budgeting 67%, improved knowledge of customer needs 65%, and improved product quality 64%.
- A very high 91% of companies agree that technology increases efficiency and 86% quality. However, only 57% of them agree that technology reduces the cost of production.
- Slightly more than a third of companies think that there is no need to invest in Industry 4.0 technologies.

Perceived barriers to technological adoption are as follows:

- Financial constraint was the most mentioned, at 55%, followed by a lack of skilled workers at 40%, technical uncertainties 38%, resistance to change 37%, and digital infrastructure gaps 36%.
- Yet 93% of consulted firms are unaware of initiatives to help address barriers to technology adoption, including the Making Indonesia 4.0 roadmap.

Figure 4.4: Manufacturing Survey Results



3D = three dimensional, AI = artificial intelligence.

Note: The survey sample was 502 firms.

Source: H. Aswicahyono and D. Rafitrandi. 2019. *Disruptive Technology in Manufacturing Sector*. Background paper produced for the ADB technical assistance to Indonesia on Supporting Technological Transformation (Project Number: 51343-001). Jakarta.

4.4 Industry 4.0 in Indonesia: Insights from Focus Group Discussions

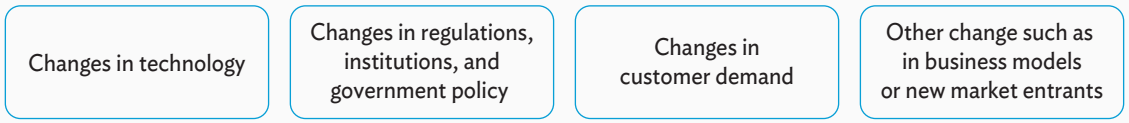
Three focus group discussions (FGDs) with more than 20 manufacturing companies were carried out to complement evidence collected through the manufacturing survey and gather more detailed views on the opportunities and challenges arising from Industry 4.0 in Indonesia. Consulted sectors included food and beverage, automotive, electronics, textiles and clothing, and footwear.

The analytical framework used to design the FGDs draws from the academic literature, previous studies on Industry 4.0, and ongoing work at the Institute for Manufacturing, University of Cambridge (Figure 4.5). FGDs were based on tried-and-tested consultation approaches, which have been successfully employed to inform sector, regional, and national strategies and policies.

Figure 4.5: Focus Group Discussion Methodological Approach

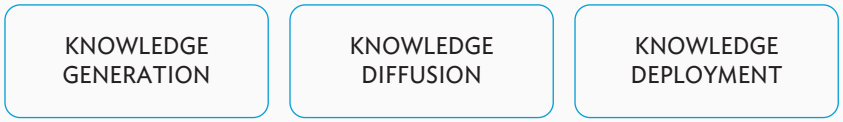
Each was structured in three sessions to discuss and identify the following:

1. **Trends and drivers arising from disruptive technologies affecting the sector** in the short term (to 5 years), medium term (to 10 years), and long term (to 20 years)



2. **Opportunities for Indonesia's industries driven by disruptive technologies**

3. **Barriers to technology exploitation in Indonesia**



Each FGD discussion was structured in three sessions:

(1) **Trends and drivers** are the key changes affecting the manufacturing sector and underpinned by disruptive emerging technologies. Those changes may refer to technology, regulations, government policies and institutions, customer demand, business models, and market structure.

(2) **Opportunities** are the universe of value capture opportunities for firms that may take different forms for distinct industries and types of firm. Examples of generic opportunities across the four value capture dimensions are as follows:

- **product or service innovation**, offering new and more functional products and services, and new business models that create value from digital data and capability;
- **process innovation**, achieving higher factory efficiency and more flexible production processes through vertical digital integration;
- **supply chain innovation**, achieving more integrated and optimized supply chain capabilities through horizontal digital integration; and
- **product or service design and delivery**, enabling superior understanding of demand, more customer-led design and delivery using digital platforms, and higher customer satisfaction.

(3) **Challenges** have to do with the barriers and challenges to digital technology exploitation arising from disruptive technologies. The discussion is framed in terms of the three fundamental stages of innovation—knowledge generation, diffusion, and absorption—and by the key barriers constraining innovation.

Key Sectoral Trends and Drivers of Change

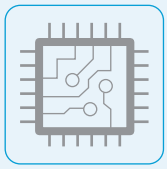
Opinions gathered from local stakeholders in relation to sectoral trends and drivers of change are summarized in Table 4.2. These include technological trends as well as expected changes in regulations, standards, consumer demand, and business models.

Opportunities Driven by Emerging Industry 4.0 Technologies

Regarding opportunities driven by the adoption of Industry 4.0 technologies in Indonesia, Table 4.3 highlights key prospects for value capture, classified in terms of four manufacturing dimensions:

- **Product innovation.** Opportunities for offering new and more functional products and services, as well as new business models that create value from digital data and capabilities.
- **Process innovation.** Opportunities for achieving higher factory efficiency and more flexible production processes through vertical digital integration.
- **Supply chain innovation.** Opportunities for more integrated and optimized supply chain capabilities.
- **Product and service delivery innovation.** Opportunities for gaining a superior understanding of demand, more customer-led design and delivery, and higher customer satisfaction.

Table 4.2: Key Trends and Drivers of Change Affecting Selected Sectors

Sector	Short Term (<5 years)	Medium Term (5–10 years)	Long Term (>10 years)
 **Automotive**	• Introduction of electric and hybrid vehicles and corresponding infrastructure • Predictive maintenance using AI • IOT-connected production lines • Adoption of stricter emissions' standards for vehicles	• Introduction of fuel cell, biofuel, ethanol, and flexible-fuel engines • Higher vehicle customization according to customer specifications • New sector players and entrants with strong know-how in information and communication technology	• Autonomous vehicle testing and adoption • Internal combustion vehicle ban • Customers shifting from car ownership to rental and/or vehicle services on demand • Electric cars driving national electrification requirements upward
 **Electronics**	• Wider adoption of solar panel technology and smart meters • Efficiency improvements in radio frequency and wireless transmission, fiber optics, and 4G network connectivity	• Smart consumer appliances incorporating the use of cloud computing, IOT, and basic AI features • Higher demand for customized electronic products • New models based on data services for smart devices	• 5G mobile communication networks • Introduction of reduce, reuse, and recycle directives for industrial waste minimization
 **Food and beverage**	• Emergence of new organic food and beverage products • More stringent environmental regulations on the use of pesticides and food waste reduction in food production and retail	• E-commerce platforms combined with big data analytics for gathering consumer insights, enabling targeted marketing, and removing retail intermediaries • Increasing demand for customized healthy products	• New fintech services to support e-commerce platforms • Homologation of environmental and food safety standards enacted in foreign markets
 **Textiles, clothing, and footwear**	• Customer demand for low-cost and high-quality personalized products • Reducing supply chain intermediaries and increasing local sourcing of raw materials	• E-commerce platforms displacing traditional retail • Widespread deployment of low-cost AI, IOT, and robotics for improved quality, productivity, waste reduction, and energy efficiency	• Demand expected to switch into full product customization • Higher sustainability standards and regulations being enforced in Indonesia

AI = artificial intelligence, IOT = internet of things.

Source: Summary of background analysis produced for ADB technical assistance to Indonesia on Supporting Technological Transformation (Project Number: 51343-001). Jakarta.

Table 4.3: Opportunities for Value Capture Arising from New Technologies in Selected Sectors

Automotive

Product innovation
- Electric, hybrid, and autonomous vehicles
- IOT platforms for vehicle connectivity with insurance providers, policy, and dealerships
- Electric vehicle charging infrastructure
- Car-sharing services

Process innovation
- AI for process decision-making, quality control, and predictive maintenance
- RFID and smart robotic systems for productivity and quality improvement
- Automated guided vehicles within factories

Supply chain innovation
- Big data for quality verification and traceability
- RFID supply chain inventory monitoring
- Integrated manufacturing zones to connect tier 1, 2, and 3 firms through ICT platforms

Product and service delivery innovation
- Data management and sharing communities for understanding consumer behavior
- IOT-based platforms to order customized products and services for real-time maintenance support services

Electronics

Product innovation
- Robotics for hospitality and food services
- IOT features for garden watering systems
- Automatic domestic lighting, security, and energy-efficiency systems
- Automatic floor-cleaning machines
- Health-care mobile applications
- Real-time data for smart agriculture
- Virtual reality applications for skills development

Process innovation
- Advanced RFID for warehouse and inventory management
- IOT applications for real-time supply of factory inputs
- Advanced material processing systems

Supply chain innovation
- Blockchain applications for supply chain logistics and payments

Product and service delivery innovation
- Big data and AI algorithms for market research

Food and beverage

Product innovation
- Digital design tools for innovative packaging
- Customized healthy food and beverage products
- Big data analytics for targeted marketing and to feed customer insights into the design of new customized products and services

Process innovation
- Automation through low-cost robotics
- Digital tools to reduce material waste
- End-to-end IOT-based process monitoring
- Machine learning for predictive maintenance
- Virtual and augmented reality tools for skills training

Supply chain innovation
- IOT-based systems with RFID tracking to improve quality control and traceability of raw materials
- Digital tools for data exchange and integration between local and global supply chains
- Robotic applications for warehouse management

Product and service delivery innovation
- Digital assistance for customer service
- Digital platforms to integrate sales channels
- Delivery drones for urban and rural areas

Textiles, clothing, and footwear

Product innovation
- New products with digital health features such as heartrate and distance monitoring
- Shoes with automatic size adjustment for children
- Virtual 3D modeling to optimize industrial processes with, for example, stitching models for garments

Process innovation
- Digitally enabled new or retrofitted machinery for higher production efficiency and labor cost reduction
- Digital tools for more flexible and scalable processes

Supply chain innovation
- Collaborative ecosystem network including key sector players to support technology adoption for sector competitiveness and productivity improvement

Product and service delivery innovation
- E-commerce platforms for direct communication between producers and customers, growth of local producers into own clothing brands, and reduced order delivery lead times
- IOT-based tracking systems for environmental footprint monitoring

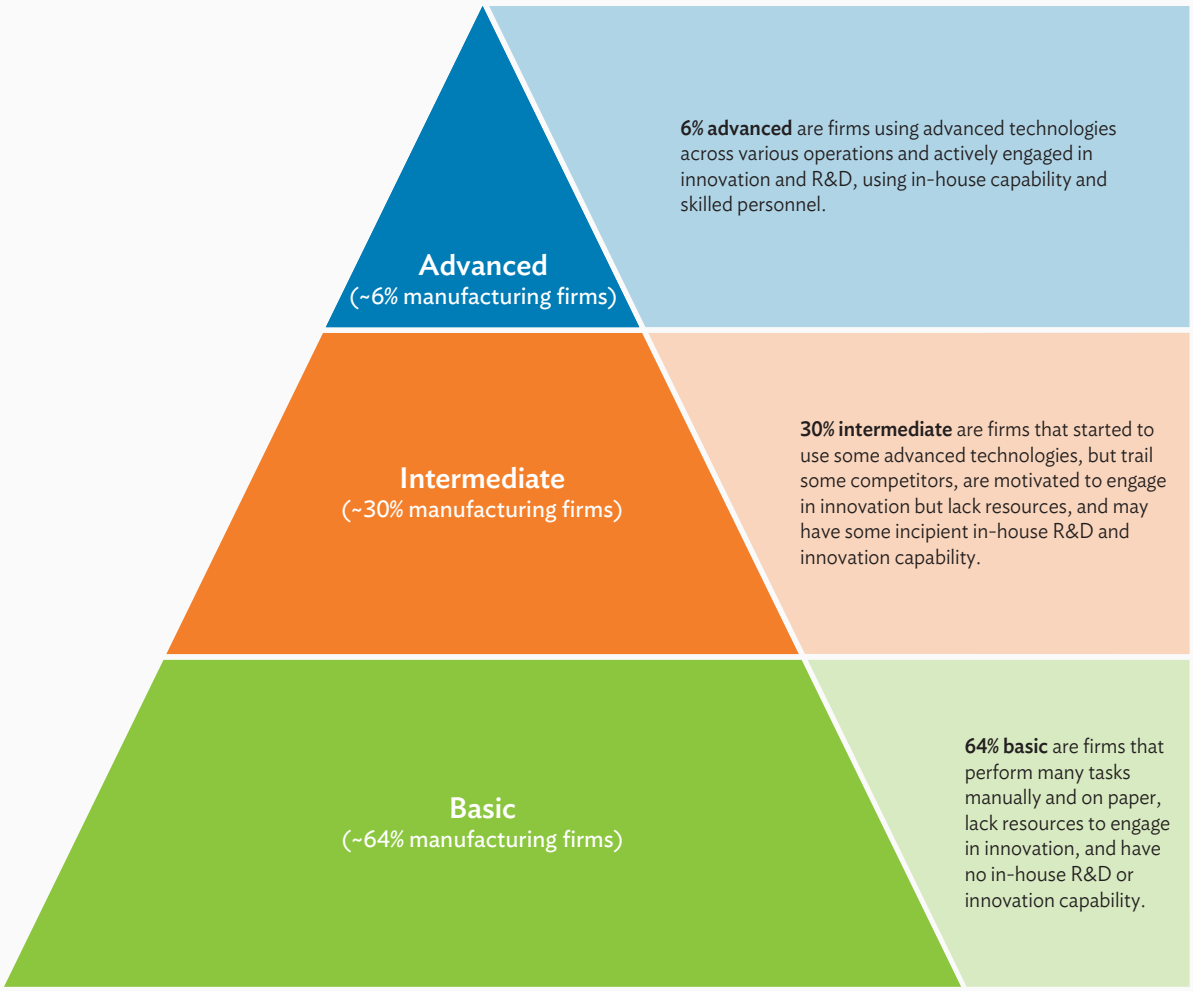
AI = artificial intelligence, ICT = information and communication technology, IOT = internet of things, RFID = radio-frequency identification.

Source: Summary of background analysis produced for ADB technical assistance to Indonesia on Supporting Technological Transformation (Project Number: 51343-001). Jakarta.

Challenges to the Adoption of Emerging Industry 4.0 Technologies

Achieving the successful deployment of digital applications and solutions across Indonesian firms is, however, not an easy task. The consulted stakeholders were asked to classify Indonesian manufacturing firms according to their current level of Industry 4.0 adoption and to share their views on the particular barriers to technology development and adoption faced by each category of firm. Three types of firm were considered in this categorization, as shown in Figure 4.6.

Figure 4.6: Self-Assessed Level of Technology Adoption by Manufacturing Firms in Indonesia



R&D = research and development.

Note: In each focus group discussion, companies were asked to classify Indonesian manufacturing firms according to their current level of Industry 4.0 adoption.

Source: H. Aswicahyono and D. Rafitrandi. 2019. *Disruptive Technology in Manufacturing Sector*. Background paper produced for the ADB technical assistance to Indonesia on Supporting Technological Transformation (Project Number: 51343-001). Jakarta.

Table 4.4 summarizes the findings from this exercise. Overall, Industry 4.0 adoption is perceived as a phased process in which many Indonesian firms might need to catch up with existing best operational practices first, before adopting more sophisticated emerging digital solutions.

Table 4.4: Selected Barriers to Technology Adoption across Manufacturing Firms in Indonesia

ADVANCED TECHNOLOGY ADOPTION FIRMS	
Automotive • *Access to skills.* Mismatch between education system and technology skills used in industry • *Technology safety.* Cybersecurity and associated risks **Electronics** • *Ecosystem enablers.* Limitations of public R&D infrastructure • *Incentives.* Insufficient technology adoption incentives for manufacturers	**Food and beverage** • *Access to skills and information.* Lack of digital skills in company managers and directors prevents them from fully visualizing business benefits of technology and prioritizing digitalization initiatives • *Technology cost.* Elevated cost of implementing digitalization technologies across company operations **Textiles, clothing, and footwear** • *Ecosystem enablers.* Weaknesses in national intellectual property system, including issues around advice on intellectual property protection, patent costs, and availability to smaller firms; immigration regulations limiting the availability of foreign experts and labor; limited access to certification and testing labs for new products
INTERMEDIATE TECHNOLOGY ADOPTION FIRMS	
Automotive • *Access to information.* Lack of awareness or knowledge of new digital technologies or their value • *Technology cost.* Lack of resources to invest in new technology development and adoption, notably to cover prohibitive licensing and capital equipment costs **Electronics** • *Access to expertise.* Limited access to specialized advice for technology development and deployment • *Access to skills.* Limited access to human resources with relevant technology and innovation skills	**Food and beverage** • *Ecosystem enablers.* Lack of opportunities to find appropriate technology partners • *Access to skills.* Lack of capabilities to make sense of available data for business purposes **Textiles, clothing, and footwear** • *Ecosystem enablers.* Difficult access to finance from banks with high interest rates • *Access to expertise and information.* Limited availability of technical experts in Indonesia; no technology demonstrators available other than vendors and conferences
BASIC TECHNOLOGY ADOPTION FIRMS	
Automotive • *Access to information.* Lack of awareness of new digital technologies and applications • *Access to expertise.* Lack of access to R&D equipment, expertise, and technical and managerial advice **Electronics** • *Access to skills.* Unaware of available training schemes on emerging technologies • *Technology infrastructure.* Need for improved broadband, cloud infrastructure, and cybersecurity tools • *Technology cost.* Lack of resources to acquire new technological solutions	**Food and beverage** • *Access to information.* Limited ability to visualize strategic business opportunities from new technologies • *Technology cost.* Even if new technologies are perceived as strategic, high technology cost often seen as a barrier to implementation **Textiles, clothing, and footwear** • *Ecosystem enablers.* Immigration rules restricting firms' ability to hire foreign workers • *Access to information.* Limit ability to identify internal opportunities for new technology adoption

R&D = research and development.

Note: See Figure 4.6 for definitions of "advanced," "intermediate," and "basic."

4.5 Conclusions

The Industry 4.0 "deep dive" collected key evidence on the current state of Industry 4.0 technology adoption across manufacturing firms in Indonesia, as well as the potential benefits and barriers arising from digitalization. The analysis centered primarily on five industries—food and beverage, automotive, textiles and clothing, electronics, and footwear—that together account for 51% of manufacturing value added and 58% of manufacturing employment.

Consulted stakeholders expect a wide range of technological trends and drivers to shape Indonesia's industries in the short, medium, and long term and foresee a number of opportunities for Indonesian firms to create new and innovative products and services, manufacturing processes, and delivery methods to interact with customers. Exploiting Industry 4.0 opportunities requires addressing key challenges identified by local industrialists: high financial needs, lack of skilled workers, technical uncertainties, resistance to change, and digital infrastructure gaps.

The challenges and opportunities described here require careful policy consideration, as discussed in the rest of this report. Efforts to support Indonesia's technological transformation through Industry 4.0 in manufacturing are likely to need detailed knowledge of the different needs of various types of enterprises, from micro to large, across a wide range of industries. The evidence collected in this "deep dive" is a first step in this direction. This could potentially complement existing efforts such as Making Indonesia 4.0, to ensure that technology development and adoption support mechanisms target those industries and firms where new technology applications can have the greatest impact.

SECTION 5

FIVE PILLARS TO SUPPORT INDONESIA'S TECHNOLOGICAL TRANSFORMATION

KEY POINTS

Five pillars for policy action have been identified to support Indonesia's technological transformation and economic development. These pillars represent areas where, considering Indonesia's particular context, policy action is critical to drive technological transformation:

- Pillar 1: Advanced innovation infrastructure and institutions
- Pillar 2: Awareness of the business value of new technologies
- Pillar 3: Technology transfer and technical support for firms
- Pillar 4: Low-cost plug-and-play technology solutions for Indonesian firms
- Pillar 5: A tech-savvy workforce

Selected international policy initiatives from around the world offer insights into the variety of strategies, institutions, and funding levels that have been deployed to support technology transformation in other countries.

An agenda for future actions in the short, medium, and long term is presented to guide the next steps of policy design and implementation.

5.1 Introduction

Five pillars for policy actions have been identified to support Indonesia's technological transformation and economic development. These pillars represent areas where, considering Indonesia's particular context, policy action is critical to address challenges and opportunities arising from the advent of new technologies and drive technological transformation.

Examples of international initiatives are presented with the intention to highlight lessons learned and perceived effective practices. Naturally, it is not suggested that initiatives established in other countries can be simply replicated in Indonesia. However, international examples can inform practical implementation by illustrating the variety of strategies, institutions, and funding levels that have been deployed to support technology transformation in other countries.

The set of policy areas described here does not constitute a full-fledged package for policy reform, nor does it intend to address all aspects relevant to growth, competitiveness, or innovation in Indonesia. Instead, it presents key building blocks that, collected evidence suggests, can help drive Indonesia's technological transformation by addressing the most pressing challenges while building on the country's strengths and complementing ongoing policy efforts.

The policy pillars recognize the importance of the national innovation system (NIS) as a key enabler of Indonesia's technological transformation. The pillars recognize that, to reap the full benefits of new technologies, efforts need to go beyond the strengthening of research and development capabilities in the country to address challenges involved in diffusing and deploying new technological applications required by firms.

It is important to note that these pillars are not centered around particular types of firms or sectors. The pervasive nature of new technologies demands concerted efforts to bring together dispersed capabilities by different types of firms in order to strengthen national capabilities. It is also important that firms engage effectively with relevant stakeholders in the wider NIS, including policy makers and academics.

An agenda for future actions in the short, medium, and long term is presented to guide next steps in policy design and implementation. However, it is outside the scope of this study to suggest a detailed implementation plan with specific responsibilities for government actors or to assess appropriate institutional forms to deliver a policy agenda around these pillars.

5.2 Pillar 1: Advanced Innovation Infrastructure and Institutions

The Challenge

Indonesia's NIS is the network of private companies, universities and research centers, and public institutions that generate, disseminate, and deploy knowledge and technologies (Section 3). The evidence collected in this report suggests that, while a number of government initiatives have been set in motion, Indonesia's NIS is still at an early stage of development. Evidence suggests that there is a need to strengthen both "hard" infrastructure, which is the physical infrastructure needed to support the diffusion of new technologies, and "soft" infrastructure, which is concerned with strengthening institutional linkages related to knowledge generation and diffusion.

For example, the consulted stakeholders pointed out that weak digital infrastructure is a constraint on investing in new technologies for companies across a number of sectors. Only 50% of Indonesia's population has access to the internet, with low coverage and connection speeds particularly affecting users outside Java (Section 3).

This report also showed that inadequate telecommunication and internet infrastructure is considered one of the main constraints on the adoption and development of digital technologies for both e-commerce and fintech in Indonesia (Section 3).

Indonesia presents low public and private investment in R&D, and scientific output is limited. Gross domestic expenditure on R&D is estimated at 0.08%, which is low compared with Indonesia's regional peers, at only one-tenth of the ASEAN average and one-thirtieth of the average among members of the OECD.

In terms of soft infrastructure, regulatory barriers to private investment were identified. In addition, there are opportunities to improve intellectual property protection, data privacy laws, and access to finance. Further, national and subnational laws and regulations are not always fully harmonized. Finally, immigration law was identified as a potential constraint on securing the workforce required by businesses.

Opportunities for Policy Action

Building advanced innovation infrastructure and institutions appears to be a priority for Indonesia. Notably, access to broadband internet and full coverage of telecommunication network infrastructure are prerequisites to ensuring that both companies and consumers take advantage of new technologies and their related platforms.

Implementing long-term investment plans to upgrade the digital infrastructure of the country therefore seems necessary to unlock the benefits of new digital technologies. Growing mobile and internet penetration have the potential to, for example, increase access to fintech lending services for both private and commercial users, as well as to e-commerce platforms for both buyers and sellers.

However, the challenge is not limited to digital infrastructure. A systemic long-term approach is required to ensure that R&D and innovation infrastructure is further developed. This includes not only sustained research funding for universities and research centers but also a reevaluation of the current support mechanisms. There is a need to ensure that international best practice is adopted in the strategic design of research investment portfolios, tax credits, and other incentives to private sector investment.

Nurturing existing or developing new institutions may be as important as designing and implementing new programs. For example, in addition to R&D funds, industry stakeholders suggested the need for "hands-on" technical assistance, including access to technological experts, and advanced testing and R&D facilities. While further analyses are required, the need was suggested for intermediate technology centers to connect public and private innovation efforts.

Considering Indonesia's geography, decentralized infrastructure and institutions are particularly important. This includes not only differentiated infrastructure investment strategies but also the institutional capacity to engage directly with firms, universities, research centers, and other stakeholders at the regional level.

In terms of soft infrastructure, stakeholders highlighted the need to ensure that Indonesia's regulatory framework evolves to appropriately reflect the changes driven by new technologies and business models, particularly in terms of labor relations, security and safety, and taxation. Key areas identified include employment safeguards to protect the rights of those who take new jobs enabled by digital sharing platforms, consumer protection to ensure appropriate quality of new services, privacy and cybersecurity legislation to avoid malign activity such as data theft and industrial espionage, tax regimes to ensure fair societal contributions from firms adopting new business models, and safeguards against monopolistic effects to counteract the power of emerging platforms with large user bases.

Finally, coordinating policies and actors is ever more important given the crosscutting impacts of new technologies and their overlapping implications. For example, new skills demanded by new technologies are likely to require close interministerial coordination (see Pillar 5). Changes are required across the education system, including basic and tertiary education, as well as continuing education programs, which usually fall under the competencies of different ministries.

International Experience

Governments around the world are making efforts to close digital infrastructure gaps and address policy coordination challenges (Box 5.1). Colombia's Vive Digital initiative has been recognized internationally as a success story in expanding the country's digital infrastructure and harnessing the power of ICT for new job creation. The initiative includes investments in optical fiber, high-speed satellite, and terrestrial connections, as well as in digital centers to provide training in basic ICT.

One of Vive Digital's strands, the National Optical Fibre Project, has been credited with increasing access to high-speed broadband internet from 17% to 96% of Colombia's 1,122 municipalities. Through public–private investment of more than $400 million, more than 19,000 kilometers of optical fiber were laid across the country from 2010 to 2017, creating the most extensive network in Latin America.

BOX 5.1

Advanced Innovation Institutions and Infrastructure

Vive Digital in Colombia

Vive Digital is a comprehensive plan overseen by the Colombian Ministry of Information and Communication Technologies, aiming to facilitate access to and the use of ICT and the creation of jobs in ICT. It addresses four dimensions of the digital ecosystem: infrastructure expansion, the creation of new services at lower prices, the development of apps and digital content, and the promotion of the effective use of ICT. Some of its key initiatives are the National Project of Optical Fibre, the High-Speed Connectivity Project, and investment in 7,832 community digital centers.

Industry 4.0 in Malaysia

Industry 4.0, or Industry4WRD, is the national manufacturing policy launched by the Government of Malaysia. The policy addresses five innovation enablers: funding, infrastructure, regulations, skills and talent, and technology. For the infrastructure enabler, the 2019 budget includes the allocation of $245 million to implement the National Fibrerisation and Connectivity Plan. The plan involves the development of broadband infrastructure to achieve a speed of 30 megabits in rural and remote areas within 5 years.

