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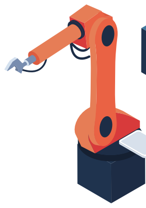
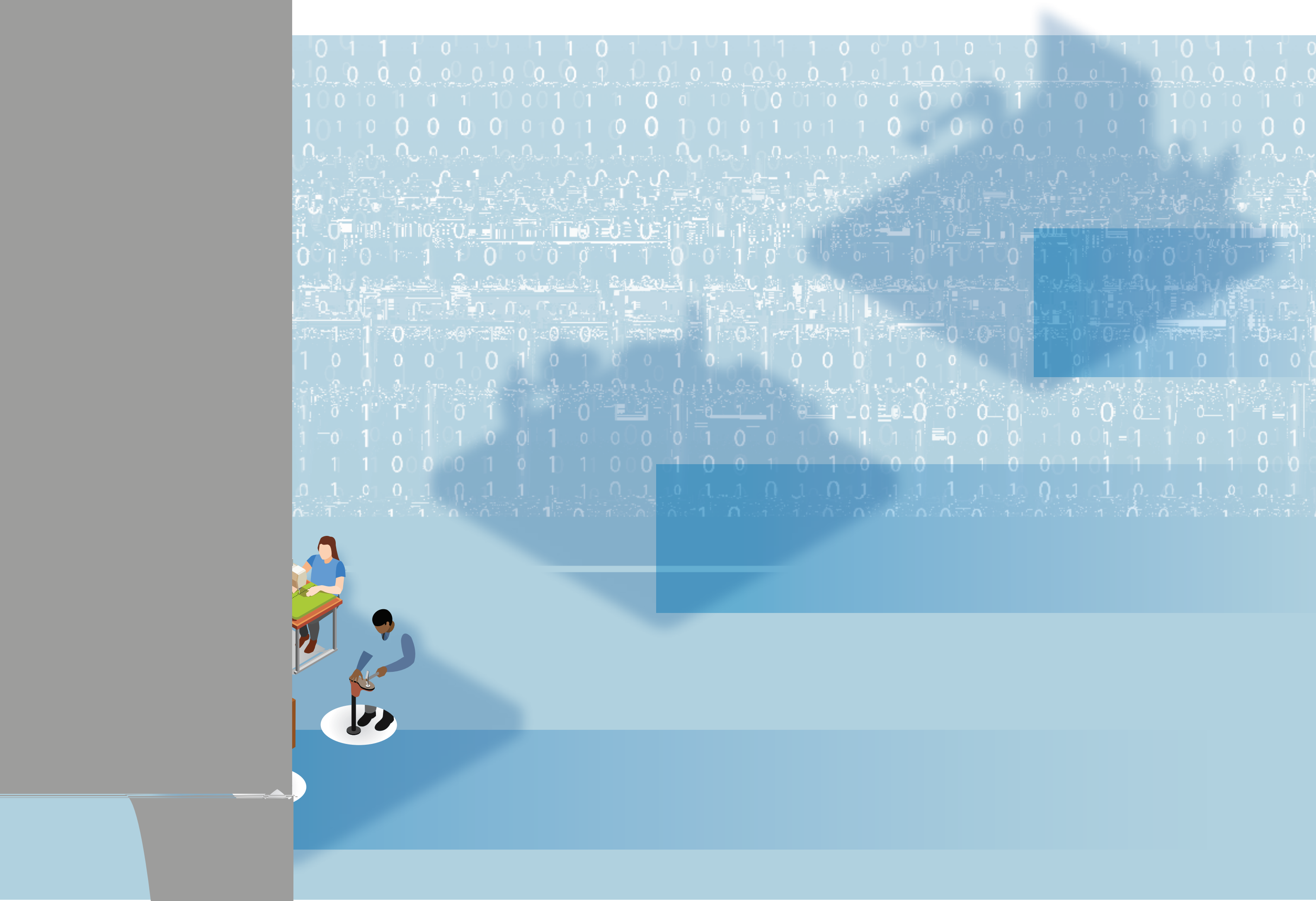


Industrializing in the digital age



UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

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, : N O , 2019. *Industrial Development Report 2020. Industrializing in the digital age*. V .

N O /449
N : .20. . .49
N: 978-92-1-106456-8
N: 978-92-1-004602-2

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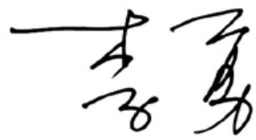

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Acknowledgements

Technical notes and abbreviations

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: *industrialized economies, emerging industrial economies, other developing economies,* *least developed countries.* *developing and emerging industrial economies.* .1

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Glossary

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Overview

Industrializing in the digital age

Advanced digital production technologies can foster inclusive and sustainable industrial development and the achievements of the SDGs

Only a few economies and firms are creating and adopting ADP technologies

But ADP technologies open new opportunities for catching up

Why should we care about new technologies?

Technologies drive ISID through new products and new processes

New technologies and inclusive and sustainable industrial development

New industries come from new technologies

Industrial competitiveness ultimately depends on technological upgrading

> New technologies are at the core of successful ISID

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What are the new technologies shaping the industrial landscape?

First came the steam, electricity and computing-driven industrial revolutions

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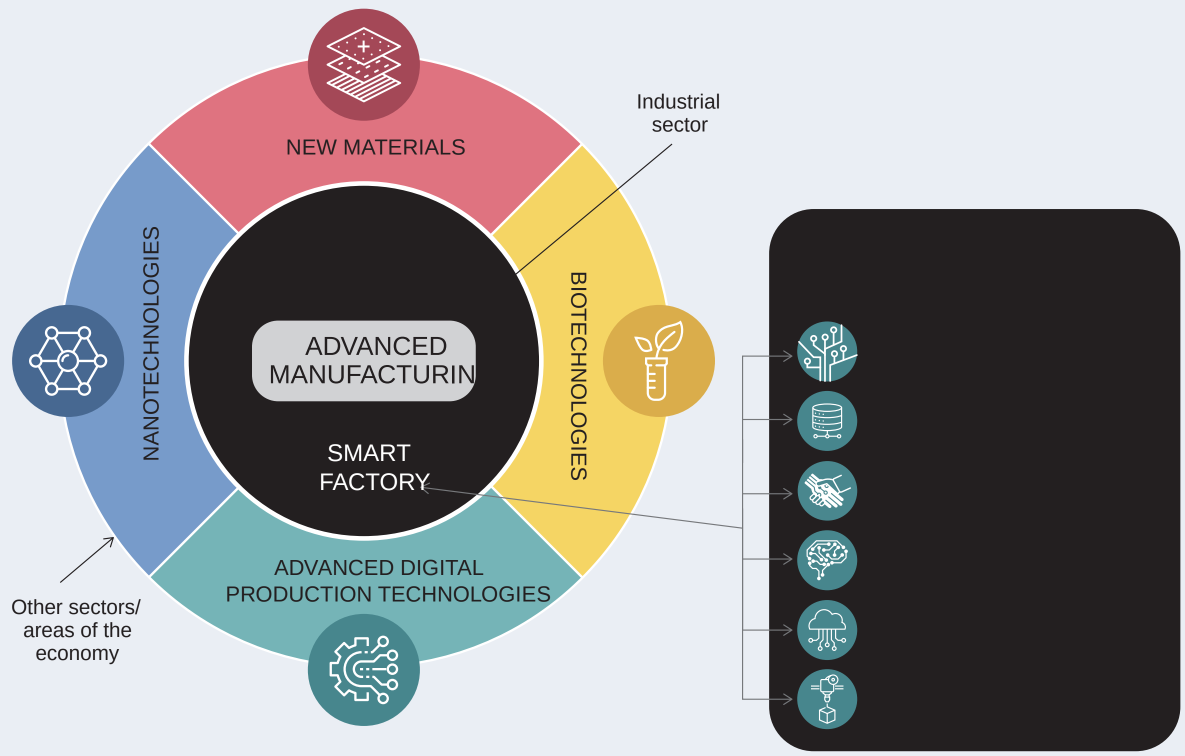
> “ ADP technologies give rise to smart manufacturing production systems

Figure 2
Broad technological domains of the fourth industrial revolution



Source: UNIDO elaboration based on OECD (2017), Schwab (2016), UNCTAD (2018), UNESCAP (2018) and UNIDO (2017d).

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An evolutionary transition to ADP technologies

Technologies of the fourth industrial revolution arise from traditional industrial production

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ADP hardware is a mix of old and new

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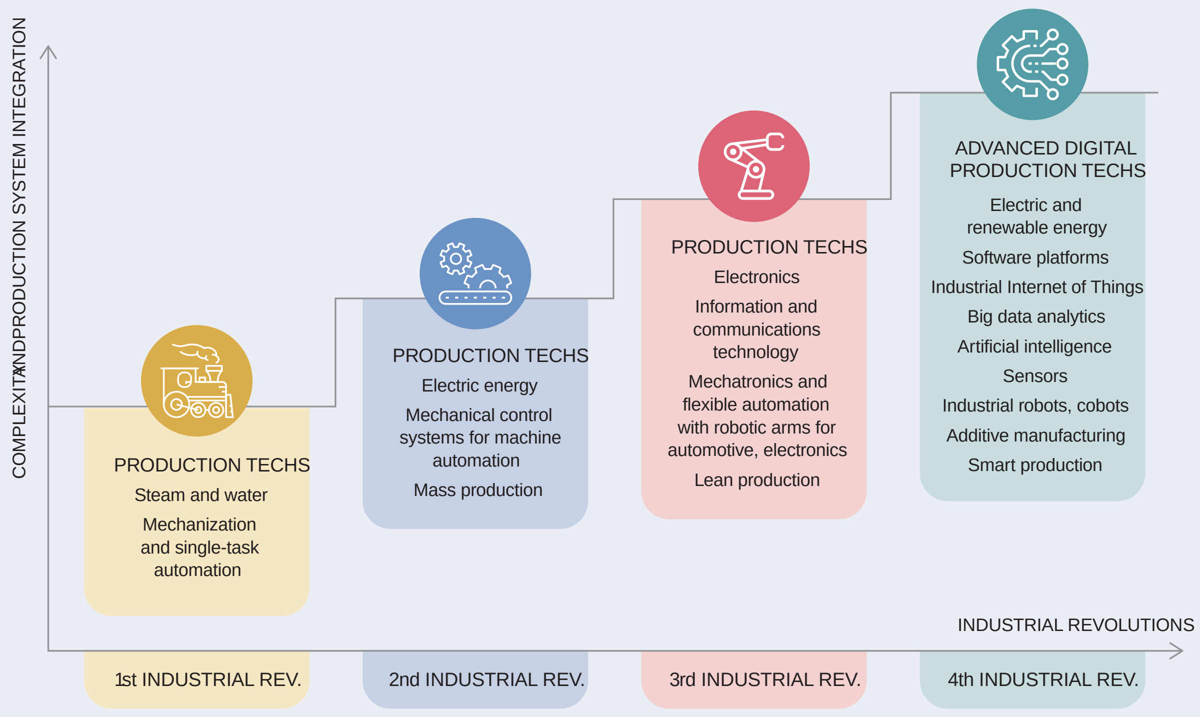
> “ History’s technological revolutions have divided the world into leading and following economies

Figure 3
Production technologies: From the rst industrial revolution to the fourth



Source: Andreoni and Anzolin 2019.

ADP connectivity is a big change from older manufacturing

Connectivity leads to smart networked systems

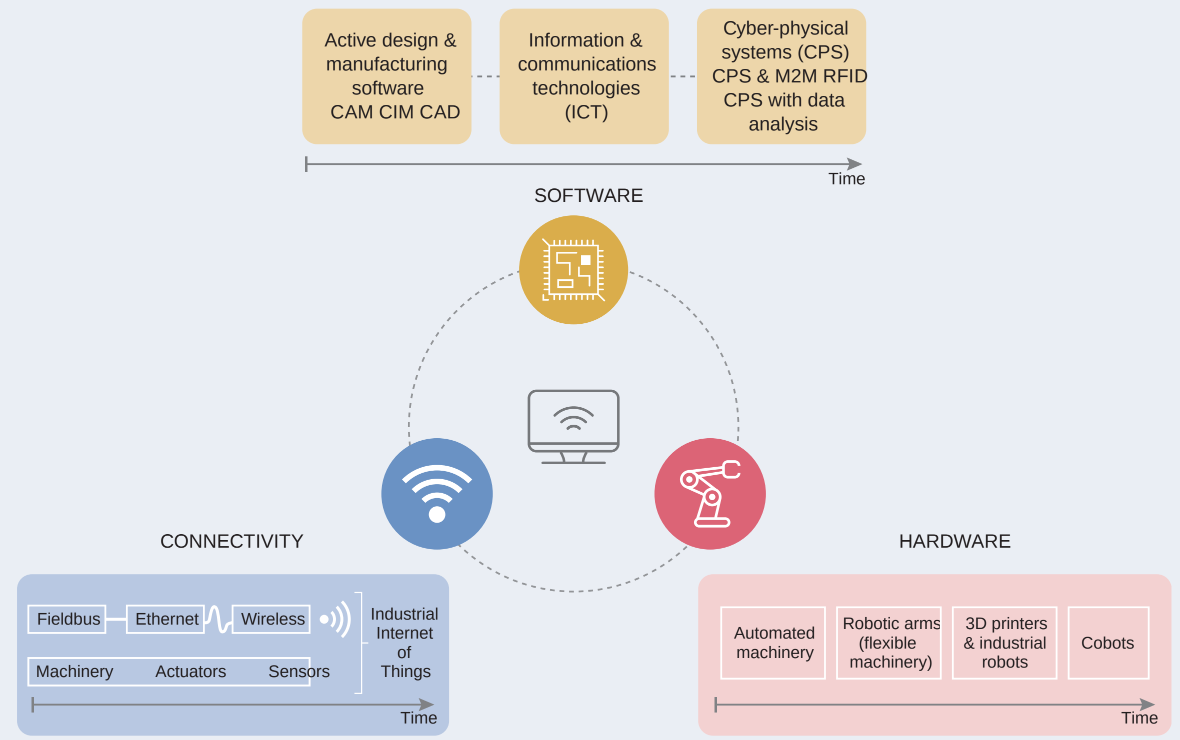
Who is creating, and who is using ADP technologies?

A concentrated global landscape

Industrial revolutions have leading and following economies

> “Ten economies account for 91 percent of global patenting in ADP technologies

Figure 4
Building blocks of ADP technologies

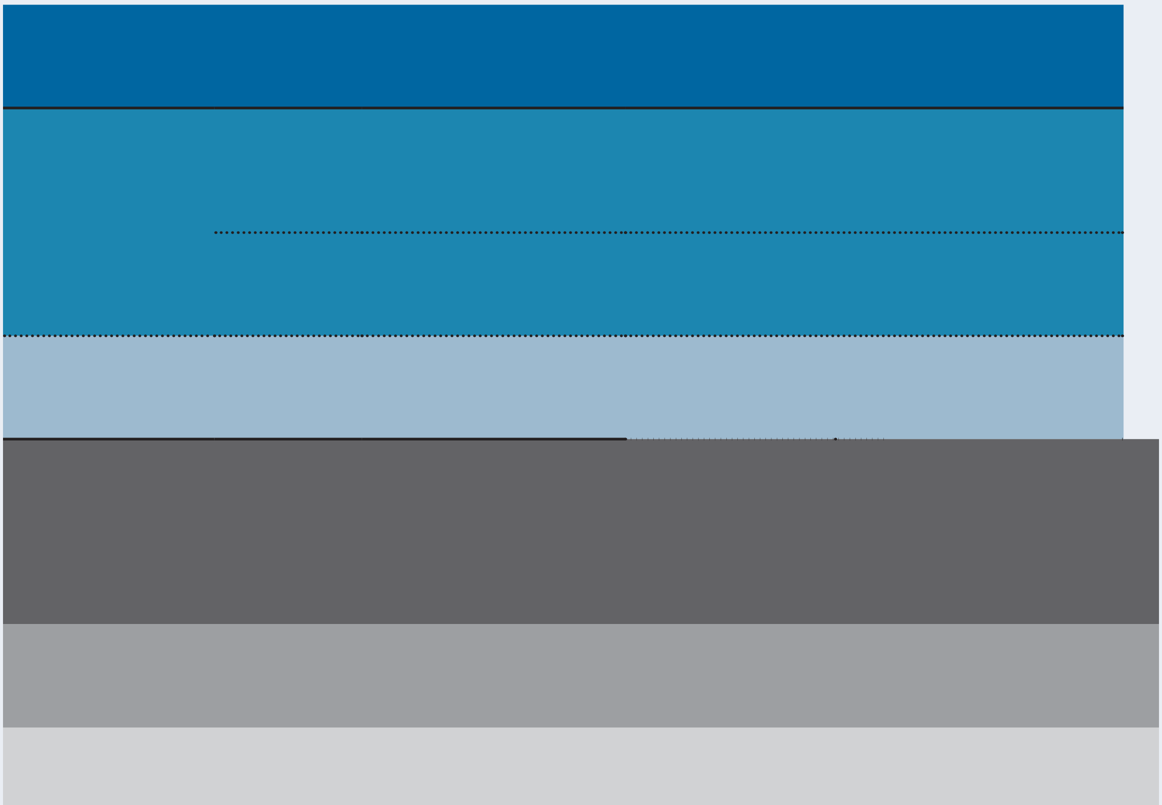


NoteCAM is computer-aided manufacturing, CAD is computer-aided design, CIM is computer-integrated manufacturing, M2M is machine to machine, and RFID is radio-frequency identi cat links CAD, CAM, industrial robotics, and machine manufacturing through unattended processing workstations.
SourceAndreoni and Anzolin 2019.

Ten frontrunner economies account for 90 percent of patents and 70 percent of exports

The very top economies express the most ADP activity

> “ Only 50 economies can be considered as actively engaging with ADP technologies



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40 economies are following, but with lower values

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The rest of the world shows low or very low to no activity in this field

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> “In most countries, different generations of digital technology applied to manufacturing coexist

Within countries, only a handful of rms are fully adopting ADP technologies

The 4IR affects a small portion of the economy in most countries

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Developing countries retrofit 4IR technologies to incomplete 3IR systems

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Different technological generations coexist

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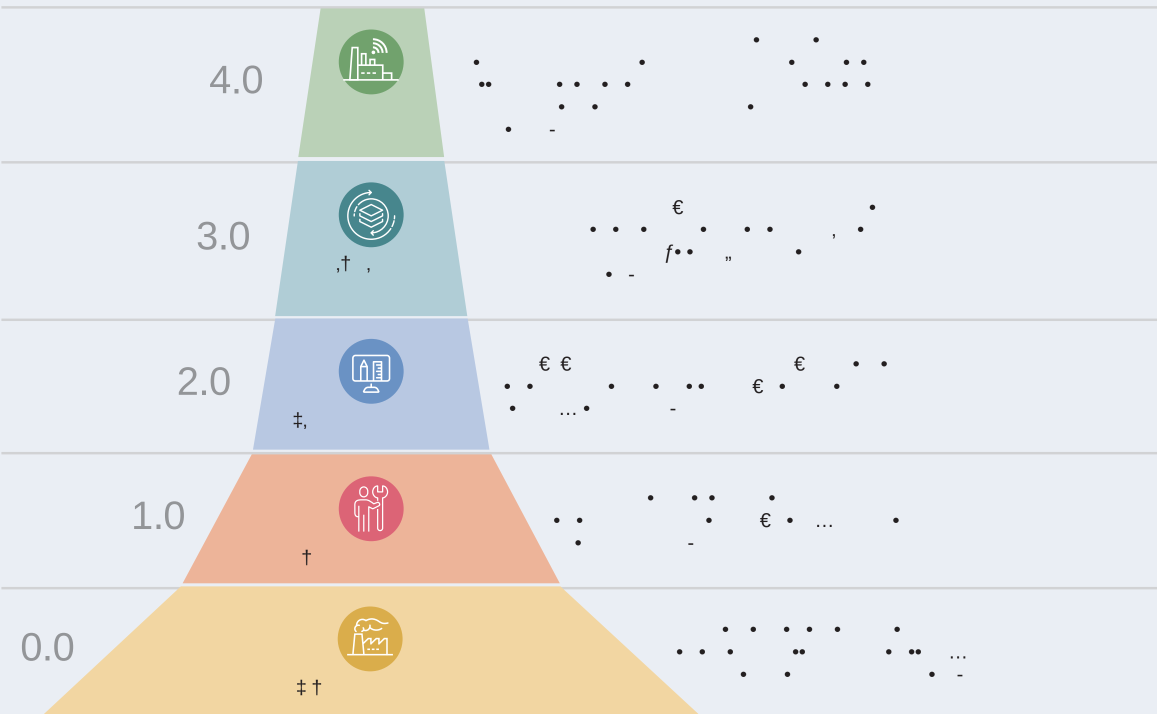
Figure 5
Four generations of digital production technologies applied to manufacturing



NoteDPT is digital production technology, CAD is computer-aided design, and CAM is computer-aided manufacturing.
SourceUNIDO elaboration based on Kupfer et al. (2019).

> **“** Only a handful of manufacturing rms are adopting ADP technologies

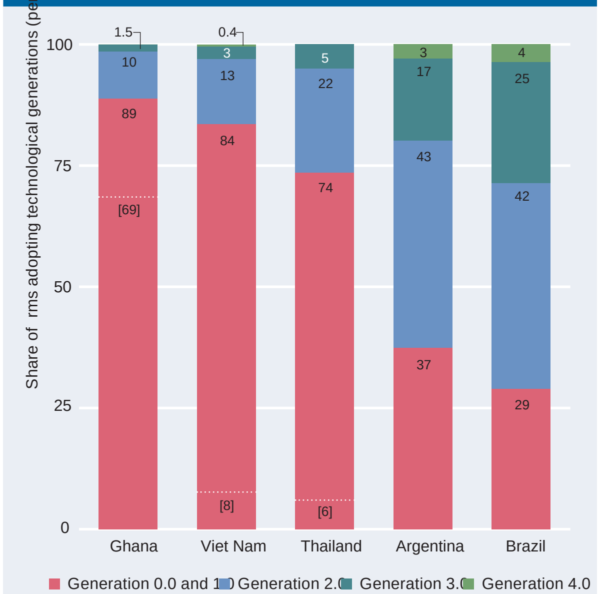
As many as 70 percent of firms are still in analog production

Moving to the next generation requires big changes

Few firms use the most advanced technologies

Leapfrogging into the 4IR depends on country and industry conditions

Figure 6
Adoption of ADP technologies is still limited among developing countries



Note: Numbers in brackets are generation 0.0 rms. For Argentina and Brazil no information on generation 0.0 is available due to the structure of their survey questionnaires. Countries are ordered according to the shares of rms currently adopting the highest generations of digital technologies (generations 3.0 and 4.0). See Annex A.3 for more detailed information on the surveys.
Source: UNIDO elaboration based on data collected by the UNIDO rm-level survey “Adoption of digital production technologies by industrial rms” (for Ghana, Thailand and Viet Nam) and Albrieu et al. (2019) and Kupfer et al. (2019) (for Argentina and Brazil).