Swedish Governmental Agency for Innovation

This is a government agency under the Ministry of Industry. Most of its efforts concentrate on stimulating collaboration between universities and other higher-education institutions, research institutes, enterprises, and public services, both in the country and internationally. Its main instruments for ensuring the coordination and alignment of efforts are its strategic innovation programs. The actors involved in their elaboration have formulated a common vision and defined the needs and strategies for developing innovation areas.

United Kingdom Research and Innovation

United Kingdom Research and Innovation (UKRI) is a nondepartmental public body sponsored by the Department for Business, Energy, and Industrial Strategy of the United Kingdom. It was established to coordinate and maximize the contribution of each of the actors involved in research and innovation bringing together seven science and humanities research councils, Innovate UK, and the research and knowledge exchange functions of the Higher Education Funding Council for England.

Sources: Ministry of International Trade and Industry. 2018a. *Industry 4WRD: National Policy on Industry 4.0.* Kuala Lumpur; Secretary General of the Treasury, Ministry of Finance, Malaysia. 2018. *Budget 2019*; OECD. 2013. *OECD Reviews of Innovation Policy: Sweden 2012*. Paris: OECD Publishing; Department for Business, Energy, and Industrial Strategy. 2018a. *UKRI Framework document.* London; Colombian Ministry of Information and Communication Technologies. *Vive Digital Colombia, 2014–2018.* Bogota; 2019. *Kioskos Digitales.* Bogota.

Malaysia's Industry4WRD strategy has allocated $245 million to develop broadband infrastructure to connect rural and remote areas in the country.

The challenge of coordinating innovation policies is addressed by the Swedish Governmental Agency for Innovation (VINNOVA), whose activities cover a broad range of functions related to the coordination and formation of a common national vision around new technologies, including promoting collaboration, developing long-term strategic programs, and funding innovation projects.

United Kingdom Research and Innovation (UKRI) is an example of a new institutional arrangement recently established to coordinate and maximize the contribution of each of the actors involved in research and innovation in the country. UKRI brings together several funding research agencies serving universities, research organizations, businesses, and charities.

5.3 Pillar 2: Awareness of the Business Value of New Technologies

The Challenge

New technologies are complex and continually evolving. They are constantly creating new opportunities and challenges across sectors. It is difficult for technology experts to keep up with the pace of change—and more so for firms, particularly SMEs focused on the day-to-day operations of their business. A key finding from this study is that new approaches are required to improve and continually update local firms' understanding of the business value arising from new technologies (Section 2). Without this understanding, companies cannot take the first steps toward new technology adoption.

Evidence collected in this report shows that, overall, firms have little awareness of key emerging technologies and their potential applications—with, for example, only 33% of survey respondents in manufacturing aware of AI technology. In addition, most companies do not receive information from external sources, with some 80% of survey respondents in manufacturing obtaining their information exclusively from in-house research (Section 4). This limits the quality and breadth of information that companies can obtain to the existing skills and experience of their personnel.

Access to information was reported as one of the main barriers to innovation and technology adoption by firms in the automotive, electronics, food and beverage, textile and clothing, and footwear industries. In particular, stakeholder consultations suggest that managers' lack of awareness about return on investment and the financial implications of new technologies is perceived as one of the main barriers to technology adoption in many firms in Indonesia. Lack of awareness about the benefits of using technology platforms is cited among the main reasons why firms fail to exploit the benefits of e-commerce in Indonesia. As a result, despite a majority of companies agreeing that technology could improve the efficiency and quality of their products and services, almost 50% do not see any urgent need to invest in new technologies.

Opportunities for Policy Action

The challenges stated above suggest the need to improve firms' understanding of newly available and emerging technologies and their potential business benefits. Information is also needed about possible implementation challenges, associated costs, and sources of support.

Technology awareness is the first step toward building viable business cases for investment in technology adoption. A key policy challenge is to identify what support mechanisms are most suitable for increasing technology awareness across Indonesian sectors, considering the local business and institutional context. These mechanisms might include knowledge exchange, technology demonstration, and industrial networking.

One option suggested by the consulted stakeholders is the development of industrial networks and business associations bringing together key stakeholders across and within industries, including both leading firms and firms lagging behind in digital technology adoption. Opportunities were also identified to create sectoral and cross-sectoral technology forums and interest groups in cooperation with universities and research centers. Technology vendors could be involved in these forums to showcase the latest available technologies and provide expert advice. Established industrial networks and business associations could work to develop international linkages connecting local factories and international suppliers and clients to state-of-the-art expertise.

Evidence collected through this study highlights the need to showcase the value of new technological applications in real-world environments. This could be done, for example, through collaboration across value chains in which companies that have successfully adopted new technologies share their experience with others. An alternative approach could include setting up demonstration facilities within public research and technology centers or universities, in which firms can see firsthand how new technologies are used in industrial environments and the operational and business benefits that can be achieved.

International Experience

International experience provides numerous examples of policy mechanisms employed around the world to increase awareness of new technologies (Box 5.2). These range from the organization of activities such as forums, innovation courses, seminars, workshops, conferences, and international events such as Sweden's Produktion2030 program,[77] to communication campaigns for industry, matchmaking websites to match technology suppliers and buyers, and online platforms for sharing data among businesses. Some countries have successfully provided information through online databases showing cases of how firms have implemented new technology applications, notably in Germany, Japan, and France.[78]

[77] Iris Group. 2015a. *Digitalisation and Automation in the Nordic Manufacturing Sector: Status, Potentials and Barriers*. Copenhagen: Nordic Council of Ministers.

[78] The following were consulted in early March 2019: Japan's Robot Revolution Initiative, Germany's Landakarte Industrie 4.0, and France's Alliance Industrie du Futur.

BOX 5.2

Awareness of the Business Value of New Technologies

The three example programs below present distinct approaches to promoting the formation of collaborative networks between SMEs and other innovation actors to raise technology awareness through knowledge exchange, technology demonstration, and industrial networking.

Manufacturing Academy of Denmark

Manufacturing Academy of Denmark (MADE) is a cluster initiative that was established in 2014 in Denmark. It comprises 152 companies, 3 research and technology organizations, 8 educational institutions, and 5 universities. The main activity of MADE is to facilitate a number of collaborative research and innovation projects aimed at various aspects of automation and digitalization in SMEs. MADE also facilitates knowledge exchange and matchmaking through open workshops, site visits, and demonstration projects, and it seeks to coordinate education and lifelong learning activities among Danish educational institutions.

Innovate UK and Business Basics in the United Kingdom

Business Basics is one of the funding instruments of Innovate UK. This fund supports the development of proof-of-concept ideas and test trials. Adoption of Digital Automation Practices and Technology (ADAPT) is one of the projects funded in the first round of Business Basics. ADAPT is managed by the Cheshire East Council's arms-length Skills and Growth Company. Through ADAPT, Siemens and RedEye will share their expertise with SMEs that adopt emerging automation techniques, marketing automation, and online selling to boost their productivity and improve their marketing efficiency.

Central Innovation Program for SMEs in Germany

Central Innovation Program for SMEs (ZIM) is a German funding program for SMEs and research organizations closely aligned with businesses. The focus of this program is on SMEs that want to develop new products, processes, or technical services or significantly improve existing ones. ZIM funds individual projects, cooperation networks between SMEs or between them and research and technology organizations, cooperation projects, and market launches of the results of R&D projects. During 2015–2017, ZIM supported 298 cooperation networks, 7,184 cooperation projects, and 1,717 individual projects. These projects received funding of approximately $1.6 billion.

R&D = research and development, SMEs = small and medium-sized enterprises.

Sources: MADE. 2019. *About MADE.* Copenhagen; MADE. 2019. *Fact Sheet: MADE in Facts and Figures.* Copenhagen; Department for Business, Energy, and Industrial Strategy. 2019. *Guidance. Business Basics Fund: Objectives and Round 1 Results.* London; Skills and Growth Company. 2019. *Businesses Offered the Chance to Learn from World-Class Digital Innovators*. Crewe; Federal Ministry for Economic Affairs and Energy. 2015. *Boosting Innovation Central Innovation Programme for SMEs.* Berlin; Federal Ministry for Economic Affairs and Energy—ZIM. 2017. *Statistik*. Berlin.

Alternative national initiatives support awareness raising through knowledge exchange, technology demonstration, and industrial networking schemes. For example, the Manufacturing Academy of Denmark (MADE) supports collaboration in a cluster initiative through the financing of small technology demonstration projects and the provision of "open labs" that include presentations, case stories, and demonstrations of state-of-the-art technologies. Similarly, Finland's 5th Gear program supports pilot and demonstration projects with a focus on the diffusion of technologies already available on the market.[79]

The Adoption of Digital Automation Practices and Technology (ADAPT) project, funded by Innovate UK, is an example of a collaboration between large and smaller companies in a value chain promoted by a regional government. In this initiative, leaders in technology adoption share their expertise with SMEs to help them better understand the benefits of productivity-enhancing technologies. Similarly, the German Central Innovation Program for SMEs funds projects and cooperation networks between SMEs or between them and research and technology organizations.

Other international examples include the creation of self-diagnosis tools for assessing the "digital level" of firms, coupled with access to the expertise of technology vendors to help companies identify how technology adoption can unlock new business value. An example includes Spain's Connected Industry 4.0 initiative.[80]

5.4 Pillar 3: Technology Transfer and Technical Support for Firms

The Challenge

Evidence collected throughout this study suggests that an immediate challenge faced by Indonesian firms is increasing their adoption of new technology. The consulted firms acknowledged the vulnerability of their competitive position if they are not capable of upgrading their technological usage and practices as quickly as their competitors.

To appropriately address this challenge, it is critical to recognize that firms in Indonesia are at different stages of their technology transformation journey. As discussed in Section 4, although 6% of surveyed firms in manufacturing are already using advanced new technologies across their operations, the majority—64% of surveyed manufacturing firms—are not yet able to exploit the benefits of technologies available on the market.

As such, technology adoption and upgrading needs to be seen as a phased process. Many Indonesian firms need to gradually build up the know-how required to transition from basic to advanced technologies. Basic capabilities need to be developed to deploy and use existing technologies effectively before building more sophisticated capabilities to create their own technological innovations.

[79] Teknologian kehittämiskeskus. 2017. *5th Gear.* Helsinki.

[80] Ministry of Industry, Commerce, and Tourism of Spain. 2019. *Industria Conectada 4.0.* Madrid.

Opportunities for Policy Action

From a policy perspective, supporting the incremental buildup of firm-level technological know-how demands a stratified approach combining a variety of support measures to address the different challenges faced by firms at varying levels of technology adoption.

As indicated by the surveyed firms, a number of support mechanisms such as access to information, technical training, fiscal incentives, and credits are desired by firms across all levels of technology adoption. However, evidence from this study also suggests that some support mechanisms are more relevant to some firms than to others, depending on current technology adoption. Examples of stratified support mechanisms for technological transfer and technical support are presented in Table 5.1.

Table 5.1: Support Mechanisms for Technological Transfer and Technical Support: A Stratified Approach

Firm Type (Industry 4.0 Label)	Typical Characteristics	Key Challenges (Industry 4.0 Challenge)	Example Support Mechanisms More Directly Relevant to Key Firm Challenges
Advanced (Industry 4.0 firms)	• Firms using advanced technologies across various operations • Technologies used by the firm at least as advanced as competitors • Actively engaged in innovation and R&D	**How to maintain a leading technological position while building invention and technology-generation capabilities**	• Funding, grants, and tax incentives for cutting-edge R&D • Contract R&D and highly specialized technology services • Funding of PhD positions and exchange of personnel with research institutions • Early stage capital and incubation support • Support for internationalization
Intermediate (Industry 3.0 firms)	• Firms starting to use some advanced technologies in specific operations • Using technologies more advanced than those of other firms, but with some competitors ahead • Motivated to engage in innovation but lacking resources	**How to develop absorption and innovation capabilities**	• Grants for innovative projects including financing for prototyping and testing • Access to advanced facilities in research and technology organizations • Advanced capacity-building and technology advisory programs • Incentives to participate in research clusters and university–industry collaboration schemes • Support to acquire foreign intellectual property over long periods of time
Basic (Industry 1.0–2.0 firms)	• Firms performing many tasks manually and on paper • New technologies not well understood • Lacking resources to engage in innovation	**How to improve basic management and technology practices to acquire best available technologies**	• Basic technology extension and business advisory programs • Development of easy-to-use "toolboxes" or "toolkits" for SMEs • Support for simple innovation projects • Mechanisms for best-practice sharing between firms in the sector • Grants or tax deductions for basic training

R&D = research and development, SMEs = small and medium-sized enterprises.

Source: Summary of background analysis produced for ADB technical assistance to Indonesia on Supporting Technological Transformation (Project Number: 51343-001). Jakarta.

Table 5.1 suggests a broad distinction between support mechanisms that appear more directly relevant to the challenges faced by advanced, intermediate, and basic firms (Section 4). According to this characterization, leading firms may more directly benefit from support mechanisms aimed at building invention and technology-generation capabilities, such as the funding of cutting-edge R&D and highly specialized technology services. Followers need to close the gap with the leaders by further developing absorption and innovation capabilities through, for example, grants to engage in new innovative projects and access to advanced facilities not commonly found in-house. Firms lagging behind, meanwhile, need to improve basic management and technology practices through, for example, basic technology extension and business advisory programs and mechanisms for sharing best practices.

International Experience

Several examples of technology transfer and technical support approaches can be drawn from international experience (Box 5.3). The Manufacturing Innovation 3.0 initiative in the Republic of Korea, for instance, offers individualized technical support for firms, which includes subsidized consulting advice on manufacturing processes and innovation, as well as technical advice on project performance management and management for innovation tasks.

BOX 5.3

Technology Transfer and Technical Support for Firms

Centers of Excellence in Trinidad and Tobago

Five centers of excellence are planned in Trinidad and Tobago to link public and private innovation efforts across five economic sectors: agritech, ICT, aviation, maritime, and energy. They are designed to fulfill a technology transfer function through the provision of customized consultancy services, including expert advice, technical training, new product development support, and access to test equipment.

Manufacturing Innovation 3.0 in the Republic of Korea

Manufacturing Innovation 3.0 addresses the gap in innovation capacity between large companies and their secondary and tertiary subcontractors. Key instruments for technology transfer and technical support include $200 million over 5 years in subsidies for consulting advice on manufacturing processes, innovation, and the replacement of old facilities, as well as technical advice on project performance and innovation management.

Innovation & Capability Voucher in Singapore

The Innovation & Capability Voucher consists of $3,800 grants for SMEs to pay for consultancy and technology solution services. Originally, the scheme included only consultancy services on innovation, productivity, human resources, and financial management. In 2014, it was extended to equipment and hardware purchases and technical, professional, and design services.

Sources: Policy Links. 2018. *Implementation Strategy for Centres of Excellence in Trinidad and Tobago*. University of Cambridge; E. Ha. 2015. *Smart Industry in Korea*. Rijksdienst voor Ondernemend Nederland; S. Y. Han. 2014. Industry Innovation 3.0. *APO News*. July–August 2014; SME portal. 2019. *Innovation & Capability Voucher (ICV)*; Gateway Law Corporation. 2014. *Innovation Capability Voucher Scheme.*

A series of planned centers of excellence in Trinidad and Tobago are expected to fulfill a technology transfer function through the provision of customized consultancy services that account for the particular needs of firms in the country. The range of services to be offered by the centers—from expert advice to technical training and new product development support—has been segmented not just by sector but also by firm technology sophistication.

Similarly, the Innovation & Capability Voucher scheme in Singapore provides customized grants for SMEs to be spent on innovation consultancy services, productivity, human resources, financial management, equipment, technical solutions, professional services, and design and renovation services. The extensive range of services eligible has evolved in response to changes in demand from client firms.

5.5 Pillar 4: Low-Cost Plug-and-Play Technology Solutions for Indonesian Firms

The Challenge

The consulted firms pointed repeatedly to one key challenge constraining their interest in and ability to adopt new technologies: the perceived high cost of the technology and the difficulty of accessing financial support. This means that even when a particular technology is commercially available, and its value is understood by firms, its widespread adoption and integration into business operations is not guaranteed because of high costs up front.

For many companies, especially SMEs operating on low margins, an unsuccessful investment of their limited resources in a new technology or innovative project can greatly affect their financial performance and even jeopardize their survival.

Beyond financial considerations, evidence from this study suggests that a considerable number of firms often suffer weak R&D, innovation, and managerial capability (Sections 3 and 4). In practice, this means that they are often unable to adopt new technologies and update processes or products on their own, regardless of technology availability.

A key challenge is therefore to facilitate access to affordable technologies that meet local business needs and are easy to use. This may be accompanied by technical advice to ensure that the benefits of new technologies are fully exploited by local firms.

Opportunities for Policy Action

A significant opportunity exists to take advantage of technologies that are becoming more widely available and whose costs steadily fall. As discussed in Section 2, lower prices are a transformative aspect of some new technologies. This is the case, for example, for a number of digital technologies associated with Industry 4.0. For Indonesia, the potential to apply affordable high-tech solutions to upgrade low-tech processes and firms seems particularly worth exploring.

Because of their pervasive nature, solutions based on a number of technologies can be applied across firms and sectors. For example, digitally enabled tools for visualization, planning, and maintenance management can all be applied across a number of firms. One approach would be to identify among all potential options those technology solutions that more directly address common requirements among Indonesian firms. Resources to develop or source the right technological solutions could be pooled, and a catalogue of customizable plug-and-play technological solutions that are easy to use could be made available to firms.

It is worth considering, however, that what seems affordable and easy to use to some firms might be out of reach for some others. Therefore, access to expert advice and funding may be required for the wide deployment of these technologies.

International Experience

Box 5.4 outlines case studies that illustrate different approaches to facilitating access to low-cost plug-and-play technology solutions for businesses, particularly SMEs. Japan's Industrial Value Chain Initiative, for example, provides "internet of things kits" for cash-constrained SMEs at a cost of $900 per kit, promoting the adoption of digital manufacturing solutions. To disseminate its benefits among SMEs, the initiative holds seminars across Japan and provides advice to help SMEs adapt these kits to their particular operations.

In Singapore, the Tech Depot initiative facilitates access to more than 25 technology solutions for SMEs across a wide range of industries and business functions, covering up to 70% of their costs through productivity solutions grants.

A collaboration called Digital Manufacturing on a Shoestring between the University of Cambridge and the University of Nottingham in the United Kingdom provides an example of a government-sponsored applied research program with potential sector impact. The aim of the project is to help SMEs find the best ways to adopt low-cost, commercially available technologies for industrial automation, developing accessible and affordable solutions based on low-cost components that account for regulations, safety, and security.

An additional British example, from the Advanced Manufacturing Research Centre, is a project that aims to retrofit old manufacturing machines with low-cost digital technologies, demonstrating an alternative approach to low-cost and low-risk technological adoption for small businesses.

5.6 Pillar 5: A Tech-Savvy Workforce

The Challenge

Exploiting the benefits of new technologies requires companies and workers with the ability to understand, adopt, and adapt them toward the development of new products, processes, and business models. This requires new skills at all levels of the firm, from shop-floor technicians to managers and directors.

BOX 5.4

Low-Cost Plug-and-Play Technology for Indonesian Firms

The case studies shown below illustrate different approaches to facilitating the development and provision of low-cost technology solutions for SMEs and increasing technology uptake in manufacturing.

Industrial Value Chain initiative in Japan

The Industrial Value Chain Initiative is a collaborative forum that promotes the development and adoption of "smart manufacturing" solutions. It was established by Japan's Ministry of Enterprise, Trade and Industry and the Manufacturing Systems Division of the Japanese Society of Mechanical Engineers. One of the most recent efforts to increase the adoption of internet of things (IOT) solutions by cash-constrained SMEs is the development of $900 IOT kits. These kits are developed by working groups, involving large and small companies, with the aim of achieving attractive prices by integrating low-cost components such as the Raspberry Pi single-board computer.

Tech Depot in Singapore

Tech Depot is a centralized platform developed by the Government of Singapore to improve SME access to technology and digital solutions. Tech Depot is managed by the SME Office of the Agency for Science, Technology, and Research. More than 25 technology solutions across a wide range of industries and business functions are featured at Tech Depot. Through productivity solutions grants, Tech Depot subsidizes companies' adaptation of IT solutions and equipment to boost their productivity, with grants covering as much as 70% of the cost. These solutions have been vetted by various government agencies such as Enterprise Singapore and the National Parks Board.

Digital Manufacturing on a Shoestring in the United Kingdom

Digital Manufacturing on a Shoestring is a 3-year project led by the Institute for Manufacturing of the University of Cambridge, in partnership with the University of Nottingham. The project follows an untraditional approach to digitalizing a manufacturing operation by focusing predominantly on nonindustrial solutions to industrial automation and information challenges. It seeks to exploit very low-cost, commercially available technologies for mobile computing, sensing, and AI to tackle the challenges associated with integrating these safely and securely into small-scale manufacturing environments. Digital Manufacturing on a Shoestring involves activities such as SME digital manufacturing assessments, hackathons, pilot studies, and demonstration sessions.

AI = artificial intelligence, IOT = internet of things, SMEs = small and medium-sized enterprises.

Sources: Industrial Value Chain Initiative (IVI). 2018. *Strategic Implementation Framework of Industrial Value Chain for Connected Industries*. Tokyo; Yasuyuki Nishioka, president of the Industrial Value Chain Initiative. Personal interview; IVI. 2016. *The IVI Approach to IOT and Current Manufacturing Projects IOT Solutions*. Barcelona: World Congress; Institute for Manufacturing. 2019. *Digital Manufacturing on a Shoestring.* Cambridge; Engineering and Physical Sciences Research Council. 2018. *Digital Manufacturing on a Shoestring.* Grant details.

The factories of the past are being replaced by smart industrial facilities, where workers are required to master new digital tools, interact with intelligent robots, and make decisions in real time. Managers need to choose from a wide range of technology and application possibilities the right investments to help the firm achieve its business objectives. Even policy makers require new skills to ensure that new regulatory frameworks, ranging from standards and certifications to competition and consumer safeguards, enable technology adoption while avoiding undesirable social outcomes.

Indonesia faces an important challenge in this area. Efforts to address skills gaps are being made by the Government of Indonesia by, for example, expanding enrollment in technical and vocational education (Section 3). However, there are indications that the lack of workers with the right skills is already preventing Indonesia from taking advantage of the opportunities offered by new technologies.

Using LinkedIn data, a recent report by the Mandiri Institute found that software and IT services are experiencing the fastest employment growth in Indonesia, and that positions such as frontend developer, creative designer, and system analyst are among the fastest-growing occupations.[81] The study found that many firms struggle to find workers with the right competencies in these areas and, as a result, are forced to relocate activities to other countries.

A lack of IT and other skilled workers is considered to be one of the main constraints hindering the adoption and development of the fintech applications in both the traditional banking sector and fintech companies (footnote 39).

The lack of workers with the required know-how in new technologies is a concern shared across all the industries consulted: automotive, electronics, food and beverage, textiles and clothing, and footwear. Companies also mentioned that they are unaware of available training schemes in Indonesia on new technologies, and there was a broad perception that the availability of technical experts is limited. Table 5.2 summarizes the skills needed in increasingly digitalized sectors in Indonesia, as well as the skills expected to be relevant across sectors.

Opportunities for Policy Action

As the skills required by industries become more complex, a critical mass of appropriately trained workers is likely to become an increasingly important driver of competitiveness and thus a critical enabler of economic growth. The policy challenge for Indonesia is to ensure that the supply of these skills matches the evolving requirements of firms in the country.

To develop a tech-savvy workforce, the challenge goes beyond expanding basic education. There is also a need to nurture knowledge and awareness of new technologies in continuing education systems. Institutions need to be able to identify the changing needs of domestic firms and redesign their post-employment training in new technology areas accordingly. As such, institutions outside the traditional basic education system of colleges and universities are increasingly important for advanced skill development.

[81] Mandiri Institute. 2018. Indonesia's Workforce: Skills for the Future. *Policy Paper on Automation and Workforce*. Jakarta.

Table 5.2: Skills Needs for a Tech-Savvy Workforce

Sector		Essential Skills	Desirable Skills
Manufacturing (automotive, textiles, and chemicals)	Technical skills	• Ability to interact with modern interfaces • Ability to organize and coordinate interactions between virtual and real machines in cyber-physical systems • Specialized knowledge about such technologies as bio manufacturing and composite manufacturing	• Awareness of ergonomics • Computer programming and coding abilities • Management of virtual tools • Data and information processing and analytics
Information and communication technologies	Technical skills	• Data and information processing and analytics • Cybersecurity competencies	• Ability to interact with modern interfaces, human–machine and human–robot • Management of virtual tools
Financial	Technical skills	• Data and information processing and analytics • Cybersecurity competencies • Understanding of legal affairs	• Computer programming and coding abilities • Ability to interact with modern interfaces, human–machine and human–robot • Specialized knowledge of technologies
Cross-sectoral	Technical skills	• Data and information processing and analytics • Information and communication technology literacy • Cybersecurity competencies • Interdisciplinary skills	• Understanding of legal affairs
	Soft skills	• Adaptability and ability to change • Mindset for independent and lifelong learning • Decision-making • Self-management	• Decision-making • Communication skills • Working in teams

Sources: ACATECH. 2013. *Recommendations for Implementing the Strategic Initiative Industrie 4.0*. Munich: German National Academy of Science and Engineering; Beecher et al. 2015. *A Review of International Approaches to Securing the Workforce for the Advanced Industries of the Future*. Cambridge: Centre for Science, Technology, and Innovation Policy, University of Cambridge; R. Berger. 2016. *Skill Development for Industry 4.0*. New Delhi: BRICS Skill Development Working Group; S. El Achkar Hilal. 2018. Creative Destruction? Technological Progress, Employment Growth, and Skills for the Future in Indonesia, the Philippines, Thailand and Viet Nam. In A. Sakamoto and J. Sung, eds. *Skills and the Future of Work Strategies for Inclusive Growth in Asia and the Pacific*. Bangkok: International Labour Organization, pp. 182–255; Association of German Engineers and American Society of Mechanical Engineers. 2015. *A Discussion of Qualifications and Skills in the Factory of the Future: A German and American Perspective*. Dusseldorf: VDI-ASME.

The consulted stakeholders suggested that funding could be allocated to training programs aimed at developing new technology skills at company level, particularly for SMEs. It was also suggested that, building on efforts made in the automotive industry, foreign firms could be encouraged to expand their training centers in Indonesia.

Access to advanced technical training needs to be ensured. It could be provided alongside specialist advice and technology transfer support. Finally, the untapped potential for skilled employment among women needs to be properly investigated.

Other areas of policy action suggested by stakeholders include the following:

- upgrading existing training centers to provide the right digital skills demanded by SMEs,
- increasing the availability of apprenticeships to support on-the-job practical training for university students, and
- technology entrepreneurship training programs.

Opportunities also exist to use new learning platforms such as Udacity, Coursera, and Udemy. Countries such as Singapore are using these platforms to give residents access to courses.

International Experience

National policy agendas around the world are giving central importance to developing skills in the digital age (Box 5.5). Brazil's National Service of Industrial Training is an example of vocational education and training led by industry. Courses on smart manufacturing offer apprenticeships, technical training, and qualification in a wide range of new technologies.

BOX 5.5

Developing a Tech-Savvy Workforce

National Service of Industrial Training in Brazil

The Brazilian National Service of Industrial Training (SENAI) is a network of vocational schools and training centers. It is managed by industry through the National Confederation of Industry and state federations. Courses range from professional learning to graduate degrees, and some of the courses are free of charge. SENAI courses on smart manufacturing focus on automation and information technologies.

Competence Track for Automation and Digitalisation in SMEs in Denmark

The Competence Track for Automation and Digitalisation in SMEs (KOMP-AD) was an education program that ran from 2013 to 2015 to address the lack of knowledge and practical competencies in automation and digitalization. It was a collaboration of 15 Danish vocational schools and colleges, 250 SMEs, business associations, and public actors with business support. Its main objective was to offer tailor-made competency-development packages for SMEs.

Upgrading Skills in Singapore

A main strength of the skills development policy undertaken by the Government of Singapore has been its capacity to adapt to rapid and continuing changes in demand for high-skilled workers. In the early 1970s the Singapore Economic Development Board undertook innovative collaboration with international companies in France, Germany, India, Japan, and the Netherlands to establish training centers to address the shortage of high-skilled workers. The next upgrading step came in the second half of the 1970s, driven by both rising wages and the increasing investment of international companies in advanced manufacturing technology.

continued next page

BOX 5.5

(continued)

Collaboration with the governments of France, Germany, and Japan was then explored to meet demand for highly trained technicians and supervisors. More recently, the government has adopted an approach centered on skills mastery and lifelong learning. Through its SkillsFuture policy, the government offers industry-relevant training programs on emerging skills, such as advanced manufacturing, cybersecurity, data analytics, and digital media.

The National Employability Through Apprenticeship Program in India

The program is a public–private partnership between TeamLease Skills University, the Confederation of Indian Industry, and the National Skill Development Corporation. It was designed to address both youth unemployment and the rigidity of the Apprentice Act, 1961, which mandates that every employer should appoint apprentices. More than 60,000 apprentices have been trained under the program. Trainees are enrolled as students of TeamLease Skills University. They can be appointed for flexible durations of 3–24 months. Trainees are paid a consolidated stipend with no deductions that must at least be equal to the applicable unskilled minimum wage, though it can be higher. All trainees are enrolled in a free 200-hour online course for soft skills, English, and computers. They can further enroll voluntarily or through the employer for other TeamLease Skills University certificate, diploma, and associate degree courses delivered online. Some courses offer postgraduate diplomas in computer applications and certificates in IT skills.

SMEs = small and medium-sized enterprises.

Sources: National Service of Industrial Training. *Courses and Programmes*; European Social Fund. 2017. *Projects. Technical Training Streamlines for Success*; Iris Group. 2015. *Digitalisation and Automation in the Nordic Manufacturing Sector. Status, Potentials and Barriers*. Copenhagen: Nordic Council of Ministers; S. Lall. 2000. Singapore. *Technology for Development Series*; C. T. Lin. 2002. Training a New Breed of Technologists. In C. B. Chan, ed. *Heart Work: Stories of How EDB Steered the Singapore Economy from 1961 to the 21st Century*; Government of Singapore. 2019b. *SkillsFuture Series*; National Employability Through Apprenticeship Program. 2014. *Apprenticeship program*; TeamLease. 2019. *NETAP—National Employability Through Apprenticeship Program*; TeamLease Skills University. 2019. *Programs for Working Professionals.* Vadodara, Gujarat.

The Danish Competence Track for Automation and Digitalisation in SMEs is a multi-stakeholder collaboration involving vocational schools, companies, business associations, and the public sector that addresses the lack of knowledge and practical competencies in the field of automation and digitalization of SMEs.

Skills development policy in Singapore offers interesting lessons with regard to its flexibility to adapt to both the changing needs of industry and the particular economic and societal goals of the country. Recently, the government adopted an approach centered on skills mastery and lifelong learning. The main policy implemented for this purpose is SkillsFuture, which includes the provision of industry-relevant training programs on emerging skills, such as advanced manufacturing, cybersecurity, data analytics, and digital media.

Finally, the National Employability Through Apprenticeship Program in India illustrates how public–private partnership can enhance apprenticeship systems. The program provides details of how it operates, such as the role of the TeamLease Skills University, the length of appointments, and the size of apprentice stipends. Courses include postgraduate diplomas in computer applications and certificate courses in IT skills.

Other international programs include efforts to raise public respect for skills by granting awards to excellent skilled workers and holding competitions for various skills.

5.7 An Agenda for Future Actions

While it is outside the scope of this study to suggest a detailed implementation plan with specific responsibilities for government departments and agencies, Table 5.3 prioritizes policy actions under each pillar in a short, medium, and long-term time frame. This classification provides a useful baseline to guide the next steps for policy design and implementation.

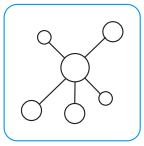
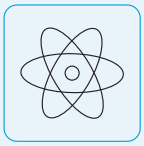
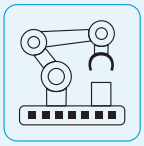
A feasible mechanism to design practical policy implementation plans could be the formation of multi-stakeholder working groups for each pillar. Working groups are typically created to address a specific challenge or to produce one or more specific deliverables, such as a detailed implementation plan or guidelines.

For the purpose of the pillars outlined here, working groups could involve a multidisciplinary collaboration between stakeholders across government departments and agencies, as well as industry and academia. These are generally expected to work for a defined period of time, with goals and objectives agreed with key public and private stakeholders.

Each working group focused on its individual pillar could be responsible for producing a detailed implementation plan that outlines steps and resources required to implement key policy actions within a feasible time frame. Once established, working groups could assume ownership of the tasks at hand and modify the order and priority of the actions outlined in Table 5.3 based on their deeper knowledge of local conditions and the resources available.

Finally, it is important to highlight that the report does not attempt to assess whether the policy agenda to drive Indonesia's technological transformation forward can or should be implemented by making use of existing institutions. It does highlight, however, that the successful delivery of a particular policy program or initiative may be determined as much by the quality of institutions involved in delivering them as by the approach adopted. Further consideration is required to make appropriate judgments regarding the need for new institutions, or for the reform of existing ones, to effectively deliver the technological transformation agenda in Indonesia.

Table 5.3: An Agenda for Future Action on Five Pillars to Support Indonesia's Technological Transformation

	Short term (2 years)	Medium term (5 years)	Long term (>5 years)
 Advanced innovation infrastructure and institutions	• Develop long-term R&D investment plans and adopt international best practices for funding research. • Ensure that regulatory frameworks are updated appropriately in response to changes brought by new technologies.	• Develop digital infrastructure nationally to narrow regional disparities. • Build institutional capacity for policy delivery across regions.	• Address gaps in both "hard" and "soft" infrastructure and develop advanced innovation institutions. • Assess needs for new extension services and intermediate institutions such as research and technology organizations to provide technological assistance to firms.
 Awareness of the business value of new technologies	• Create sector and cross-sector technology forums in cooperation with universities, research centers, and technology vendors. • Develop industrial networks and business associations to promote linkages and knowledge exchange between firms in Indonesia and abroad.	• Establish mechanisms to share best practices across firms in value chains.	• Set up facilities to demonstrate technology in research centers and universities.
 Technology transfer and technical support for firms	• For the largest group, firms that have adopted only basic technology, emphasize support to improve basic management and technology practices.	• For followers, the second-largest group, put emphasis on support mechanisms aimed at further developing absorption and innovation capabilities.	• For the small group of leading firms, emphasize support in building capacity to invent and generate new technology.
 Low-cost plug-and-play technology solutions for Indonesian firms	• Identify technology solutions that address common issues faced by Indonesian firms through, for example, industrial working groups. • Take advantage of technologies that are becoming cheaper and more widely available.	• Develop a catalogue of affordable plug-and-play technological solutions that are easy to use.	• For wider technology deployment, provide access to expert technical advice—such as sector-specific support offered by public and private institutions—and to funds through grants and loans.
 Tech-savvy workforce	• Provide funding to new technology training programs for small and medium-sized enterprises. • Expand funding for apprenticeships to provide on-the-job training to university students, taking advantage of the growing number of Indonesian graduates in science, technology, engineering, and math.	• Upgrade existing training centers to expand offerings in new technologies. • Ensure learner access to institutions that offer advanced technical training. • Establish training programs in technological entrepreneurship.	• Encourage foreign firms to expand their training centers, building on lessons from the automotive industry. • Exploit potential for skilled employment for women.

APPENDIX 1

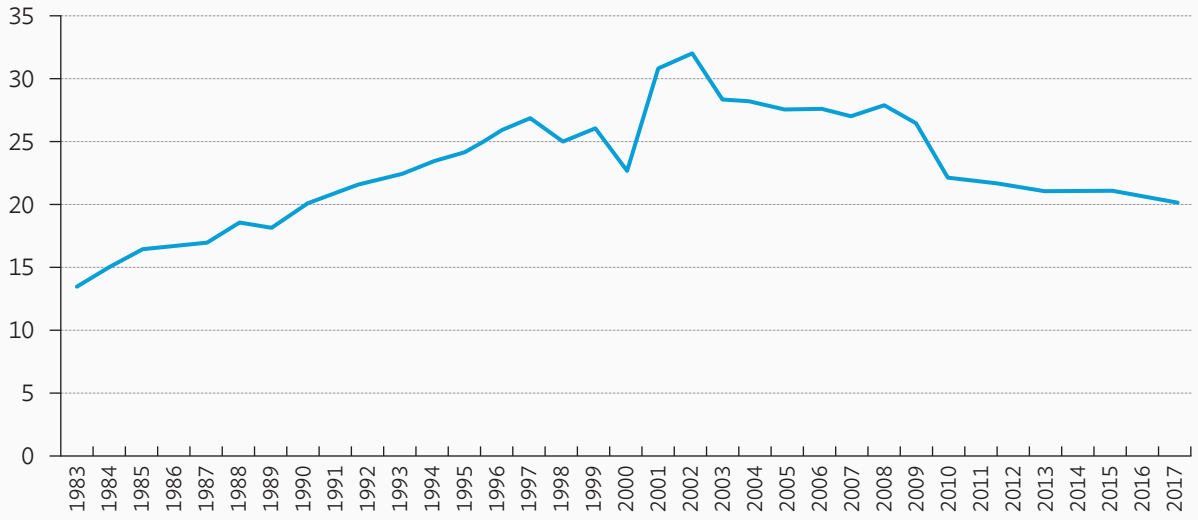
OVERVIEW OF MANUFACTURING IN INDONESIA

A1.1 | Introduction

Indonesia's manufacturing sector has experienced an important structural transformation in recent decades, having entered a declining trend since the Asian financial crisis of 1997–1998.

During 1990–1996, Indonesia's economy aside from oil and gas grew at an average rate of 12% per year. Manufacturing expanded to contribute 32% of gross domestic product (GDP) in 2002, despite contraction in the aftermath of the Asian financial crisis, which severely affected textiles, clothing, footwear, and wood products (Figure A1.1).[1]

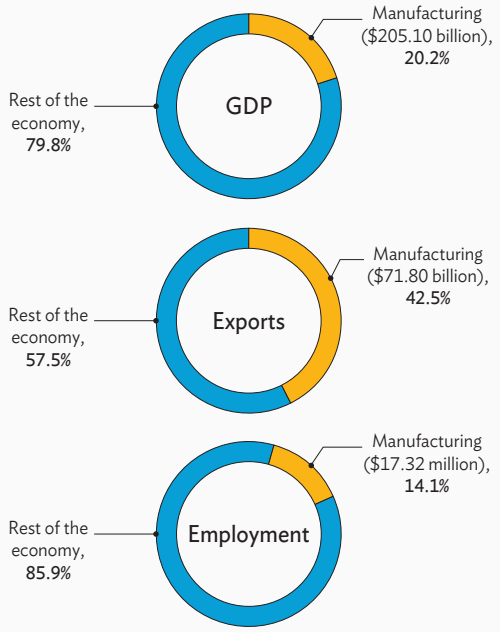
Figure A1.1: Indonesia Manufacturing Value Added, 1983–2017
(% of GDP)



Source: World Bank. 2019. *World Development Indicators*.

[1] ADB–BAPPENAS. 2019. *Policies to Support the Development of Indonesia's Manufacturing Sector during 2020–2024.* Manila: Asian Development Bank.

Figure A1.2: Contribution of Manufacturing to the Indonesian Economy, 2017

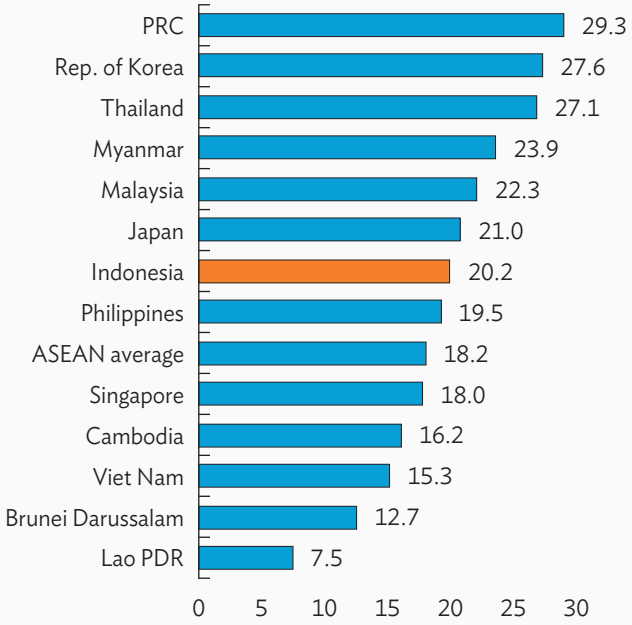


GDP = gross domestic product.

Note: Current US dollars.

Sources: World Bank. 2019. *World Development Indicators*; *World Integrated Trade Solution*; Badan Pusat Statistik. 2019. *Labour Survey*.

Figure A1.3: Manufacturing Value Added in Selected Countries, 2017
(% of GDP)



ASEAN = Association of Southeast Asian Nations, GDP = gross domestic product, Lao PDR = Lao People's Democratic Republic, PRC = People's Republic of China.

Source: World Bank. 2019. *World Development Indicators*.

The current contribution of manufacturing to Indonesia's economy is shown in Figure A1.2. In 2017, Indonesia had 3,695,195 manufacturing firms employing 17,321,468 workers and contributing 14.1% of total employment.[2] Moreover, manufacturing contributed 20.2% to Indonesia's GDP and 42.5% to its exports.

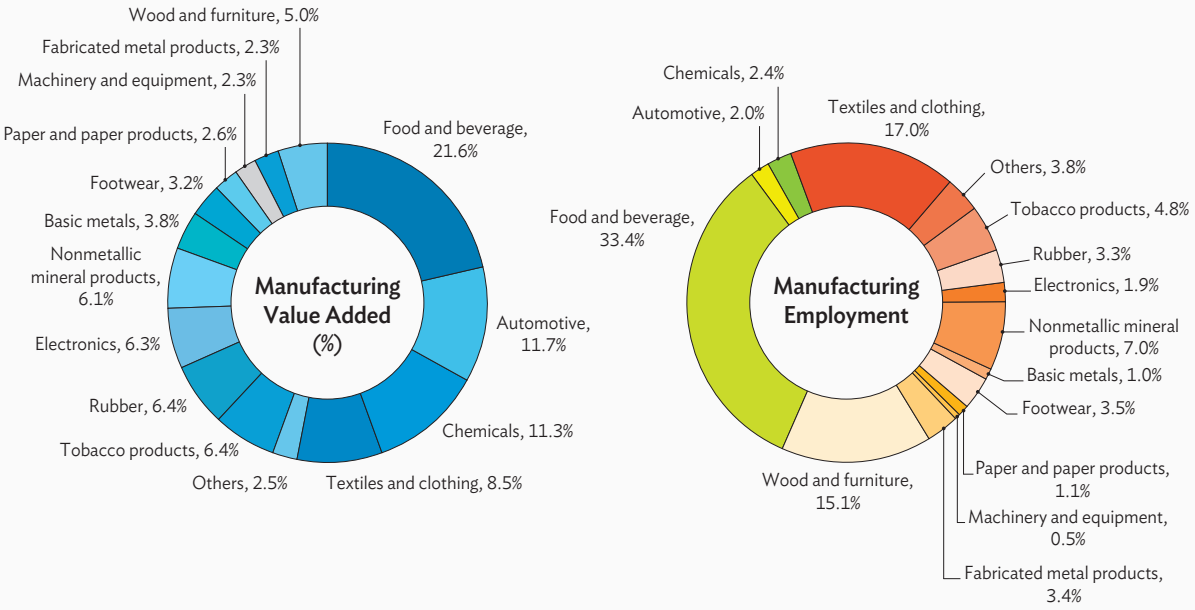
As shown in Figure A1.3, Indonesia's share of manufacturing value added (MVA) as a share of GDP is above the Association of Southeast Asian Nations (ASEAN) average of 18.2%.

[2] A high 31.2% of Indonesian employment was still in the primary sector in 2017 mainly because of its importance, including not just agriculture but also mining and quarrying. This figure aligns with other members of the Association of Southeast Asian Nations (ASEAN)—32.8% in Thailand, 40.9% in Viet Nam, and 61.3% in the Lao People's Democratic Republic—but is higher than in other emerging economies, for example 10.3% in Brazil and 5.6% in South Africa. Finally, as a comparison, the Organisation for Economic Co-operation and Development (OECD) average share of agriculture contribution to the total economy employment was 4.7% in 2017. Source: World Bank. 2019. *World Development Indicators.*

A1.2 | Composition of Indonesia's Manufacturing Sector

The composition of the manufacturing sector in Indonesia is shown in Figure A1.4, highlighting the contribution of each industry to total MVA and manufacturing employment.

Figure A1.4: Contribution to Manufacturing in Indonesia by Subsector, 2015



Sources: Badan Pusat Statistik. 2015. *Survey of Micro and Small Manufacturing*; *Survey of Medium and Large Manufacturing*.

Key characteristics of Indonesia's manufacturing structure include the following:

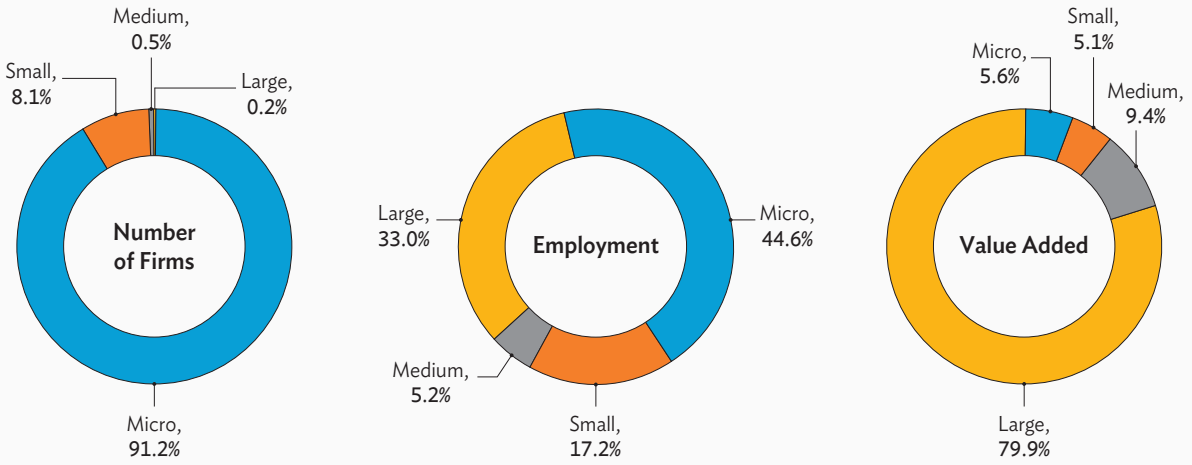
- The food and beverage subsector is the largest in terms of both value added at 21.6% and employment at 33.4%.
- Other subsectors with a relatively high shares of the MVA are automotive at 11.7%, chemicals at 11.3%, and textiles and clothing at 8.5%.
- In terms of employment, food and beverage is followed by textiles and clothing at 17.0%, wood and furniture at 15.1%, and nonmetallic products at 7.0%.

The following points emerge when considering sector technology intensity:[3]

- The largest share of Indonesia's manufacturing structure is the 49.6% in low technology.
- Medium-high and high technology represents 31.7% of the structure, and analysis conducted by the Asian Development Bank (ADB) shows that the share of MVA of high-technology sectors has increased fourfold since 2000.[4]
- The medium-technology sector occupies 16.2% of the industrial structure.

Analysis of the distribution of manufacturing firms aids understanding of the productive structure of Indonesian manufacturing. In 2015, there were 3,695,195 manufacturing firms in Indonesia, of which 91.2% were classified as microenterprises, employing 1–4 employees. This category of firms supplies 44.6% of all employment in manufacturing but generates only 5.6% of total MVA. Large enterprises with more than 100 employees generate 80% of Indonesia's total MVA (Figure A1.5).

Figure A1.5: Indonesian Manufacturing by Firm Size, 2015



Note: Microenterprises have 1–4 employees, small enterprises 5–19, medium-sized enterprises 20–99, and large enterprises 100 or more.

Sources: Badan Pusat Statistik. 2015. *Survey of Micro and Small Manufacturing*; *Survey of Medium and Large Manufacturing*; ADB–BAPPENAS. 2019. *Policies to Support the Development of Indonesia's Manufacturing Sector during 2020–2024*. Manila: Asian Development Bank.

[3] The UNIDO classification of manufacturing sectors by technological intensity (ISIC Revision 4) includes three groups of industries: medium-high and high technology, medium technology, and low technology. The full classification is available at the following link: https://goo.gl/uVSQtG.

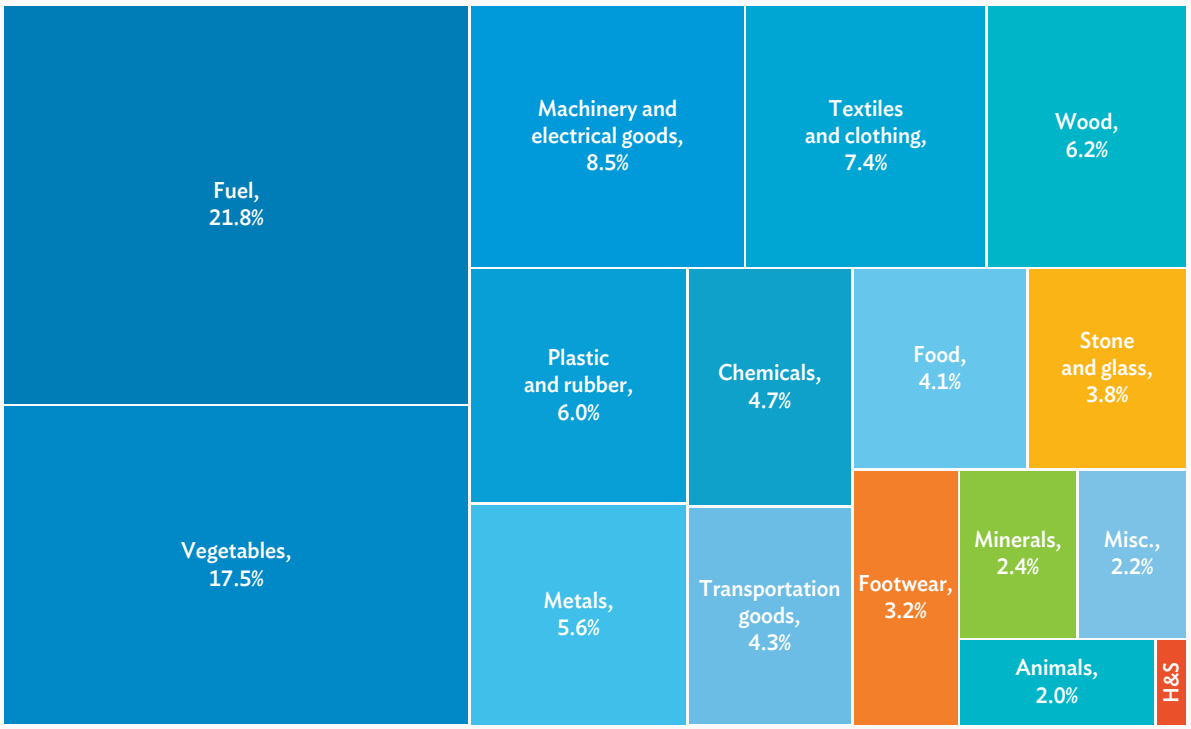
[4] ADB–BAPPENAS. 2019. *Policies to Support the Development of Indonesia's Manufacturing Sector during 2020–2024.* Manila: Asian Development Bank.

The main constraints on firm enlargement were a lack of access to finance, the regulatory environment, and, to a lesser extent, a cultural mindset that included a desire to evade taxes and inspections.[5]

A1.3 | International Trade in Manufactured Goods

In 2017, manufactured exports amounted to $71.8 billion, accounting for 42.5% of Indonesia's total merchandise exports (Figure A1.6). Fuel and vegetables together accounted for 39.3% of Indonesia's total exports.