> **"** Some manufacturing industries are more likely to adopt ADP technologies

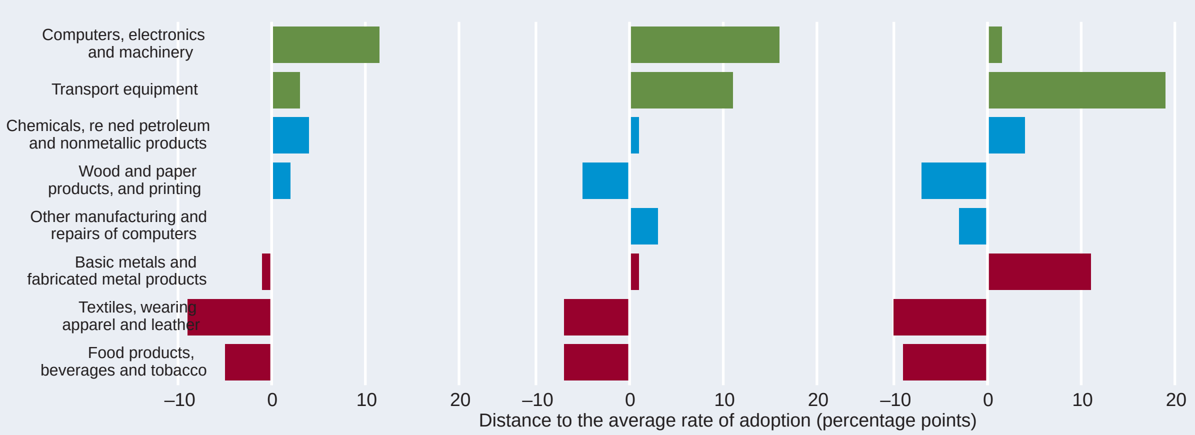
New technology diffusion is also concentrated by industry and size

The diffusion of ADP technologies is uneven across industries

Frontrunners and followers tend to specialize in these industries

Larger firms adopt more ADP technologies

Figure 7
Rates of adoption of key ADP technologies differ across industries in Europe



NoteAll values are for 2018 and are aggregates for the 28 countries of the European Union. Rate of adoption is de ned as the percentage of rms in an industry using a chosen technology. D

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What is needed to engage with ADP technologies?

Engaging requires industrial capabilities at the country level

Developing countries face five broad challenges

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Basic capabilities.

Industrial capabilities distinguish frontrunners and followers from latecomers and laggards

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> In developing countries, a large number of low-capability actors coexists with more advanced ones

Table 2
Accumulating investment, technology and production capabilities for advanced digital production

		Investment	Technology	Production
BASIC	Simple, routine-based	Feasibility study Basic market and competitors analysis Basic finance and financial flow management	External sourcing of information (for example from suppliers, industry networking, public information) Basic training and skills upgrading Recruitment of skilled personnel	Plant routine coordination Routine engineering Routine maintenance Minor adaptation of production processes and process optimization Basic product design, prototyping and customization Product and process standards compliance, product quality management Quality management Basic bookkeeping Basic packaging and logistics Basic advertising Supplier monitoring Basic export analysis and some links with foreign buyers

Basic L3.7 (f) 0 Tw 0 -.9 (sk)-0.6 (g)-5.1 (n)715 Tw 013.7 (ewJ5 (r

The digital capability gap may harm both advanced and low-capability firms

Each company has a "unique bundle of capabilities"

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> “ The gap turns a technology upgrading opportunity into a digital industrialization bottleneck

Table 2 (continued)
Accumulating investment, technology and production capabilities for advanced digital production

		Investment	Technology	Production
ADVANCED	Innovative, risky, based on advanced forms of collaboration and R&D	World-class project management capabilities Risk management Equipment design	Research in process and product, R&D Formal training system Continuous links with R&D institutions and universities, cooperative R&D Innovative links with other firms and market actors Licensing own technology to others Open innovation ecosystem	Process engineering Continuous process improvement New process innovation New product innovation Mastering product design Advanced organizational capacity for innovation World-class industrial engineering, supply chain and logistics Inventory management Brand creation and brand deepening Advanced distribution system and coordination with retailers/buyers Own marketing channels and affiliates abroad Foreign acquisition and foreign direct investment
ADVANCED	Production system integration capabilities	Seizing technology integration solutions Seizing organizational integration solutions Data analytics for decision-making and risk management	Integrated product and process R&D Advanced digital skills development Internal/own software platform development	Predictive and real-time maintenance Cyber- physical systems for virtual product/ process design Technological and organizational integration Agile and smart production Digital and automated inventory control Real-time production and supply chain data Fully integrated information systems across all functions (for example, enterprise resource planning) Big data analytics throughout all production stages (product design, production, marketing, logistics…)
SYSTEMIC				
	Enabling institutional and infrastructure capabilities	Reliable energy supply Reliable connectivity Bandwidth connectivity infrastructure (ethernet and wireless) Digital technology institutions infrastructure Data ownership policy and software licensing accessibility		

SourceUNIDO elaboration based on UNIDO (2002) and Andreoni and Anzolin (2019).

(9).

Engaging in industrial production is key to closing the gap

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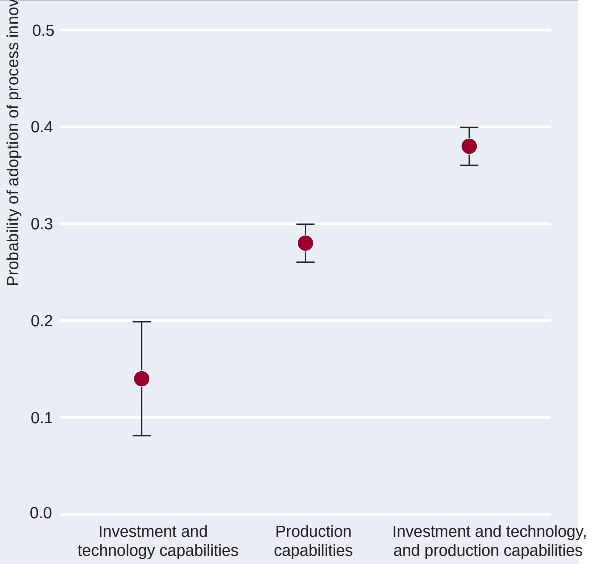
Combined, the investment, technology and production capabilities lead to innovation

> Participation in GVCs positively affects the probability of adopting new technologies

Figure 9
Production capabilities are key for the adoption of technological process innovation



Note: The analysis includes 13 African economies (Democratic Republic of Congo, Ghana, Kenya, Malawi, Namibia, Nigeria, Rwanda, South Sudan, Sudan, the United Republic of Tanzania, Uganda, Zambia and Zimbabwe) and four South Asian economies (Bangladesh, India, Nepal and Pakistan). Only manufacturing rms are considered. The graph depicts coef cients and con dence intervals (at 95 percent) for the average marginal effects of the variables of interest on the probability of adopting a process innovation. A linear probability model was implemented, with bootstrapped standard errors. Country and sector dummies are included.
Source: UNIDO elaboration based on Bogliacino and Codagnone (2019) derived from World Bank Enterprise Survey (Innovation Follow-up, 2013–2014).

Firm participation in global value chains is associated with using ADP technology

Engaging also requires speci c skills in the labour force

ADP technologies require "skills of the future"

Firms with higher technological intensity have more STEM professionals

> ADP technologies can increase rm pro ts and capital use and improve environmental sustainability

What dividends can ADP technologies deliver?

ADP technologies can improve profits, sustain the environment and expand the labour force

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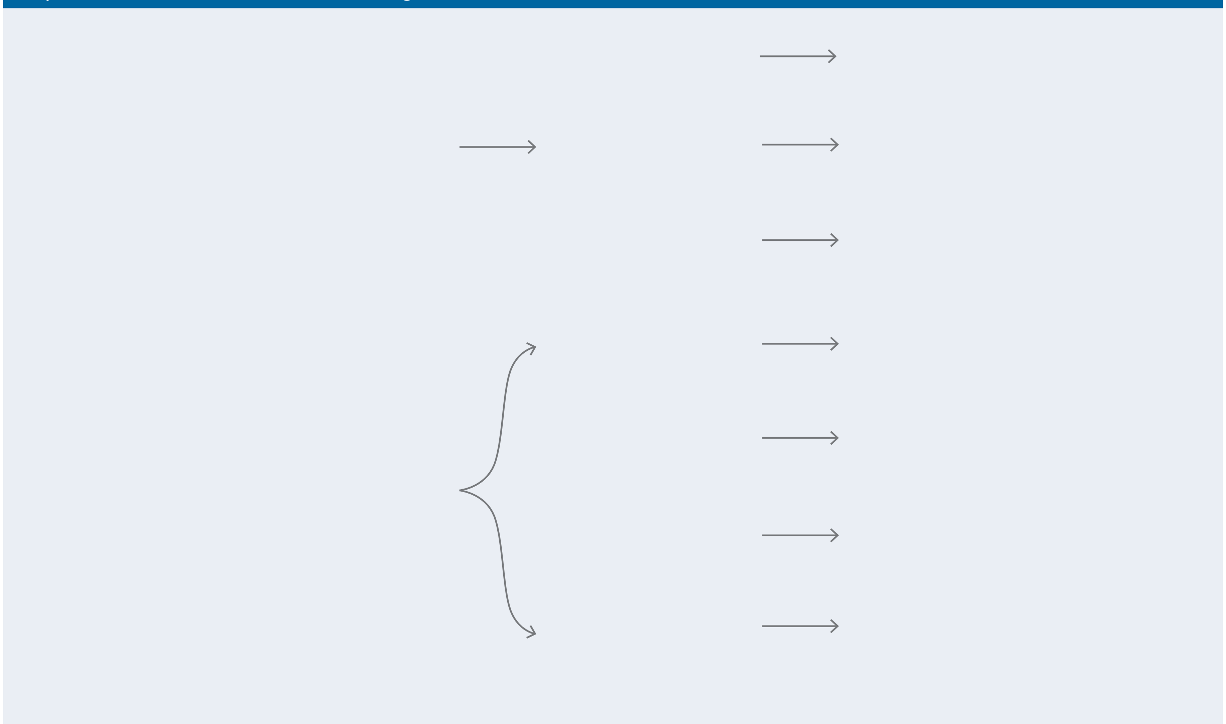
Expanded data analytics improve products and services

Figure 10
Expected dividends from ADP technologies

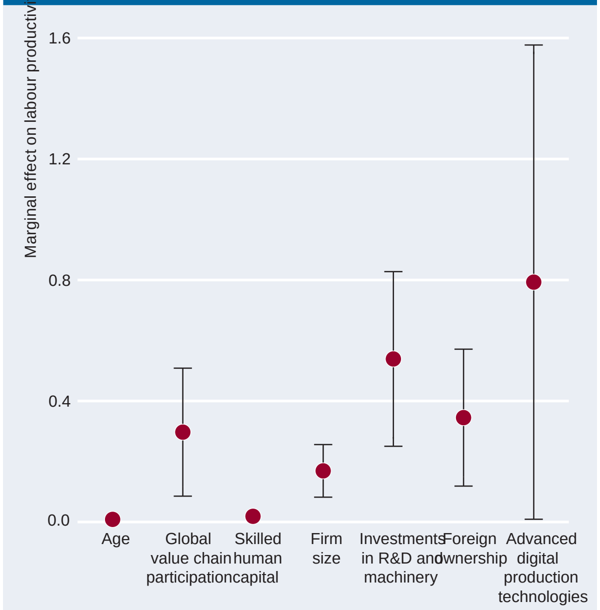


> “ Economies actively engaging with ADP technologies show much faster growth than the rest

Fostering productivity

Firms adopting advanced technology have higher productivity

Figure 11
The adoption of ADP technologies is positively associated with productivity



Note: The graph depicts the coef cients and con dence intervals (at 90 percent) of the variables of interest on labour productivity, obtained implementing regression analysis on the rms surveyed in Ghana, Thailand and Viet Nam. The variable “Advanced digital production technologies” is a binary variable that takes the value of 1 if a rm is using generations 3.0 or 4.0 technologies, 0 otherwise. Country and sector dummies are included.
Source: UNIDO elaboration based on Pietrobelli et al. (2019) derived from the data collected by the UNIDO rm-level survey “Adoption of digital production technologies by industrial rms.”

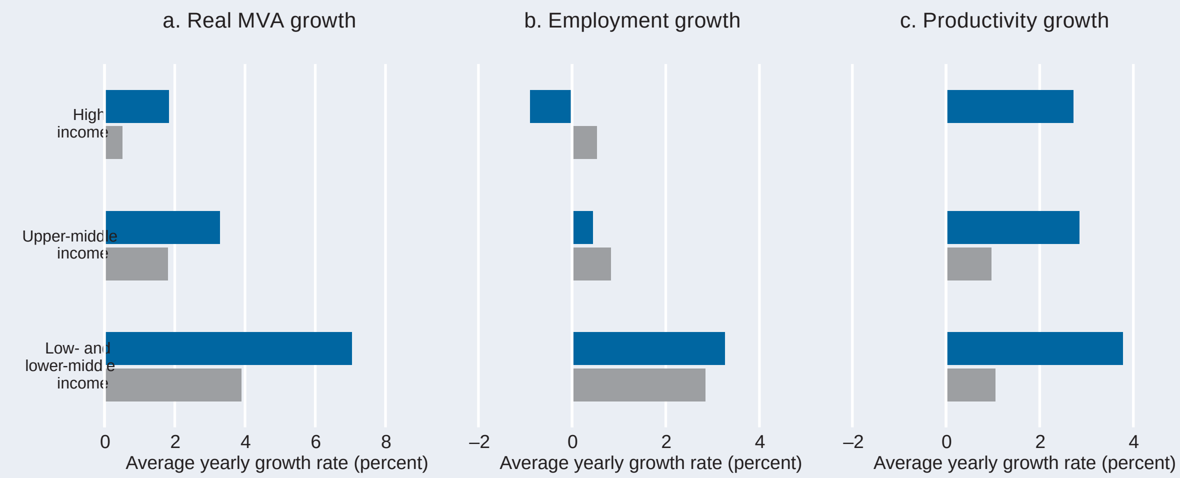
Frontrunners and followers lead in manufacturing value added growth due to productivity growth

Strengthening intersectoral linkages

New technologies foster knowledge-intensive business services

> “ As countries deploy ADP technologies, knowledge-intensive business services play an increasing role

Figure 12
Economies active in ADP technologies grow faster than the rest, across all income groups



NoteADP is advanced digital production. MVA is manufacturing value added. Each panel shows the average yearly growth rate of the corresponding group and variable between 2005 and analysis includes 166 economies (from which 50 are actively engaging with ADP technologies), which are classi ed according to World Bank’s income group de nitions for 2017: 73 low and middle income economies (of which 4 are active); 44 upper-middle income economies (of which 13 are active), and 49 high income economies (of which 33 are active). Productivity is calcul manufacturing value added in constant $ 2010 per number of workers. See Annex A.1 for the classi cation of economies by their level of engagement with ADP technologies.
SourceUNIDO elaboration based on the Manufacturing Value Added 2019 database (UNIDO 2019g), ILO (2018), and dataset by Foster-McGregor et al. (2019) derived from Worldwide Pate Database 2018 Autumn Edition (EPO 2018).

Such services produce innovation and transmit new knowledge

Frontrunners and followers tend to rely more on KIBS when producing industrial goods

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Creating jobs, not destroying them

Look beyond direct effects (workers displaced) to indirect and net effects

The indirect effects can outweigh the direct effects

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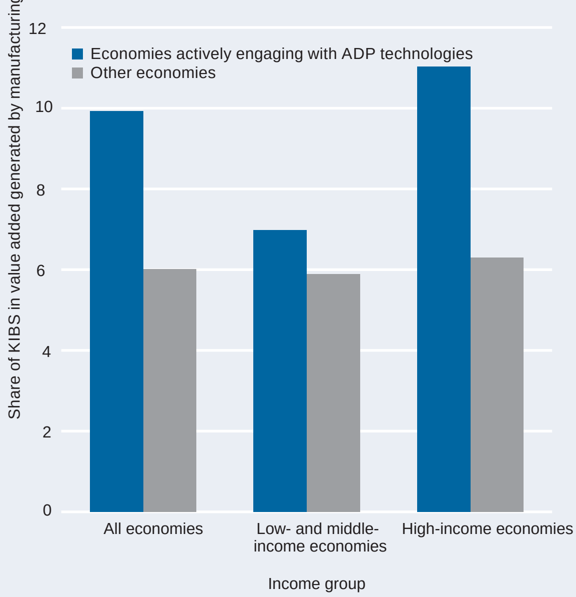
> “ Increasing the stock of robots in one industry has indirect effects on the rest of the value chain

Figure 13
Manufacturing industries in economies actively engaging with ADP technologies are more integrated with KIBS, at all incomes

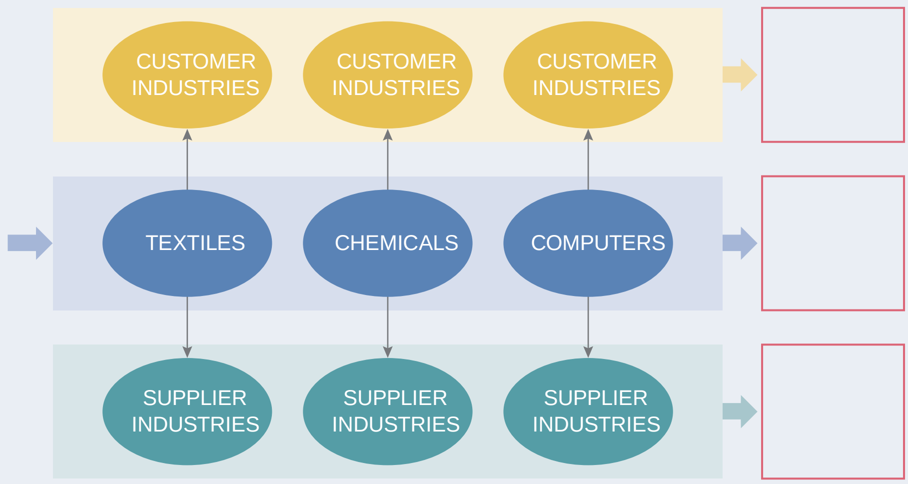


Note KIBS is knowledge-intensive business services. ADP is advanced digital production. Average values for the period 2005–2015. Manufacturing value added is in current $. The analysis includes 63 economies, which are classi ed according to World Bank’s income group de nitions for 2005: 30 low and middle income economies (of which 9 are active), and 33 high income economies (of which 24 are active). See Annex A.1 for the classi cation of economies by their level of engagement with ADP technologies.
Source UNIDO elaboration based on Inter-Country Input-Output (ICIO) Tables (OECD 2016, 2018b).

Between 2000 and 2014, the increase in industrial robots in manufacturing led to net job creation globally

2000 2014

Figure 14
Aggregate impact of the increase in industrial robot use in individual industries on world employment



Source UNIDO elaboration.

> “Firms engaging with ADP technologies expect to increase—or at least keep—their employees

Firms using robots can generate more jobs than firms not using them

Technologically dynamic firms anticipate stable (or even greater) employment

. 2018).

New technologies can also improve workers’ conditions and involvement

Sustaining the environment

ADP technologies tend towards environmentally friendly solutions

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ADP technologies boost circular economy processes

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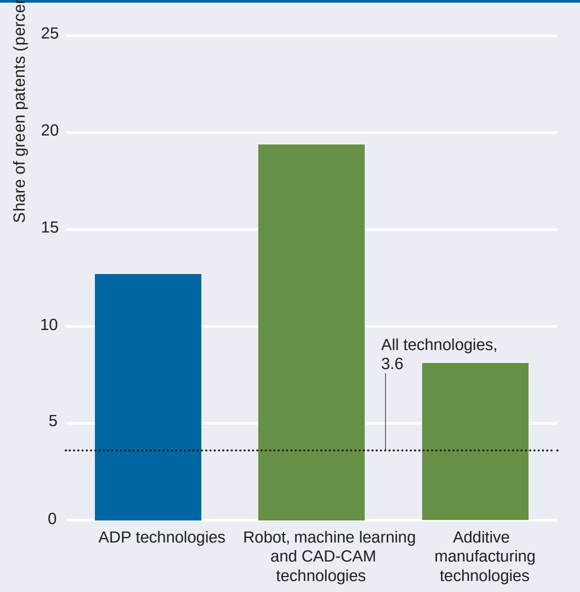
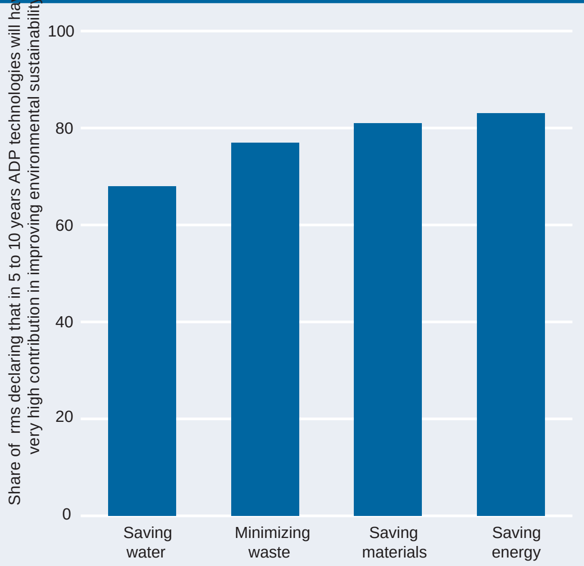
> "The use of ADP technologies would lead to environmental improvements

Figure 15
ADP technologies have above-average green content



NoteADP is advanced digital production. CAD-CAM is computer-aided design and c aided manufacturing. When a patent examiner considers that a patent is contributing change mitigation, a special Y02 tag is attached. This tag makes it possible to identi patents the subgroup that refers to green technologies and compare with it the corre share of green patents in all patents applied in any technology eld (not only ADP tec in the past 20 years.
SourceUNIDO elaboration based on dataset by Foster-McGregor et al. (2019) derived from Worldwide Patent Statistical Database 2018 Autumn Edition (EPO 2018).

Figure 16
The majority of rms engaging or ready to engage with ADP technologies agree that these will lead to environmental improvements



NoteData refers to rms surveyed in Ghana, Thailand and Viet Nam and includes only those rms currently engaging or ready to engage with ADP technologies. See Annex A.3 for more detailed information on the surveys.
SourceUNIDO elaboration based on data collected by the UNIDO rm-level survey "Adoption of digital production technologies by industrial rms" and Kupfer et al. (2019).

. 2018).

Technologically dynamic firms are optimistic about environmental improvements

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The dividends are not automatic and entail risks

Developing country firms face supply-chain reorganization and backshoring

Digitalization could increase oligopoly and power concentration

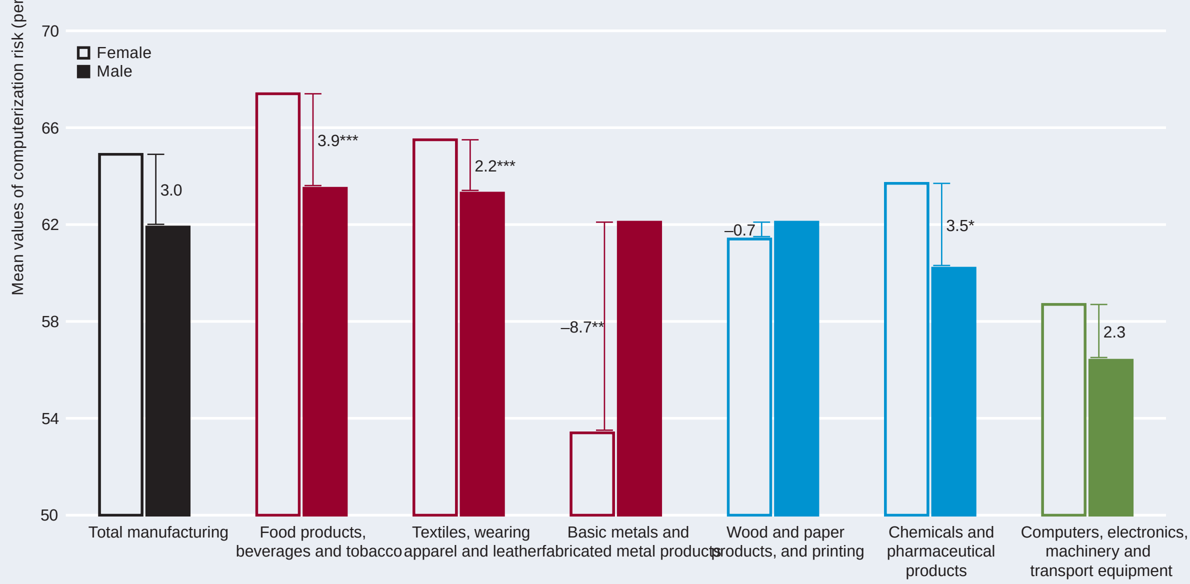
> “ADP technologies might induce backshoring, even though it is not frequent

Advanced country backshoring could make developing country cheap labour irrelevant

Not much backshoring is evident

“ There are no one-size- ts -all solutions

Figure 17
Female workers are more likely to face a higher computerization risk than men if they are employed in food, textiles and chemicals



Note: Computerization risk refers to the probability that an occupation will be computerized in the near future. The gure shows the female–male differences in mean values of computerization risk sector. t-test of differences in means: *** p < 0.000; ** p < 0.05; * p < 0.1. The analysis includes Armenia, Colombia, Georgia, Ghana, Kenya, Lao People's Democratic Republic, North Macedonia Plurinational State of Bolivia, Sri Lanka, Ukraine and Viet Nam. The colours of the bars re ect the technology and digital intensity classi cation of industries. Green = TDI industries (industries that simultaneously intensive on digitalization and technology). Blue = industries that are intensive on either digitalization or technology but not both. Red = industries that are intensive on neither digit nor technology.
Source: UNIDO elaboration based on dataset by Sorgner (2019) derived from the STEP Skills Measurement Program (World Bank 2016).

4 . (N O 2019).

What policy responses can make ADP technologies work for ISID?

Responses are highly contextual

Increasing women's equitable participation promotes inclusive and sustainable industrial development

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> “ Adoption of ADP technologies requires important efforts in developing framework conditions

Some general areas for policy action need special attention

And depend on the relative position of economies

Although responses are highly contextual, three areas are very important

Framework conditions include the institutionalization of multistakeholder approaches to industrial policy formulation

Table 3
Areas of policy action to make ADP technologies work for ISID

Broad area	Issue to be tackled	Specific actions	Country examples
Developing framework conditions	Regulations and digital infrastructure	Update and develop regulatory reforms to facilitate a digital economy	• In 2018, Mauritius launched a comprehensive policy framework, Digital Mauritius 2030, to boost economic development. Specific areas of intervention include ICT governance, talent management, a national broadband strategy and stronger protection of intellectual property rights and data, data privacy and cyber-security. • Over the past 15 years, Viet Nam has enacted a complex governance reform to support the emergence of smart manufacturing. This includes policies, master plans and laws around e-commerce, e-transactions, cyber-security, information technologies, intellectual property, investment in digital infrastructure and introduction of advanced technologies in production and business.
		Investment in ICT and broadband infrastructure to foster access to high-speed internet	• In 2016, Chile announced the Strategic Programme Smart Industries 2015–2025 to upgrade ICT infrastructure, to increase speed in national broadband and expand penetration of high-speed internet in the country. • The national strategy Thailand 4.0, contained in the country’s 20-Year National Strategy (2017–2036) promotes institutional reforms to improve framework conditions, including incentives (corporate tax reductions and R&D subsidies), investments in high-speed internet infrastructure and the establishment of digital parks and development zones.

Broad area	Issue to be tackled	Specific actions	Country examples
Developing framework conditions	Institutional infrastructure and private sector role	Institutionalize multistakeholder and participatory approaches to industrial policy formulation, including public–private dialogue and shared leadership between different ministries	• In Brazil, the development of the Science and Technology and Innovation Plan for Advanced Manufacturing involved a triple-helix approach (government, private entities and education and research organizations). The Ministry of Science, Technology, Innovation and Communications and the Ministry of Industry, International Trade and Services lead from the government side. Significant knowledge came from a task force consulting private organizations about their perspectives on the challenges and opportunities stemming from smart manufacturing across different Brazilian industries and regions. • In Mexico, the national strategy Roadmap 2030 built on a collaboration among the Ministry of Economy, ProSoft 3.0 (an official programme to promote the domestic software industry), the Mexican Association of Information Technologies and other private sector organizations. • In South Africa, the Department of Telecommunications and Postal Services, the Department of Science and Technology and the Department of Trade and Industry led an integrated strategy, in consultation with industry, labour and civil society. In addition, a Presidential Commission on the 4IR was established in 2019 to coordinate work across all involved governmental institutions.
	International collaboration and technology transfer	Facilitate connections with international initiatives around the adoption of ADP technologies	• In 2015, China and Germany agreed to promote readiness of their respective economies for ADP technologies in a memorandum of understanding linking Made in China 2025 and Industrie 4.0. The proposed activities consider the promotion of networks of Chinese and German enterprises in smart manufacturing. Collaboration is already bearing fruit through a Sino-German Industrial Park jointly established as a platform to connect Chinese enterprises and German technology. • In 2018, Nuevo León, Mexico signed a two-year memorandum of understanding with the Basque Country, Spain, to underpin collaboration between their respective ADP technology strategies. The government of Nuevo León recently launched the programme MIND4.0 Monterrey 2019, a start-up accelerator that emulates a similar pilot initiative in the Basque Country (BIND 4.0) matching local manufacturing firms with domestic and foreign innovators and entrepreneurs.
		Establish partnerships with foreign organization and MNCs or consulting rms	• Kazakhstan's new digitalization strategy, Digital Kazakhstan, benefited from collaboration of Germany's Fraunhofer Institute with the Kazakhstan Ministry of Industry and Infrastructure Development. Activities included a diagnostic study on about 600 domestic companies' readiness to adopt ADP technologies. Firm with semiautomated production will be supported to progressively transform into digital factories. Pilot companies started implementation in October 2018.
Fostering demand and adoption	Access and affordability of ADP technologies	Develop innovative funding mechanisms and support instruments or expand public funding for ecosystem enablers	• The government of South Africa proposed a Sovereign Innovation Fund to fund high-technology projects on smart manufacturing–related areas. The government pledged a seed investment of 1–1.5 billion rand (around $111 million) for 2019/2020. The fund is part of a strategy to support domestic firms to benefit from technology transfer. • In 2017, the government of Zhejiang Province, China, launched the Plan for Enterprises Deploying the Cloud, an initiative to promote adoption of and innovation in cloud technologies, particularly among small and medium-sized enterprises. The initiative combines funding through voucher schemes to lower the cost of cloud technology with a complex approach to foster capabilities. As part of the programme more than 1,100 seminars on cloud computing have been organized, covering more than 90,000 industrial firms and 100,000 participants.

> “ Governments can support the strengthening of capabilities through dedicated learning centres

Table 3 (continued)
Areas of policy action to make ADP technologies work for ISID

Broad area	Issue to be tackled	Specific actions	Country examples
Fostering demand and adoption	Awareness regarding use and benefits of ADP technologies	Develop awareness centres and organize international summits, conferences and workshops to expand rms’ knowledge of ADP technologies	• In 2017, the government of India opened four new centres for promoting ADP technologies in Bangalore, New Delhi and Pune. While independent, the centres fall under the purview of the Ministry of Industry, Department of Heavy Industry. Their mandate is to support the implementation of Make-in-India, particularly by enhancing manufacturing competitiveness through a better understanding and broader adoption of ADP technologies by manufacturing small and medium-sized enterprises. • Since 2015, the government of Viet Nam has organized annual summits or international gatherings to raise awareness, explore and possibly tighten public–private collaboration or demonstrate technologies and solutions available for domestic agents interested in ADP technologies.
	Readiness of vulnerable actors, such as small and medium-sized enterprises	Provide targeted support to actors that are technologically lagging behind	• In Spain, the government of the Basque country launched Basque Industry 4.0, which includes pilot activities to assist domestic SMEs in accessing training on ADP technologies associated with manufacturing, and spaces designed for self-diagnosis and fine-tuning for advanced manufacturing. • In 2019, the government of Malaysia launched Industry4WRD Readiness Assessment, a programme under the national strategy Industry4WRD that helps to determine small and medium-sized enterprises’ readiness to adopt ADP technologies.
Strengthening capabilities	Development of human resources	Enhance international collaboration around skill development and employability	• In Colombia, universities in Valle del Cauca recently agreed to collaborate with the Association of Electronic and Information Technologies (GAIA) of the Basque country. The parties expect to foster digital culture and entrepreneurship among students in Valle del Cauca.
		Offer/facilitate direct experience and exposure and learning from the new technologies, including new approaches to technical and vocational education and training (TVET)	• The government of Uruguay, in collaboration with UNIDO and the German industrial control and automation company Festo, has established the Centre of Industrial Automation and Mechatronics (CAIME), a public technology centre to upgrade technical skills and encourage domestic firms to adopt smart manufacturing processes. • In Malaysia, the Ministry of Human Resources offers a National Dual Training Scheme, inspired by the German Dual Vocational Training Programme, aimed at equipping workers to use ADP technologies.
	Development of research capabilities	Expand the scope and number of research institutions	• In Chile, the Office of Economy of the Future launched the project Astrodata, whose objective is to capitalize on the processing potential of astronomical big data and cloud computing, not only for scientific applications and human capital development but also for economic purposes. • In Kazakhstan, the Ministry of Education and Science will mobilize research capacities at the Industrial Automation Institute (based in the Kazakh National Research Technical University) to carry out applied research and technology transfer connected with technological problems faced by business seeking to use ADP technologies.

SourceUNIDO elaboration.

(2007, 2018).

Fostering demand requires awareness and funding

> “Without international support, low-income countries run the risk of being stymied even more

Capabilities build on new skills and research

A call for further international collaboration

New windows of opportunity will depend on individual responses and readiness

Remember that it takes commitments and substantial resources to develop capabilities

The international community should support lagging economies

There is good scope for further international collaboration

Closer collaboration should be the basis of national strategies

4

Notes

1. , : O , O , O N O .
2. L (2018) N O . (2019).
3. N O . (2019).
4. N O . (2019) (2017), (2018) (2018).
5 N O (2019) .

Part A

Industrializing in the digital age

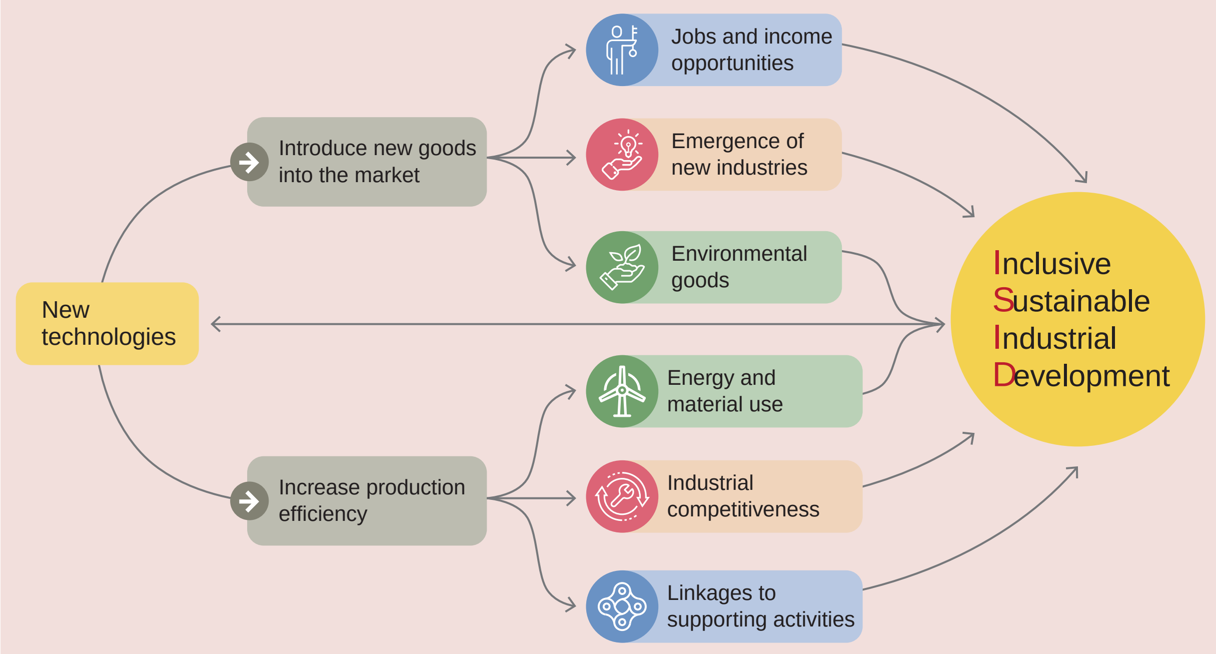
Chapter 1

Advanced digital production technologies and industrial development: A global perspective

> Learning by producing is fundamental in absorbing advanced digital technologies

1

Figure 1.1
New technologies and ISID: A conceptual framework



Note: The upper part of the gure shows how new technologies drive inclusive and sustainable industrial development (ISID) by introducing new goods into the market. The lower part shows how new pro technologies also contribute to ISID by increasing production ef ciency. As industrialization evolves, the innovative potential of countries also increases. This is shown by the straight arrow going from rig
Source: UNIDO elaboration.

New production technologies increase efficiency

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1.1

Introducing new goods into the market

New technologies need enlarged human and infrastructure capacities to produce benefits

Historically, new technologies have led to new products and industries

> “The emergence of new industries is the result of product innovations

Cars from Daimler to the Ford Model T

Personal computers from hobbyist models to the first Apple

Inventions spread from the United States to the world

80 percent of US households had a car by 1968, and 75 percent had a personal computer by 2010

Cars and computers are now at the heart of US manufacturing value added

New industries boost employment and trigger growth

> “ Product innovations can render industrial development sustainable over time

1.3

The multiplier effect of new jobs is as big as the effect of the jobs themselves

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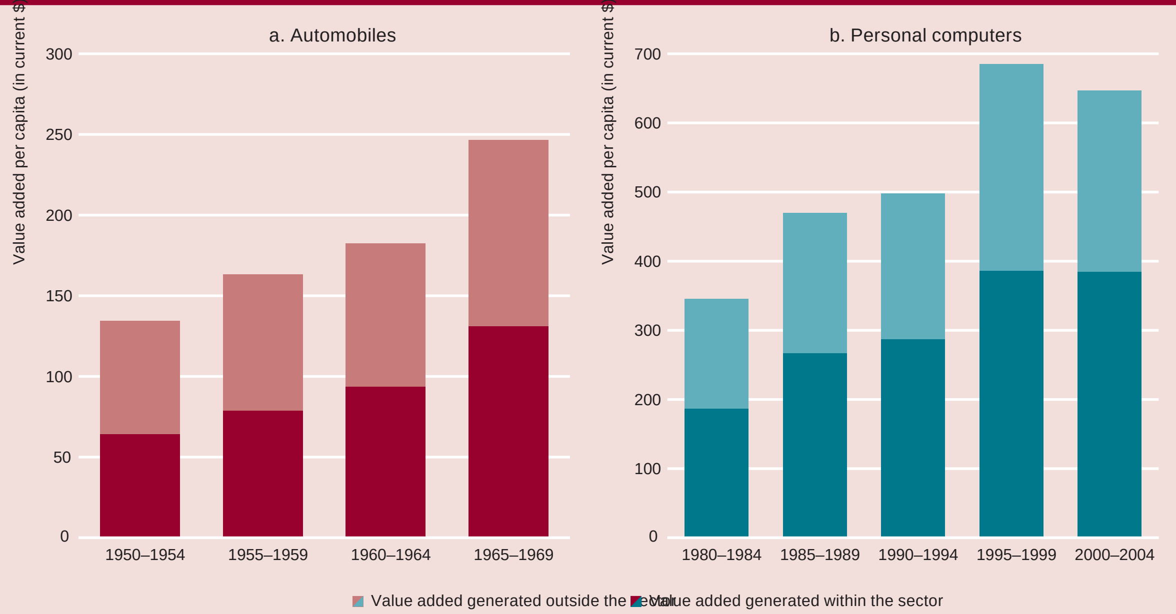
> “ Electric vehicles could take over up to 50 percent of the world market by 2040

Figure 1.3
Economy-wide income creation by new industries: Automobiles and personal computers in the United States



Note: The gure presents the income per capita generated by the production of these industries in the entire economy, taking productive linkages into account. Input–output techniques estim value added generated by the nal consumption of cars (panel a) and personal computers (panel b). Each bar presents the average income generated in a span of ve years and distinguish that corresponds to the same sector (for instance, the automobile industry) and the portion created in other sectors of the economy (for instance, suppliers of auto parts or service providers

Source: UNIDO elaboration based on US Bureau of Economic Analysis (2019c).

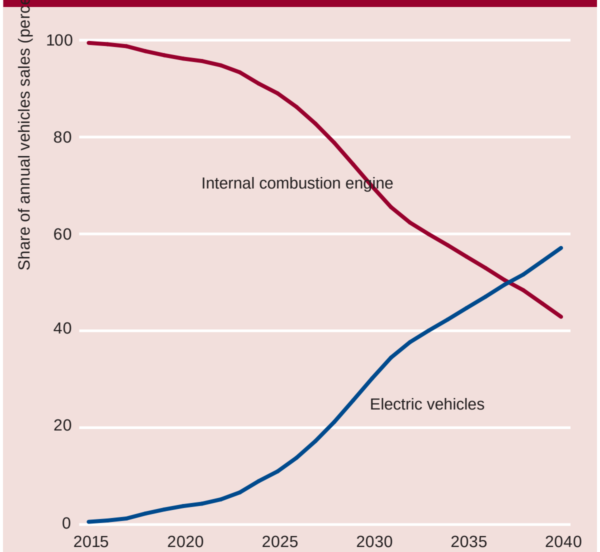
(2018). , 50 2040 (1.4). , 13 .

Fostering production ef ciency

New technologies foster production efficiency and consumer affordability

N , , , (1.1). (1.5).

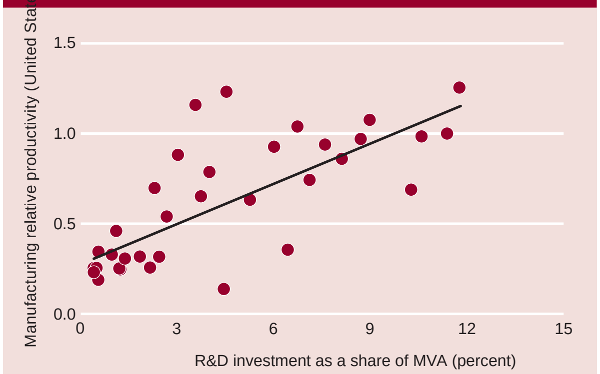
Figure 1.4
The global rise of electric vehicles: Projected sales to 2040



Source: Bloomberg New Energy Finance.

> “Technology has a powerful in uence on industrial performance

Figure1.5
Larger investments in manufacturing research and development are associated with higher production ef ciency



NoteMVA is manufacturing value added. R&D is research and development. All values are for 2015 (or closest year). The 34 economies presented in the gure were selected due to the availability of data on R&D expenditures in manufacturing. Manufacturing relative productivity is calculated as the value added per worker (in constant $ 2010) of each economy divided by that of the United States. R&D investments as a share of manufacturing value added are calculated at constant $ 2010.
SourceUNIDO elaboration based on the Analytical Business Enterprise R&D database (OECD 2018a), ILO (2018) and the Manufacturing Value Added 2019 database (UNIDO 2019g).

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Higher efficiency increases competitiveness and reduces environmental impacts

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Countries that improve productivity become more competitive

Countries that invest more in research and development have higher productivity

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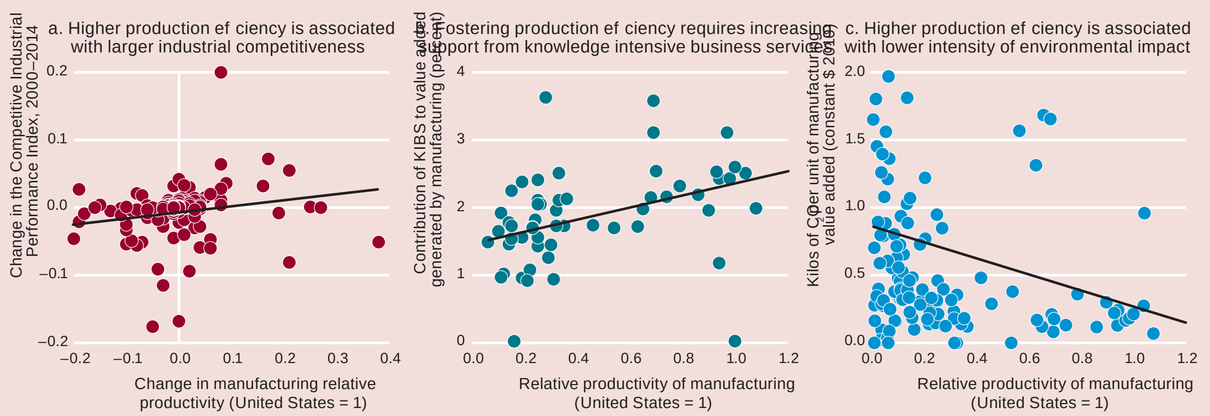
Figure 1.6
From production ef ciency to ISID



NoteKIBS is knowledge-intensive business services. MVA is manufacturing value added. All values are for 2015 in panels a and c and for 2000–2015 in panel b. Panel a includes data for 145 economies, panel b for 57, and panel c for 129. The 57 economies in panel b were selected based on the availability of input–output tables in OECD (2018b). Productivity is calculated as MVA in constant $ 2010 per number of workers.
SourceUNIDO elaboration based on ILO (2018), Inter-Country Input-Output (ICIO) tables (OECD 2018b), the Competitive Industrial Performance Index (CIP) 2019 database (UNIDO 2019c) and Manufacturing Value Added 2019 database (UNIDO 2019g).