Figure A1.6: Indonesian Exports by Sector, 2017

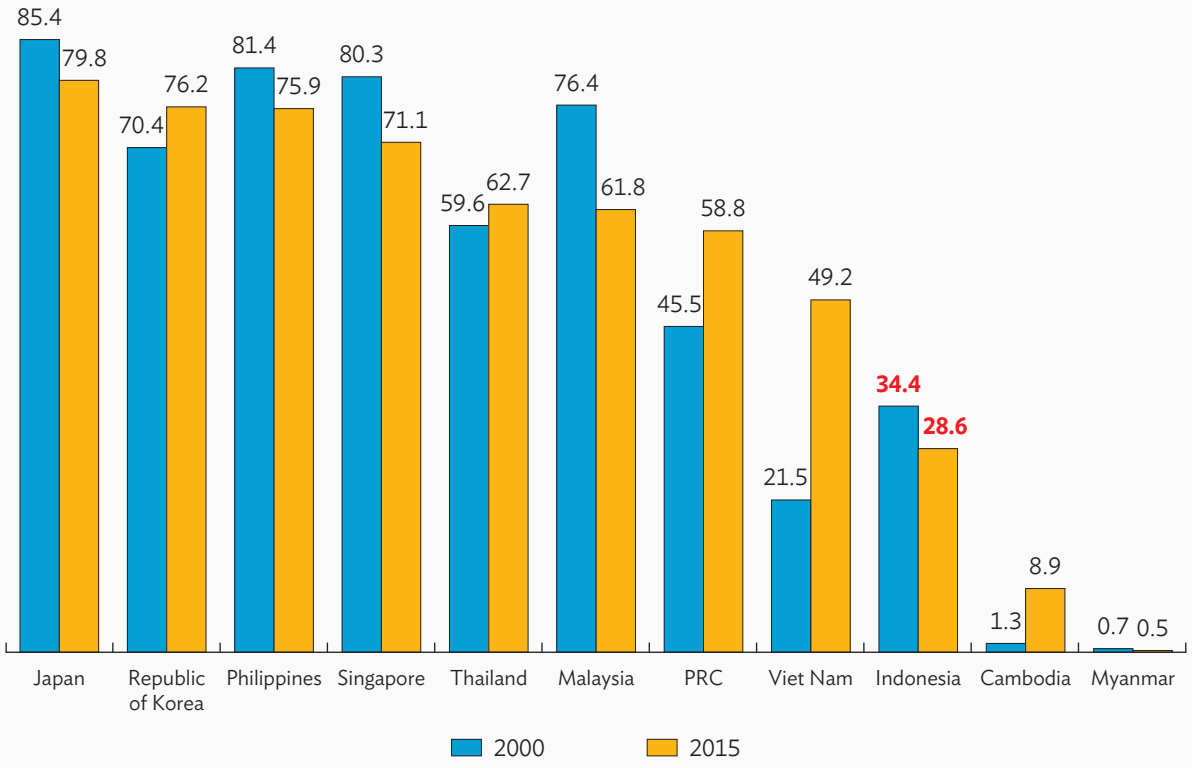


H&S = hides and skins (0.3%), Misc. = miscellaneous.
Source: World Bank. 2019. *World Integrated Trade Solution.*

[5] World Bank. 2012. *Productivity Performance in Indonesia's Manufacturing Sector.*

A key characteristic of Indonesia's manufacturing exports is the relatively low share of medium- and high-technology manufactured goods. Not only is it one of the lowest in ASEAN and more broadly in Asia, it is declining (Figure A1.7).

Figure A1.7: Medium- and High-Tech Exports from Selected Countries, 2000 and 2015
(% of manufactured exports)

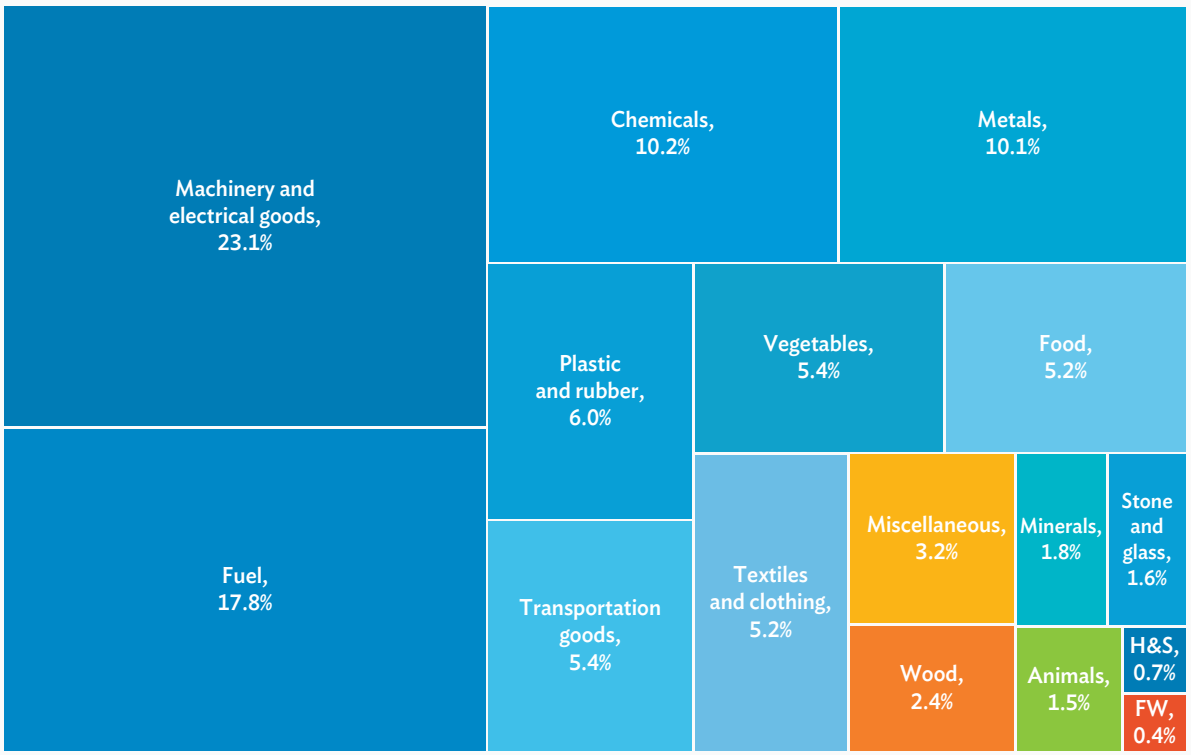


PRC = People's Republic of China.
Source: World Bank. 2019. *World Development Indicators.*

In 2017, manufactured imports amounted to $97.4 billion, accounting for 62% of Indonesia's total merchandise imports (Figure A1.8).

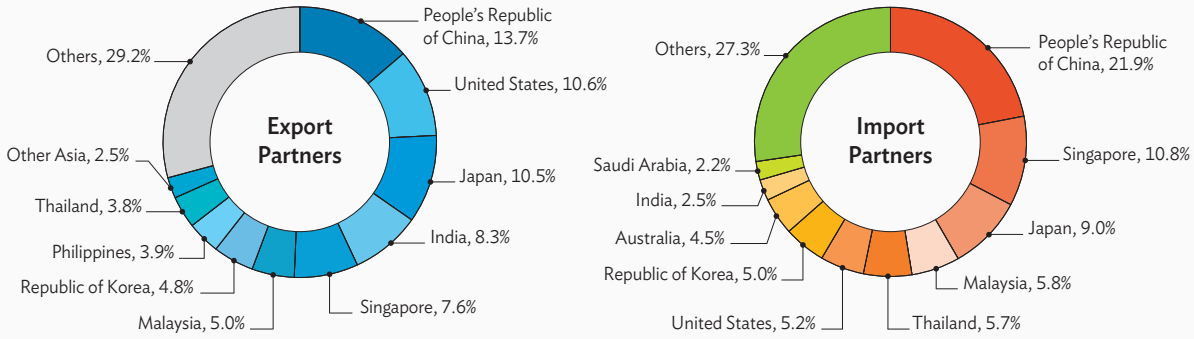
The People's Republic of China (PRC) and the United States are the main markets for Indonesia's goods exports. The PRC, Singapore, Japan, Malaysia, and Thailand are the largest importers to Indonesia (Figure A1.9).

Figure A1.8: Indonesian Imports by Sector, 2017
(%)



FW = footwear, H&S = hides and skins.
Source: World Bank. 2019. *World Integrated Trade Solution.*

Figure A1.9: Indonesia's Top 10 Export and Import Trade Partners, 2017
(%)



Source: World Bank. 2019. *World Integrated Trade Solution*.

A1.4 | Conclusions

The Asian financial crisis of 1997–2018 marked a turning point for the dynamic of Indonesia's manufacturing structural transformation, when the contribution of manufacturing to the economy started to decline.

In 2017, Indonesia had 3,695,195 manufacturing firms, which employed 17,321,468 workers and contributed 14.1% of total employment. Manufacturing contributed 20.2% of Indonesia's GDP and 42.5% of its exports.

The following points emerge when the structure of manufacturing is considered:

- Food and beverage is the largest sector in terms of both value added to total MVA at 21.6% and contribution to manufacturing employment at 33.4%.
- Medium-high and high-technology sectors represent a relatively high 31.7% of total MVA.
- The sector is mostly small firms, 91.2% of them classified as microenterprises, employing 1–4 employees and contributing 44.6% of employment in the sector. Large enterprises with at least 100 employees generate 80% of Indonesia's MVA.

In 2017, manufactured exports amounted to $71.8 billion, accounting for 42.54% of Indonesia's total merchandise exports. The share of high-technology manufactured goods in manufacturing exports was low compared with other Asian economies.

Table A1.1 reports the key opportunities and challenges faces Indonesian manufacturing, as identified in the literature, and Table A1.2 lists the sectors and statistical codes used in the analysis.

Table A1.1: Key Opportunities and Challenges for Indonesian Manufacturing

Key Opportunities	Key Challenges
• Large domestic market and growing middle class driving up domestic demand for consumer goods • Fast-growing economy that is expected to become one of the largest economies in the world by 2030 • Geographical proximity to a growing ASEAN consumer market • Government support and incentives for manufacturing, including tax holidays and notably through the Industry 4.0 roadmap, which aims to increase foreign direct investment and strengthen national digital infrastructure and the quality of human resources • Low labor costs enabling the relocation of firms from the People's Republic of China, where labor costs are increasing • Natural resource abundance in a variety of commodities that can feed domestic processing industries	• Poor infrastructure and, in particular, digital infrastructure such as high-speed fiber optics and cloud solutions to support new technologies • Limited technology adoption in a manufacturing sector dominated by SMEs • Insufficient government funding for innovation and high-tech activities • Lack of skilled labor and low productivity • Food processing, footwear, and automotive industries still highly dependent on imported raw materials

ASEAN = Association of Southeast Asian Nations, SMEs = small and medium-sized enterprises.

Sources: Business Sweden. 2018. *Industry 4.0 in Indonesia Market Opportunities, Future Trends and Challenges.* The Swedish Trade & Invest Council. Stockholm; Indonesia-Investments. 2017. *Shoes & Footwear: Indonesia the World's 5th-Largest Exporter*; Indonesia-Investments. 2017. *Indonesia's Electronics Industry Plagued by Weak Purchasing Power*; Indonesia-Investments. 2018. *Automotive Manufacturing Industry Indonesia*; Global Business Guide Indonesia. 2013. *Indonesia's Electronics and Home Appliances Sector*; Global Business Guide Indonesia. 2014. *Thirst Quenching: Indonesia's Food & Beverage Industry*; Indonesian Footwear Association. 2017. *Indonesian Footwear Industry Country Report 2017.* Presented at the 36th IFC 2017 of CIFA at Dhaka. Fair Wear Foundation. 2018. *Indonesia Country Study 2018*.

Table A1.2: Sectors and Statistical Codes Used in the Analysis

Sector	Division and Description[a]
Food and beverage	10 Manufacture of food products
	11 Manufacture of beverages
Tobacco products	12 Manufacture of tobacco products
Textiles and clothing	13 Manufacture of textiles
	14 Manufacture of wearing apparel
Footwear	15 Manufacture of leather and related products
Wood and furniture	16 Manufacture of wood and products made of wood and cork, except furniture; manufacture of articles made of straw and plaiting materials
	31 Manufacture of furniture
Paper and paper products	17 Manufacture of paper and paper products
Chemicals	19 Manufacture of coke and refined petroleum products
	20 Manufacture of chemicals and chemical products
	21 Manufacture of pharmaceuticals, medicinal, chemical, and botanical products
Rubber	22 Manufacture of rubber and plastic products
Nonmetallic mineral products	23 Manufacture of other nonmetallic mineral products
Base metals	24 Manufacture of base metals
Fabricated metal products	25 Manufacture of fabricated metal products except machinery and equipment
Electronics	26 Manufacture of computer, electronic, and optical products
	27 Manufacture of electrical equipment
Machinery and equipment	28 Manufacture of machinery and equipment
Automotive	29 Manufacture of motor vehicles, trailers, and semi-trailers
	30 Manufacture of other transport equipment
Other sectors	18 Printing and reproduction of recorded media
	32 Other manufacturing
	33 Repair and installation of machinery and equipment

[a] As per International Standard Industrial Classification of All Economic Activities, Revision 4.

APPENDIX 2

FINDINGS FROM STAKEHOLDER CONSULTATIONS

This appendix consists of four sector briefs: food and beverage; automotive; textiles, clothing, and footwear; and electronics.

Each sector brief consists of two parts:

- The first part is a sector overview based on the available literature.
- The second part reports on the findings of a series of focus group discussions (FGDs) convened to gather evidence from local stakeholders in Indonesia, as part of the project Supporting Technological Transformation in Indonesia, and organized with the support of the Centre for Strategic and International Studies and the Asian Development Bank (ADB) Indonesia Resident Mission.

Recognizing the need to draw evidence from local stakeholders, researchers carried out a variety of consultations with Indonesian stakeholders in academia, the private sector, and government to ensure that project findings and progression remained grounded in the realities of the country. FGDs were opportunities to test the findings from parallel phases of work by bringing together local stakeholders in industry able to present different views of future opportunities and challenges faced by selected economic sectors. The sessions provided participants with an interactive communication platform to explore, learn, and discuss thoughts, opinions, and views regarding how disruptive technologies will impact Indonesia's manufacturing industries in the short and long term.

The focus of the FGDs was on five manufacturing industries previously identified in the study.[1] Considering logistical factors and participant availability, FGDs were grouped as follows:

- automotive;
- electronics;
- food and beverage; and
- textiles, clothing, and footwear.

[1] Manufacturing industries were identified in the early stages of the project on the basis of the following considerations: their importance to Indonesia's economy, accounting for 51.4% of total manufacturing value added and 57.7% of manufacturing employment; their mix of labor- and capital-intensive industries; their mix of domestic-oriented industries and those more integrated into global value chains; their ability to complement government roadmaps such as 2020 Go Digital Vision and Making Indonesia 4.0.

FGDs were based on tried-and-tested consultation approaches, which had been successfully employed to inform sector, regional, and national strategies and policies.

The sessions were carried out in Jakarta in November 2018, with the following aims:

- Bring together key stakeholders to discuss the trends and drivers of change, as well as specific opportunities and challenges for Indonesia's manufacturing industries arising from disruptive technologies, including digital technologies such as artificial intelligence, the internet of things, and robotics.
- Identify sectoral and cross-sectoral challenges and opportunities from key disruptive technologies in the short and long term.
- Identify key government policies and interventions needed to address challenges.

The three FGDs focused on gathering stakeholder views on the opportunities and challenges for Indonesia's manufacturing industries arising from disruptive technologies. The analytical framework used to design the FGD sessions draws from the academic literature, previous studies on the digitalization of manufacturing, and ongoing work at the Institute for Manufacturing of the University of Cambridge.[2]

Table A2.1: Industry 4.0 Adoption Challenges: Implications for Indonesia

Cross-Sectoral Barriers	Support Measures Suggested by the Consulted Stakeholders
Gaps in digital infrastructure and national enablers for technology diffusion	• Implementation roadmap for Making Indonesia 4.0 • Broadband and cloud infrastructure development and deployment in industry • Cybersecurity policy and regulations for data privacy and protection • Adoption of effective technical standards for digital technology
Investment barriers and cost limitations on new technologies	• R&D financial support for local information technology companies to enable them to compete with foreign firms in the field of manufacturing digitalization • Incentive schemes for adopting advanced digital technologies, such as exemption from import duties and other tax incentives
Limited access to information on new technologies, including limited access to technological expertise and advice, particularly for SMEs	• Support for building awareness of advanced digital technologies such as technology demonstrators or application case studies across sectors • Platforms to share knowledge, develop skills, and transfer digital technologies and best practices to Indonesia from abroad, such as by connecting international technology suppliers and vendors with local firms, and connecting leading firms in Indonesia with those lagging behind in digitalization • Support for accessing professional and technical services for manufacturing companies in Indonesia, including advice on intellectual property rights • Market research services to identify opportunities for SMEs in manufacturing digitalization • Establishment of research and technology organizations in Indonesia

continued next page

[2] In particular, research at the Centre for Science, Technology & Innovation Policy and studies carried out by Policy Links, at the Institute for Manufacturing, University of Cambridge.

Table A2.1: *Continued*

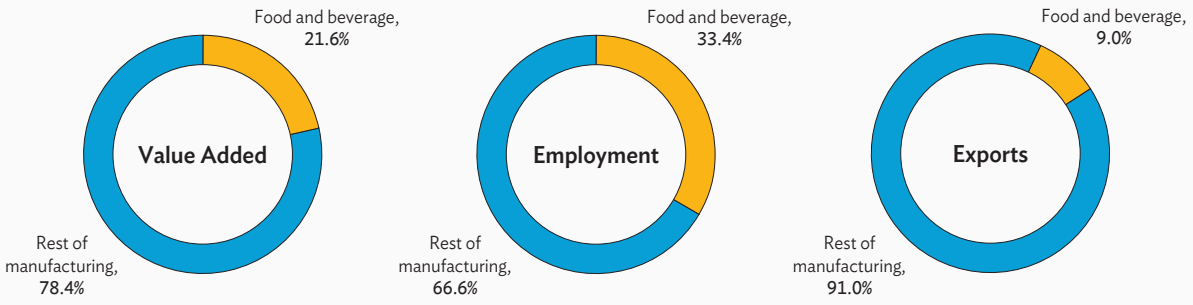
Cross-Sectoral Barriers	Support Measures Suggested by the Consulted Stakeholders
Opportunity areas in technical and business skills needed to adopt new technologies	• Upgrading existing training centers for digital skills development in SMEs • Technology and knowledge-transfer support for SMEs through, for example, research and technology organizations • Educational policy for developing appropriate university curriculums and programs for digital manufacturing, and running capacity-development programs • On-the-job training schemes for university students • Financial support for digital technology R&D and capacity development that link technology vendors and users • Technology entrepreneurship training programs • Cross-ministerial funding mechanisms for digital skills training in SMEs
Network linkages to strengthen collaboration between local stakeholders	• Developing industrial networks that bring together key stakeholders across industries—particularly digital leaders and firms lagging behind in digital technology adoption—as well as universities, technology institutes, and technology vendors for awareness building, knowledge sharing, and technology transfer • Technology forums for all sectors in cooperation with universities • Industry–university collaboration schemes for digital technology R&D development and technology transfer • Developing international networks connecting local factories and international suppliers or clients

R&D = research and development, SMEs = small and medium-sized enterprises.

Source: Policy Links. 2019. Focus group discussions with industry stakeholders for Supporting Technological Transformation in Indonesia, a project for the Asian Development Bank.

FOOD AND BEVERAGE

Figure A2.1: Food and Beverage Contributions to Manufacturing



Note: 2015 data.

Sources: World Bank. 2019. *World Integrated Trade Solution*; Badan Pusat Statistik. 2019. *Survey of Micro and Small Manufacturing; Survey of Medium and Large Manufacturing.*

Overview

- The food and beverage industry is the largest in Indonesian manufacturing in terms of both value added and employment.
- While the majority of firms in the sector are small or microenterprises, a small number of large domestic companies dominate the market, notably Indofood Sukses Makmur, the world's largest instant noodle maker; Wings Group; Mayora Indah; and Garuda Food. These local companies have evolved into successful global exporters, are cost-competitive, and innovate to produce tailored products with high value added.[3]
- Over 90% of firms in the sector are domestically owned, and only 3% are at least 10% foreign owned.[4] Some foreign brands, notably Nestlé, Kraft Foods, and Unilever, are also well integrated into the market.
- Major export products include snacks, special beverages, sauces, condiments, pickles, processed fruit, vegetables, and shellfish. The United States is the top export destination for Indonesian food and beverage products in recent years.
- The food industry was the single largest recipient of investment in 2015, with 879 projects worth a combined $1.8 billion. In 2013, roughly 60% of total investment was foreign direct investment.[5]

Opportunities

- Indonesia's food and beverage industry is supported by demand driven by the country's large population, rising personal incomes, and increased spending on food and drink.
- The domestic availability of numerous agricultural commodities such as coffee, cocoa, and palm oil is another attractive factor of the Indonesian food and beverage industry. However, supplies of agriculture goods from local farmers have often failed to meet domestic demand from processing industries, notably for cocoa (footnote 5).

Challenges[6]

- Domestic industry is highly fragmented, with many local SMEs that display limited technological readiness.
- Value chain infrastructure across the country is underdeveloped.
- Food processing industries still depend heavily on imported raw materials.
- Although reliance on the domestic market has limited vulnerability to global market fluctuations and trends, local firms are still vulnerable to fluctuating global prices for imported commodities.
- Many Indonesian consumers still prefer foreign brands over local ones, particularly for feeding babies and other children.

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3 Global Business Guide Indonesia. 2014. *Thirst Quenching: Indonesia's Food & Beverage Industry*.

4 World Bank. 2014. *Enterprise Surveys: Indonesia*. Washington, DC: World Bank.

5 Oxford Business Group. 2016. *Sustained Growth Makes Indonesia's Food and Beverage Industry a Priority for Spending.*

6 Business Sweden. 2018. *Industry 4.0 in Indonesia Market Opportunities, Future Trends and Challenges*. Swedish Trade & Invest Council, Stockholm; Global Business Guide Indonesia. 2014. *Thirst Quenching: Indonesia's Food & Beverage Industry*.

Government policy[7]

- Food and beverage is one of the industries prioritized by the government as part of the Master Plan of National Industry Development, 2015–2035.
- The government's objectives for this sector consist of improving the productivity of upstream agriculture, strengthening SMEs, and promoting regional hubs for packaged food production.
- The main objective of the Industry 4.0 roadmap with respect to the food and beverage industry is to position Indonesia as a regional export hub. As such, Indonesian manufacturers' adoption of new technologies—including automation and robotics in the production line, new sensor technologies, and improved data monitoring for warehouses—will be crucial in the coming years to boost productivity.

Sectoral Trends and Drivers

A variety of digital technologies, from 3D printing to the internet of things (IOT), big data, robotics, e-commerce, and finance technology (fintech), are expected to find transformational applications in food and beverage in the next 10 years and beyond, according to the consulted stakeholders. In the short term, participants foresee, for example, the development of new manufacturing and production processes in Indonesia based on 3D printing techniques for innovative bottle and package design, IOT-based product traceability tools for quality control across supply chains, and low-cost automated food and beverage processing machines. In the medium term, example innovations mentioned by participants include the development and deployment of centralized smart production control techniques to maximize energy efficiency and minimize waste, and barcode-based labeling for IOT coupled with big data analytics for product and input traceability. Further, consulted stakeholders discussed the possible emergence of e-commerce platforms for getting consumers closer to producers by removing intermediaries such as retailers and other entities involved in the distribution of goods to consumers. It is anticipated that e-commerce platforms could lower prices for consumers and raise margins for producers. Beyond the next 10 years, stakeholders expect that more advanced technologies will become available in the Indonesian market, including advanced robotic systems enabled by artificial intelligence (AI) to improve production efficiency through real-time decision-making. For the consumer market, the consulted stakeholders discussed the possible emergence of new innovative fintech services to enable and support the deployment of e-commerce platforms in Indonesia.

In terms of changes to regulations, government policies, or institutions, the consulted stakeholders do not envisage any considerable variation in the short term. However, in the 5-year medium term and beyond, participants believe that national authorities and sectoral stakeholders may launch an Industry 4.0 framework and implementation plan tailored specifically to the food and beverage industry, as well as new regulations on environmental impact and waste reduction in line with global sustainability trends.

[7] Business Sweden. 2018. *Industry 4.0 in Indonesia Market Opportunities, Future Trends and Challenges.* Swedish Trade & Invest Council, Stockholm.

From customers, the consulted stakeholders expect a surge in demand for more personalized and healthier products in the next 10 years and beyond. This demand could benefit from more developed e-commerce platforms and fintech tools that could enable personalized food and beverage products to be delivered directly to individuals, rather than sold through retailers. In this regard, participants forecast changes in business models for firms operating in this sector during the next 5 years. In particular, e-commerce platforms and new entrants, including Tokopedia, Bukalapak, and Shopee, are expected to gradually increase their participation in the Indonesian market. Data analytics for gaining insights into customer preferences for customized food and beverage products and marketing activities employing such social media platforms as Instagram and YouTube have already been introduced in the Indonesian market as part of emerging trends in marketing and manufacturers' introduction of ancillary services. To cope with these changes in customer demand, the consulted stakeholders expect the increased use of more efficient and effective information and business management systems by food and beverage manufacturers. In addition, new data-sharing businesses may emerge to help food and beverage manufacturers understand consumer behavior patterns by using fully integrated data with AI and machine-learning applications.

The consulted stakeholders foresee the adoption of more stringent environmental regulations in Indonesia in the medium term, pertaining to the use of pesticides and fertilizers for the production of raw materials. It is likely that local and foreign firms operating in Indonesia will be required to comply with environmental and food safety standards enacted in foreign markets, particularly in Europe and North America, with potential implications for the export of raw materials and finished food and beverage products (Table A2.2).

Table A2.2: Trends and Drivers Identified in Food and Beverage Focus Group Discussions

	Short Term (<5 years)	Medium Term (5–10 years)	Long Term (>10 years)
Changes in technology	**Process innovation:** New 3D printing-based processes for innovative bottle and package design **Process innovation:** Low-cost automated food and beverage processing machines (e.g., lemon-squeezing machine, filtering lemon and seeds) **Product innovation:** Emergence of new organic food and beverage products **Technology strategy:** Digital roadmaps within firms	**Process innovation:** Barcode-based labeling for the internet of things coupled with big data analytics for product and input traceability and quality control **Product delivery innovation:** E-commerce platforms with big data analytics for gathering consumer insights, personalized products, targeted marketing, and removing intermediaries such as retailers **Process innovation:** Centralized smart production control techniques to maximize energy efficiency and minimize waste	**Service innovation:** New innovative fintech services to enable and support the deployment of e-commerce platforms **Process innovation:** Advanced AI-enabled robotic systems to improve production efficiency through real-time decision-making

continued next page

Table A2.2: *Continued*

	Short Term (<5 years)	Medium Term (5–10 years)	Long Term (>10 years)
Changes in regulations, standards, policies, and institutions	**Technology strategy:** Establishment of an Industry 4.0 framework and implementation plan tailored specifically to the food and beverage industry	**Environmental regulations:** More stringent environmental regulations pertaining to the use of pesticides and waste reduction (e.g., maximum residue limits for food production and supermarkets)	**Environmental regulations:** Potential homologation of environmental and food safety standards enacted in foreign markets to gain export access
Changes in customer demand	**New products:** Increasing demand for customized healthy products	**Consumer data-sharing acceptance:** Data gathering about consumer preferences becoming more acceptable in order to provide customized products and targeted marketing	**New products:** Increasing demand for customized healthy products
Other trends and drivers	**E-commerce business models:** Expected increase in new e-commerce services and business models **Social media marketing:** Increased use of social media (e.g., Instagram, Facebook, YouTube) for marketing	**Healthy lifestyle:** Indonesians expected to follow healthier nutrition and lifestyles **Management innovation:** Increased use of more efficient and effective information and business management systems	**National innovation infrastructure:** Sectoral benefits expected from increased government investment in innovation and skills training for the food and beverage industry

Source: Policy Links. 2019. Focus group discussions with industry stakeholders for Supporting Technological Transformation in Indonesia, a project for the Asian Development Bank.

Opportunities for Value Capture Arising from New Technologies

Beyond the trends and drivers mentioned in the previous subsection, the consulted stakeholders were asked to express their views on specific business opportunities enabled by emerging disruptive technologies, particularly in the Indonesian context. Digital technologies are seen by consulted stakeholders as enablers of a variety of new food and beverage products and services. For example, new digital design tools could aid the development of environmentally friendly packaging materials, while growing demand for healthier and more personalized products presents an opportunity to develop data services to provide nutritional data tailored to consumers. Big data analytics are perceived as a fundamental tool to understand consumer insights that could inform the design of new products, services, and targeted marketing campaigns.

In terms of manufacturing process innovations, example opportunities discussed by the consulted stakeholders include the use of robotics to substitute manual operations such as tea-leaf plucking. Furthermore, prospects exist to create business value through the use of machine learning for predictive maintenance and the establishment of end-to-end IOT-based systems for process planning and monitoring. Similarly, new automation systems and tools are expected to minimize material waste and reduce costs. Participants visualize opportunities for leveraging new technologies such as virtual and augmented reality for skills training.

Regarding opportunities for supply chain innovation, IOT-based systems with advanced radio-frequency identification tracking could be deployed to improve the quality control and traceability of raw materials across supply chains, minimizing the distribution of substandard raw materials and enabling more efficient warehousing. Digital tools for integrating local and global supply chains were discussed as innovations that could make local producers more competitive and attractive on the global market.

Innovative product and service delivery methods were discussed by participants. Examples included the use of big data for customer behavior analysis to inform the design of new products and digital data services. Additional opportunities mentioned by participants covered the development of digital platforms for integrating sales channels, as well as delivery drones for shipping products in urban and rural areas, overcoming shortcomings in existing logistical channels and infrastructure (Table A2.3).

Table A2.3: Opportunities for Value Capture Identified in Food and Beverage Focus Group Discussions

Product Innovation	Process Innovation
• Digital design tools for environmentally friendly packaging • Data services in support of customized healthy food and beverage products • Big data analytics to feed customer insights into the design process of new products, services, and targeted marketing	• Low-cost robotics to substitute traditionally manual operations such as tea-leaf plucking • Digital tools to reduce material waste • RFID tracking for components and parts in manufacturing processes • End-to-end IOT-based process monitoring • Machine learning for predictive maintenance • Virtual and augmented reality tools for skills training
Supply Chain Innovation	**Product & Service Delivery Innovation**
• IOT-based systems with RFID tracking to improve the quality control and traceability of raw materials • Digital tools for data exchange and integration between local and global supply chains • Integration of enterprise resource planning systems across supply chains • Robotic applications for warehouse management	• Big data analytics and automatic forecasting to analyze and better understand customer needs • Digital assistance for customer service • Digital platforms to integrate sales channels • Delivery drones for urban and rural areas

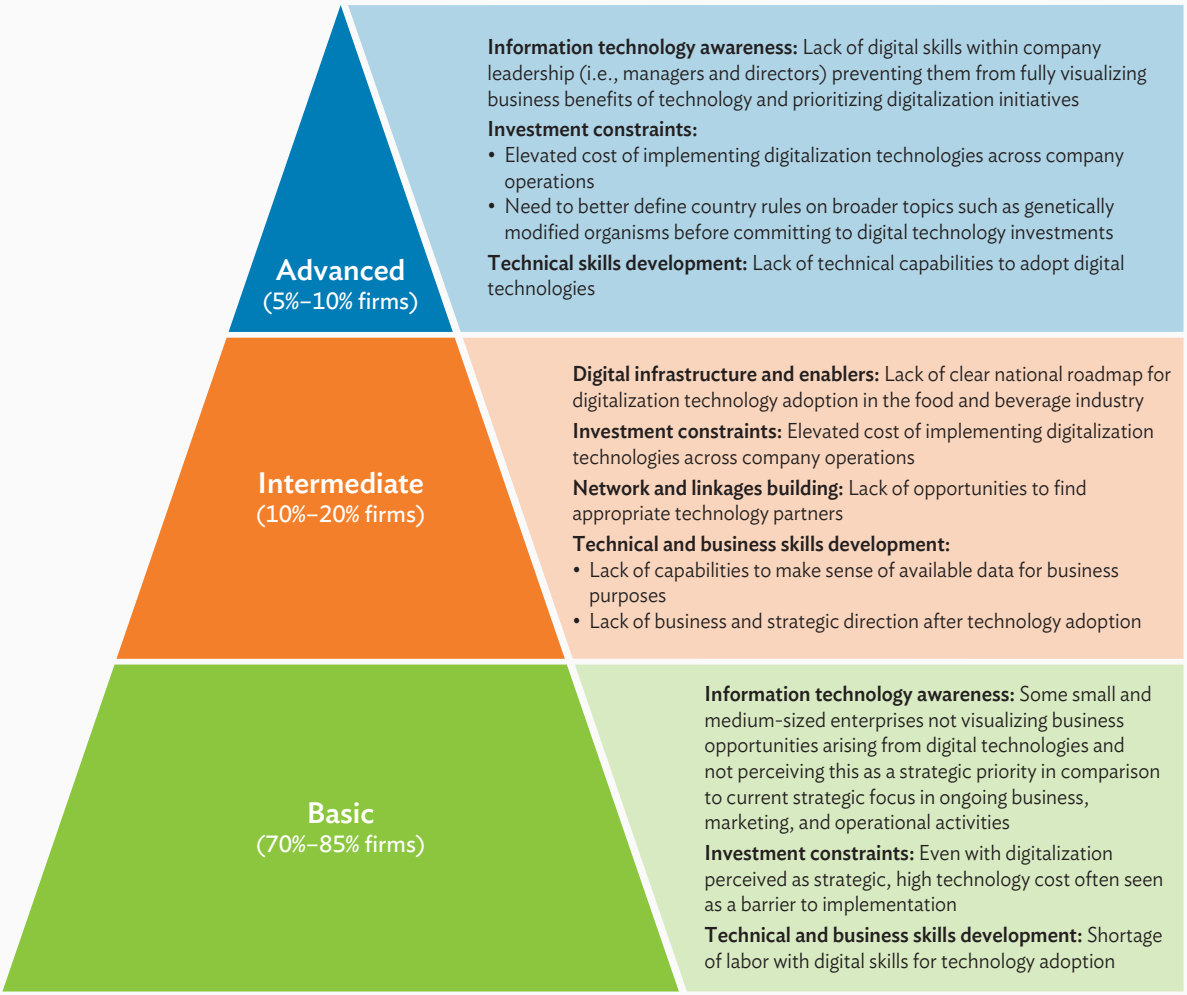
IOT = internet of things, RFID = radio-frequency identification.

Source: Policy Links. 2019. Focus group discussions with industry stakeholders for Supporting Technological Transformation in Indonesia, a project for the Asian Development Bank.

Barriers to Technology Development, Diffusion, and Adoption

Figure A2.2 categorizes the barriers to technology development, diffusion, and adoption stakeholders see confronting distinct types of firms in the food and beverage industry in Indonesia, classified in terms of digital leaders, followers, and firms lagging behind in digitalization.

Figure A2.2: Barriers to Technological Innovation and Adoption in the Food and Beverage Industry

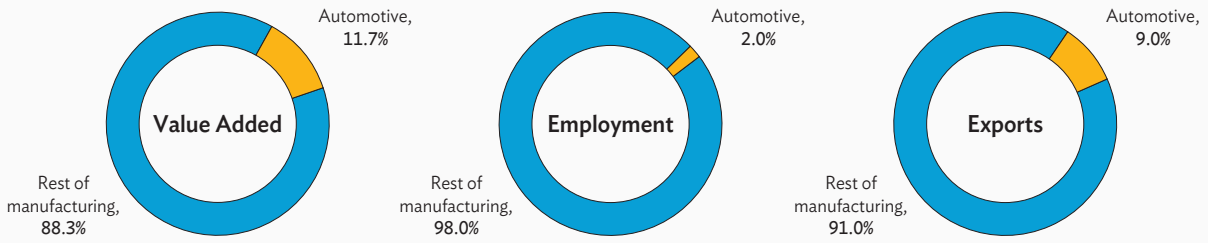


Notes: Advanced firms were actively engaged in innovation and research and development (R&D) with in-house R&D and/or innovation capabilities (e.g., skilled personnel and/or equipment) or purchased R&D and innovation services from external organizations. Intermediate firms were motivated to engage in innovation but lacking resources, though they might have had incipient in-house R&D and innovation capabilities and engaged in minor R&D and/or innovation projects with external organizations. Basic firms lacked resources to engage in innovation and had no in-house R&D and/or innovation capabilities or external R&D and/or innovation projects.

Source: Policy Links. 2019. Focus group discussions with industry stakeholders for Supporting Technological Transformation in Indonesia, a project for the Asian Development Bank.

AUTOMOTIVE

Figure A2.3: Automotive Sector Contributions to Manufacturing



Note: 2015 data.

Sources: World Bank. 2019. *World Integrated Trade Solution*; Badan Pusat Statistik. 2019. *Survey of Micro and Small Manufacturing; Survey of Medium and Large Manufacturing.*

Overview[8]

- Indonesia accounts for one-third of annual car sales in ASEAN, followed by Thailand. Indeed, with annual production of almost 2 million four-wheelers and 6 million two-wheelers, the Indonesian automotive industry is the second largest in ASEAN in terms of output, behind Thailand.
- Most of Indonesia's automotive industry is located near Jakarta, where infrastructure is relatively well developed, providing good access to electricity and nearby seaports.
- Major multinational corporations such as Toyota, Honda, and Mitsubishi have established plants in Indonesia, and Indonesia's automotive industry is highly dependent on foreign direct investment, particularly from Japan. Toyota supplies over half of domestic car sales.
- Low-cost green cars now contribute nearly 25% to domestic car sales.
- Indonesia's largest car export markets are Japan, the Philippines, Saudi Arabia, and Thailand.
- In 2017, Indonesia's installed car production capacity stood at 2.2 million units per year.

Opportunities

- Domestic market demand for motor vehicles is expected to increase, given currently low car ownership per capita and a rapidly growing middle class.
- The automotive industry will benefit from expanded roads and transportability following large investments in infrastructure across the country.

[8] Indonesia-Investments. 2018. *Automotive Manufacturing Industry Indonesia*; Business Sweden. 2018. *Industry 4.0 in Indonesia*; Association of Indonesia Automotive Industries (GAIKINDO). 2016. *Indonesian Automobile Industry Data*; Aswicahyono et al. 2018. *A Case of the Automotive Industry in Indonesia.*

Challenges

- Productivity remains low in Indonesia in comparison with neighboring countries, which diverts original equipment manufacturer investment to other countries.
- The domestic production of components remains low, and automotive manufacturing is still dependent on imports of components and parts.
- Limitations on increasing car exports include noncompliance with international safety and technology standards. For instance, the Indonesian automotive industry is still at the Euro 2 standard for reducing carbon monoxide emissions, while other nations are already at Euro 5.[9]

Government Policy[10]

- The Government of Indonesia has set ambitious targets for the automotive industry to become a regional exporter that can overtake Thailand and become a leading producer of electric vehicles.
- To achieve this goal, the government aims to increase the adoption of robotics and human–machine interface technologies, as well as promote the production of components and parts to meet domestic demand for them.
- In 2013, the government offered tax incentives to low-cost green car manufacturers who met its fuel efficiency targets.
- In 2015, the central bank of Indonesia revised down-payment requirements for the purchase of a car, reducing from 30% to 25% the minimum down payment for consumers who use a loan from a financial institution to purchase a passenger car. An estimated 65% of car purchases in Indonesia are made with a loan.
- While Indonesia has well-developed multipurpose and sport-utility vehicle lines, the domestic sedan industry is underdeveloped, despite 80% of drivers globally driving sedans. This is because the government taxes sedans more heavily than other types of vehicles.

Sectoral Trends and Drivers

Consulted stakeholders expect the industry to undergo profound technological change in the short and medium term with the advent of new vehicles with low carbon emissions, including plug-in hybrid cars; electric vehicles; and vehicles powered by biofuel, fuel cells, and flexible-fuel engines. At factory level, increased automation is expected through IOT platforms for production processes. The implementation of blockchain payments for trusted suppliers of parts, components, and subsystems is also possible. AI-predictive maintenance solutions are expected to emerge.

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[9] Indonesia-Investments. 2018. *Automotive Manufacturing Industry Indonesia*.

[10] Indonesia-Investments. 2018. *Automotive Manufacturing Industry Indonesia*; Business Sweden. 2018. *Industry 4.0 in Indonesia*.

Against this backdrop, new start-up companies with nontraditional capabilities such as cloud computing, big data analytics, and IOT know-how may enter the automotive industry in Indonesia. In the medium term, technological changes are expected in terms of efficiency gains for battery-powered, plug-in hybrid, and fuel-cell vehicles, such as through the development of solid-state batteries. There may also be expansion in new mobility services such as connected cars and car-sharing services. Beyond the next 10 years, changes in technology could include the introduction of self-driving cars and hydrogen vehicles. However, the deployment of these technologies is likely to require the development of suitable infrastructure in Indonesia, because autonomous cars may not be able to coexist with bicycles and motorcycles, needing separate lanes.

New government policies and regulations are expected by local stakeholders in the short term for regulating electric vehicles and creating the required infrastructure such as charging stations. Additionally, automotive stakeholders envisage changes to import and export regulations for manufacturing companies, together with cost reductions for technology. Further, the consulted stakeholders foresee changes in environmental tax incentives for purchasing or using low-carbon vehicles, as well as new regulations for automotive manufacturing supply chain traceability and quality standards for car production. In the next 10 years and beyond, the Government of Indonesia may seek to align vehicle environmental and safety regulations with best global standards, including alignment with European emission standards.

In terms of customer demand, a push for smarter vehicles using information and communication technology (ICT) devices and smartphone connectivity is expected in the next 5 years. Client desire for higher car customization is anticipated, including potential upgrades and model changes, allowing car owners to forego buying an entirely new car by customizing and upgrading their old car to acquire the features of new models. In the next 10 years and beyond, the consulted stakeholders consider it possible that car ownership will become less attractive to consumers. Customer demand may increasingly shift from owning to renting and on-demand vehicle services such as Grab and Go Car, including the emergence of self-driving vehicles and related infrastructure. In sum, the consulted stakeholders see business models in the automotive industry evolving as new entrants emerge, particularly in downstream activities, through the development and offering of new smart mobility services (Table A2.4).

Opportunities for Value Capture Arising from New Technologies

Consulted stakeholders perceive opportunities for new technology development in Indonesia in support of key emerging product innovations such as hybrid, electric, and other low-carbon vehicles. These opportunities could include, for example, the introduction of IOT platforms for car control with smartphones, electric vehicle charging stations, and autonomous driving technologies using AI for vehicle automation. In line with the discussion of trends and drivers, the consulted stakeholders visualize opportunities for new business model development around service innovations, including car-sharing services; car connectivity services with insurance companies, police, and dealerships' and financial services for buying or leasing electric or plug-in hybrid vehicles. One example highlighted during the FGD session was the "E-pallet," which is a mobility ecosystem concept using electronic vehicles introduced by Toyota Motors.

Table A2.4: Trends and Drivers Identified in Automotive Industry Focus Group Discussions

	Short Term (<5 years)	Medium Term (5–10 years)	Long Term (>10 years)
Changes in technology	• **Product trends:** Introduction of electric, hybrid, and other vehicles with low carbon emissions • Process trends • Predictive maintenance using AI • IOT-connected production lines • **Supply chain trends:** Blockchain payments for trusted suppliers	• **Product trends:** Introduction of fuel cell, biofuel, ethanol, and flexible-fuel engines • **Service trends:** Connected cars and increased car sharing • **Process trends:** Advanced smart robotics in production • **Technology infrastructure:** Charging and refueling networks for electric and other low-carbon vehicles	• **Product trends:** Widespread adoption of electric and hydrogen vehicles • **Product trends:** Autonomous vehicle testing and adoption • **Technology infrastructure:** Roads adapted for autonomous vehicles
Changes in regulations, standards, policies, and institutions	• **Electric vehicle manufacturing:** New regulations for electric vehicle manufacturing and use, including associated infrastructure • **Environmental regulations:** Environmental tax incentives for purchasing or using vehicles with low carbon emissions	• **Environmental regulations:** Adoption of stricter environmental emission standards for vehicles in Indonesia	• **Regulations:** A ban on vehicles with internal combustion engines • **Local content:** Refinement of import and export regulations for firms and increased local content requirements
Changes in customer demand	• **Product trends:** Demand for more user-friendly vehicles with more digital features and connectivity • **Product trends:** Demand for improved safety and comfort in vehicles • **Service trends:** Shorter product delivery times and improved order traceability	• **Service trends:** Customers shifting from car ownership to rental and on-demand vehicle services • **Product and service trends:** Higher vehicle customization according to individual customer specifications	• **Service trends:** Emergence of new autonomous car services on demand
Other trends and drivers	• **Business models:** New business models built around low-carbon vehicles and car sharing	• **Competition:** New entrants with strong ICT technical know-how, not necessarily from the automotive industry, perhaps merging with ICT	• **Competitiveness:** Higher labor cost in Indonesian automotive manufacturing

AI = artificial intelligence, ICT = information and communication technology, IOT = internet of things.

Source: Policy Links. 2019. Focus group discussions with industry stakeholders for Supporting Technological Transformation in Indonesia, a project for the Asian Development Bank.

Opportunities discussed for new process innovation were mainly about improvements in manufacturing efficiency. Examples included the simplification of processes for assembling components with AI robotics; improved quality, precision, and accuracy of production processes through advanced computer software and robotic systems; and new predictive maintenance systems to reduce machine downtime. Automated guided vehicles were discussed as a new process innovation opportunity for delivering goods more efficiently and effectively inside factories.

New supply chain innovations perceived by local stakeholders include big data used for quality verification and traceability, real-time supply chain monitoring and logistics to reduce excess stock inventory, cutting out middlemen, and achieving efficiency improvements. An opportunity for establishing integrated manufacturing zones was discussed. In theory, this could connect tier 1, tier 2, and tier 3 supply chain firms through ICT platforms.

Additional opportunities discussed by the consulted stakeholders included new approaches to product and service delivery based on the use of big data analytics to better understand customer needs. For consumers, discussions mentioned on-demand mobile platforms including IOT-based smart apps to order and customize spare parts and components and to request real-time maintenance services. For industry, data management and sharing communities for better understanding consumer behavior, needs, and expectations were identified as potential opportunities for product and service delivery innovation (Table A2.5).

Table A2.5: Opportunities for Value Capture Identified in Automotive Industry Focus Group Discussions

Product Innovation	Process Innovation
• Electric, hybrid, and autonomous vehicles • IOT platforms for vehicle connectivity with insurance providers, policy makers, and dealerships • Electric vehicle charging stations and other infrastructure • Car-sharing services • Financial services for buying or leasing vehicles	• AI for process simplification and quality control • RFID and smart robotic systems for productivity and quality improvement • Predictive maintenance to minimize equipment downtime • Automated guided vehicles within factories
Supply Chain Innovation	**Product & Service Delivery Innovation**
• Big data for quality verification and traceability • Real-time supply chain monitoring to reduce inventory stock • Real-time logistics for efficiency improvement • Integrated manufacturing zones, connecting tier 1, 2, and 3 firms through ICT platforms	• Big data and AI to analyze customer insights • Data management and sharing communities for understanding consumer behavior • IOT-based platforms to order and customize products and services such as real-time maintenance

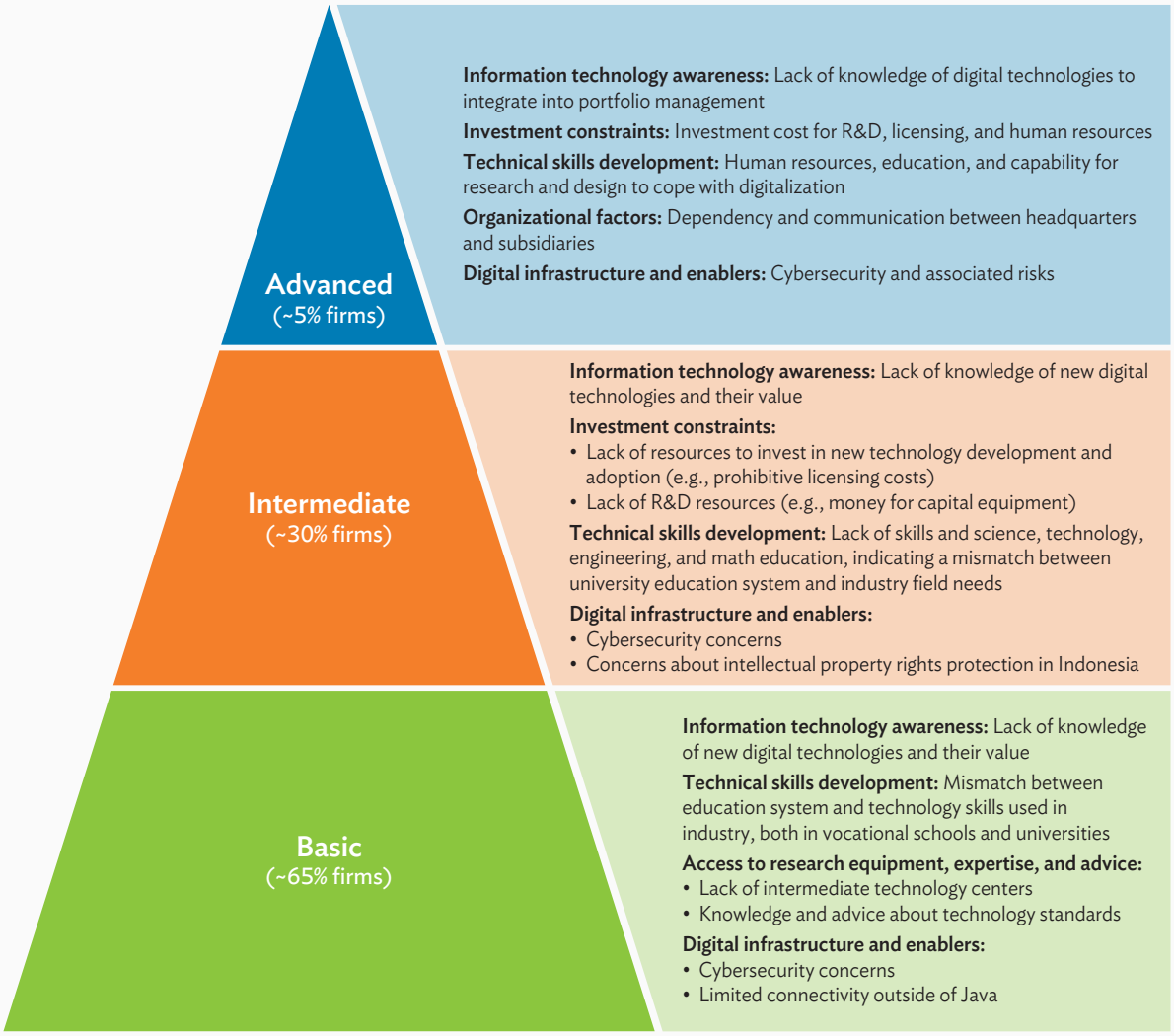
AI = artificial intelligence, RFID = radio-frequency identification.

Source: Policy Links. 2019. Focus group discussions with industry stakeholders for Supporting Technological Transformation in Indonesia, a project for the Asian Development Bank.

Barriers to Technology Development, Diffusion, and Adoption

Figure A2.4 categorizes the barriers to technology development, diffusion, and adoption stakeholders see confronting distinct types of firm in the automotive industry in Indonesia, classified in terms of digital leaders, followers, and firms lagging behind in digitalization.

Figure A2.4: Barriers to Technological Innovation and Adoption in the Automotive Industry

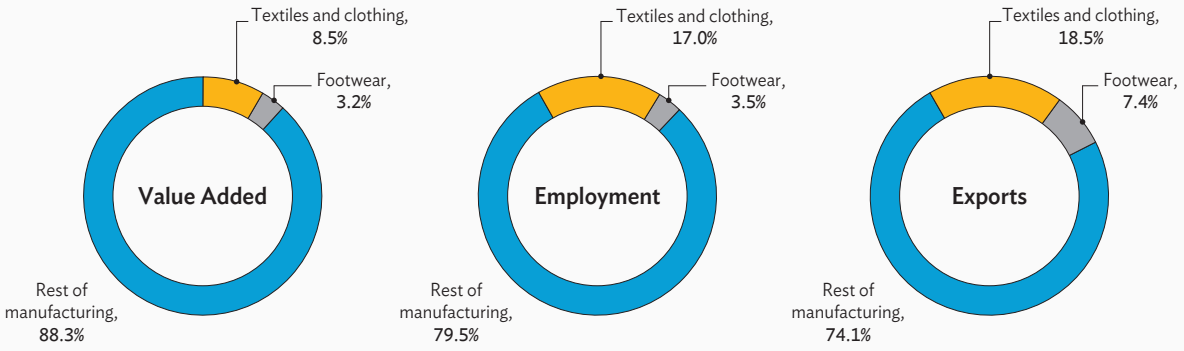


Notes: Advanced firms were actively engaged in innovation and research and development (R&D) with in-house R&D and/or innovation capabilities (e.g., skilled personnel and/or equipment) or purchased R&D and innovation services from external organizations. Intermediate firms were motivated to engage in innovation but lacking resources, though they might have had incipient in-house R&D and innovation capabilities and engaged in minor R&D and/or innovation projects with external organizations. Basic firms lacked resources to engage in innovation and had no in-house R&D and/or innovation capabilities or external R&D and/or innovation projects.

Source: Policy Links. 2019. Focus group discussions with industry stakeholders for Supporting Technological Transformation in Indonesia, a project for the Asian Development Bank.

TEXTILES, CLOTHING, AND FOOTWEAR

Figure A2.5: Textile, Clothing, and Footwear Contributions to Manufacturing



Note: 2015 data.