> **Increasing linkages to services boosts jobs outside manufacturing**

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Improving productivity requires KIBS

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Increasing KIBS helps industry create indirect jobs

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Increasing efficiency promotes environmental sustainability

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New technologies are key to ISID

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The new technologies shaping the industrial landscape

The steam-, electricity- and computing-driven industrial revolutions

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Digital production technologies, nanotechnology, biotechnology and new and improved materials

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> "Smart production results from the application of advanced digital technologies to manufacturing production

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Digital technologies and smart manufacturing

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> “ Production technologies become fully digital once their connectivity is enhanced by software

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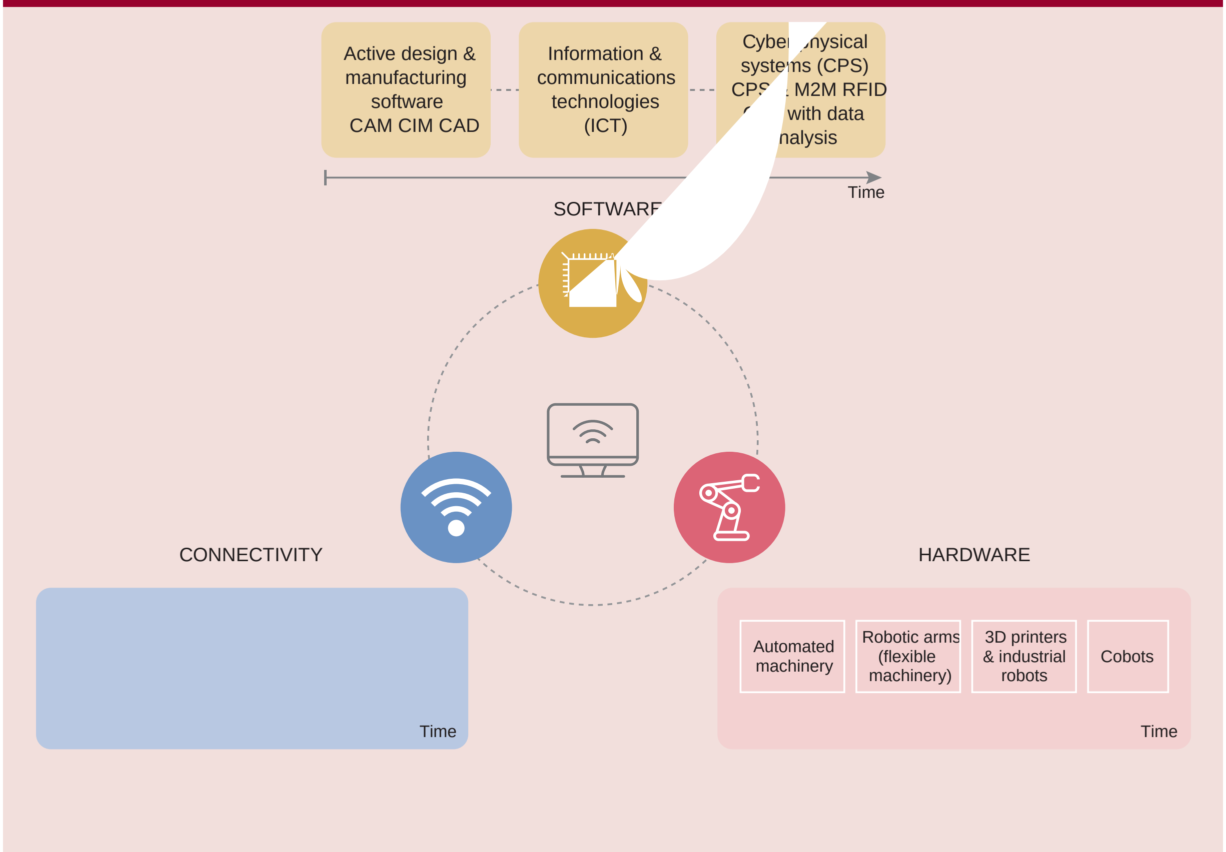
Advanced digital production connectivity is one big change from older manufacturing

The other big change is advanced digital production software for smart networked systems

> “ Cyber-physical systems can create new production ecosystems

Figure 1.9
Building blocks of ADP technologies



(1.5; 1.8).

Advanced software changes the factory, the supply chain and the product life cycle

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The potential bene ts of ADP technologies

ADP technologies can improve profits, sustain the environment and expand the labour force

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> “Cobots are being increasingly adopted in manufacturing rms in advanced and emerging economies

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Box 1.2
Collaborating with the robots

Source: UNIDO elaboration.

Box 1.3
Manufacturing complex metal parts through 3D printing

Source: UNIDO elaboration.

> “Cloud technology can enable industrial companies to optimize operations and coordinate different business areas

Box 1.4
Using the Internet of Things for remote control of water treatment plants

[illegible]

Source: UNIDO elaboration.

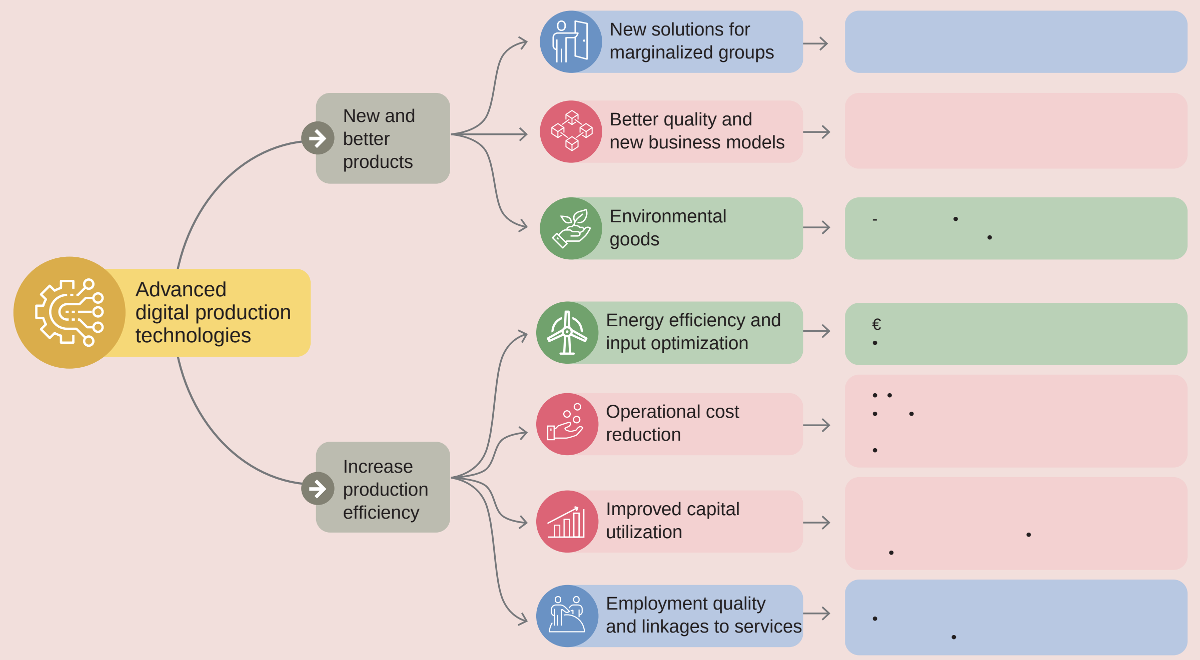
Box 1.5
Improving the accuracy of rubber production through cloud computing and big data analytics

[illegible]

Source: UNIDO elaboration.

> ADP technologies offer the possibility of revitalizing industrialization

Figure 1.10
Expected dividends from ADP technologies



Source: UNIDO elaboration based on Andreoni and Anzolin (2019).

Better products and increased efficiency advance development

Expanded data analytics are key to improving products and services

Data quality and access improve labour productivity

> Adoption and diffusion of ADP technologies are expected to boost economic growth, job creation and poverty alleviation

(2016).

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> “ Collected data may provide a foundation for circular economy business models

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ADP technologies can meet some of the consumption needs of marginalized groups

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3D printing saves energy

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New technologies can improve working conditions and workers’ involvement

> "Technological revolutions have divided the world into leading and following economies

Characterizing the global landscape of ADP technologies

Industrial revolutions have leading and following economies

Identifying the leading economies in advanced digital production technologies

Patents, exports and imports characterize the leading economies

> “One striking feature is the extreme concentration of patenting and exporting activity

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The very top economies explain most of the advanced digital production activity

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Who is doing what?

The top 50 economies in advanced digital production

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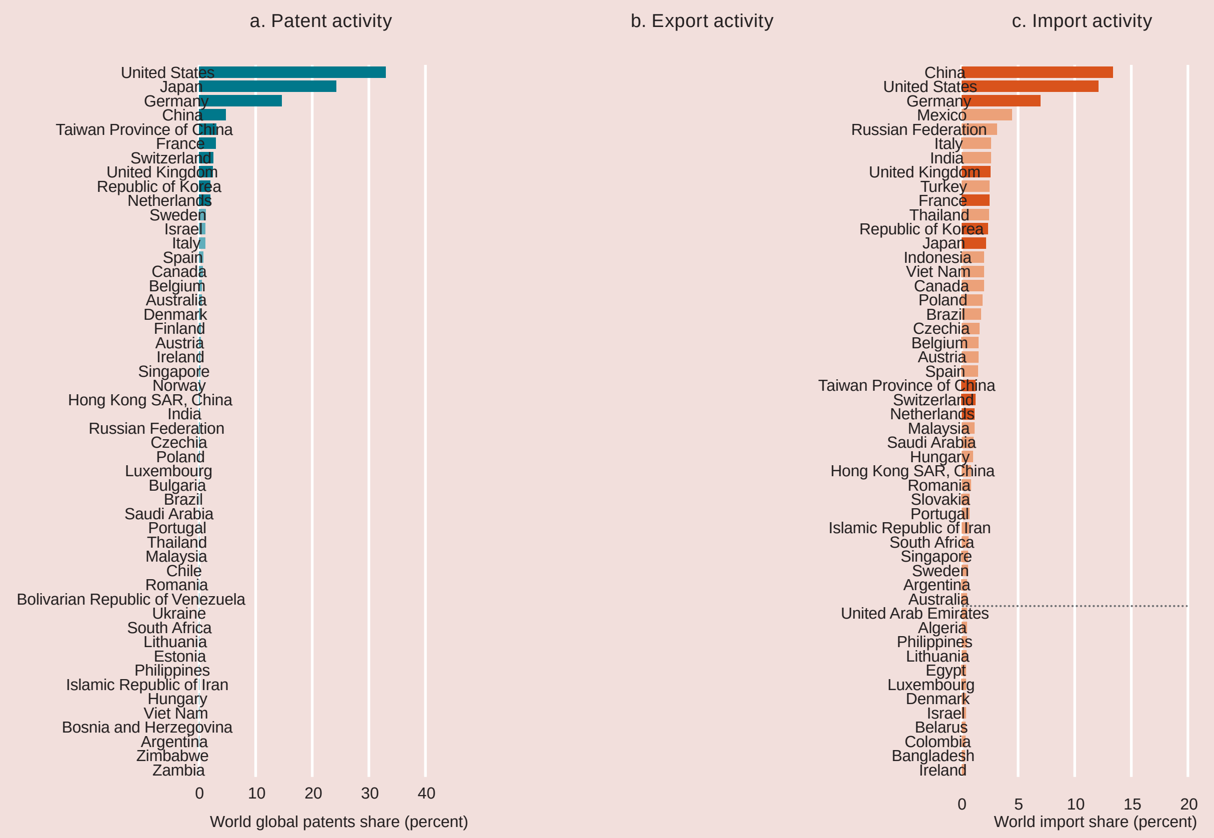
Figure 1.12
Patenting, exporting and importing of ADP technologies: Different roles but similar concentration of the top 50 economies



"Ten frontrunner economies account for 91 percent of patents in ADP technology

Ten frontrunner economies account for 91 percent of patents, 70 percent of exports and 46 percent of imports of new technologies

O 50 10 N 91 (1.12). 70 46 *frontrunners*

Other economies in the top 50, though with lower values, are also engaging in the new technologies

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Looking just at global shares may be deceptive: Comparative indices of patents, exports and imports indicate other notable economies

1.13

How to distinguish followers, latecomers and laggards

follower, latecomer laggard (.1).

“Large parts of the world remain excluded from recent technological breakthroughs

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Much of the world, especially in Africa, is not engaging with the new technologies

Frontrunners and followers are actively engaging with ADP technologies

The roles are diverse among economies engaging in new technologies

Table 1.1
From laggards to frontrunners in the emerging technological landscape

Group		Short description	Criteria
Frontrunners (10 economies)		Top 10 leaders in the field of ADP technologies	Economies with 100 or more global patent family applications in ADP technologies (average value for all economies with some patent activity in this field)
Followers in production (23 economies)	As innovators	Economies actively involved in patenting in the field of ADP technologies	Economies with at least 20 regular patent family applications, or 10 global patent family applications in ADP technologies (average values for all economies with some patent activity, once frontrunners are excluded)
	As exporters	Economies actively involved in exporting ADP-related goods	Economies relatively specialized in exporting ADP-related goods that sell large volumes in world markets (above the average market share once frontrunners are excluded)
Followers in use (17 economies)	As importers	Economies actively involved in importing ADP-related goods	Economies relatively specialized in importing ADP-related goods that purchase large volumes in world markets (above the average market share once frontrunners are excluded)
Latecomers in production (16 economies)	As innovators	Economies with some patenting activity in ADP technologies	Economies with at least one regular patent family application in ADP technologies
	As exporters	Economies with some exporting activity of ADP-related goods	Economies that either show relative specialization in exporting ADP-related goods or sell large volumes in world markets (above the average market share once frontrunners are excluded)
Latecomers in use (13 economies)	As importers	Economies with some importing activity of ADP-related goods	Economies that either show relative specialization in importing ADP-related goods or sell large volumes in world markets (above the average market share once frontrunners are excluded)
Laggards (88 economies)		Economies showing no or very low engagement with ADP technologies	All other economies not included in the previous groups

Economies actively engaging with ADP technologies

Note: The characterization is for 167 economies that, according to the United Nations Statistical Division, had more than 500,000 inhabitants in 2017. See Annex A.1 for the classi cation of economies by their level of engagement with ADP technologies

Source: UNIDO elaboration.

> “ Without international support, low-income countries run the risk of lagging further behind

steps to engage with the new technologies, but it is not yet clear whether they will succeed in becoming [illegible]lowers. And among the followers, a large number [illegible] engaging in ADP technologies by importing cap[illegible] goods produced aboard, with very little or no dom[illegible]tic innovating and exporting activity. e prospects for these economies to move up the technological lad[illegible] are limited; advancing upward will require large inv[illegible]ments in industrial and technological capabilities.

e international community should support lagging economies

ese two features call for immediate action from the international community to support developi[illegible] countries—especially the least developed countr[illegible] —in adopting ADP technological breakthrough[illegible] Without international support, low-income coun[illegible]tries run the risk of lagging further behind and fa[illegible]ing to achieve the SDGs. As discussed in the [illegible] sections, this support should be oriented towa[illegible] building basic, intermediate and advanced indust[illegible] and technological capabilities, together with dig[illegible] infrastructure.

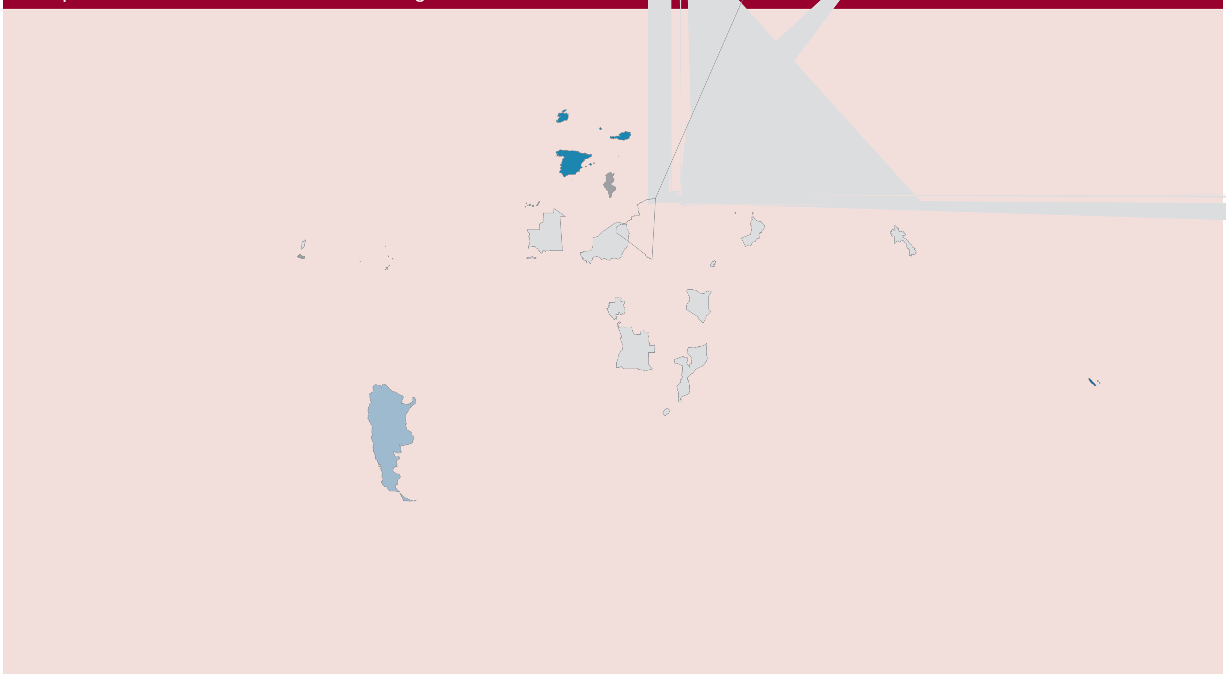
The need for wider industrial capabilities [illegible]

Developing countries face multiple challe[illegible]

Most developing countries are far from [illegible] established players in this field because [illegible] challenges they face in engaging with the n[illegible] These challenges can be grouped und[illegible] headings (Andreoni and Anzolin 2019):

1. Basic capabilities. The production cap[illegible] required for absorbing, deploying an[illegible] ADP technologies along supply chain[illegible] and unevenly distributed. ese technol[illegible] also raised the “basic capability thre[illegible] because they are entirely new but b[illegible] simply the fusion of new and existing te[illegible] into complex integrated systems.
2. Retrofitting and integration. Companies in developing countries that could make technology investments in this area have already committed resources to older technologies, and they need to learn how to retrofit and integrate the new ADP technologies into their production plants. Setting up new plants is rarer, because it requires

Figure 1.14
The production and use of ADP technologies are concentrated in a fe[illegible] frontrunners



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> “ The ADP technology landscape reflects the global heterogeneity of industrial capabilities

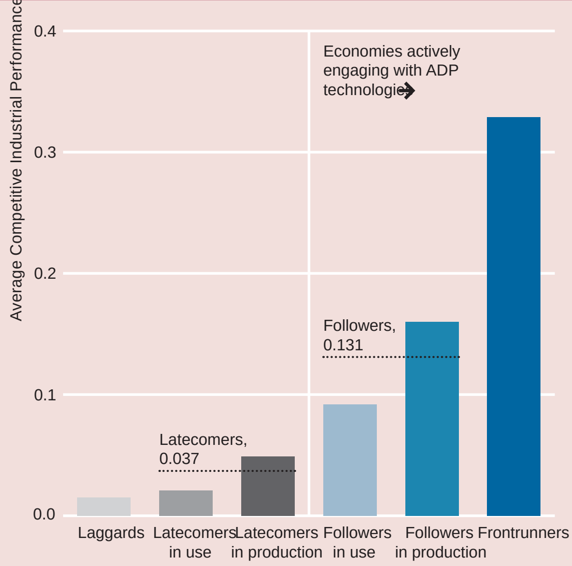
3. *Digital infrastructure.*

4. *Digital capability gap.*

5. *Access and affordability.*

To engage with ADP technologies, developing economies must build industrial capabilities

Figure 1.15
Engaging with ADP technologies requires increasing industrial capabilities

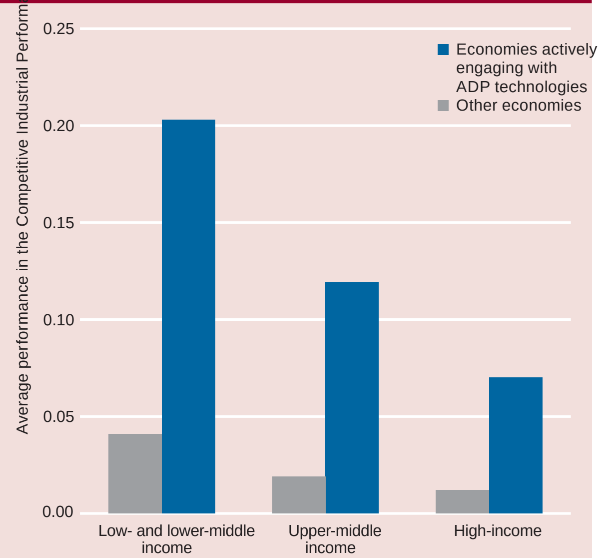


Note: ADP is advanced digital production. All values are average for the year 2017. See Annex A.1 for the classification of economies by their level of engagement with ADP technologies, and Table 1.1 for the description and criteria used in the classification. CIP is Competitive Industrial Performance.
Source: UNIDO elaboration based on the Competitive Industrial Performance Index 2019 database (UNIDO 2019c) and dataset by Foster-McGregor et al. (2019) derived from Worldwide Patent Statistical Database 2018 Autumn Edition (EPO 2018) and BACI International Trade Database (Gaulier and Zignago 2010).