Sources: World Bank. 2019. *World Integrated Trade Solution*; Badan Pusat Statistik. 2019. *Survey of Micro and Small Manufacturing; Survey of Medium and Large Manufacturing.*

Overview

- Indonesia is one of the top 10 largest textile-producing countries in the world. The textile and apparel industry is also one of Indonesia's oldest industries, providing significant employment because it is labor intensive.[11]
- Domestic investment accounted for 61.4% of total investment in the textile industry in 2017, which local SMEs still dominate. Over 96% of textile and clothing firms in Indonesia are domestically owned by private shareholders. Only 0.5% of textile firms have at least 10% of foreign ownership, as do only 5.3% clothing firms.[12]
- Indonesia is the world's fifth largest footwear exporter, with 3.5% of world market share. One-third of production was exported in 2016, earning $4.7 billion. The United States and the European Union are the largest markets for Indonesia's footwear exports, and the PRC is the largest supplier of footwear inputs.
- Indonesia's footwear exports consist mostly of finished leather products, representing half of footwear exports, while Indonesia's footwear imports are mostly shoe components.[13]

[11] Fair Wear Foundation. 2018. *Indonesia Country Study 2018*.

[12] World Bank. 2014. *Enterprise Surveys: Indonesia.* Washington, DC: World Bank.

[13] Indonesia-Investments. 2017. *Shoes & Footwear: Indonesia the World's 5th-Largest Exporter*.

- The industry invested $150 million in 2016, of which 96% was foreign direct investment, coming mostly from the PRC; the Republic of Korea; and Taipei,China. Growing PRC investment in Indonesia's footwear industry can be explained by rising labor costs in the PRC, which encourages delocalization to ASEAN, notably Cambodia, Indonesia, and Viet Nam.
- The footwear industry is concentrated on Java Island.

Opportunities[14]

- Indonesia has a large domestic market, with a population of over 250 million. Meanwhile, Indonesian footwear consumption was only 2.3 pairs per capita in 2016, lower than the world average of 2.5.
- Relocation of footwear firms away from the PRC, where production costs are increasing, presents an opportunity for Indonesia if it manages to compete with Viet Nam to capture market share from the PRC.

Challenges[15]

- Rising labor costs, particularly in West Java and Jakarta, are incentivizing firms to increase automation to reduce the number of workers or to relocate their factories to cheaper provinces or other countries. Gas and electricity prices in Indonesia are some of the highest in textile-producing countries, which undermines the competitiveness of domestic firms.
- Aging machinery and equipment is lowering productivity and efficiency, particularly in traditional and small-scale manufacturers. Currently, 30% of textile factories in Indonesia use equipment that is over 25 years old.
- There is rising competition from other ASEAN countries such as Cambodia and Viet Nam. In addition, illegal textile imports from the PRC are damaging the Indonesian textile industry. In 2017, some 310,000 tons of textiles were illegally imported from the PRC into Indonesia.
- The Indonesian footwear industry still depends heavily on foreign brands, with relatively low development of domestic brands.
- The upstream footwear industry is still limited.

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[14] Indonesia-Investments. 2017. *Shoes & Footwear: Indonesia the World's 5th-Largest Exporter*; Global Business Guide Indonesia. 2014. *Indonesia's Footwear Industry—Challenging Opportunities*.

[15] Global Business Guide Indonesia. 2013. *Indonesia's Electronics and Home Appliances Sector*; Indonesian Footwear Association. 2017. *Indonesian Footwear Industry Country Report 2017.* Presented at the 36th International Footwear Conference 2017 of the Confederation of International Footwear Associations at Dhaka; Business Sweden. 2018. *Industry 4.0 in Indonesia Market Opportunities, Future Trends and Challenges.* Swedish Trade & Invest Council, Stockholm.

Government Support

- Government strategy for the industry emphasizes building upstream capabilities in high-quality materials, improving cost competitiveness through higher labor productivity, functional clothing production and innovation, and scaling up to meet demand from domestic and export markets.[16]
- Tougher law enforcement is required to stem illegal textile imports and to improve skills and capacity to adopt new technologies such as 3D printing, sensor-based waste control systems, and digital prototyping.
- The Indonesia–Australia Comprehensive Economic Partnership Agreement will waive import duties on a number of Indonesian products, including clothing and textiles. Australian import duty on Indonesia's textiles previously stood at 10%–20%. The Indonesian government is currently pursuing similar agreements with the United States and the European Union to make Indonesian textile products more competitive.[17]
- The footwear industry is one of the 10 industries prioritized by the Ministry of Industry in various strategic national industrial development plans.
- In 2016, the government introduced tax incentives for labor-intensive industries, including the footwear industry.

Sectoral Trends and Drivers

Textiles, clothing, and footwear could be considered less technologically intensive than some of the other sectors discussed in this section. As such, a key strategic consideration for the location of these sectors has traditionally been the availability of low-cost labor in low- or middle-income countries, rather than high technological innovation capability. However, changes in technology could have significant implications for these industries in Indonesia if firms are unable to upgrade their current operations to meet international best practices, which could undermine productivity and market share for Indonesian firms, as expressed by consulted stakeholders. In addition, participants expressed concern that new automation solutions, if adopted in Indonesia, would cause job losses. In the short term, example technological trends anticipated by the consulted stakeholders include AI and IOT applications for production efficiency gains and incremental automation of traditionally manual or semi-manual manufacturing and production processes. In the next 10 years and beyond, participants foresee the deployment of low-cost AI, IOT, and robotics, which could encourage their widespread adoption for improved quality, productivity, waste reduction, and energy efficiency in textile, clothing, and footwear manufacturing.

[16] Business Sweden. 2018. *Industry 4.0 in Indonesia.*

[17] Global Business Guide Indonesia. 2013. *Indonesia's Electronics and Home Appliances Sector.*

Beyond technological trends, the consulted stakeholders visualize changes in government policies that could affect the sector in the short term. In particular, fiscal incentives currently available to new entrants to the Indonesian market could be made available to long-standing companies already operating in the country. Participants would expect stronger regulatory certainty to be achieved through socialization of government sectoral regulations in the short and medium term, complemented by the development of clearer interministerial coordination mechanisms for sector policy development and support. The industrial stakeholders consulted during the FGD believe that improved communication strategies for new government regulations could enhance the business environment, and they therefore expect this to have an impact in the short term. There was also mention of potential raw material import regulations to favor local consumption of, for example, leather. Similarly, participants believe export programs comparable to the European Union–Viet Nam trade and investment agreement could be developed in Indonesia in the short or medium term to improve productivity.

In the opinion of consulted stakeholders, textiles, clothing, and footwear are relatively stable industries in terms of customer demand trends, compared with other sectors. In any case, some changes in customer demand preferences are expected during the next 5–10 years and beyond, mostly in terms of product value and quality, as well as greater product customization. Additionally, participants see e-commerce platforms as fundamental developments in the future for the sector, as traditional retailers are expected to be less prominent in the medium and long term.

Beyond these trends, the consulted stakeholders foresee two major trends affecting the business models of firms during the next 5–10 years and beyond: a push toward reducing supply chain intermediaries and increasing local sourcing of raw materials, and higher sustainability standards and regulations starting to be enforced in Indonesia, which would have implications for how firms operate and ensure that their cost margins remain competitive (Table A2.6).

Opportunities for Value Capture Arising from New Technologies

Although textiles, clothing, and footwear are not traditionally considered technologically sophisticated, a number of opportunities for new product innovations in Indonesia were discussed by consulted stakeholders: the addition of embedded digital components or features to clothing or footwear such as digitalized shoes with health condition monitoring, or new clothing designs with digital features monitoring heartbeat rates. Additional examples mentioned by participants include shoes with automatic size adjustment for children as they grow, thereby reducing the frequency of new shoe purchases. For industrial applications, new opportunities discussed included clothing models for virtual 3D stitching modeling to test and sample distinct approaches to reduce production time.

In terms of opportunities for new process innovation in Indonesia, consulted stakeholders visualize either adopting new digitally enabled machinery or retrofitting existing systems to achieve higher production efficiency and perhaps labor cost reduction through digital technology adoption. Participants foresee opportunities for local firms and innovators to develop digital tools that could enable more flexible and scalable processes in textiles, clothing, and footwear to improve productivity.

Table A2.6: Trends and Drivers Identified in Textile, Clothing, and Footwear Focus Group Discussions

	Short Term (<5 years)	Medium Term (5–10 years)	Long Term (>10 years)
Changes in technology	• **Process innovation:** Incremental automation of traditionally manual or semi-manual manufacturing and production processes	• **Process innovation:** AI and IOT applications for production efficiency gains	• **Process innovation:** Widespread deployment of low-cost AI, IOT, and robotics for improved quality, productivity, waste reduction, and energy efficiency
Changes in regulations, standards, policies, and/or institutions	• **Fiscal incentives:** Fiscal incentives available to new entrants perhaps becoming available to existing firms • **Government coordination:** Clearer interministerial coordination mechanisms expected for sector policy development and support • **Regulatory consensus:** Stronger regulatory certainty perhaps achieved through socialization of government sectoral regulations • **Government communication:** Improved communication strategies for new government regulations perhaps enhancing the business environment	• **Local content:** Raw material import regulations expected to favor local consumption of, for example, leather • **Export incentives:** Export programs comparable to the European Union–Viet Nam trade and investment agreement could be developed in Indonesia in the short or medium term to improve sector productivity • **Technology support programs:** Sector policy for technological upgrading expected as part of the Industry 4.0 strategy	• **Sector strategy:** Coherent sector policy expected for improving productivity, as with the Viet Nam case study • **Environmental regulations:** Higher sustainability standards and regulations starting to be enforced in Indonesia
Changes in customer demand	• **Higher product standards:** Expected customer push for low-cost and high-quality personalized products	• **Product delivery:** E-commerce platforms expected to become preferred shopping method	• **Product customization:** Demand expected to switch into full product customization
Other trends and drivers	• **New business models:** Reducing supply chain intermediaries and increasing local sourcing of raw materials	• **Labor work hours:** Labor work hours expected to increase to match competitor countries • **Business environment:** Government-led effort to improve business environment expected	• **Skills development strategy:** Government roadmap expected for skills training to support research and development in textiles and footwear

AI = artificial intelligence, IOT = internet of things.

Source: Policy Links. 2019. Focus group discussions with industry stakeholders for Supporting Technological Transformation in Indonesia, a project for the Asian Development Bank.

Regarding supply chain management innovations, one key idea was brought forward by consulted stakeholders: a collaborative ecosystem or network including key industry players to support technology adoption, aiming to improve the competitiveness and productivity of the industry as a whole by, for example, shortening production lead times. Participants believe that the wider adoption of digital technologies across the industry could help companies to implement just-in-time production principles, among other improvements.

Product and service delivery innovation was an additional area discussed by FGD participants. In particular, e-commerce platforms are seen as the opportunity with the highest disruption potential in the sector, as they could enable current suppliers to become clothing brands in their own right, selling products and services directly to customers through an e-commerce environment, or simply reaching larger global markets. Digital e-commerce platforms could enable shorter lead times for order delivery by removing intermediaries between clients and producers. Additionally, the adoption of IOT-based tracking systems for environmental footprint monitoring was discussed as an opportunity to develop more eco-friendly products (Table A2.7).

Table A2.7: Opportunities for Value Capture Identified in Textile, Clothing, and Footwear Focus Group Discussions

Product Innovation	Process Innovation
• New products with digital features such as heart rate and distance monitoring • Shoes with automatic size adjustment for children • Virtual 3D modeling for optimization of industrial processes (e.g., stitching models for clothing)	• Digitally enabled machinery, new or retrofitted, for higher production efficiency and labor cost reduction • Digital tools for more flexible and scalable processes
Supply Chain Innovation	**Product & Service Delivery Innovation**
• Collaborative ecosystem and network including key players to support technology adoption for industry competitiveness and productivity improvement	• E-commerce platforms for direct communication between producers and customers, growth of local producers into own clothing brands, and reduced order delivery lead times • IOT-based tracking systems for environmental footprint monitoring

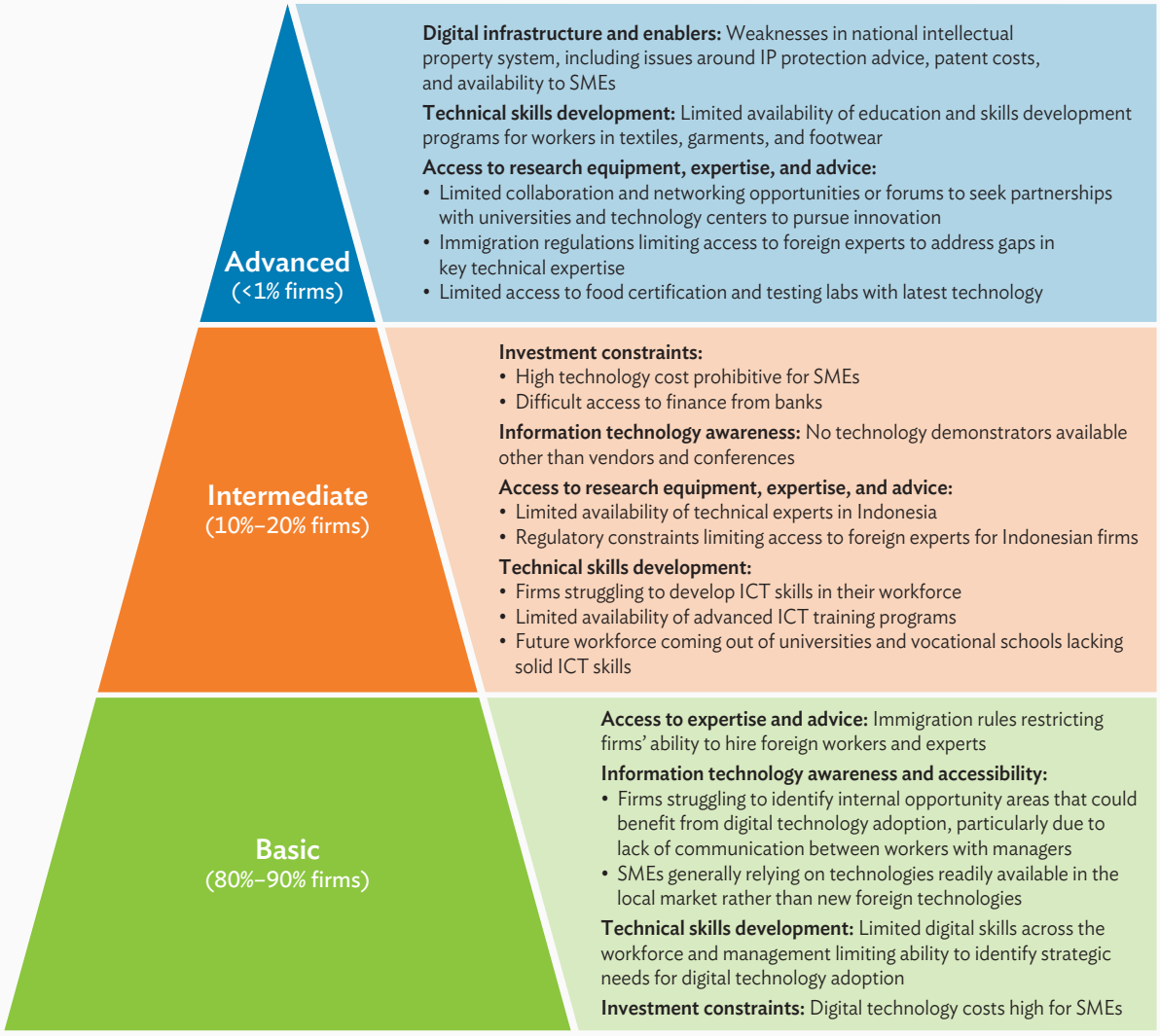
IOT = internet of things.

Source: Policy Links. 2019. Focus group discussions with industry stakeholders for Supporting Technological Transformation in Indonesia, a project for the Asian Development Bank.

Barriers to Technology Development, Diffusion, and Adoption

Figure A2.6 categorizes the barriers to technology development, diffusion, and adoption stakeholders see confronting distinct types of firm in the textiles, clothing, and footwear industry in Indonesia, classified in terms of digital leaders, followers, and firms lagging behind in digitalization.

Figure A2.6: Barriers to Technological Innovation and Adoption in Textiles, Clothing, and Footwear



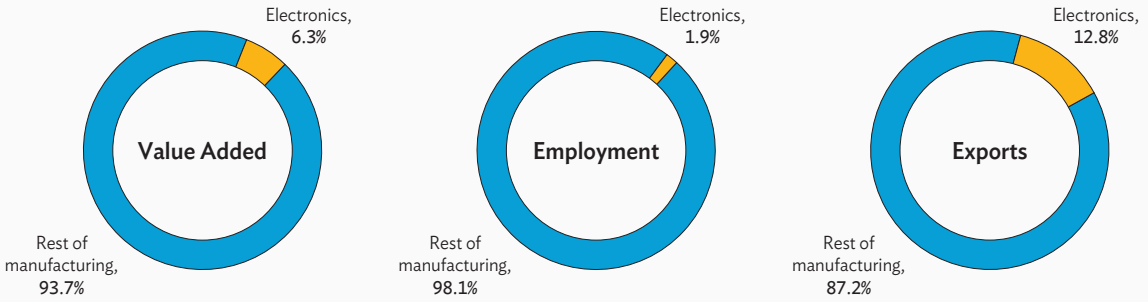
ICT = information and communication technology, IP = intellectual property, SMEs = small and medium-sized enterprises.

Note: Advanced firms were actively engaged in innovation and research and development (R&D) with in-house R&D and/or innovation capabilities (e.g., skilled personnel and/or equipment) or purchased R&D and innovation services from external organizations. Intermediate firms were motivated to engage in innovation but lacking resources, though they might have had incipient in-house R&D and innovation capabilities and engaged in minor R&D and/or innovation projects with external organizations. Basic firms lacked resources to engage in innovation and had no in-house R&D and/or innovation capabilities or external R&D and/or innovation projects.

Source: Policy Links. 2019. Focus group discussions with industry stakeholders for Supporting Technological Transformation in Indonesia, a project for the Asian Development Bank.

ELECTRONICS

Figure A2.7: Electronics Contributions to Manufacturing



Note: 2015 data.

Sources: World Bank. 2019. *World Integrated Trade Solution*; Badan Pusat Statistik. 2019. *Survey of Micro and Small Manufacturing; Survey of Medium and Large Manufacturing.*

Overview[18]

- The electronics and electrical appliances industry in Indonesia specializes mostly in producing consumer electronics, its televisions capturing the largest share of domestic sales with a third of the market. Important products include refrigerators and other electrical appliances such as air-conditioners and washing machines.
- Several multinational corporations, notably Sharp and Siemens, have established production facilities in Indonesia. International brands dominate higher-end digital electronics, such as LCD televisions, air-conditioning units, and refrigerators, often through joint ventures with local manufacturers, which mainly assemble imported components into products for sale at home and abroad. The brands LG, Panasonic, Samsung, Sony, and Toshiba are well established throughout the country, distributed through both modern and traditional retail networks.
- Domestic firms are highly competitive in the domestic market with their low- to mid-range technology, the goods being mostly home appliances like irons, rice cookers, gas stoves, and fans.
- Indonesia benefited from the relocation of electronics manufacturing from Japan; the Republic of Korea; Singapore; and Taipei,China following the appreciation of their currencies after the Plaza Accord in 1985.

[18] Global Business Guide Indonesia. 2013. *Indonesia's Electronics and Home Appliances Sector*; E. A. San Andres. 2016. *Manufacturing of Consumer Electronic Appliances in Indonesia*.

Government policy[19]

- The government aims to encourage electronics production and make domestic firms more competitive through various policy measures: attracting global manufacturers with high value added and creating a highly skilled and innovative workforce.

Opportunities

- Indonesia's rapidly growing middle class will foster demand in electronic products with its rising disposable income.
- In addition, having achieved almost 2 decades of economic growth, Indonesia is projected to become one of the largest economies in the world by 2030.

Challenges[20]

- Most domestic firms cannot compete with foreign companies with only limited public support for research and development and for design and development.
- Domestic electronics production suffers from high import duties on raw materials, in contrast to zero tariffs for finished goods from other ASEAN countries, some of which can produce electronics goods more competitively than Indonesia.
- The electronics industry suffers from rising production costs as labor productivity stagnates—a result of a sharp increase in minimum wages following strong political pressure from trade unions, as well as rigid employment policies that make it costly to lay off staff. As a consequence, some companies have moved their production facilities out of western Java to central and eastern Java, or other Islands, where minimum wages are lower and land is cheaper.
- Despite a rising middle class, sales of domestically produced electronics goods, in particular LED televisions, have slowed because of weak domestic purchasing power.

Sectoral Trends and Drivers

Technological change in the electronics industry is seen as the main driver behind digital transformation in most other industrial sectors. As such, consulted stakeholders foresee a wide range of new technological applications that could have a significant impact in Indonesia in the coming years. In the short term, for example, the white goods segment, or larger home appliances like refrigerators, oven, and air-conditioners, is expected to undergo significant transformation as it develops new products, including smart consumer appliances incorporating the use of cloud computing, IOT, and basic AI features. In addition, data-based services are expected to emerge from customer data collected from these devices.

[19] Business Sweden. 2018. *Industry 4.0 in Indonesia.*

[20] Business Sweden. 2018. *Industry 4.0 in Indonesia*; Global Business Guide Indonesia. 2013. *Indonesia's Electronics and Home Appliances Sector*; Indonesia-Investments. 2017. *Indonesia's Electronics Industry Plagued by Weak Purchasing Power*.

In terms of product customization, broader application of 3D printing in the consumer and industrial markets is expected within the next 10 years. Efficiency improvements in communication technologies such as radio frequency and wireless transmission, fiber optics, and stable 4G connectivity for smartphones are expected in the short term, allowing faster data communication across devices. This, combined with increased computing power, will enable the widespread use of big data applications.

Beyond consumer electronics, short-term technological changes discussed by consulted stakeholders include efficiency improvements and cost reductions for solar panel technologies and smart meters, which will enable the distributed microgeneration of electricity by households and industrial users off the traditional power grid. Additional developments related to low-carbon technology involve enabling infrastructure for key products from other prominent sectors in Indonesia such as charging stations for electric vehicles, which are among the most important technological innovations transforming the automotive industry worldwide. In this regard, Perusahaan Listrik Negara, the state power company in Indonesia, has already begun installing charging stations for electric vehicles across the country. Consulted stakeholders perceive this as an opportunity to deploy renewable energy generation and smart grid technologies, as they anticipate that electric vehicles will increase demand for electricity (and the electrification ratio in Indonesia could increase to as high as 95.0% from 92.8% in 2017).[21] In the medium term, the most important technological trend discussed by participants is the prospect of broader adoption of AI in consumer electronics. Beyond the next 10 years, expected changes in technology may include the emergence of IOT platforms for wireless battery charging, wider use of solar panels in home applications, and virtual reality and holographic applications for consumer electronics and education.

Technological trends are expected to drive regulatory changes related to safety and environmental compliance, in addition to customer protection. In the short term, participants discussed the potential for new policies to regulate cross-sectoral products such as electric vehicles and associated infrastructure. In the next 10 years and beyond, changes in policy could include the introduction of 3R directives to reduce, reuse, and recycle to minimize industrial waste in electronics manufacturing. Further, regulations aiming to provide a clear set of rules for the adoption of communication standards such as 4G networks are expected. Alternative regulations discussed by participants relate to industrial policy, notably the potential modification of local content rules for electronics and other manufactures, though this was perceived as being less likely.

Additional sectoral trends discussed by consulted stakeholders include the potential for developing new business models based on smart devices, including data services, as part of their offering, and the impact of expected labor wage increments in Indonesia, which were estimated by some participants at 8%–10% per year (Table A2.8).

[21] The 95.0% estimate is the opinion of consulted stakeholders, while the 2019 target for the Government of Indonesia is 99.9%, according to Tokyo Electric Power Services Company Jakarta.

Table A2.8: Trends and Drivers in Electronics Focus Group Discussions

	Short Term (<5 years)	Medium Term (5–10 years)	Long Term (>10 years)
Changes in technology	• **Product trends:** Wider adoption of solar panel technology and smart meters • **Product trends:** Smart consumer appliances incorporating cloud computing, IOT, and basic AI features • **Service trends:** Services for consumer electronics using big data • **Technology infrastructure:** Implementation of electric vehicle charging infrastructure • **Technology infrastructure:** Efficiency improvements in communication technologies such as radio frequency and wireless transmission, fiber optics, and 4G mobile network connectivity	• **Product trends:** Broader availability of AI features in consumer electronics • **Technology infrastructure:** Electric cars perhaps increasing electricity consumption needs in the country • **Process trends:** 3D printing for product customization in consumer and industrial markets	• **Product trends:** IOT platforms for wireless battery charging • **Product trends:** Generalized use of solar panels and other green technologies for energy generation, distribution, and use • **Product trends:** Virtual reality and holographic applications for consumer electronics, notably televisions, and education • **Technology infrastructure:** 5G mobile communication networks
Changes in regulations, standards, policies, and institutions	• **Communications technology regulations:** Aimed at providing a clear set of rules for the adoption of communication standards such as 4G networks	• **Industrial strategy:** Modification of local content rules for the electronics sector • **Electric vehicle deployment:** Regulations for the establishment of electric vehicle infrastructure and adoption incentives	• **Environmental regulations:** Introduction of 3R directives to reduce, reuse, and recycle, toward minimizing industrial waste in electronics manufacturing
Changes in customer demand	• **Data services:** Higher demand for data services attached to electronic products	• **Personalized products:** Higher demand for customized electronic products	
Other trends and drivers		• **Business models:** New models based on smart devices that include offering data services	• **Labor cost:** Expected higher labor wages in Indonesia

3D = three dimensional, 4G = fourth generation, 5G = fifth generation, AI = artificial intelligence, IOT = internet of things.

Source: Policy Links. 2019. Focus group discussions with industry stakeholders for Supporting Technological Transformation in Indonesia, a project for the Asian Development Bank.

Opportunities for Value Capture Arising from New Technologies

In addition to the global technological trends shown in the table below, FGD participants shared their views on specific opportunities for value capture that could be pursued in Indonesia, based on the current capabilities of the local electronics industry and the wider national innovation system. The discussion about opportunities centered mostly on ideas for new products and services underpinned by emerging digital technologies, as well as on industrial process innovations in electronics manufacturing.

Opportunities for product and service innovation were discussed and identified, for both consumer and industrial electronics, including automated robotics for the hospitality industry, such as waiting staff, and food services, for domestic and commercial food preparation; IOT-enabled devices for watering plants; automatic floor-cleaning machines; automatic lighting and security control applications; and smart controllers for domestic energy efficiency. Consulted stakeholders foresee opportunities for Indonesian firms to develop new business ideas using new mobile applications. Examples include consumer health-care mobile applications for the detection of lifestyle-related diseases and the provision of advice on how to minimize risk factors, and smart agriculture applications providing real-time information for farmers, such as through data acquisition apps tied to the HARA data exchange platform. Virtual reality applications were discussed as new opportunities, including as support for various kinds of manufacturing and sales training and skills development in virtual environments.

In terms of opportunities for process innovation, consulted stakeholders envisage opportunities for local firms to collaborate with research institutions in the development of advanced radio-frequency identification for warehouse and inventory management, building on the growing knowledge base that exists around this topic in the literature. Also mentioned was strategic collaboration for the development of IOT applications for the real-time supply of factory inputs, as well as advanced production systems tailored to Indonesian industries, particularly for material processing across manufacturing industries.

In relation to supply chain innovation, participants see opportunities for locally developing blockchain-based applications to simplify and integrate logistics and payments operations across supply chains. Finally, regarding product and service delivery innovations, consulted stakeholders visualize opportunities using big data and AI algorithms for market research, to better understand customer insights and needs that could be targeted through the development of new products and services (Table A2.9).

Table A2.9: Opportunities for Value Capture in Electronics Focus Group Discussions

Product Innovation	Process Innovation
• Robotics for hospitality and food services • IOT features for garden water systems • Automatic domestic lighting, security, and energy efficiency systems • Automatic floor-cleaning machines • Healthcare and lifestyle mobile applications • Real-time data or smart agriculture • Virtual reality applications for skills development	• Advanced RFID for warehouse and inventory management • IOT applications for real-time supply of factory inputs • Advanced material processing systems
Supply Chain Innovation	**Product & Service Delivery Innovation**
• Blockchain applications for supply chain logistics and payments	• Big data and AI algorithms for market research

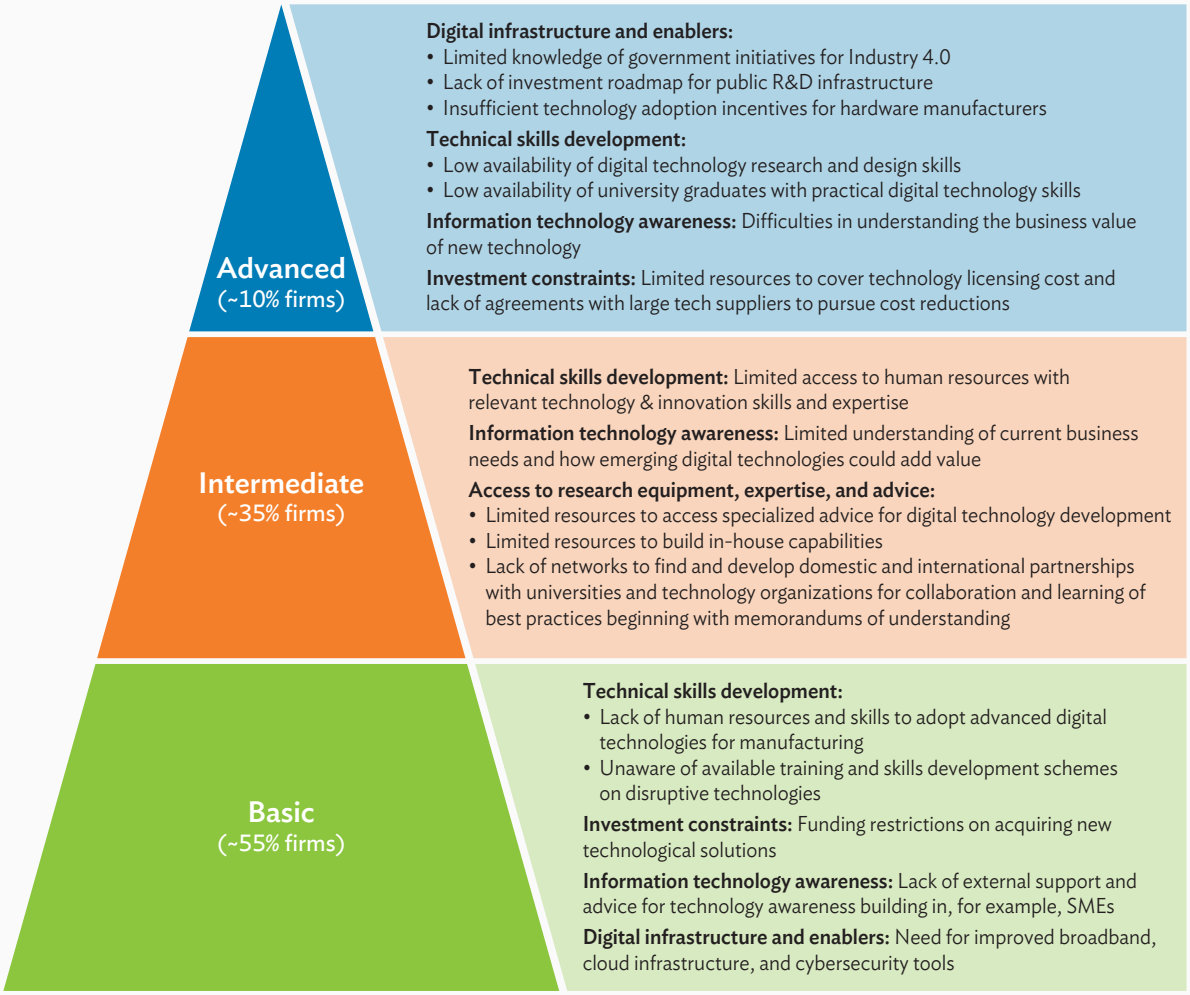
AI = artificial intelligence, IOT = internet of things, RFID = radio-frequency identification.

Source: Policy Links. 2019. Focus group discussions with industry stakeholders for Supporting Technological Transformation in Indonesia, a project for the Asian Development Bank.

Barriers to Technology Development, Diffusion, and Adoption

Figure A2.8 categorizes the barriers to technology development, diffusion, and adoption stakeholders see confronting distinct types of firm in the electronics industry in Indonesia, classified in terms of digital leaders, followers, and firms lagging behind in digitalization.

Figure A2.8: Barriers to Technological Innovation and Adoption in Electronics



SMEs = small and medium-sized enterprises, R&D = research and development.

Note: Advanced firms were actively engaged in innovation and research and development (R&D) with in-house R&D and/or innovation capabilities (e.g., skilled personnel and/or equipment) or purchased R&D and innovation services from external organizations. Intermediate firms were motivated to engage in innovation but lacking resources, though they might have had incipient in-house R&D and innovation capabilities and engaged in minor R&D and/or innovation projects with external organizations. Basic firms lacked resources to engage in innovation and had no in-house R&D and/or innovation capabilities or external R&D and/or innovation projects.

Source: Policy Links. 2019. Focus group discussions with industry stakeholders for Supporting Technological Transformation in Indonesia, a project for the Asian Development Bank.

APPENDIX 3

CASE STUDIES OF INTERNATIONAL POLICY INITIATIVES

This appendix presents a review of selected international initiatives addressing the challenges arising from new technologies. Case studies are meant to inform the policy debate in Indonesia.

International programs and initiatives highlight the variety of lessons learned and perceived effective outcomes. Naturally, it is not suggested that initiatives established in other countries can simply be replicated in Indonesia. However, international examples can inform practical implementation by illustrating the variety of strategies, institutions, and levels of funding that have been deployed to support technology transformation in other countries (Table A3.1).

Table A3.1: International Policy Initiatives Addressing New Technologies

	CASE STUDIES	
PILLARS	Country	Program
Advanced innovation infrastructure and institutions	Colombia	Vive Digital plan
	Malaysia	Industry 4.0
	Sweden	Swedish Governmental Agency for Innovation (VINNOVA)
	United Kingdom	United Kingdom Research and Innovation (UKRI)
Awareness of the business value of new technologies	Denmark	Manufacturing Academy of Denmark (MADE)
	United Kingdom	Innovate UK—Business Basics
	Germany	Central Innovation Program for SMEs (ZIM)
A stratified approach to technology transfer and technical support	Trinidad and Tobago	Centers of Excellence
	Republic of Korea	Manufacturing Innovation 3.0
	Singapore	Innovation & Capability Voucher (ICV)
Low-cost plug-and-play technology solutions for Indonesian firms	Japan	Industrial Value Chain Initiative (IVI)
	Singapore	Tech Depot
	United Kingdom	Digital Manufacturing on a Shoestring
Tech-savvy workforce	Brazil	National Service of Industrial Training (SENAI)
	Denmark	Competence Track for Automation and Digitalisation in SMEs (KOMP-AD)
	Singapore	Upgrading skills
	India	National Employability Through Apprenticeship Program (NETAP)

Source: Policy Links. 2019. Supporting Technological Transformation in Indonesia, a project for the Asian Development Bank.

PILLAR 1: ADVANCED INNOVATION INFRASTRUCTURE AND INSTITUTIONS

Colombia: Vive Digital Plan

▼ KEY INSIGHTS

Colombia's Vive Digital is a comprehensive two-phase plan (2010–2014 and 2014–2018) with the aim of facilitating access to and the use of information and communication technologies and the creation of jobs in information and communication technology (ICT).[1] It includes four main strategies: employment, city and region, education and entrepreneurship, and digital government. Vive Digital addresses four dimensions of the digital ecosystem: infrastructure expansion, the creation of new services at lower prices, the development of apps and digital content, and promoting the effective use of ICTs.[2] This plan was overseen by the Ministry of Information and Communication Technologies. Some of Vive Digital's key initiatives were the National Fiber-Optic Project, the High-Speed Connectivity Project, and investment in 7,832 community digital centers.[3] Among the main achievements of this policy were to expand digital infrastructure and facilitate access to ICTs (footnote 1).

■ OVERVIEW

MISSION OF THE PROGRAM

The aims of Colombia's Vive Digital plan were to reduce poverty and generate employment through the use of information and communication technologies.[4]

FOCUS AREAS

Information and communication technologies and their applications in health, education, and other social issues (footnote 2).

INSTRUMENTS AND IMPLEMENTATION

Initiatives to expand digital infrastructure and facilitate access to ICTs include the following:

- *National Fiber-Optic Project*. Through a public–private partnership with initial investments of over $129,200, more than 19,000 kilometers (km) of fiber-optic cable were laid across the country from 2010 to 2017.[5]

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1 Departamento Nacional de Planeación. 2015. *Evaluación de Impacto del Plan Vive Digital*.

2 Ministerio de Tecnologías de la Información y las Comunicaciones. *Vive Digital Colombia, 2014–2018*.

3 Ministerio de Tecnologías de la Información y las Comunicaciones. 2019. *Kioskos Digitales*.

4 Ministerio de Tecnologías de la Información y las Comunicaciones. *El Plan Vive Digital 2014–2018*.

5 World Economic Forum. 2017. *Digital Policy Playbook 2017. Approaches to National Digital Governance*. Geneva.

- *High-Speed Connectivity Project.* High-speed satellite and terrestrial connections are used to connect municipalities that are too remote to be reached via the fiber-optic network (footnote 5).
- The government worked to transition from 3G to 4G by holding auctions for the 700 megahertz (MHz) band, as well as the 900 MHz, 1.9 gigahertz (GHz), and 2.5 GHz bands. As a result, Colombia now has six 4G operators and 770 municipalities on the 4G network (footnote 5).
- *Kioscos Vive Digital* (KVD) and *Puntos Vive Digital* (PVD). These initiatives provide community digital centers where people from rural areas and marginalized urban areas can access the internet and receive training on the use of ICTs. By 2015, $236.2 million had been invested in the centers (footnote 1).

Assessments of Vive Digital have highlighted its role in expanding digital infrastructure and providing training in the use of ICTs.[6]

Malaysia: Industry 4.0—Industry4WRD

▼ KEY INSIGHTS

The Government of Malaysia launched the national policy Industry 4.0—Industry4WRD, which sets out a vision for manufacturing over the next 10 years. Four goals guide Industry4WRD: (i) increase the productivity of manufacturing output per person by 30%, (ii) elevate the contribution from manufacturing to the economy to $96.2 billion, (iii) strengthen national innovation capacity to reach inclusion in the top 30 nations in international innovation rankings, and (iv) increase the percentage of high-skilled workers in manufacturing to 35%.[7] The policy focuses on three shift factors—people, process, and technology—and addresses five enablers: funding, infrastructure, regulations, skills and talent, and technology.
To enable efficient digital infrastructure, Industry4WRD considers three strategies: (i) strengthen digital connectivity and remove connectivity bottlenecks, (ii) enhance the digitalization and integration of government processes and infrastructure along supply and manufacturing value chains, and (iii) involve service providers for Industry 4.0 and link them to manufacturing firms.[8]

6 Departamento Nacional de Planeación. 2015. *Evaluación de Impacto del Plan Vive Digital*; World Economic Forum. 2017. *Digital Policy Playbook 2017. Approaches to National Digital Governance.* Geneva.

7 Targets for 2025, developed from 2016 baseline figures.

8 Ministry of International Trade and Industry. 2018. *Industry 4WRD: National Policy on Industry 4.0.* Kuala Lumpur.

OVERVIEW

MISSION OF THE PROGRAM

The Industry 4.0 policy has a threefold aim (footnote 8):

- Attract stakeholders to Industry 4.0 technologies and processes and increase Malaysia's attractiveness as a preferred manufacturing location.
- Create the right ecosystem for Industry 4.0 to be adopted and align with existing and future development initiatives.
- Transform Malaysia's industry capabilities in a holistic and accelerated manner.

FOCUS AREAS

Catalytic and high-potential areas are electrical and electronics, machinery and equipment, chemicals, medical devices, aerospace, automotive, transport, textiles, pharmaceuticals, metal, food processing, and services (footnote 8).

INSTRUMENTS AND IMPLEMENTATION

The Ministry of International Trade and Industry oversees and manages the Malaysia Industry4WRD Council, chaired by its minister. The council comprises key actors in government and industry. From the government side, other ministries that are involved are the Ministry of Finance; Ministry of Multimedia and Communications; Ministry of Human Resources; Ministry of Education; and Ministry of Energy, Science, Technology, Environment, and Climate Change.[9]

As infrastructure enablers, specific measures include prioritizing and expediting the implementation of high-speed broadband at key industrial areas and training centers and encouraging the deployment of converged networks. The 2019 budget includes an allocation of $245 million to implement the National Fibrerisation and Connectivity Plan, which will develop the broadband infrastructure needed to achieve a speed of 30 million bytes per second in rural and remote areas within 5 years.[10]

[9] Ministry of International Trade and Industry. 2018. *Industry 4WRD: National Policy on Industry 4.0.* Kuala Lumpur; Ministry of International Trade and Industry. 2018. *Industry4wrd: The National Policy on Industry 4.0. Shaping the Future of Industry.* Media release. Kuala Lumpur.

[10] Secretary General of the Treasury, Ministry of Finance Malaysia. 2018. *Budget 2019*.

Sweden: Governmental Agency for Innovation

KEY INSIGHTS

The Swedish Governmental Agency for Innovation (VINNOVA) is under the Ministry of Industry and the National Contact Authority for the European Union Framework Programme for Research and Innovation.[11] VINNOVA activities cover a broad range of functions related to the coordination and formation of a common national vision around new technologies (footnote 11). VINNOVA's initiatives go from supporting incubators, promoting collaboration, and developing strategic long-term programs to funding innovation projects. The agency argues that innovation often occurs where knowledge and skills from different areas interact and where organizations learn from one another. For this reason, most of its efforts concentrate on stimulating collaboration between universities and other higher-education institutions, research institutes, enterprises, and public services, both at home and internationally.[12] VINNOVA has offices in Stockholm, Brussels, and Silicon Valley.[13]

OVERVIEW

MISSION OF THE PROGRAM

The aim of VINNOVA is to contribute to sustainable growth by improving conditions for innovation.[14]

FOCUS AREAS

Key fields targeted by VINNOVA are a circular and bio-based economy, industry and materials, smart cities, life sciences, and travel and transport.[15]

INSTRUMENTS AND IMPLEMENTATION

VINNOVA works with other research financiers and innovation-promoting organizations, including the Swedish Research Council, the Swedish Energy Agency, Almi, and the Swedish Agency for Economic and Regional Growth (footnote 11).

11 Swedish Governmental Agency for Innovation. 2014. *Information VI 2014:10.*

12 Organisation for Economic Co-operation and Development (OECD). 2013. *OECD Reviews of Innovation Policy: Sweden 2012*. OECD Publishing.

13 Organisation for Economic Co-operation and Development (OECD). 2013. *OECD Reviews of Innovation Policy: Sweden 2012*; VINNOVA, *Our Activities*.

14 Swedish Governmental Agency for Innovation. 2018. *Årsredovisning 2017.*

15 Organisation for Economic Co-operation and Development (OECD). 2013. *OECD Reviews of Innovation Policy: Sweden 2012*; Swedish Governmental Agency for Innovation. 2014. *Information VI 2014:10.*

The main VINNOVA instruments for ensuring the coordination and alignment of efforts are strategic innovation programs, which were launched in 2013 in collaboration with the Swedish Energy Agency and the Swedish Research Council. The actors involved in their elaboration formulated a common vision and defined needs and strategies for developing innovation areas. The starting point for their agendas was to meet important societal challenges and to create growth and strengthen Sweden's competitiveness in the area. In 2017, there were 17 strategic programs.[16]

In 2018, VINNOVA invested $342.7 million into promoting innovation, supporting over 4,000 projects. Some 45% of the agency's budget goes to universities and 30% to companies. Nearly 60% of company funding goes to small and medium-sized enterprises (SMEs), and several VINNOVA funding programs are reserved for SMEs (footnote 11).

United Kingdom: UK Research and Innovation

▼ KEY INSIGHTS

United Kingdom Research and Innovation (UKRI) is a nondepartmental public body sponsored by the Department for Business, Energy, and Industrial Strategy of the United Kingdom. It was established to coordinate and maximize the contribution of each of the actors involved in research and innovation. UKRI brings together seven science and humanities research councils, Innovate UK, and the research and the knowledge exchange functions of the Higher Education Funding Council for England.[17] UKRI works in partnership with universities, research organizations, businesses, charities, and government.[18] Its main purpose is to "invest in and facilitate research and innovation activities across the United Kingdom, and, through Research England, directly support higher-education providers in England to carry out research and knowledge exchange activities (footnote 17)." UKRI operates a combined budget of more than $9.2 billion (footnote 18).

16 Swedish Governmental Agency for Innovation. 2019. *Årsredovisning 2018.*

17 Department for Business, Energy, and Industrial Strategy. 2018. *UKRI Framework Document*.

18 United Kingdom Research and Innovation (UKRI). *About Us.*

OVERVIEW

MISSION OF THE PROGRAM

The aim of UKRI is to work with its partners "to ensure that world-leading research and innovation continues to grow and flourish in the UK." The progress in achieving this mission is assessed in terms of three objectives:

- Push the frontiers of human knowledge and understanding.
- Deliver economic impact.
- Create social and cultural impact by supporting society to become enriched, healthier, more resilient, and sustainable.[19]

UKRI has as its framework the UK Industrial Strategy, which sets four Grand Challenges (footnote 19):

- artificial intelligence and data economy,
- future of mobility,
- clean growth, and
- an aging society.

UK Research and Innovation comprises a board, nine councils that are overseen by the board, and a strategic and corporate center. The councils and the strategic and corporate center are coordinated by the executive committee, which is led by a chief executive officer. The councils are responsible for both advising the board and making decisions on scientific, research, and innovation matters in their discipline (footnote 17). The UK Research and Innovation Board provides strategic direction and oversight, while the executive committee is the day-to-day coordinating body. It provides leadership to the organization, including across the collective activities of the separate councils to ensure collaboration on strategy and operational matters.[20]

[19] UKRI. 2018. *Strategic Prospectus: Building the UKRI Strategy*.

[20] UKRI. *Governance and Structure.*

PILLAR 2: AWARENESS OF THE BUSINESS VALUE OF NEW TECHNOLOGIES

Denmark: Manufacturing Academy of Denmark

▼ KEY INSIGHTS

The Manufacturing Academy of Denmark (MADE) is a cluster initiative established in 2014 by industry, universities, research institutions, and advanced technology groups.[21] MADE comprises 152 entities, 3 of which are SMEs, 3 research and technology organizations (RTOs), 8 educational institutions, and 8 universities.[22] The MADE value proposition is to generate, share, and implement knowledge.[23] The main activity of MADE is facilitating a number of collaborative research and innovation projects addressing various aspects of automation and digitalization in SMEs. MADE also facilitates knowledge exchange and matchmaking through open workshops, site visits, and demonstration projects, and it seeks to coordinate education and lifelong learning in Danish educational institutions.[24]

■ OVERVIEW

MISSION OF THE PROGRAM

The aim of MADE is to "ensure that Denmark remains a world-class manufacturing nation in the future (footnote 21)."

FOCUS AREAS

MADE focuses on strengthening the ability of Danish manufacturing companies to

- introduce new products and production equipment using technologies such as 3D printing and modular production platforms;
- optimize and model production processes using technologies such as augmented reality and smart factories; and
- control and organize the complex, modern manufacturing company using technologies such as flexible robots and big data.[25]

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21 Manufacturing Academy of Denmark (MADE). 2019. *About MADE.*

22 MADE. 2019. *Fact Sheet: MADE in Facts and Figures*.

23 MADE. 2019. *How Do We Create World Class Manufacturing in Denmark?* Copenhagen.

24 Iris Group. 2015. *Digitalisation and Automation in the Nordic Manufacturing Sector. Status, Potentials and Barriers.* Nordic Council of Ministers.

25 MADE. 2019. *Innovation.*

INSTRUMENTS AND IMPLEMENTATION

The MADE board consists of five industry representatives, three university representatives, and one representative from the Danish RTOs known as the GTS institutes.

Some key MADE instruments and programs are as follows:

- *OpenLab.* Short presentations, case stories, and demonstrations of state-of-the-art technologies.
- *Demonstration projects.* Financial (up to $13,900) and knowledge support. This scheme targets MADE industry members with fewer than 250 employees.
- *Strategic Platform for Innovation and Research.* This provides funding to initiatives that strengthen the link between strategic research and innovation (footnote 21).

From 2014 to 2019 funding for MADE came to $57.6 million, of which 47.7% came from companies, 37.8% from the Innovation Fund Denmark, 8.5% from universities and RTOs, and 6% from private funds and associations (footnote 23).

United Kingdom: Innovate UK—Business Basics

KEY INSIGHTS

Business Basics is one of the funding instruments of Innovate UK. Business Basics provides funding for developing proof-of-concept ideas or running trials. In its first round, a fund of $2.6 million was available and used to fund 15 projects.[26] One of these projects is the Adoption of Digital Automation Practices and Technology (ADAPT), a proof-of-concept project. The ADAPT program was set up by Cheshire East Council's arms-length Skills and Growth Company.[27] The aim of ADAPT is to overcome the information barriers that prevent SMEs with high growth potential from adopting marketing automation and industrial digitalization technologies. ADAPT has two strategic partners: Siemens in Congleton and RedEye in Crewe. The ADAPT project will take high-growth SMEs on "learning visits" to Siemens and RedEye to "learn from their best practice, understand benefits and costs, and identify how they could adopt the technology within their own businesses."[28]

[26] Department for Business, Energy, and Industrial Strategy. 2019. *Guidance. Business Basics Fund: Objectives and Round 1 Results*. London.

[27] Skills and Growth Company. 2019. *Businesses offered the chance to learn from world-class digital innovators*.

[28] Department for Business, Energy, and Industrial Strategy. 2018. *Results of Competition: Business Basics: Boosting SME Productivity (Proof of Concept Strand).*

OVERVIEW

MISSION OF THE PROGRAM

With the Business Basics Fund, the aim of Innovate UK is to

- raise the productivity of SMEs,
- drive innovation, and
- enable better investment decisions locally and nationally (footnote 26).

FOCUS AREAS

The ADAPT program focuses on overcoming the information barriers that prevent smaller businesses with high growth potential from adopting two types of existing digital automation practices and technology:

- *marketing automation*, the use of software and AI systems to automate marketing processes such as customer segmentation, customer data integration, and campaign management, and
- *industrial digitalization technologies* such as AI, IOT, robotics, and analytics (footnote 28).

INSTRUMENTS AND IMPLEMENTATION

In the first round of the Business Basics Fund, a share of $2.6 million was available to develop proof-of-concept ideas or to run trials in 15 projects (footnote 26). One of them was ADAPT, a proof-of-concept project that received funding of $76,157 (footnote 28). ADAPT is managed by Cheshire East Council's arms-length Skills and Growth Company. It has two strategic partners: Siemens PLC; and Red Eye International Ltd. Through ADAPT, Siemens and RedEye will share their expertise with SMEs in adopting digital, automation techniques, marketing automation, and online selling to boost their productivity and improve their marketing efficiency (footnote 27).

Germany: Central Innovation Program for SMEs

KEY INSIGHTS

The Central Innovation Program for SMEs (ZIM) is a nationwide funding program for SMEs and research organizations closely aligned with business. Its focus is on SMEs that want to develop new products, processes, or technical services or significantly improve existing ones. Funding is open to German SMEs of all sectors and using any technology.[29] ZIM funds individual projects, cooperation networks, cooperation projects, and market launches of the results of research and development (R&D) projects. During 2015–2017, it supported 298 cooperative networks, 7,184 cooperative projects, and

[29] Federal Ministry for Economic Affairs and Energy. 2015. *Boosting Innovation Central Innovation Programme for SMEs.* Berlin.

1,717 individual projects with $1,617 million.[30] Since 1 January 2018, the Federal Ministry for Economic Affairs and Energy has opened ZIM to international cooperative networks. It has bilateral funding agreements with Argentina; Brazil; Canada; Spain; Finland; France; Japan; the Republic of Korea; Singapore; Sweden; Taipei,China; and Viet Nam.[31]

OVERVIEW

MISSION OF THE PROGRAM

ZIM was designed to "enhance companies' capacity to innovate and to strengthen their long-term competitiveness."[32]

FOCUS AREAS

Funding is open to German SMEs in all sectors and using any technology (footnote 29).

INSTRUMENTS AND IMPLEMENTATION

ZIM is managed by the Federal Ministry for Economic Affairs and Energy. The program has several support modalities:

- Single projects, funding of R&D projects undertaken by a single SME.
- Cooperation projects, funding cooperative R&D projects combining SMEs or SMEs with RTOs.
- Cooperation networks, funding of the management of innovative company networks and R&D projects generated by them with a minimum of six German SME partners.
- Market launch of the results of the R&D projects (footnote 29).

The maximum project costs that are eligible for funding are €380,000 ($429,717) per company, and €190,000 ($214,859) per research institute. The maximum support available for network management is €380,000 ($429,717), and for the market launch the eligible costs amount to €50,000 ($56,542) (footnote 29).

An evaluation conducted in 2016 found positive impacts of ZIM on sales by 12% and on employment by 15% for companies funded during 2012–2015, with 70% of them able to increase sales in the period. An average of 0.5 jobs were created, and 2.4 jobs retained, and nearly 90% of the companies intensified cooperation with other companies.[33]

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30 Federal Ministry for Economic Affairs and Energy—ZIM. 2017. *Statistik*. Berlin.