Average Competitive Industrial Performance Index scores differentiate laggards, latecomers, followers and leaders

> “ Actively engaging in the new technologies requires building strong industrial capabilities

Figure 1.16
Within income groups, economies actively engaging with ADP technologies show much greater industrial capabilities than the rest



Note: ADP is advanced digital production. All values are average for the year 2017. The analysis includes 140 economies, of which 50 are actively engaging with advanced digital production (ADP) technologies). By World Bank income group de nitions for 2017: 53 are low- and lower-middle income economies (of which 4 are active), 38 are upper-middle income economies (of which 13 are active) and 49 are high-income economies (of which 33 are active). Se A.1 for the classi cation of economies by their level of engagement with ADP techno
Source: UNIDO elaboration based on the Competitive Industrial Performance Index 2 database (UNIDO 2019c) and dataset by Foster-McGregor et al. (2019) derived fro Patent Statistical Database 2018 Autumn Edition (EPO 2018) and BACI Internationa Database (Gaulier and Zignago 2010).

Dividends from engaging: Growth, employment and sustainability

Economies engaging with the new technologies have grown fastest

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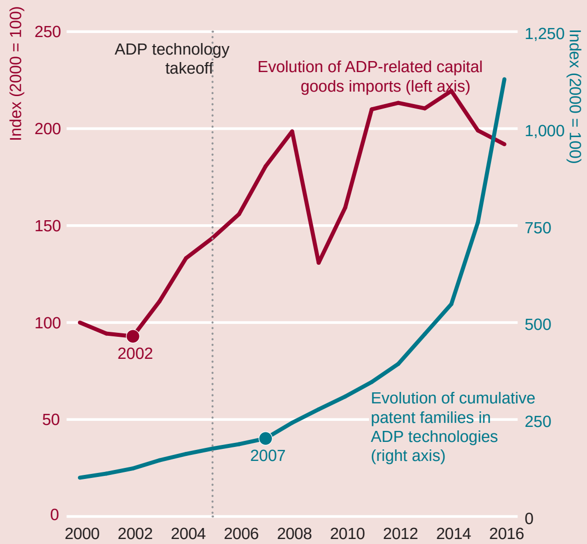
Digital production technology took off in the 2000s

2002 (1.17).

Figure 1.17
The production of ADP technologies takes off after 2005



Note: ADP is advanced digital production. Import values are in current $. The blue line shows the evolution in the total value of imports related to ADP technologies at the world level for three groups of goods: 3D printers, computer-aided design and computer-aided manufacturing (CAD-CAM) equipment and industrial robots. The green line shows the evolution in the cumulative number of patent families in four ADP technologies: additive manufacturing, CAD-CAM, robotics and machine learning.
Source: UNIDO elaboration based on the dataset by Foster-McGregor et al. (2019) derived from Worldwide Patent Statistical Database 2018 Autumn Edition (EPO 2018) and BACI International Trade Database (Gaulier and Zignago 2010).

CIP Index values tell more about new technology engagement than country income group

(1.16).

> "Average MVA growth is much faster for frontrunners and followers than for latecomers and laggards

Growth dynamics differ across country income groups

Frontrunners and followers lead in MVA growth because of productivity growth

ADP technologies tend towards environmentally friendly solutions

Figure 1.18
Economies active in ADP technologies grow faster than the rest, across all income groups

Note: ADP is advanced digital production. MVA is manufacturing value added. Each panel shows the average yearly growth rate of the corresponding group and variable between 2005 and 2017. The analysis includes 166 economies (of which 50 are actively engaging with ADP technologies), which are classified according to World Bank's income group definitions for 2017: 73 low- and lower-middle income economies (of which 4 are active); 44 upper-middle income economies (of which 13 are active) and 49 high-income economies (of which 33 are active). Productivity is calculated as manufacturing value added in constant $ 2010 divided by the number of workers. See Annex A.1 for the classification of economies by their level of engagement with ADP technologies.
Source: UNIDO elaboration based on the Manufacturing Value Added 2019 database (UNIDO 2019g), ILO (2018), and dataset by Foster-McGregor et al. (2019) derived from Worldwide Patent Statistical Database 2018 Autumn Edition (EPO 2018) and BACI International Trade Database (Gaulier and Zignago 2010).

“ ADP technologies have above-average green content

Robots, machine learning and CAD-CAM systems have above-average green content

New windows of opportunity? Catching up, stage-skipping and leapfrogging

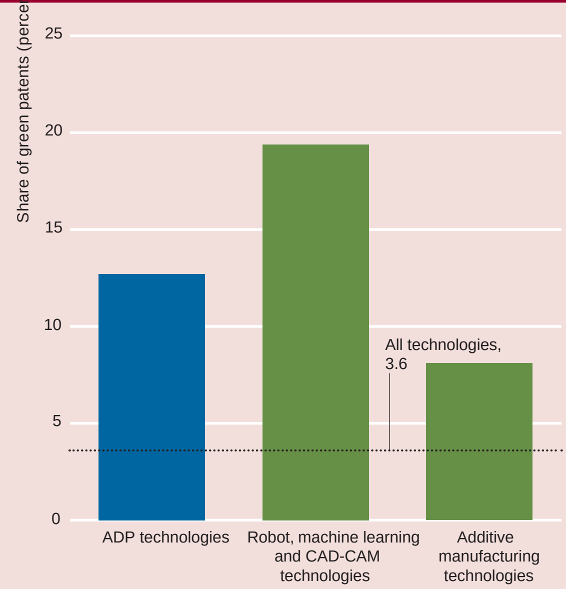
ADP technologies are the tip of the iceberg

ADP technologies require industrial and technological capabilities

Only a small portion of the economy in most countries has entered the fourth industrial revolution

Developing countries fit incomplete third industrial revolution systems with 4IR technologies

Figure 1.19
ADP technologies have above-average green content



Note: ADP is advanced digital production. CAD-CAM is computer-aided design and computer-aided manufacturing. When patent examiners consider that a patent is contributing to climate change mitigation, they attach a special Y02 tag. This tag makes it possible to identify the subgroup of patents that refer to green technologies and compare it with it the share of green patents in all patents applied in any technology field (not only ADP technologies) in the last 20 years.
Source: UNIDO elaboration based on dataset by Foster-McGregor et al. (2019) derived from Worldwide Patent Statistical Database 2018 Autumn Edition (EPO 2018).

> Firms use a combination of digital technologies emerging from different paradigms

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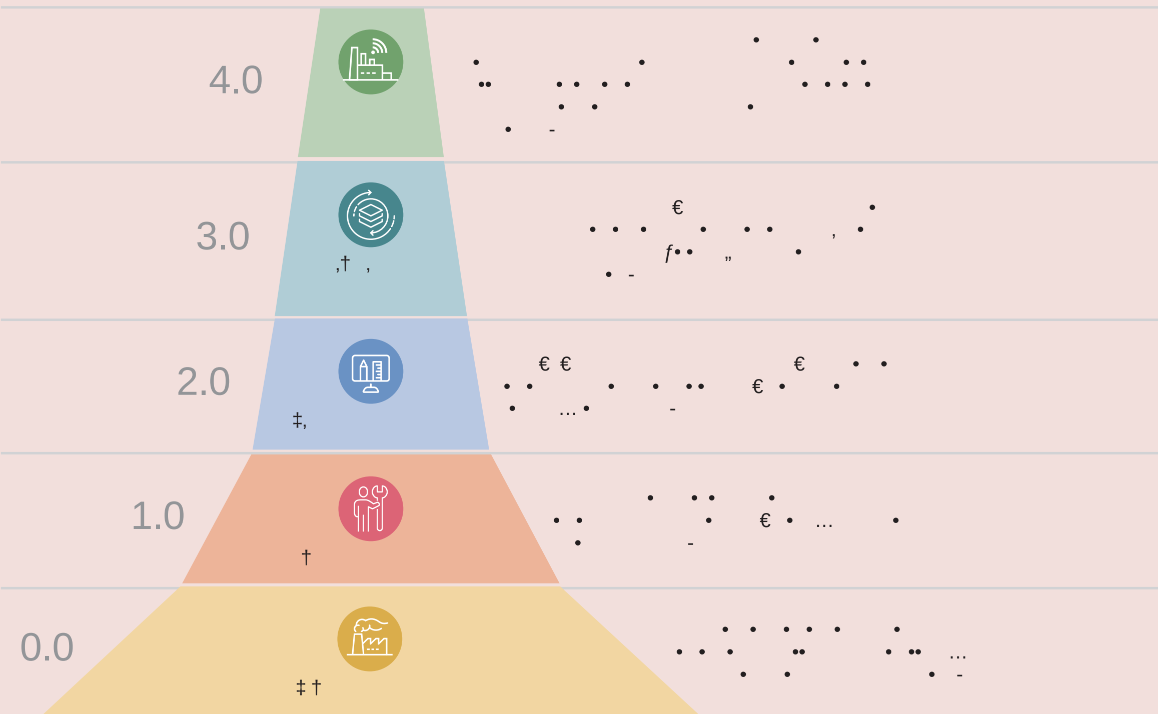
Different technological generations coexist

Up to 70 percent of firms are still in analog production

Figure 1.20
Four generations of digital production technologies applied to manufacturing production



NoteDPT is digital production technology. CAD is computer-aided design. CAM is computer-aided manufacturing.
SourceUNIDO elaboration based on Kupfer et al. (2019).

“ Latecomer economies do not simply follow the technological path of advanced countries

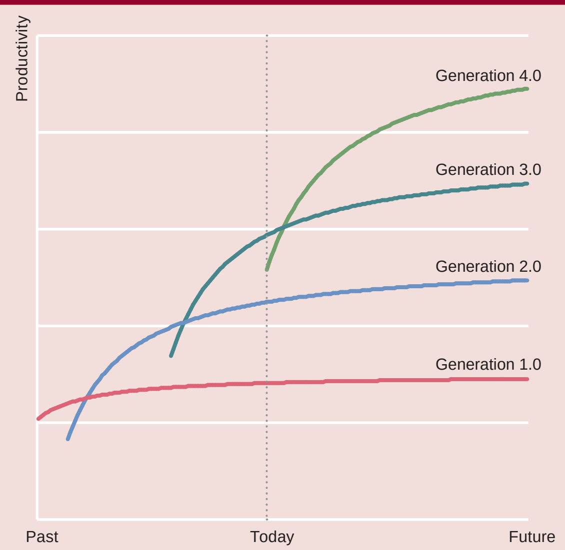
The newest technology's highest productivity is yet to come

Leapfrogging into the 4IR depends on country and industry conditions

Moving towards the frontier

Development by latecomers often includes leapfrogging

Figure 1.21
Leapfrogging in digital technologies for manufacturing production



Note: The figure illustrates conceptually the time trajectory of different technology generations in terms of their average productivity. The curves indicate the level of productivity (vertical axis) associated with the use of that generation at a specific point in time (horizontal axis). The vertical dotted line indicates the present time. For a firm using Generation 1.0 today, a path-following strategy would entail moving to Generation 2.0, a stage skipping strategy would entail moving to Generation 3.0, and a path creating strategy would entail moving to Generation 4.0.
Source: UNIDO elaboration based on Lee (2019).

> “ In a path-creating strategy, the latecomer adopts the newest generation of technology

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A choice between path following, stage skipping and path creating

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> “In times of paradigm shifts, new windows of opportunity emerge for latecomers

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Small start-up firms have advantages in exploiting opportunities

(L 2019).

> “Leapfrogging into emerging technologies requires policy support

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Trying to leapfrog creates risky choices

Latecomers need research and development capabilities to leapfrog

Adopting ADP technologies requires new public policies and subsidies

Country possibilities depend on industrial structure, domestic firm capabilities and policies

Manufacturing is still important

The diffusion of ADP technologies depends on cost-effectiveness and digital capabilities

> Industrialization is fundamental for embarking on a 4IR learning pathway

Industrialization is the pathway toward the fourth industrial revolution

Manufacturing is central to developing productive capabilities

The 4IR stems from earlier manufacturing technologies

> " The application of ADP technologies to services has remained in activities that do not deliver structural transformation

Services using ADP technologies do not spur much production

Notes

1. (2019), 2017, 16.2 V , (14.1) (12.9).
2. . (2004).
3. (1979, 1988), V (2004), . (2018).
4. (2006), O' V (2009), . (2006).
5. ( )
6. *servicification* (2005, . 2003) (2010, . 2015). (O 2018, . 2015) (2007, 2009, 2016, 2008).
7. 71 Q (*Renting of machinery and equipment*), 72 (*Computer and related activities*), 73 74O (*R&D and other business activities*) O -O (O). O O (.2.1).
8. 1.6 V .
9. (2019).
10. , O (2017), (2016), (2018), (2018), O (2017).
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Chapter 2

The evolving landscape of industrialization under advanced digital production technologies

The path of a country's technological change is determined by industrial sector changes

Changes in industrial structure drive changes in employment

ADP technologies and the structure of manufacturing

Some manufacturing industries are more likely than others to adopt new technologies

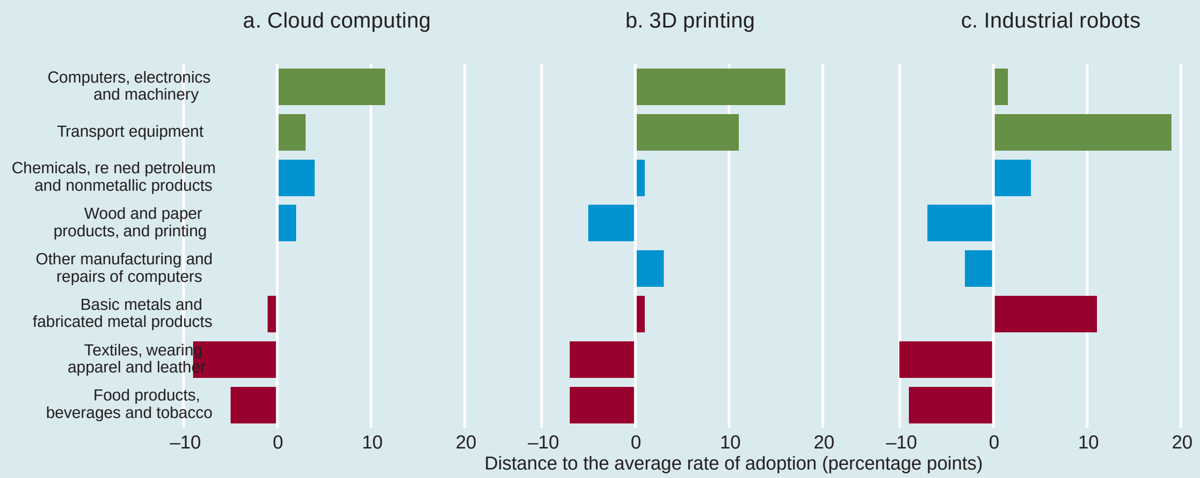
The computer and transport equipment industries are most likely to adopt ADP technologies

The computer and transport equipment industries are technology and digital intensive

> “The productive structure of countries has a key role in determining the diffusion of ADP technologies

2

Figure 2.1
Rates of adoption of key ADP technologies differ across industries in Europe



Note: All values are for 2018 and are aggregates for the 28 countries of the European Union. Adoption rate is de ned as the percentage of rms in an industry using a chosen technology. Due to dat availability, chemicals are presented together with re ned petroleum and nonmetallic products (ISIC codes 19 to 23). The colours of the bars re ect the technology and digital intensity classi cation industries. Green = TDI industries (industries that are simultaneously intensive on digitalization and technology). Blue = industries that are intensive on either digitalization or technology but not bo Red = industries that are intensive on neither digitalization nor technology. The bars show the distance from the average rate of adoption in all manufacturing industries, in percentage points. (See Tab
Source: UNIDO elaboration based on Eurostat (2019).

Table 2.1
Typology of industries by digital intensity and technology intensity

		Digital intensity: Low and medium-low	Digital intensity: Medium-high and high
Technology intensity	Low and medium-low	• Food products, beverages and tobacco (ISIC 10t12) • Textiles, wearing apparel and leather (ISIC 13t15) • Coke and refined petroleum products (ISIC 19) • Rubber and plastics products (ISIC 22t23) • Basic metals and fabricated metal products (ISIC 24t25)	• Wood and paper products, and printing (ISIC 16t18) • Other manufacturing (including furniture) and repairs of computers (ISIC 31t33)
Technology intensity	Medium-high and high	• Chemicals and pharmaceutical products (ISIC 20t21)	• Computers, electronics and machinery (ISIC 26t28) • Transport equipment (ISIC 29t30)

Source: UNIDO elaboration based on Calvino et al. (2018) and OECD (2011).

Countries with a higher share of TDI industries adopt more ADP technologies

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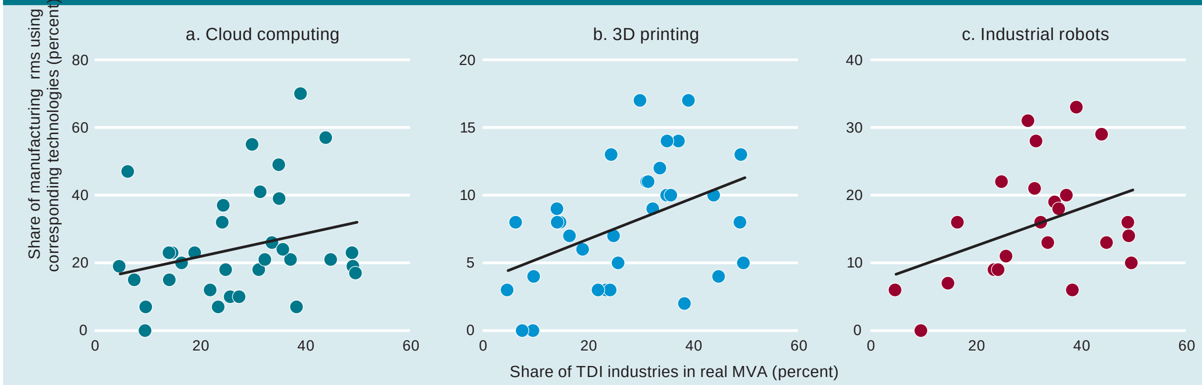
(2.2).

“ TDI industries are the main bases for the development, learning and use of the new technologies

Figure 2.2
The adoption of key ADP technologies in manufacturing is positively associated with the share of TDI industries in MVA



Note: TDI is technology- and digital-intensive. MVA is manufacturing value added. All values are for 35 European economies in 2018 in real value added in constant $ 2010. The scatter plots average diffusion of each technology in the manufacturing sector against the share of TDI industries in real MVA.
Source: UNIDO elaboration based on Eurostat (2019) and the INDSTAT2 ISIC, Rev. 3. database (UNIDO 2019e).

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Frontrunners and followers have a larger share of TDI industries

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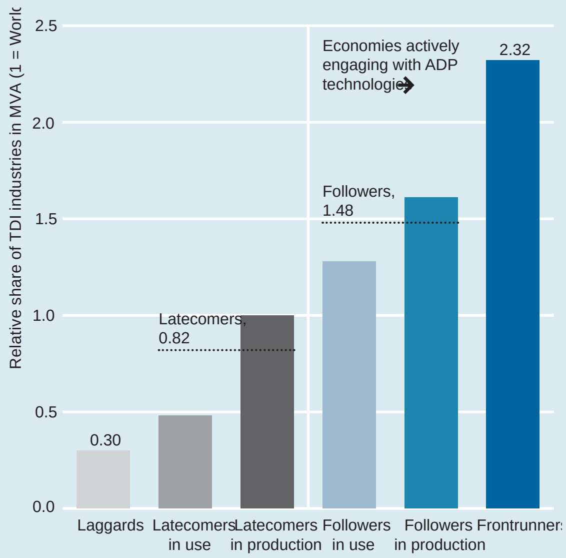
Figure 2.3
Economies actively engaging with ADP technologies tend to have a much larger share of TDI industries in MVA



Note: ADP is advanced digital production. TDI is technology- and digital-intensive. MVA is manufacturing value added. All values are for 2017 or the closest year and are in current $. The analysis includes 109 economies, 49 of which are actively engaged with ADP technologies. See Annex A.1 for the classification of economies by their level of engagement with ADP technologies.
Source: UNIDO elaboration based on Foster-McGregor et al. (2019) dataset derived from Worldwide Patent Statistical Database 2018 Autumn Edition (EPO 2018) and BACI International Trade Database (Gaulier and Zignago 2010) and on the INDSTAT2 ISIC, Rev. 3. database (UNIDO 2019e).

The positive relationship also holds within economies of similar income

( ) (2.4).

> "TDI industries are crucial for a deeper engagement with the new technologies

Changing patterns of manufacturing development

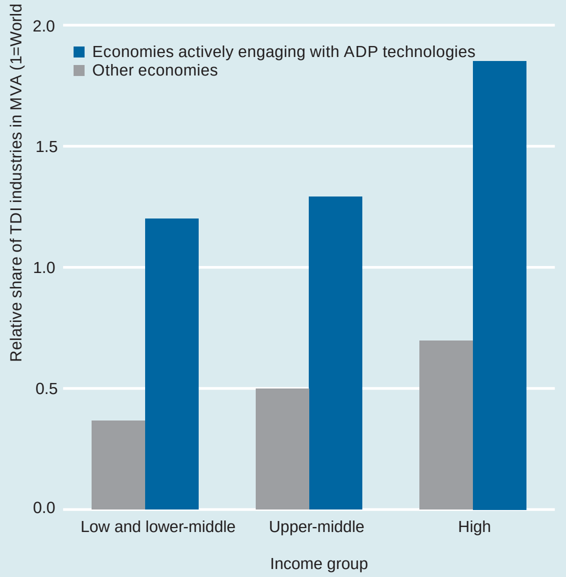
How does adopting ADP technologies affect industries' performance?

Shares of real MVA

TDI industries' share in MVA increased after ADP technology takeoff

Frontrunners and followers have comparative advantages in TDI industries

Figure 2.4
Within country income groups, economies actively engaging with ADP technologies also tend to have a much larger share of TDI industries in MVA



Note: ADP is advanced digital production. TDI is technology- and digital-intensive. MVA is manufacturing value added. All values are for 2017 or the closest year and are in current $. The analysis includes 109 economies, 49 of which are actively engaged with ADP technologies, classified according to World Bank's income group definitions for 2017: 31 low and lower-middle income economies (of which 4 are active); 31 upper-middle income economies (of which 13 are active); and 47 high income economies (of which 32 are active). See Annex A.1 for the classification of economies by their level of engagement with ADP technologies.
Source: UNIDO elaboration based on dataset by Foster-McGregor et al. (2019) derived from Worldwide Patent Statistical Database 2018 Autumn Edition (EPO 2018) and BACI International Trade Database (Gaulier and Zignago 2010) and on the INDSTAT2 ISIC, Rev. 3. database (UNIDO 2019e).

As countries get richer, TDI industries increase in importance

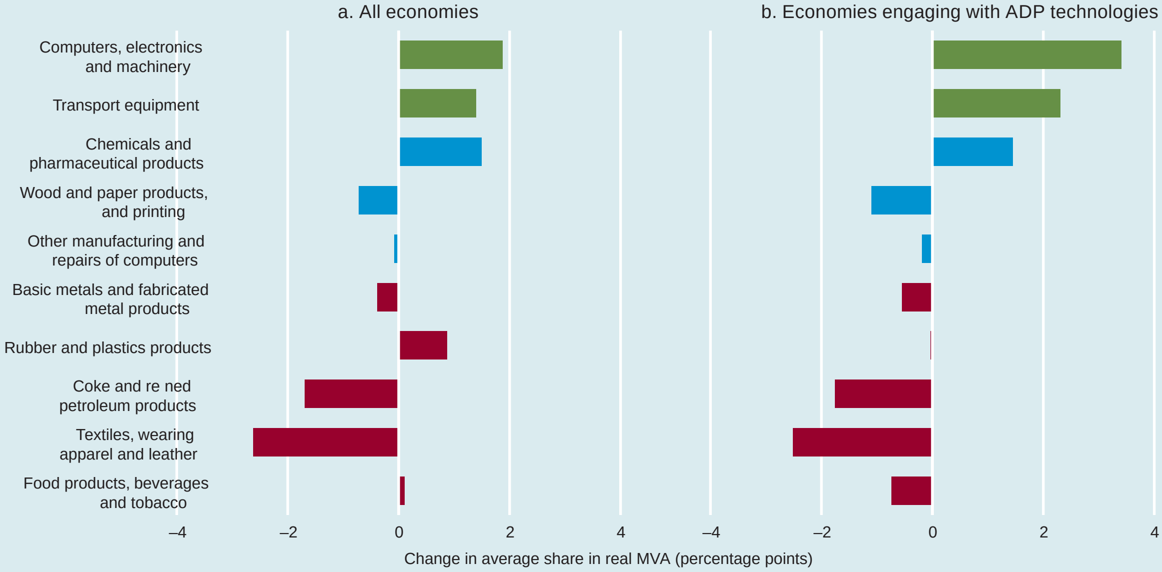
> “ Firms that have adopted the predictive maintenance system have a competitive edge

Box 2.1
Fostering competitiveness through ADP technologies in South African machinery, equipment and electronics industry

[illegible]

Source: Kaziboni et al. 2019.

Figure 2.5
The average share of TDI industries increased after 2005, especially for economies actively engaging with ADP technologies



Note: ADP is advanced digital production. MVA is manufacturing value added. The gure shows the change in the average share in real MVA in constant $ 2010 between 1990–2004 and 20
The colours of the bars re ect the technology and digital intensity classi cation of industries. Green = TDI industries (industries that are simultaneously intensive on digitalization and techno
Blue = industries that are intensive on either digitalization or technology but not both. Red = industries that are intensive on neither digitalization nor technology. Panel b includes only frontr
follower economies, as de ned in Chapter 1. See Annex A.1 for the classi cation of economies by their level of engagement with ADP technologies and Table 1.1 for the description and crite
the classi cation.
Source: UNIDO elaboration based on the INDSTAT2 ISIC, Rev. 3. database (UNIDO 2019e) with some data gaps lled using UNIDO (2012, 2019f), the World Input-Output Database (Timme
and Los et al. (2015).

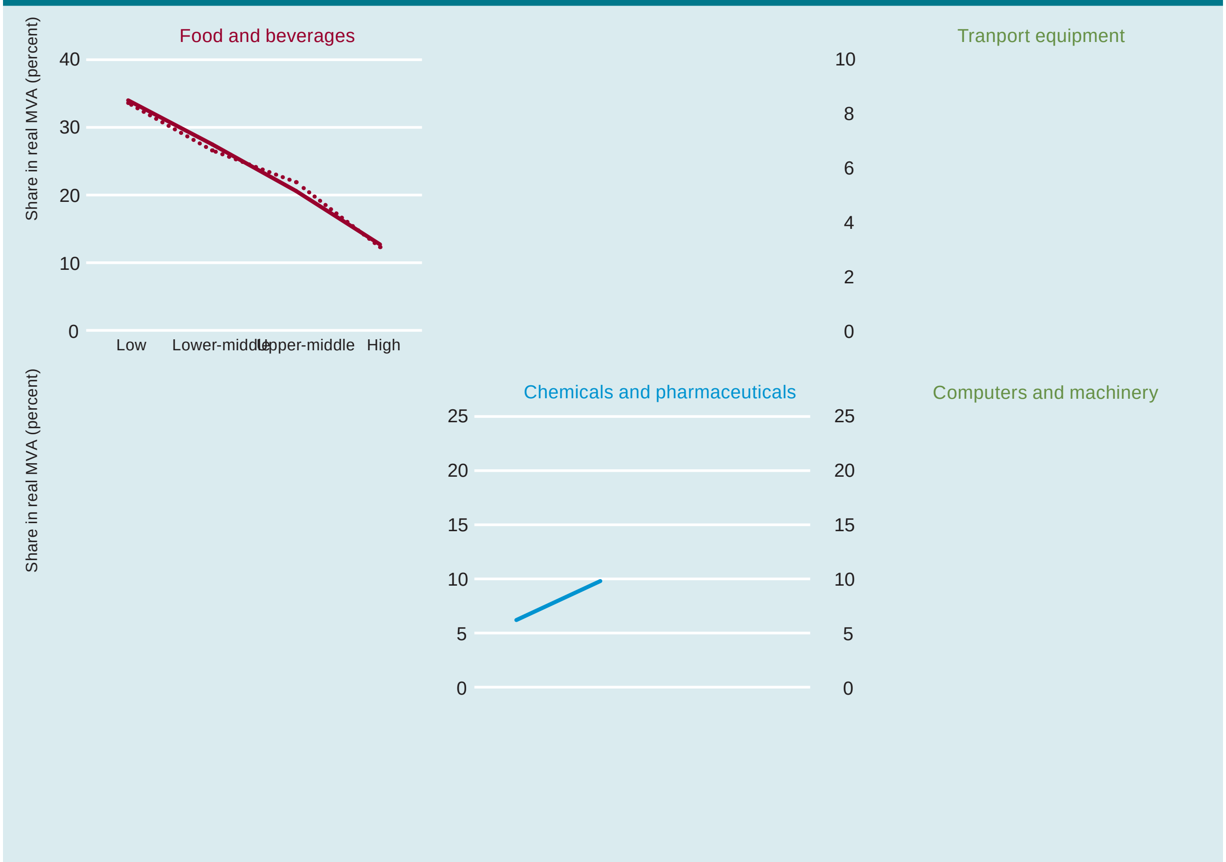
> “ Low-technology industries decline in importance as countries get richer, while TDI industries increase in importance

The importance of TDI industries increased after 2005

Drivers of real MVA growth: Employment and productivity

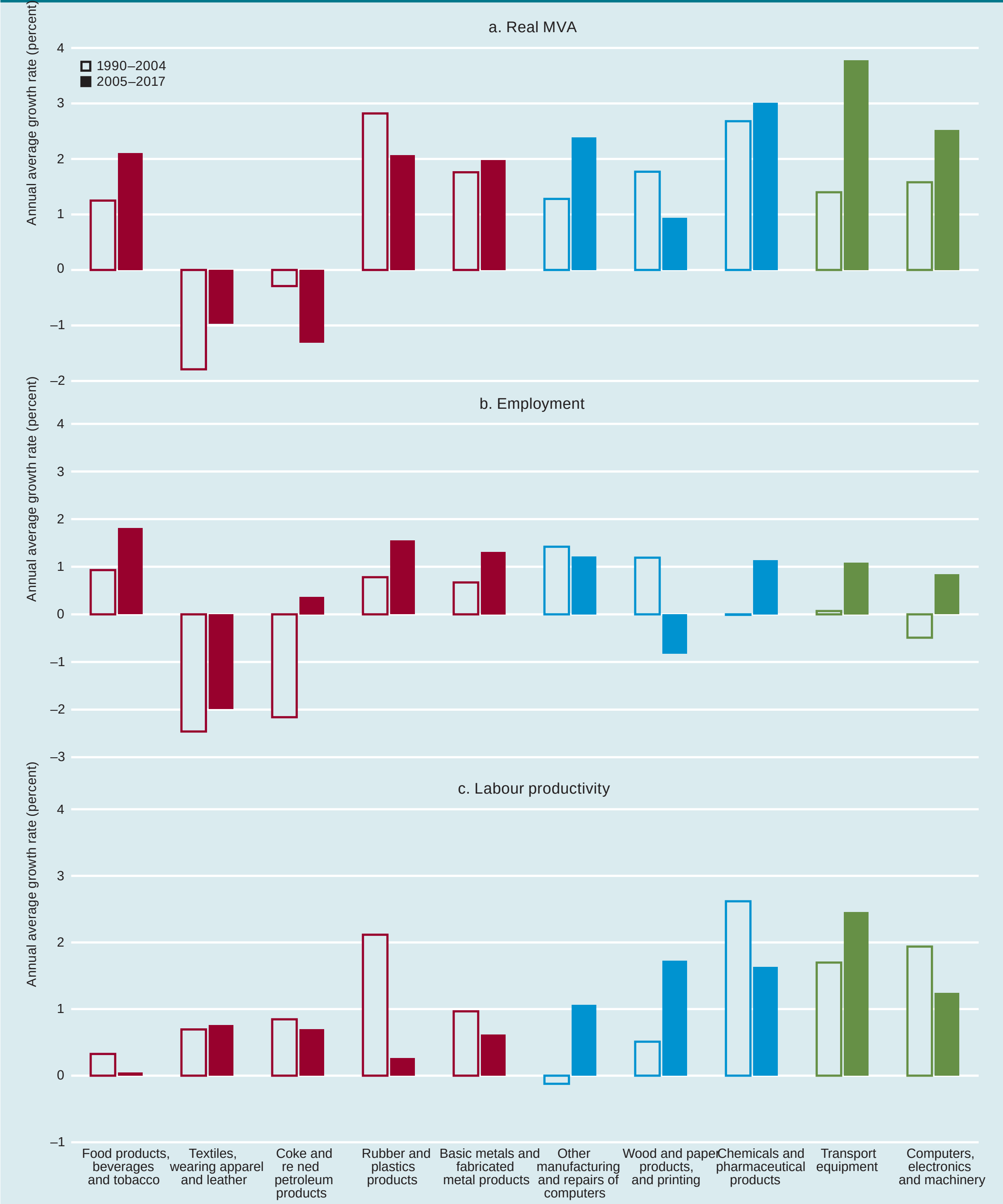
TDI industries grew in both employment and productivity

Figure 2.6
Shifts in the patterns of structural change before and after 2005 for selected industries by country income group



“ TDI industries grew faster than other manufacturing industries

Figure 2.7
Real MVA growth and its drivers: Employment and productivity



NoteMVA is manufacturing value added. The analysis includes 86 economies. Productivity is calculated as real MVA (in constant $ 2010) per number of workers. The colours of the bars re technology- and digital-intensity classification of industries. Green = TDI industries (industries that are simultaneously intensive on digitalization and technology). Blue = industries that are i either digitalization or technology but not both. Red = industries that are intensive on neither digitalization nor technology.
SourceUNIDO elaboration based on the INDSTAT2 ISIC, Rev. 3. database (UNIDO 2019e) with some data gaps filled using UNIDO (2012, 2019f), the World Input-Output Database (Timme and Los et al. (2015).

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> “Active engagement with ADP technologies requires increasing support from knowledge-intensive services

The takeoff of ADP technologies after 2005 favoured TDI industries

> “ Frontrunners and followers have a much higher share of TDI industries in their MVA

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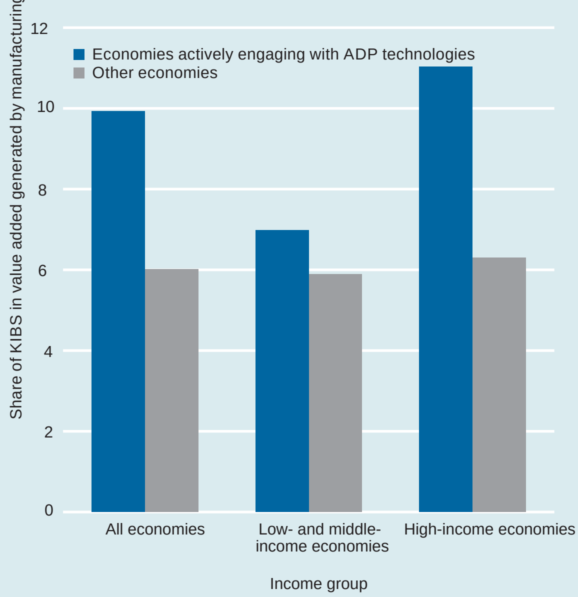
Differences in industrial structure at different levels of ADP engagement

In ADP technology frontrunner and follower economies, the share of TDI industries in MVA is high

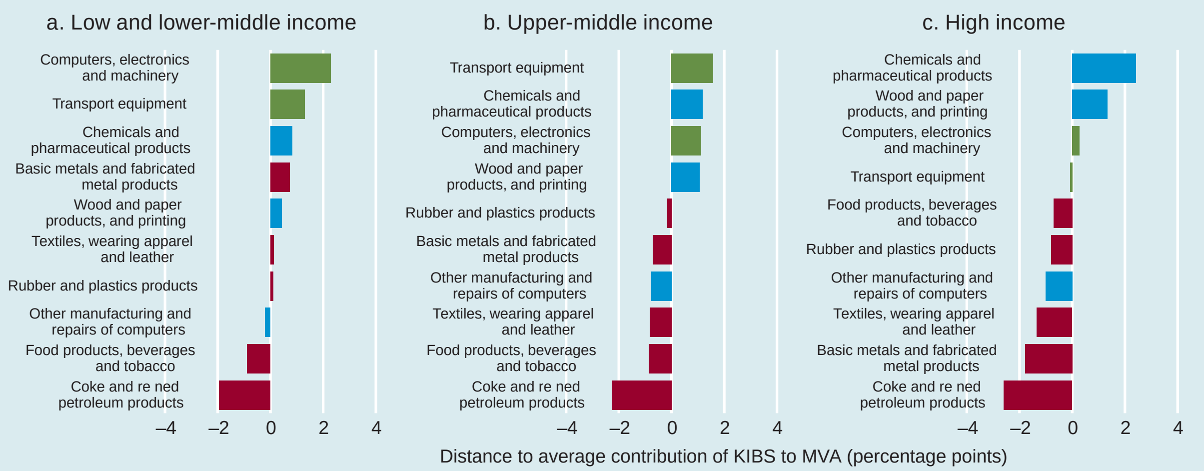
Figure 2.9
Manufacturing industries in economies actively engaging with ADP technologies are more integrated with KIBS at all country group income levels



Note: KIBS is knowledge-intensive business services. ADP is advanced digital production. Values are averages for the period 2005–2015. Manufacturing value added is in current $. The analysis includes 63 economies, which are classified according to World Bank income group definitions for 2005: 30 low and middle income economies (of which 9 are active) and 33 high income economies (of which 24 are active). See Annex A.1 for the classification of economies by their level of engagement with ADP technologies.
Source: UNIDO elaboration based on Inter-Country Input-Output (ICIO) Tables (OECD, 2016, 2018b).

ADP technologies foster productivity and employment growth that make development inclusive

Figure 2.10
KIBS are more integrated with TDI industries than average, especially in developing countries



Note: MVA is manufacturing value added is in current $. KIBS is knowledge-intensive business services. Average values for the period 2005–2015. This analysis includes 63 economies, which are classified according to World Bank's income group definitions for 2005: 30 low and middle income economies (of which 9 are active), and 33 high income economies (of which 24 are active). The c… of the bars reflect the technology- and digital-intensity classification of industries. Green = TDI industries (industries that are simultaneously intensive on digitalization and technology). Blue = indus… that are intensive on either digitalization or technology but not both. Red = industries that are intensive on neither digitalization nor technology.
Source: UNIDO elaboration based on Inter-Country Input-Output (ICIO) Tables (OECD, 2016, 2018b).

> “ ADP technologies could shift the distribution of value added and employment across sectors

Frontrunner and follower economies have a high share of KIBS in manufacturing

But technological advances may also create new kinds of occupations and so create employment

ADP technologies and the “skills of the future”: Risks of digitalization

ADP technologies could change manufacturing, employment, and value added across industries and sectors

Analytical, technology-related and soft skills will be needed in jobs created by ADP technologies

Effects of ADP technologies on the labour market are unclear

Technological advances are increasing machines’ ability to substitute for labour

> “There is still no clear-cut evidence on whether ADP technologies will make some occupations redundant

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(2.3).

(. 2018, 2019).

More study is needed on the employment effects of ADP technologies for developing countries and for women

( )(N O 2019).

Gender differences in the risk of digitalization

How will ADP technologies affect men and women’s jobs in developing countries?

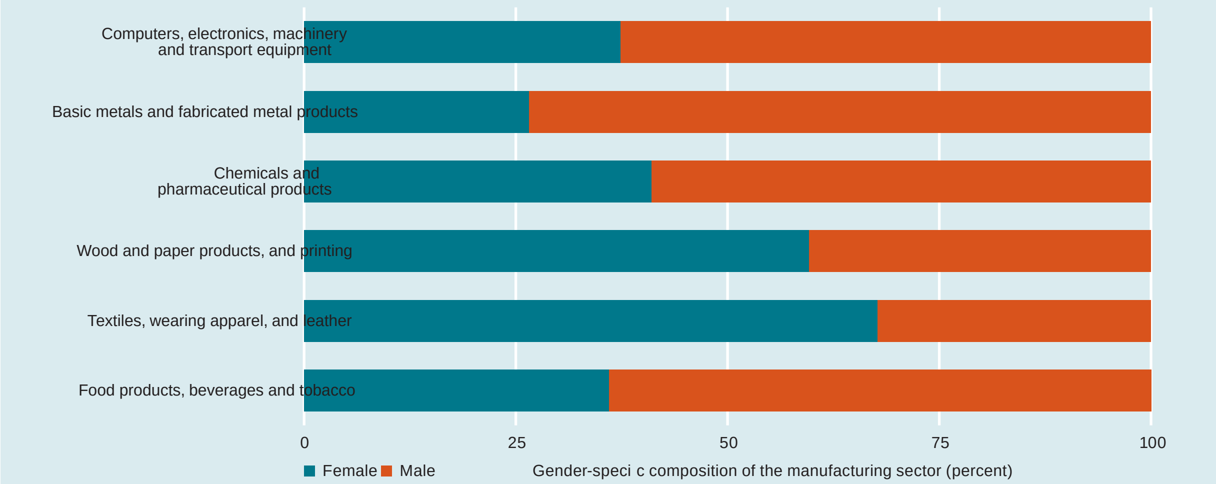
> “The risk of computerization varies widely across manufacturing sectors

Women concentrate in sectors with low technological intensity and low value added

Using workers’ skills and competencies to study the risk of computerizing jobs

Risks of computerization vary by sector and gender

Figure 2.11
Women constitute the largest share of workers in textile and wood industries



Note: Shares of male and female workers in each subcategory of manufacturing sector were calculated using country-speci c sample weights provided in Skills Towards Employability and Pr (STEP) program surveys. The analysis includes Armenia, Colombia, Georgia, Ghana, Kenya, Lao People’s Democratic Republic, North Macedonia, Sri Lanka, the Plurinational State of Bo Viet Nam.
Source: UNIDO elaboration based on dataset by Sorgner (2019) derived from the STEP Skills Measurement Program (World Bank 2016).

> “ Women’s computerization risk is about 2–3 percentage points higher at each level of formal education

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. 2018, . 2017),

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High-skilled jobs risk computerization less, but at all skill levels, women’s risk is higher than men’s

Jobs requiring analytical and ICT skills are less vulnerable to digitalization but show major gender gaps

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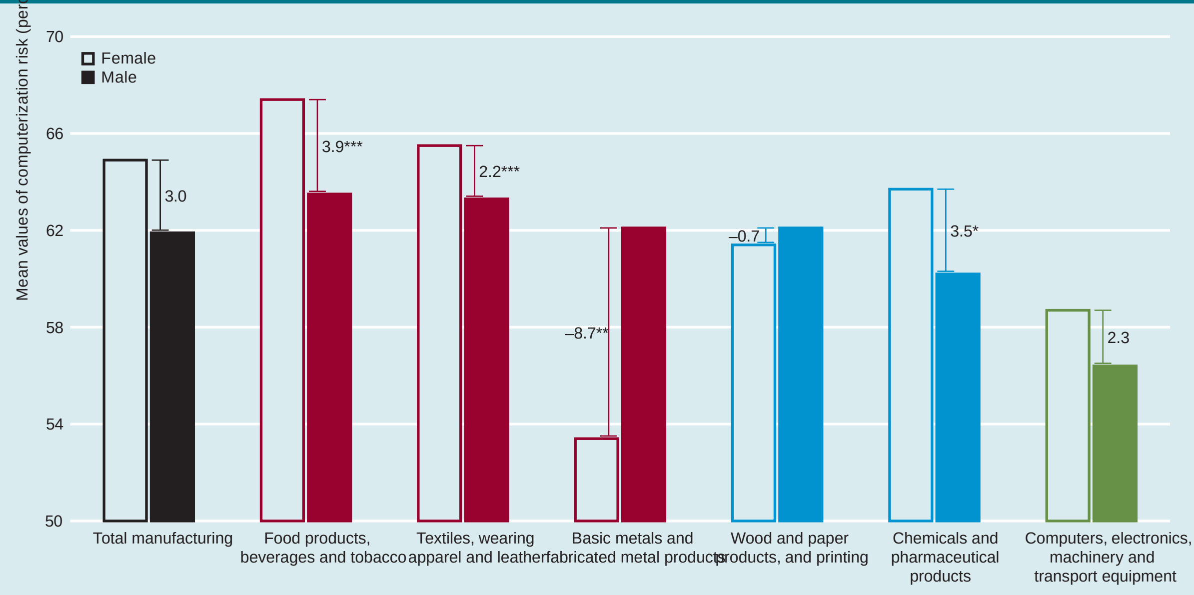
Figure 2.12
Female workers are more likely to face a higher computerization risk than men if they are employed in food, textiles and chemicals



Note: Computerization risk refers to the probability that an occupation will be computerized in the near future. The gure shows the female–male differences in mean values of computerization risk sector. t-test of differences in means: *** p < 0.000; ** p < 0.05; * p < 0.1. The analysis includes Armenia, Colombia, Georgia, Ghana, Kenya, Lao People’s Democratic Republic, North Macedonia Plurinational State of Bolivia, Sri Lanka, Ukraine and Viet Nam. The colours of the bars re ect the technology and digital intensity classi cation of industries. Green = TDI industries (industries that simultaneously intensive on digitalization and technology). Blue = industries that are intensive on either digitalization or technology but not both. Red = industries that are intensive on neither digita nor technology.
Source: UNIDO elaboration based on dataset by Sorgner (2019) derived from the STEP Skills Measurement Program (World Bank 2016).