31 Federal Ministry for Economic Affairs and Energy—ZIM. 2018. *International Cooperation Projects Through ZIM.* Berlin.

32 Federal Ministry for Economic Affairs and Energy. 2019. *Central Innovation Program for SMEs (ZIM)*.

33 H. Depner et al. 2017. *Wirksamkeit der geförderten FuE-Projekte des Zentralen Innovationsprogramm Mittelstand (ZIM)*. RKW Kompetenz-zentrum; T. Vollborth et al. 2017. *Wirtschaftliche Wirksamkeit der Förderung von ZIM-NEMO-Netzwerken, Fokus: ZIM-NEMO-Netzwerke*. RKW Kompetenz-zentrum.

PILLAR 3: TECHNOLOGY TRANSFER AND TECHNICAL SUPPORT

Trinidad and Tobago: Centers of Excellence

▼ KEY INSIGHTS

The Government of the Republic of Trinidad and Tobago recognizes the potential of centers of excellence to step up the competitiveness and innovation performance of selected activities.[34] Leaving aside the hydrocarbon industry, it focuses on indigenous agricultural products with high value added, ICT products and services, aviation services, maritime services, and energy engineering services. While still in the planning stage, centers of excellence are expected to address the needs of firms operating in Trinidad and Tobago, particularly SMEs. In broad terms, their planned functions fall under three categories:

- knowledge generator or importer, either through their own research and development or through the acquisition of foreign know-how;
- knowledge mediator and diffuser, bridging universities and industry, diffusing relevant market and technological know-how among the industrial community; and
- knowledge supplier and absorption facilitator, offering customized consultancy services, including expert advice, technical training, and new product development support.

■ OVERVIEW

MISSION OF THE PROGRAM

The mission statements of each center of excellence are as follows:

- Establish excellence in ICT capabilities for industry.
- Create high value from indigenous agricultural species.
- Position Trinidad and Tobago as a globally recognized knowledge center for Energy Services.
- Strengthen Trinidad and Tobago's natural competitive advantages in the maritime industry.
- Position Trinidad and Tobago in the global aviation sector map.

FOCUS AREAS

Five centers of excellence are planned in key strategic specialization areas for economic diversification beyond the hydrocarbon industry: indigenous agricultural products with high value added, ICT products and services, aviation services, maritime services, and energy engineering services.

[34] Policy Links. 2018. *Implementation Strategy for Centres of Excellence in Trinidad and Tobago: Summary Report*.

INSTRUMENTS AND IMPLEMENTATION

The aim of the centers is to help firms address key innovation barriers through the provision of services such as the following:

- skills development programs in technical and business areas;
- apprenticeships and internships;
- certification schemes;
- advisory and mentorship services;
- business incubation;
- network building through conferences, seminars, and case study databases;
- information provision on technical standards, regulations, and sources of funding;
- advice on intellectual property rights;
- specialized R&D expertise and equipment; and
- contract R&D projects for product design and development.

The funding model for these centers includes strong core funding from the government during their first year at 80%, reduced to 60% in years 2–3 and 45% from the fourth year. Centers are expected to develop a viable portfolio of services that can gradually come to provide a stable revenue stream to replace some core government funding. In terms of governance, centers are expected to be autonomous, with long-term missions defined as 5- to 7-year rolling programs and sustained government commitment, while keeping strong links with the private sector.

Republic of Korea: Manufacturing Innovation 3.0

▼ KEY INSIGHTS

Manufacturing Innovation 3.0 was introduced in 2014 as part of the Korean Creative Economy, a 5-year strategy from 2013 to 2017 aiming to strengthen manufacturing industry through IOT, 3D printing, and big data.[35] The strategy addressed the gap in innovation capacity between large companies and their secondary and tertiary subcontractors. Three measures were implemented to narrow this gap: (i) setting up 10,000 smart factories by 2020, and 30,000 by 2025, to facilitate convergence between software and hardware technologies; (ii) training more than 40,000 skilled workers for the operation of smart factories; and (iii) spreading innovation capacity and wealth, going beyond a focus on enhanced automatization of manufacturing.[36]

[35] E. Ha. 2015. *Smart Industry in Korea*. Rijksdienst voor Ondernemend Nederland.

[36] M. Wiktorssona, S. D. Nohb, M. Bellgrana, and L. Hanson. 2018. Smart Factories: South Korean and Swedish Examples on Manufacturing Settings. *Procedia Manufacturing*. 25. pp. 471–478.

OVERVIEW

MISSION OF THE PROGRAM

The aim of Manufacturing Innovation 3.0 was to create new value and competitiveness in manufacturing by converging factories and IT to accelerate the smart factory system (footnote 35).

FOCUS AREAS

Eight key technologies were identified in the Manufacturing Innovation 3.0 strategy: smart sensors, IOT, cloud computing, big data, cyber-physical systems, 3D printing, holograms, and energy saving.

INSTRUMENTS AND IMPLEMENTATION

The strategy was coordinated by the Ministry of Commerce and Industry in collaboration with industry associations. A steering committee of large, medium-sized, and public companies assisted all activities.

Key instruments for technology transfer included the following:

- Subsidized consulting support for manufacturing processes, innovation, and replacing old facilities, worth $200 million over 5 years.
- A main analysis and consulting tool, the Korea Production System developed by the Korea Productivity Center, which offers know-how on project performance management and management for innovation tasks.
- Three-quarters of the fund was allocated to SMEs supplying their products to large, medium-sized, and public companies that participated in the program. The remaining quarter was allocated to SMEs with no links to contributing companies.[37]

[37] S. Y. Han. 2014. Industry Innovation 3.0. *APO News*. July–August 2014.

Singapore: Innovation & Capability Voucher

KEY INSIGHTS

The Innovation & Capability Voucher (ICV) is a scheme managed by Enterprise Singapore, an agency under the Singaporean Ministry of Trade and Industry.[38] The ICV consists of grants for SMEs in the form of $3,800 vouchers to pay for consultancy and technology solutions services. The scheme was launched in July 2012, with a budget of $24.2 million, to be spent over 4 years. Originally, it included only consultancy services on innovation, productivity, human resources, and financial management, then in 2014 it was extended to funding equipment and hardware, technical solutions, professional services, and design and renovation services, in part with additional resources of $7.6 million.[39] The ICV program is fully funded by the government, but its implementation relies on service providers, some of them universities and research centers, which are pre-qualified to ensure that they deliver high-quality consultancy services.[40]

OVERVIEW

MISSION OF THE PROGRAM

Through ICVs, the Standards, Productivity, and Innovation Board claims to help SMEs to

- upgrade and strengthen their core business operations through consultancy in innovation, productivity, human resources, and financial management, and
- adopt and implement integrated solutions to improve business efficiency and productivity.[41]

FOCUS AREAS

The supported categories of projects are as follows:

- equipment and hardware,
- technical solutions and training,
- design and renovation,
- payroll and human resource systems, and
- customer relations management systems (footnote 38).

38 SME portal. 2019. *Innovation & Capability Voucher (ICV).*

39 Gateway Law Corporation. 2014. *Innovation Capability Voucher Scheme.*

40 Standards, Productivity, and Innovation Board. 2017. *ICV.*

41 Standards, Productivity, and Innovation Board. *Innovation & Capability Voucher.*

INSTRUMENTS AND IMPLEMENTATION

Enterprise Singapore, an agency under the Ministry of Trade and Industry, manages the ICV scheme.[42] The ICV consists of grants for SMEs in the form of $3,800 vouchers. ICVs support knowledge deployment, facilitating access to expertise and technology through the following:

- consultancy projects supporting capability in technology feasibility studies, implementing ISO certification, productivity improvement projects, and implementing learning and development programs, and
- integrated solutions, which are tried-and-tested plug-and-play tools that help SMEs overcome common business challenges and achieve productivity gains.

Companies can apply for a maximum of eight vouchers, but they have to complete their ICV project before submitting a new voucher application. The maximum duration of projects is 6 months (footnote 38).

[42] International Enterprise Singapore and the Standards, Productivity, and Innovation Board came together on 1 April 2018 as a single agency to form Enterprise Singapore.

PILLAR 4: LOW-COST PLUG-AND-PLAY TECHNOLOGY SOLUTIONS FOR INDONESIAN FIRMS

Japan: Industrial Value Chain Initiative

▼ KEY INSIGHTS

The Industrial Value Chain Initiative (IVI) is a collaborative forum that promotes the development and adoption of "smart manufacturing" solutions. IVI was established in June 2015 by Japan's Ministry of Enterprise, Trade and Industry and the Manufacturing Systems Division of the Japanese Society of Mechanical Engineers, with an initial membership of some 50 manufacturers, exceeding 260 companies by February 2018.[43] As part of the initiative, large and small firms come together to develop "smart manufacturing scenarios," which describe ways in which the combination of manufacturing and ICT technologies can improve common industrial operations, both within a firm and between firms in the value chain. These scenarios are developed bottom-up based on Japanese concepts of continuous improvement, with a common aim of creating value from data. Solutions are then made available to members of the initiative, with advice available to help SMEs adapt them to their particular operations. The initiative focuses on capability development in the field of digital technologies and their integration into manufacturing services.[44]

■ OVERVIEW

MISSION OF THE PROGRAM

IVI promotes "smart manufacturing based on the concept of 'loosely defined standard,' responding to needs in the IOT era when manufacturing and IT are rapidly merged (footnote 43)."

FOCUS AREAS

Smart manufacturing, with an emphasis on IOT solutions for manufacturing processes.[45]

INSTRUMENTS AND IMPLEMENTATION

IVI instruments include the following:

- *Working groups.* They bring together experts from several companies to create "smart manufacturing scenarios" based on real concerns and improvement opportunities identified in manufacturing operations. Scenarios may focus on processes within a firm or on the integration of processes across firms in the value chain.

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43 Industrial Value Chain Initiative (IVI). 2018. *Strategic implementation framework of industrial value chain for connected industries*. Tokyo.

44 IVI. 2016. *The IVI Approach to IOT and Current Manufacturing Projects IOT Solutions*. World Congress.

45 IVI. 2019. *What is IVI*.

- *Solutions, including tools, software, and databases*. Combining manufacturing and ICT technologies is developed based on "loosely defined standards." This approach allows agile development of solutions and flexible adoption, adaptation, and updating.
- *Experiments.* They are then conducted to verify whether IVI solutions address firms' needs. Solutions can be made available to all members of the initiative, with advice available to help SMEs on how to adapt them to their particular operations (footnote 44).

A recent effort to increase the adoption of IOT solutions by cash-constrained SMEs is the development of $900 "IOT kits."[46] These kits are developed by working groups, involving large and small companies, with the aim of achieving attractive prices by integrating low-cost components, such as the Raspberry Pi single-board computer.

Singapore: Tech Depot

▼ KEY INSIGHTS

Tech Depot is a centralized platform developed by the Government of Singapore to improve SME access to technology and digital solutions.[47] Tech Depot is managed by the SME Office of the Agency for Science, Technology, and Research. This platform emerged as an outcome of the Future of Manufacturing initiative, which included the development of a roadmap of capabilities needed to achieve the competencies required in an advanced manufacturing operation.[48] More than 25 technology solutions across a wide range of industries and business functions are featured at Tech Depot (footnote 47). Through productivity solutions grants (PSGs), Tech Depot supports companies' adoption of IT solutions and equipment to boost their productivity. A PSG covers up to 70% of the costs of the technology solutions, which have been screened by various government agencies such as Enterprise Singapore and the National Parks Board.[49]

■ OVERVIEW

MISSION OF THE PROGRAM

The Tech Depot initiative aims to provide "readily accessible and deployable technologies for SMEs' adoption (footnote 48)."

46 Personal interview with Professor Yasuyuki Nishioka, president of the Industrial Value Chain Initiative.

47 Enterprise Singapore. 2019a. *TechDepot. About.*

48 Agency for Science, Technology, and Research. 2017. *Future of Manufacturing Initiative.*

49 Enterprise Singapore. 2019b. *TechDepot. Productivity Solutions Grant.*

FOCUS AREAS

Technology solutions supported by Tech Depot include the following areas:

- customer management,
- inventory management,
- quality assurance,
- data analytics,
- finance management,
- human resource management,
- machine effectiveness,
- marketing and content management, and
- project management (footnote 47).

INSTRUMENTS AND IMPLEMENTATION

The implementation of Tech Depot is overseen by the Agency for Science, Technology, and Research SME Office. The platform supports over 25 technology solutions across a wide range of industries and business functions. Funding for up to 70% of the cost of the technology solutions is provided through productivity solutions grants (PSGs). A PSG covers sector-specific solutions in the retail, food, logistics, precision engineering, construction, and landscaping industries. In addition to sector-specific solutions, PSGs support the adoption of solutions in areas that cut across industries: customer management, data analytics, financial management, and inventory tracking. These solutions have been screened by various government agencies such as Enterprise Singapore and the National Parks Board (footnote 49).

United Kingdom: Digital Manufacturing on a Shoestring

▼ KEY INSIGHTS

Digital Manufacturing on a Shoestring is a 3-year project led by the Institute for Manufacturing, part of the University of Cambridge. It is funded through a grant from the Engineering and Physical Sciences Research Council. The University of Nottingham is a key partner in the delivery of the project.[50] Digital Manufacturing on a Shoestring addresses the challenges and constraints faced by SMEs in adopting digital solutions because of the capital cost of upgrading industrial computing and communication environments.

[50] Institute for Manufacturing. 2019. *Digital Manufacturing on a Shoestring.*

The project follows an untraditional approach to the digital evolution of a manufacturing operation by focusing predominantly on nonindustrial solutions to industrial automation and information challenges. It seeks to exploit very low-cost, commercially available technologies for mobile computing, sensing, and AI and to tackle the challenges associated with integrating these safely and securely into a small-scale manufacturing environment.[51]

OVERVIEW

MISSION OF THE PROGRAM

The aim of Digital Manufacturing on a Shoestring is to "explore challenges, constraints and standards for SMEs, creating appropriate digital solutions that demonstrate significant value and will deliver extensive impact across the SME community (footnote 50)."

FOCUS AREAS

Low-cost digital solutions for manufacturing SMEs involving technologies such as mobile computing, sensing, and artificial intelligence (footnote 51).

INSTRUMENTS AND IMPLEMENTATION

Digital Manufacturing on a Shoestring is a 3-year project led by the Institute for Manufacturing, part of the University of Cambridge's Department of Engineering, and with the University of Nottingham as a key partner. The project is funded through a grant from the Engineering and Physical Sciences Research Council.

Project activities include the following:

- requirement gathering,
- SME digital manufacturing assessments,
- hackathon to stimulate low-cost software and hardware development,
- pilot studies,
- engagement and application workshops,
- demonstration sessions,
- direct engagement with the High Value Manufacturing catapult demonstration network as a means of reaching the maximum number of potential users,
- in-house technology transfer organization, and
- low-cost digital solution development.[52]

[51] Engineering and Physical Sciences Research Council. 2018. *Digital Manufacturing on a Shoestring.* Details of grant.

[52] Institute for Manufacturing. 2019. *Digital Manufacturing on a Shoestring*; Engineering and Physical Sciences Research Council. 2018. *Digital Manufacturing on a Shoestring.* Details of grant.

PILLAR 5: TECH-SAVVY WORKFORCE

Brazil: National Service of Industrial Training

▼ KEY INSIGHTS

The Brazilian Service of Industrial Training (SENAI) is a network of vocational schools and training centers. It is managed by the industry through the National Confederation of Industry and through state federations.[53] Since its creation in 1942, around 55 million professionals have graduated from SENAI.[54] Courses range from professional learning to graduate degrees. Some of these courses are free of charge.[55] In partnership with the Ministry of External Relations, SENAI operates training and professional education centers abroad in Cape Verde, Guinea Bissau, Guatemala, Haiti, Jamaica, Mozambique, Paraguay, Peru, Sao Tome and Principe, and Timor-Leste. In addition, SENAI operates a certified network of 208 laboratories that offer technical and technological services to companies throughout the country (footnote 54).

■ OVERVIEW

MISSION OF THE PROGRAM

SENAI was created to provide training for workers of the Brazilian industry (footnote 54).

FOCUS AREAS

SENAI courses on smart manufacturing focus on automation and information technologies (footnote 53).

INSTRUMENTS AND IMPLEMENTATION

SENAI offers course on smart manufacturing that include the following:

- *Automation.* Apprenticeships in programming and operation courses in the areas of computerized numeric command, industrial processes, and micro-controller digital systems. Technical courses in mechatronics and control systems. Qualification and perfection of worker skills and programs in computer-aided design and computer-aided manufacturing, computerized numeric command, hydraulic commands, pneumatic commands, process and instrumentation control, integrated manufacturing, building automation, mechatronics, and robotics (footnote 53).

53 Brazilian Service of Industrial Training. *Courses and programmes.*

54 National Confederation of Industry. *SENAI.*

55 Brazilian Service of Industrial Training. 2019. *Cursos Técnicos.*

- *Information technology.* Apprenticeships in data transmission, system programming, assembly, and maintenance of microcomputers and peripherals. Technical courses in industrial data processing and computer science, or network data communication. Graduate level courses in computer networks, software engineering, and network services (footnote 53).
- *Industry 4.0.* Distance course: Introduction to the Industry 4.0 technologies IOT, big data, advanced robotics, digital security, cloud computing, digital manufacturing, additive manufacturing, and systems integration.[56]

Denmark: Competence Track for Automation and Digitalisation in SMEs

▼ KEY INSIGHTS

United Competence Track for Automation and Digitalisation in SMEs (KOMP-AD) was an education program that ran from 2013 to 2015. It addressed the lack of knowledge and practical competency in automation and digitalization. KOMP-AD was a collaboration of 15 Danish vocational schools and colleges, 250 SMEs, business associations, and public actors in business support.[57] Its main objective was to offer tailor-made competency-development packages for SMEs.[58] KOMP-AD was partly funded by the European Social Fund. Impact evaluations found positive impacts of the program on the productivity, revenue, and profits of the participating companies.[59]

■ OVERVIEW

MISSION OF THE PROGRAM

The aim of KOMP-AD was to improve SME productivity and growth by increasing their use of digital and automated solutions in products and services (footnote 57).

FOCUS AREAS

Automation and digitalization of SMEs (footnote 57).

56 Brazilian Service of Industrial Training. 2019. *Desvendando a indústria 4.0.*

57 European Social Fund. 2017. *Projects. Technical Training Streamlines for Success.*

58 Iris Group. 2015. *Digitalisation and Automation in the Nordic Manufacturing Sector. Status, Potentials and Barriers*. Nordic Council of Ministers.

59 Iris Group. 2015. *Evaluering af KOMP-AD*. KOMP-AD. European Union.

INSTRUMENTS AND IMPLEMENTATION

The KOMP-AD strategy consisted of three phases:

- recruitment and screening of SMEs to identify companies with potential and challenges in automation and digitalization,
- initial problem identification and dialogue with the SMEs, and
- tailor-made competency-development courses for employees and managers in the SMEs based on the practical challenges facing individual companies (footnote 58).

The project budget was $6.4 million, of which the European Social Fund contributed $4.5 million.

Assessments of the program found the following impacts on the 250 companies that participated from January 2013 to June 2015:

- 72% experienced productivity improvement,
- 41% experienced revenue increase, and
- 55% experienced increased profits (footnote 59).

Singapore: Upgrading Skills

KEY INSIGHTS

Skills development is recognized as a key factor in the successful technological upgrading of Singapore.[60] In the early 1970s, the Singapore Economic Development Board (EDB) undertook innovative collaboration with international companies to establish training centers to address the shortage of high-skilled workers. The Tata-Government Training Centre was established in 1972, the Rollei-Government Training Centre in 1973, and the Philips-Government Training Centre in 1975.[61] The government provided to the centers buildings and equipment and funded a large part of employee salaries (footnote 94). The centers followed the German apprenticeship model, in which 2 years of intensive in-center training was followed by 2 years of on-the-job training. The second phase of the policy expanded the training centers to respond to the increasing demand for high-skilled workers, with the EDB taking a larger role. Its strategy included 3.5 years of overseas training for young people in Germany and Switzerland. They then returned to Singapore to become the trainers in the EDB centers.

[60] S. Lall. 2000. Singapore. *Technology for Development Series*; C. T. Lin. 2002. Training a New Breed of Technologists. In C. B. Chan, ed. *Heart Work: Stories of How EDB Steered the Singapore Economy from 1961 to the 21st Century*. Singapore: Singapore Economic Development Board.

[61] C. T. Lin. 2002. Training a New Breed of Technologists. In C. B. Chan, ed. *Heart Work: Stories of How EDB Steered the Singapore Economy from 1961 to the 21st Century.* Singapore: Singapore Economic Development Board.

The next upgrade came in the second half of the 1970s, driven by rising wages and investment from international companies in more complex manufacturing operations in Singapore using advanced technology. Collaboration with foreign governments was explored to meet demand for highly trained technicians and supervisors. The Japan–Singapore Training Centre, Japan–Singapore Institute of Software Technology, German–Singapore Institute, and French–Singapore Institute were established in the early 1980s. The Japan–Singapore Institute of Software Technology was later transferred to Singapore Polytechnic in 1987, and the others were integrated into Nanyang Polytechnic in 1992 to achieve greater scale (footnote 61). In addition, the Government of Singapore set up in 1979 the Skills Development Fund and the Skill Development Levy, which collected the equivalent of 1% of the payroll from employers to subsidize training for low-paid workers.[62] The Skills Development Fund was implemented incrementally, starting with efforts to create awareness among employers and reimbursement for some courses. The policy then added in-plant training, with, for added incentive, reimbursement increased to 90% of costs (footnote 62). A main strength of the skills development policy of the Government of Singapore has been its rapid adaptability. More recently, through the SkillsFuture policy, the government has adopted "skills mastery and lifelong learning" to address the challenges of "an advanced economy and inclusive society."[63]

OVERVIEW

MISSION OF THE PROGRAM

The aim of SkillsFuture is "to provide Singaporeans with the opportunities to develop their fullest potential throughout life, regardless of their starting points (footnote 63)."

FOCUS AREAS

The short, industry-relevant training programs of the SkillsFuture Series focus on the following emerging skills:

- *data analytics*: artificial intelligence, IOT, machine learning, cloud computing, data mining, data visualization, and coding;
- *finance:* blockchain, fintech, asset management, wealth management, risk management, and compliance;
- *tech-enabled services*: electronic technologies such as web and e-payment solutions, geospatial technology, supply chain management, security systems, and digital marketing;
- *cybersecurity:* encryption technologies, cyber intelligence and cyber risk management, cyber incident investigation, and cyber compliance;
- *digital media*: such immersive media as virtual and augmented reality, social media, interactive media, and games development;

62 S. Lall. 2000. Singapore. *Technology for Development Series.*

63 Government of Singapore. 2019. *About SkillsFuture.*

- *entrepreneurship*: start-up, technopreneurship, financing, platform models, business models, going global, product and market development, and sustainable growth;
- *urban solutions*: systems engineering, sustainability solutions, and autonomous transport solutions; and
- *advanced manufacturing*: industrial IOT, additive manufacturing, and robotics and automation.[64]

INSTRUMENTS AND IMPLEMENTATION

In addition to the SkillsFuture Series, the following are other initiatives on smart manufacturing that form part of SkillsFuture:

- *TechSkills Accelerator,* an initiative driven by Infocomm Media Development Authority in partnership with Workforce Singapore and SkillsFuture Singapore in collaboration with industry partners and hiring employers, aims to enhance training and placement opportunities for ICT jobs across the economy by facilitating the reskilling or upskilling of individuals to meet industry needs.[65]
- *Digital Transformation & Innovation Programme*, a joint initiative of the Singapore Institute of Manufacturing Technology and the SkillsFuture Singapore, to train and guide personnel in leveraging digital technologies.[66]

India: National Employability Through Apprenticeship Program

▼ KEY INSIGHTS

The National Employability Through Apprenticeship Program (NETAP) is a public–private partnership of TeamLease Skills University (TLSU), the Confederation of Indian Industry, and the National Skill Development Corporation. NETAP operates under the umbrella of the National Employability Enhancement Mission of the Ministry of Human Resource Development.[67] The program is designed to address both youth unemployment and the rigidity of the Apprentice Act of 1961, which mandates that every employer should appoint apprentices.[68] It builds on the experience of other countries with apprenticeship programs, notably Germany, Japan, the PRC, and the United Kingdom. TeamLease is a private company that owns TLSU, India's first private vocational university. Over 60,000 apprentices have been trained under the NETAP program.[69] Courses include postgraduate diplomas in computer applications and certificate courses in IT skills.[70]

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64 Government of Singapore. 2019. *SkillsFuture Series*.

65 Government of Singapore. 2019. *TechSkills Accelerator (TESA)*.

66 Singapore Institute of Manufacturing Technology. 2015. *Programme Digital Transformation & Innovation™*.

67 National Employability Through Apprenticeship Program. 2014. *Apprenticeship program.*

68 TeamLease. 2019. *NETAP—National Employability Through Apprenticeship Program*.

69 TeamLease. undated. *National Employability Through Apprenticeship Program. India's Fastest Growing Apprenticeship Program.*

70 TeamLease Skills University. 2019. *Programs for Working Professionals.*

OVERVIEW

MISSION OF THE PROGRAM

The aim of NETAP is to help unemployed youths build skills through learning by doing and learning while earning (footnote 67).

FOCUS AREAS

Manufacturing; banking, financial services, and insurance; IT and networks; food and beverage; retail; hospitality and tourism; and logistics and automotive.

INSTRUMENTS AND IMPLEMENTATION

NETAP is a public–private partnership of TLSU, the Confederation of Indian Industry, and the National Skill Development Corporation under the National Employability Enhancement Mission of the Ministry of Human Resource Development (footnote 67).

Operating structure of NETAP:

- Trainees are enrolled students of TLSU.
- Trainees can be appointed for flexible durations of 3–24 months.
- TLSU signs an agreement with the employer for the payment of stipends, administrative fees, and provision of training slots.
- Trainees are paid a consolidated stipend with no deductions, which must be at least equal to the applicable unskilled minimum wage but can be higher.
- All trainees are enrolled in a free 200-hour online course for soft skills, English, and computers. They can further enroll voluntarily or through the employer for other TLSU certificate, diploma, or associate degree courses delivered online.
- At the end of the training period, the employer has the first choice to hire the candidate; otherwise, he or she returns to TLSU (footnote 68).

Innovate Indonesia

Unlocking Growth Through Technological Transformation

New technologies present governments with opportunities and challenges in a range of key policy areas such as employment, competitiveness, equity, and sustainability. A consensus is that the national government can play an important role in stimulating innovation. This report explores policy options to facilitate Indonesia's technological transformation and unlock its economic growth potential.

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