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> “ Labour markets increasingly reward social skills

2017).

. 2017).

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Gender gaps are less pronounced in socio-emotional or soft skills

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Women’s access to high-quality jobs in manufacturing is limited

More female workers are at high risk of computerization

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The risk of computerization is lowest in TDI industries—for both men and women

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“ Jobs in TDI industries are less susceptible to displacement

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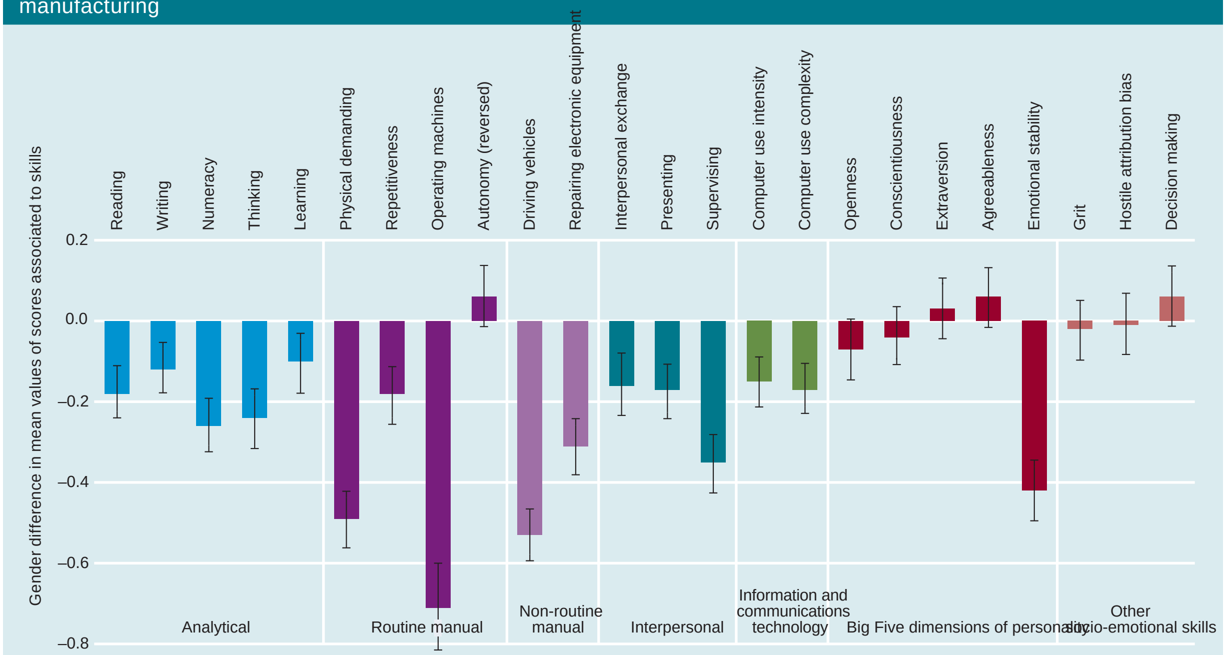
Figure 2.14
Women score lower than men on skills that may protect jobs from loss through computerization in manufacturing



Note: The vertical axis shows the female–male differences in mean values of scores associated with each skill. The variables measuring skills have been standardized to make the scales compara
The analysis includes Armenia, Colombia, Georgia, Ghana, Kenya, Lao People's Democratic Republic, North Macedonia, Sri Lanka, the Plurinational State of Bolivia, Ukraine and Viet Nam. See background paper prepared by Sorgner (2019) for a detailed description of the classi cation of the skills measured in the STEP program.
Source: UNIDO elaboration based on the background paper prepared by Sorgner (2019) derived from the STEP Skills Measuremnt Program (World Bank 2016).

Table 2.2
Skills categories and corresponding measures in the Skills Towards Employability and Productivity program

Skill category	STEP measure
Analytical/cognitive	Reading, writing, numeracy, thinking for at least 30 minutes to do tasks, learning new things at work
Manual	Routine (physical demanding, repetitive tasks, operating machines, autonomy) and non-routine (driving vehicles, repair electronic equipment)
Interpersonal	Collaborating with co-workers, contacting clients, making presentations, supervising co-workers
Information and communications technologies	Computer use: intensity and complexity
Soft skills	Big Five dimensions of personality (openness to experience, conscientiousness, extraversion, agreeableness and emotional stability) and other socio-emotional skills (grit, hostile attribution bias, decision-making)

Source: UNIDO elaboration based on Sorgner (2019).

Computerizing jobs is only likely where it will be profitable

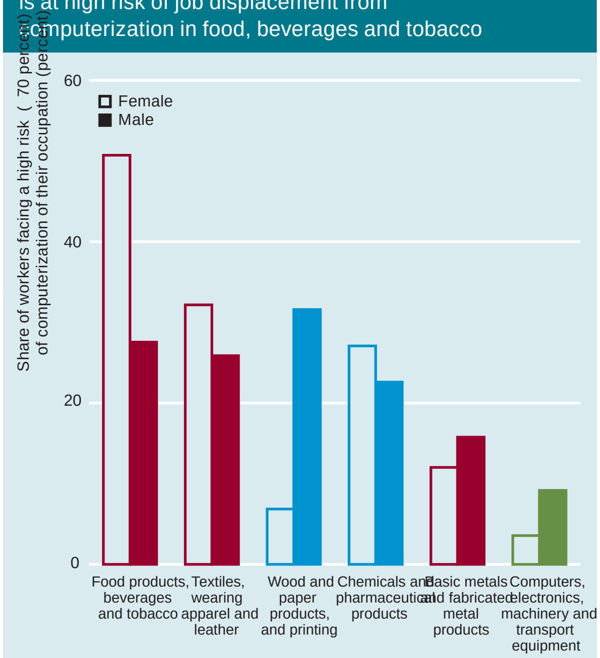
2018, N 2017).

> “ The potential adverse employment effects of digitalization may be overestimated

Figure 2.15
Women are underrepresented in managerial position in manufacturing

Note: The shares of male and female workers by occupation within the manufacturing sector are weighted using country-speci c sample weights provided in Skills Towards Employability and Produ program surveys. The analysis includes Armenia, Colombia, Georgia, Ghana, Kenya, Lao People's Democratic Republic, North Macedonia, Sri Lanka, the Plurinational State of Bolivia, Ukraine a
Source: UNIDO elaboration based on dataset by Sorgner (2019) derived from the STEP Skills Measurement Program (World Bank 2016).

Figure 2.16
A larger proportion of the female workforce is at high risk of job displacement from computerization in food, beverages and tobacco



Note: The observations are weighted using country-speci c sample weights provided in Skills Towards Employability and Productivity (STEP) program surveys. The analysis includes Armenia, Colombia, Georgia, Ghana, Kenya, Lao People's Democratic Republic, North Macedonia, Sri Lanka, the Plurinational State of Bolivia, Ukraine and Viet Nam. The colours of the bars re ect the technology and digital intensity classi cation of industries. Green = TDI industries (industries that are simultaneously intensive on digitalization and technology). Blue = industries that are intensive on either digitalization or technology but not both. Red = industries that are intensive on neither digitalization nor technology.
Source: UNIDO elaboration based on dataset by Sorgner (2019) derived from the STEP Skills Measurement Program (World Bank 2016).

Policies to close gender gaps

The overall impact of ADP technologies on inclusiveness will depend on public policies

(N O 2019).

Encouraging women in the labour force will fail if polices replicate gender segregation

> “ The impact of ADP technologies on inclusiveness will ultimately depend on policies

Promoting gender equality requires fostering women’s participation in new sectors and occupations

Developing adequate skills for both female and male workers to meet future demand

ADP technologies and inclusive industrialization: Direct, indirect and net effects of the use of industrial robots

How will industrial robots affect the economy directly and indirectly?

Growth in the stock of robots in manufacturing

Industrial robots have been operating for nearly two decades

By 2014, there were more than 1 million industrial robots, 175,000 in emerging industrial economies

> “ From 2000 to 2014, global investment in industrial robots doubled

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Impact on employment

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How to find the direct aggregate effect of robotization on employment

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2000 2014)
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And the indirect effect in customer and supplier industries

> The annual growth in the stocks of robots had a positive but small effect on employment growth from 2000 to 2014

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(0.24).

0.32 .[13]

Employment growth occurred mostly in emerging industrial economies, not industrialized economies

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(2.20).

Manufacturing accounts for two-thirds of world employment growth attributable to robotization

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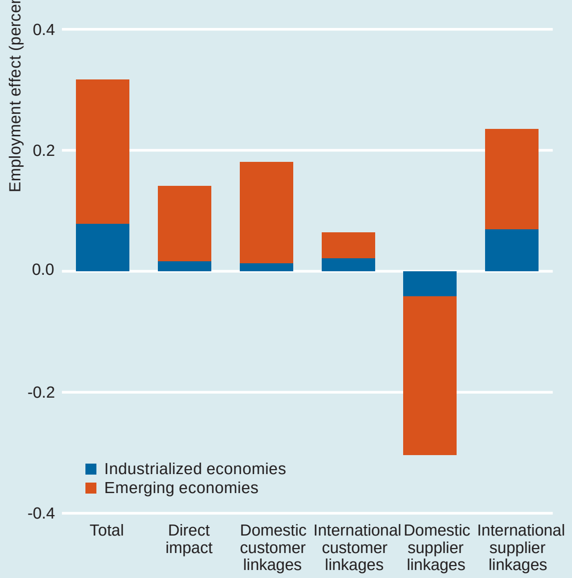
> “ Manufacturing accounts for two-thirds of the growth in world employment attributable to the adoption of robots

Figure 2.19
Where were jobs created? Employment growth due to robots, by economy groups, 2000–2014



Note: Coef cients are applied to the weighted averages of the growth rates of the stoc
robots across economies and industries. Coef cients are from estimations in Ghodsi
(2019), Table 6 (model 1).
Source: UNIDO elaboration based on dataset by Ghodsi et al. (2019) based on Timmer e

Figure 2.20
Who created the jobs? Employment growth due to robots, by economy groups, 2000–2014

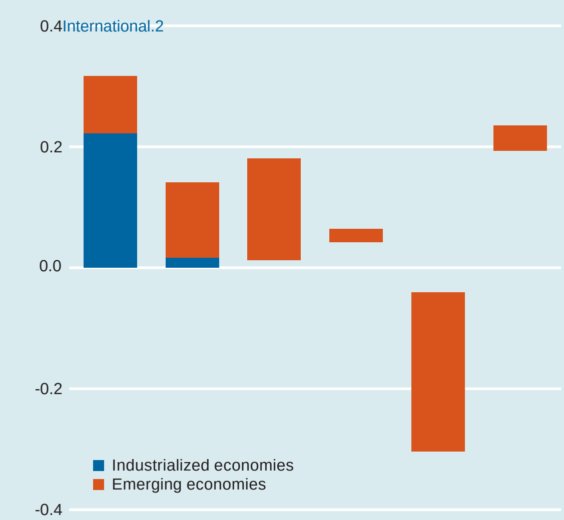
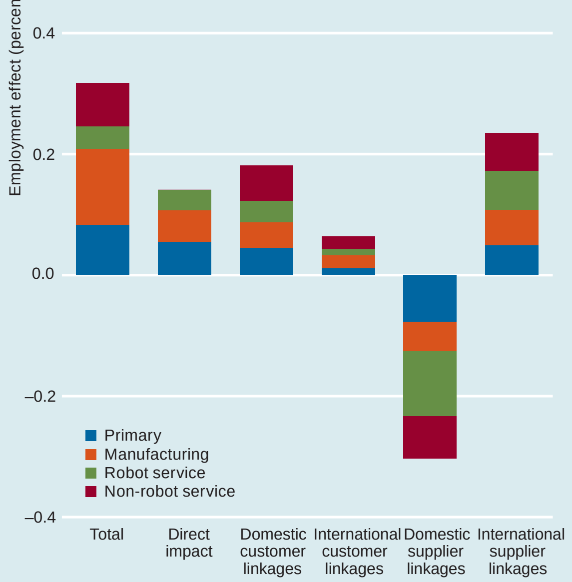


Figure 2.21
Where were the jobs created? Employment growth due to robots, by sector, 2000–2014



Note: Coef cients are applied to the weighted averages of the growth rates of the stock of robots across economies and industries. Coef cients are from estimations in Ghodsi et al. (2019), Table 6 (model 1).
Source: UNIDO elaboration based on dataset by Ghodsi et al. (2019) based on Timmer et al. (2015).

> “ It is unrealistic to evaluate the impact of robotization on employment based exclusively on technological replacement potential

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(O 2017).

(2.23).

A more detailed picture of employment and output effects

In a study of Germany, robotization did not increase workers' risk of displacement

Future effects of robotization may be different

. (2018),

1994 2014,

“ Output growth due to robot adoption needs to be considered in addition to the effect on production processes

In a study of Spain, robotization reduced labour cost share but increased the number of jobs

. (2019) 1990 2016. (. 2019).

So, output growth is another possible effect of robotization

Notes

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Chapter 3

How manufacturing firms can absorb and exploit advanced digital production technologies

Qualitative firm-level evidence on the adoption of ADP technologies and its implications

Firm-level evidence in Argentina, Brazil, Ghana, Thailand and Viet Nam

Impacts on revenue and productivity—and more

Backshoring is not widespread

> “ Evidence is still scarce about the implications for manufacturing rms of ADP technologies

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Getting the most out of it by building on production capabilities

Digitalization as necessary condition

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Production capabilities are key for industrial and innovation policies

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ADP technologies: What’s in it for rms in developing countries?

Big hype, little evidence

ADP technologies are at the centre of global debates

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(O 2017).

Most firm-level data come from international consulting firms

> “Lack of capabilities is a major obstacle to technological upgrading

(. 2017; , 2018; 2017; 2016, 2018).

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Getting ready for ADP technologies

How can developing country firms engage with advanced technologies?

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Firm capabilities are preconditions of adopting and effectively using new technologies

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Diffusion of ADP technologies is still limited, according to the scarce evidence available

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> "Acquisition and development of capabilities are often complex and gradual

Firm capabilities are accumulated gradually

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Capabilities as a roadmap for cumulative learning

Table 3.1
Accumulating investment, technology and production capabilities for advanced digital production

		Investment	Technology	Production
BASIC	Simple, routine-based	Feasibility study Basic market and competitors analysis Basic finance and financial flow management	External sourcing of information (for example from suppliers, industry networking, public information) Basic training and skills upgrading Recruitment of skilled personnel	Plant routine coordination Routine engineering Routine maintenance Minor adaptation of production processes and process optimization Basic product design, prototyping and customization Product and process standards compliance, product quality management Quality management Basic bookkeeping Basic packaging and logistics Basic advertising Supplier monitoring Basic export analysis and some links with foreign buyers
INTERMEDIATE	Adaptive, based on search, experimentation, external cooperation	Seizing market opportunities Search for equipment and machinery Procurement of equipment and machinery Contract negotiation Credit negotiation	Seizing technology opportunities Technology transfer Technological collaboration with suppliers/buyers (downstream and upstream) Vertical technology transfer (if in global value chain) Linkages with (foreign) technology institutions Licensing new technology and software Alliances and networks abroad Formal process of staff recruitment Formalized training, retraining and reskilling Software engineering, automation and information and communications technology skills	Routinized process engineering Preventive maintenance Adaptation/improvement of externally acquired production technology Introduction of externally developed techniques Process remodularization and scaling up Reorganisation of workforce

> “ Developing basic and intermediate capabilities depends on an industrial ecosystem in which rms operate

Table 3.1 (continued)
Accumulating investment, technology and production capabilities for advanced digital production

		Investment	Technology	Production
ADVANCED	Innovative, risky, based on advanced forms of collaboration and R&D	World-class project management capabilities Risk management Equipment design	Research in process and product, R&D Formal training system Continuous links with R&D institutions and universities, cooperative R&D Innovative links with other firms and market actors Licensing own technology to others Open innovation ecosystem	Process engineering Continuous process improvement New process innovation New product innovation Mastering product design Advanced organizational capacity for innovation World-class industrial engineering, supply chain and logistics Inventory management Brand creation and brand deepening Advanced distribution system and coordination with retailers/buyers Own marketing channels and affiliates abroad Foreign acquisition and foreign direct investment
	Production system integration capabilities	Seizing technology integration solutions Seizing organizational integration solutions Data analytics for decision-making and risk management	Integrated product and process R&D Advanced digital skills development Internal/own software platform development	Predictive and real-time maintenance Cyber- physical systems for virtual product/process design Technological and organizational integration Agile and smart production Digital and automated inventory control Real-time production and supply chain data Fully integrated information systems across all functions (for example, enterprise resource planning) Big data analytics throughout all production stages (product design, production, marketing, logistics…)

SYSTEMIC	
Enabling institutional and infrastructure capabilities	Reliable energy supply Reliable connectivity Bandwidth connectivity infrastructure (ethernet and wireless) Digital technology institutions infrastructure Data ownership policy and software licensing accessibility

SourceUNIDO elaboration based on UNIDO (2002) and Andreoni and Anzolin (2019).

> Inadequate digital infrastructure can inhibit the adoption of digital industrialization

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(2.1 2).

Each company is a unique bundle of capabilities

(2019).

The digital capability gap may harm advanced as well as low-capability firms

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(2018).

Field case studies: A qualitative approach

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(3.2).

Exploiting the potential of ADP technologies

Enhanced efficiency and flexibility boost competitiveness

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Improved competitiveness is more than an enhanced efficiency story: It's also about quality...

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" New technologies improved precision and reduced errors at almost all interviewed rms

Table 3.2
Case studies examined the impact of advanced technology on the competitiveness, environmental sustainability and social inclusiveness of developing country rms

			AEDesign Pakistan Engineering services	Arçelik Turkey Washing machines	AVS Technology AG Uruguay Chlorine plants	China Baowu Steel Group Corporation China Steel	Genesis Bionics Kyrgyzstan Bionic prostheses	Haier China Air conditioning systems	Mahindra & Mahindra India Automotive	New-Tek Kyrgyzstan Solar panels	Penang Automation Cluster Malaysia Metal components	Thales 3D Morocco Components for aerospace sector	ZC Rubber China Rubber and tires
New and better products	New solutions for marginalized groups	• Medical devices at affordable prices					●						
	Better quality and new business models	• Personalized products, mass customization • New and data-based services • New pricing models		●	●		●	●		●		●	
	Environmental goods	• Goods produced with eco-friendly materials • Increased product energy efficiency					●	●		●			
Increased production efficiency	Energy efficiency and input optimization	• Emission and waste reduction • Acceleration of circular economy transition	●	●	●	●		●		●		●	●
	Operational cost reduction	• Flexible and decentralized production • Supply chain connectivity, delivery performance and logistics • Agile, adaptive organization		●		●		●					
	Improved capital utilization	• Productive and automatic maintenance, downtime reduction • Lower inventory rate, increased cash-to-cash cycle			●	●				●			
	Employment quality and linkages to services	• Improved work conditions, safety • Foster female employment • New skills, task efficiency	●	●		●		●	●	●	●	●	
Affecting adoption	Enablers	• External knowledge • Pre-existing industrial and production capabilities	●	●	●	●	●	●		●			●
	Challenges	• Lack of qualified personnel • Changing internal culture						●		●	●	●	●

Note: The circles identify the topics covered in each case study.
Source: UNIDO elaboration based on Calza and Fokeer (2019).

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> "New production technologies can generate positive environmental spillovers by reducing hazardous and polluting processes

ADP technologies shape factories and manufacturing processes as well as products

...and sustainability

3D printing makes complex products without costly tooling

New products and new business and organizational models emerge from ADP technology

ADP technologies reshape skills, work conditions and roles

> “ Pre-existing industrial and production capabilities are crucial to absorbing and using ADP technologies

3

Automation removes workers from backbreaking and hazardous tasks

3

> “Firms tend to access new technologies mostly through an external source

Adopting new technologies is a stepping stone to technological learning

Only a few isolated firms use ADP technologies

Yet, technologically advanced firms can develop ties with local actors

Firms vary in hiring trends, government support, foreign ownership and location decisions

> “Various generations of production technologies tend to be used at the same time

A micro-level perspective based on surveys

More data are needed on ADP technologies in developing and emerging economies

Surveys provide new evidence on technology adoption and its effects

UNIDO surveys

Various generations of production technologies are used at the same time

Diffusing and adopting ADP technologies

Brazil and Argentina have the largest shares of firms using more advanced technologies

> Data con rm heterogeneity across countries as well as within them

3

2.0 (3.1).

[6]:

0.0 1.0 , (

0.0) , 11.5

2.0 .

Few firms in any country use the most advanced technologies

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(3.0 4.0) :

, 1.5

30 .

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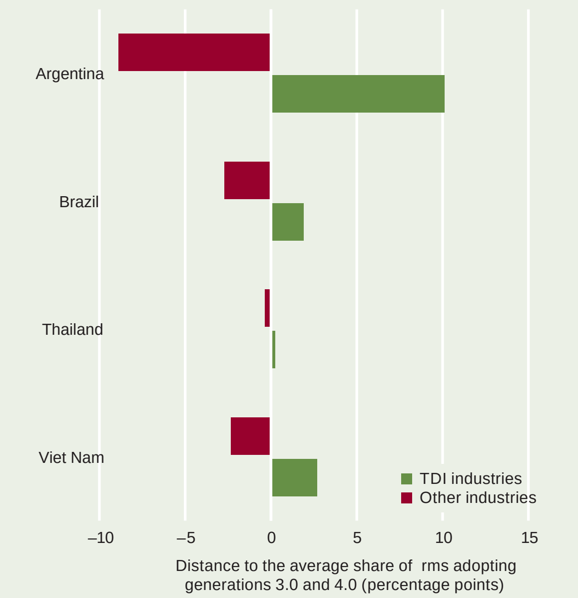
, .

> “Large firms enjoy technological and productive capabilities that make them more likely to adopt new technologies

Figure 3.2
Firms in TDI industries tend to adopt more ADP technologies



Note:

(3.0 4.0) (3.3).[9]

3.0 4.0 [10]

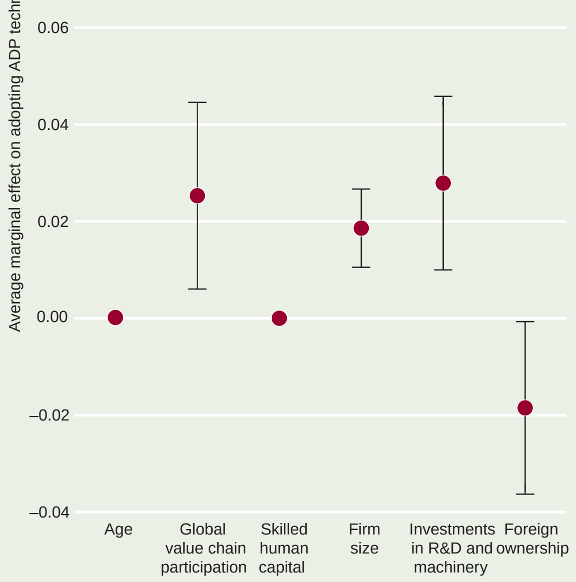
Larger firms adopt more advanced technologies

Firm participation in global value chains is associated with advanced technologies

2016).

> "Participation in GVCs positively affects the probability of adopting advanced technologies

Figure 3.4
Firms participating in GVCs are more likely to adopt ADP technologies



Note: The graph depicts coefficients and confidence intervals (at 95 percent) for the average marginal effects of the variables of interest on the probability of belonging to the group of firms characterized by the highest generations of digital technologies (generations 3.0 and 4.0), rather than belonging to the other groups of firms (generations 1.0 and 2.0). An ordered probit model was implemented on firms surveyed in Ghana, Thailand and Viet Nam. Country and sector dummies are included.
Source: UNIDO elaboration based on Pietrobelli et al. (2019) derived from the data collected by the UNIDO firm-level surveys "Adoption of digital production technologies by industrial firms."

The lack of funds, infrastructure and human resources are the main obstacles to advanced technology adoption

Small firms identify lack of funds as an obstacle

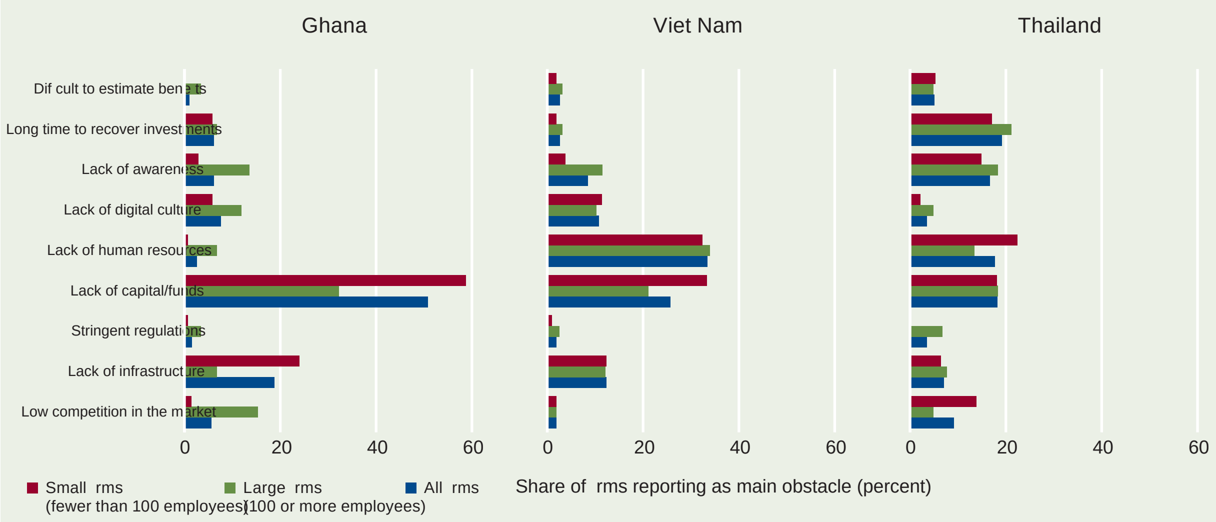
A dynamic approach to firm digital readiness

Expected technology adoption and efforts matter

> “ Progression to generation 3.0 or 4.0 requires substantial changes in competences, production and organization

3

Figure 3.5
The main obstacles to adopting ADP technologies re ect county-speci c challenges



Note: For Argentina and Brazil no information is available on the main obstacles to the adoption of ADP technologies, due to the structure of their survey questionnaires. For each category, t shows the share of rms reporting it as the main obstacle to adopting ADP technologies (multiple answers not allowed). See Annex A.3 for more detailed information on sample composition methodology of the UNIDO survey.
Source: UNIDO elaboration based on data collected by the UNIDO rm-level surveys “Adoption of digital production technologies by industrial rms.”

, . , ’ - , - 5 10 ’ .

The majority of firms in Argentina and Brazil expect to use advanced technologies in 5–10 years

, (- 3.0 4.0) 5 10 (3.6). , 44.8 4.0 33.5 3.0. , 25 - 4.0 (2.9 3.1), 40 3.0. V N : 17 24 V N 4.0.

V N , 2.0 - 1.0, L , 2.0 (3.0 4.0). : 32 4.0 5 10 . - 0 4.0 4.0 V N .

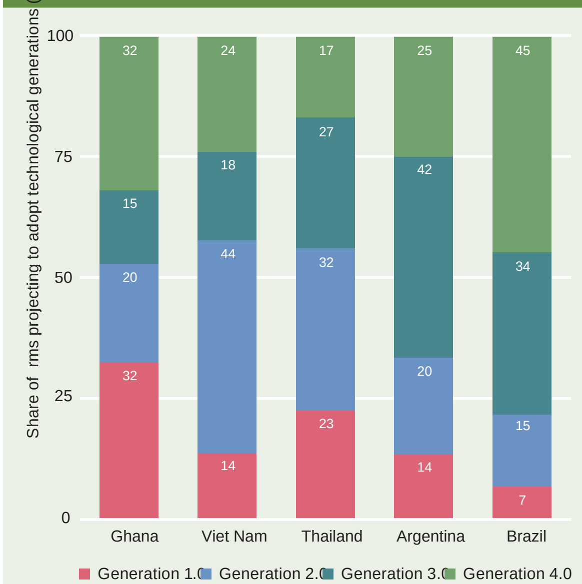
Are firms taking steps to upgrade technology?

. , . , - - V N -

> “ A small proportion of rms are ready to leapfrog to the most advanced digital production technologies

3

Figure 3.6
Firms expect a marked increase in adopting ADP technologies in the next 5 to 10 years



NoteCountries are ordered according to the shares of rms currently adopting the highest generations of digital technologies (generations 3.0 and 4.0). See Annex A.3 for more detailed information on sample composition and the methodology of the UNIDO survey, including the de nition of technological generations applied in the survey questionnaires.
SourceUNIDO elaboration based on data collected by the UNIDO rm-level survey “Adoption

The picture is mixed of firms’ steps to upgrade technology

(- . (1986),

3.0 4.0)

(, *forging ahead,*

3.7). , (4.0)

, , . *Catching up* :

. V N , -

, - ,

3.0 4.0 . *Lagging behind*

. , ,

.

.

Firms can be classified according to their digital readiness

N O ( ) *Few firms expect to leapfrog*

O

.[13] .

" More technologically dynamic rms have higher capabilities

7.3 , 38.8 - 63.9

(3.8). V N

Firms with higher technological intensity and larger firms have more STEM professionals

V N

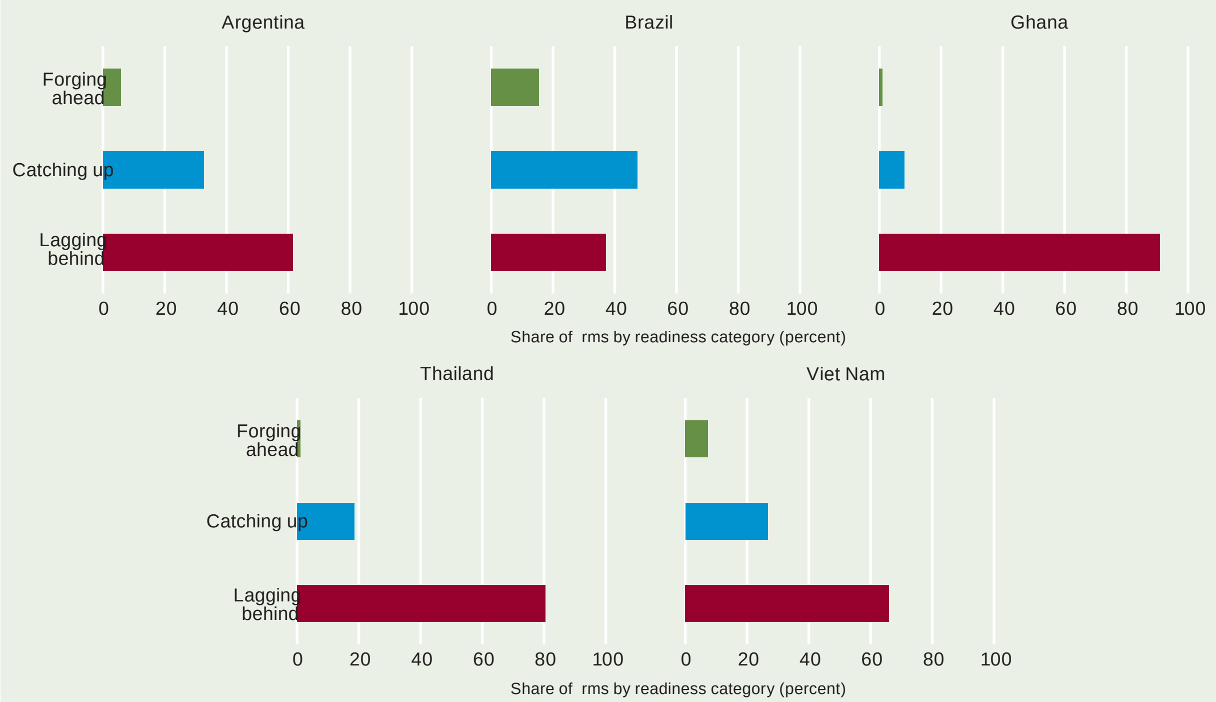
V N [14]

(3.7). (3.9).

(3.1).

Digital readiness and human capital

Figure 3.8
Few rms are ready to leapfrog to ADP technologies

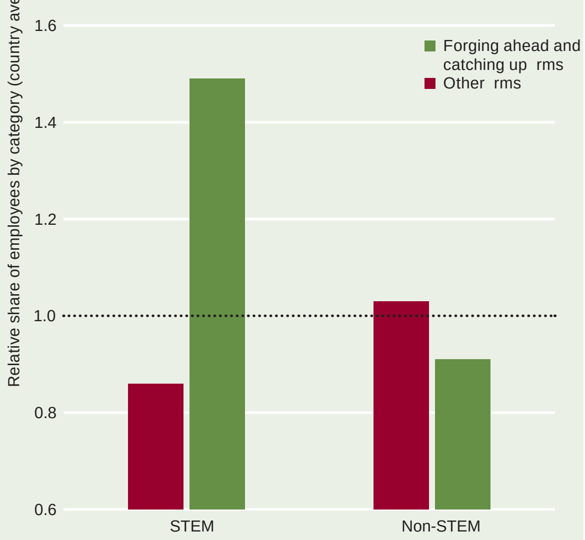


Note: The gure presents the distribution of rms in three readiness categories (forging ahead, catching up, lagging behind) according to their score in the UNIDO Digitalization Readiness Inc Annex A.3 for more detailed information on sample composition and the methodology of the UNIDO survey.
Source: UNIDO elaboration based on data collected by the UNIDO rm-level survey "Adoption of digital production technologies by industrial rms" (for Ghana, Thailand and Viet Nam) and Al (2019) and Kupfer et al. (2019) (for Argentina and Brazil).

3

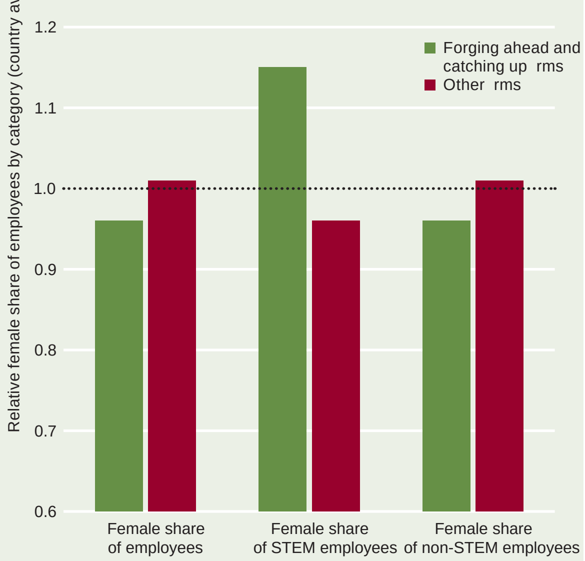
> "Forging ahead and catching up rms may create more opportunities for female STEM professionals

Figure 3.9
Firms in the forging ahead and catching up categories have a larger share of STEM employees



Note: STEM is science, technology, engineering and mathematics. Data refer to rms surveyed in Ghana, Thailand and Viet Nam. See Annex A.3 for more detailed information on sample composition and the methodology of the UNIDO survey.
Source: UNIDO elaboration based on data collected by the UNIDO rm-level surveys "Adoption of digital production technologies by industrial rms."

Figure 3.10
Firms in the forging ahead and catching up categories have a higher female share of employees with STEM quali cations



Note: STEM is science, technology, engineering and mathematics. Data refer to rms surveyed in Ghana, Thailand and Viet Nam. See Annex A.3 for more detailed information on sample composition and the methodology of the UNIDO survey.
Source: UNIDO elaboration based on data collected by the UNIDO rm-level surveys "Adoption of digital production technologies by industrial rms."

Increasing women's equitable participation is necessary to promote inclusive and sustainable industrial development

N O

2,

(, N O 2019).

(3.10).[15]

Implications of ADP technologies

Productivity

Firms adopting advanced technologies have higher productivity

(1).

N O

(3.11).

(3.0

4.0)

> “ Adoption of ADP technologies was positively and signi cantly associated with rm productivity

(1.18 1).

The technology–productivity relation holds regardless of human capital and GVC participation

& V

(3.12).[16]

Organization of global production

“Firms in developing countries may be harmed by the progressive diffusion of ADP technologies in advanced economies

3

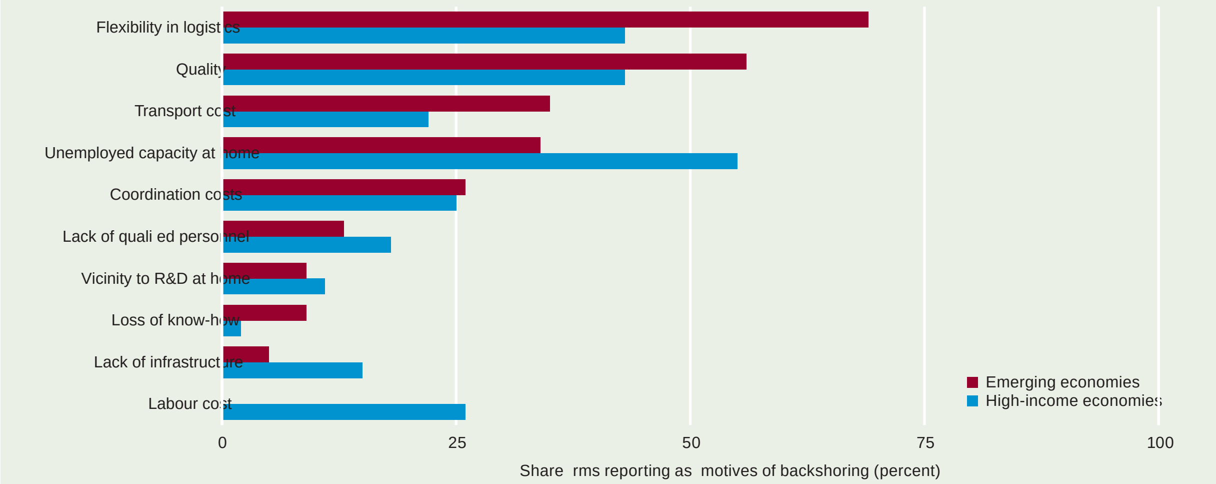
Digitalization could increase oligopoly and power concentration in GVCs

ADP technologies could foster backshoring

Not much backshoring is evident

“ Adopting ADP technologies might prompt backshoring, though not frequently

Figure 3.13
Flexibility was the main motive of backshoring from emerging economies in 2013–2015



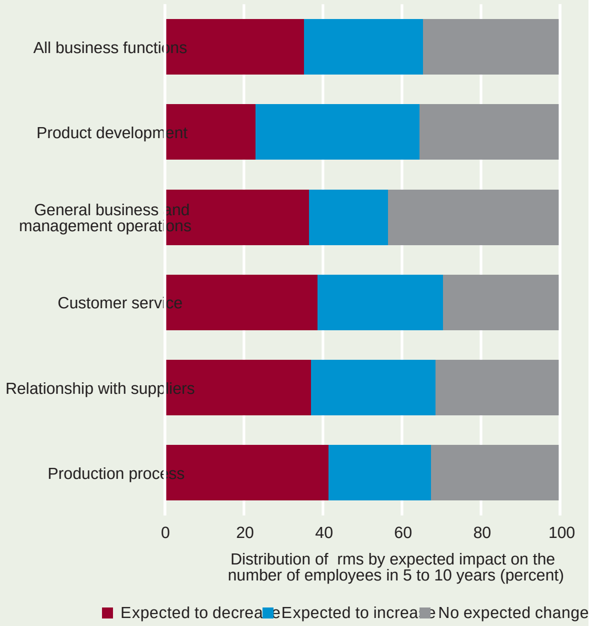
Note: The survey, conducted in 2013–2015, included 2,448 European rms with at least 20 employees from Austria, Croatia, Germany, the Netherlands, Serbia, Slovenia, Spain and Switzerland. rms engaged in backshoring are considered. Multiple answers are allowed.
Source: Dachs and Seric (2019), based on the European Manufacturing Survey (EMS 2015).

Employment and skills

Technologically dynamic firms anticipate stable employment

> “Soft skills are projected to become very important, according to almost all technologically dynamic rms

Figure 3.15
The majority of rms in the forging ahead and catching up categories expect to increase or keep the same number of employees as they adopt ADP technologies



NoteData refer to rms surveyed in Argentina, Ghana, Thailand and Viet Nam and include only rms classi ed as forging ahead and catching up. See Annex A.3 for more detailed information on sample composition and the methodology of the UNIDO survey.

V N.

Technologically dynamic firms emphasize skills related to STEM, human–machine interaction and soft skills

(3.16).

2,

Getting the most out of it: Capabilities for industrializing in the digital age

Building production capabilities through industrial experience

Production capabilities represent firm manufacturing learning

> “ Production capabilities increase innovation performance

3

(, & ,)

) (3.3).

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(,)

The policy debate should focus on production capabilities

13

19

(3.17).[20]

Combined, investment and technology and production capabilities lead to innovation

11 0 0 11 0.002 0.491 5.5 ( )-9 ( )-5 -9.2512.7 ()-184

“ Production capabilities have to be built up before moving into high innovation activities

3

1)

> “ Digital rms are a niche in developing countries

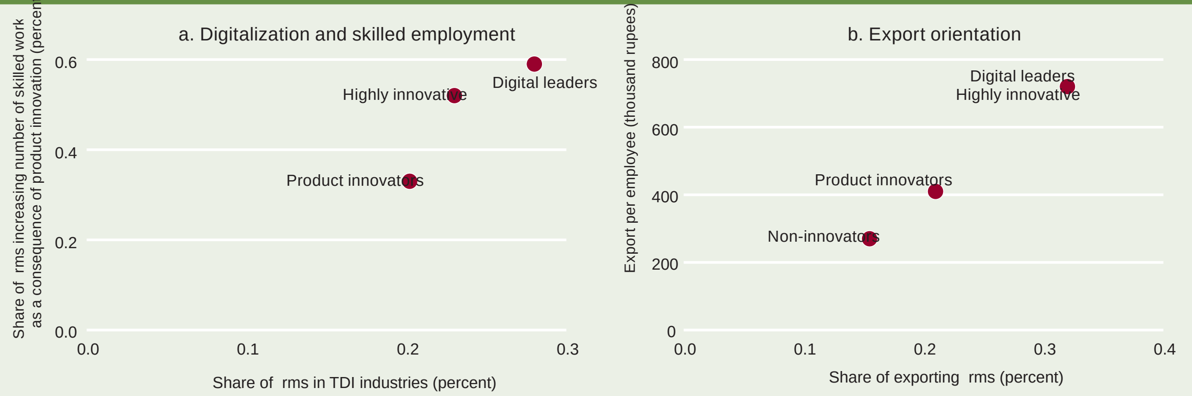
Digital firms are a niche in developing countries

Digital leaders in India generate high exports and sustain employment

Firms’ classification mirrors their technological and production hierarchy

Some top industrial firms are becoming top digital firms

Figure 3.18
Digital leaders show a better performance in terms of presence in TDI industries, export and employment generation



Note: TDI is technology- and digital-intensive. Data include only manufacturing rms in India. TDI industries include machinery, electronics and information and technology services.
Source: Pianta (2019) based on World Bank Enterprise Survey (Innovation Follow-up, 2013–2014).

> “Manufacturing tends to be the key sector for innovation

3

Country	Digi674.5 774.8712 r36747 9 (x)-12 rd(s o9.3 (v7-22.9 (n m)10s.018 Tc 0.014 Tw 80 0 813.7(

16 percent of firms in India and Bangladesh are classified as highly innovative

: 17, 16, 11, 10 N.

50 46, 33, 27 N 23, N, 83 N 31. O,

The manufacturing sector has the lion's share of technologically advanced firms

, 88, N, 75, 50, 94, 92, 58. 2016, &, (1961).

Mostly—but not only—large firms

. L &

> “Smaller rms can share in new technology adoption if they nd digital niches connected to expanding markets and GVCs

. L

, - . -

, . .

(2019). , 60 - , -

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100 , . V

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Notes

1. (2019).
2. ( ) , - , - , , (1986).
3. (2019). 1 2 .
4. . (2019) . (2019). .3 - .
5. 2017 N (N) 2018 - L (- N L) ( ) ( ).
.3.
6. , - 0.0 , - . , - .
7. .
8. , , . - , . 1.0.
9. 100 , .
10. 1.0 . , V N , -
2.0 .
11. V , V N .
.3.
12. , . (2019).
13. ( ) .3.
14. - , , , - . , .
15. V N : 50 . , : 30 .

3

16. , , - , 10 .
17. (2019) .
18. O (2000) / ; , , - , , .
19. , , , , N , N , , L , , , , , , , N .
20. (2019) .
21. (2019).

Chapter 4

Responding to advanced digital production technologies

Few economies possess the required foundation of technological and manufacturing capabilities

(4)

( )

A capability-building approach helps to understand strategic responses

(N O 2002, 2005, 2015).

National strategy documents signal efforts to build readiness

(L . 2019). N

( ).

Be wary of one-size-fits all solutions

Remember that it takes commitment and substantial resources to develop capabilities

(L 2019,

2001).

> “ Different countries respond differently, according to their accumulated capabilities and exposure and experience with manufacturing

Characterizing strategic responses to ADP technologies

Trends underpinning the 4IR are expected to deepen

Multistakeholder and participatory approaches are key

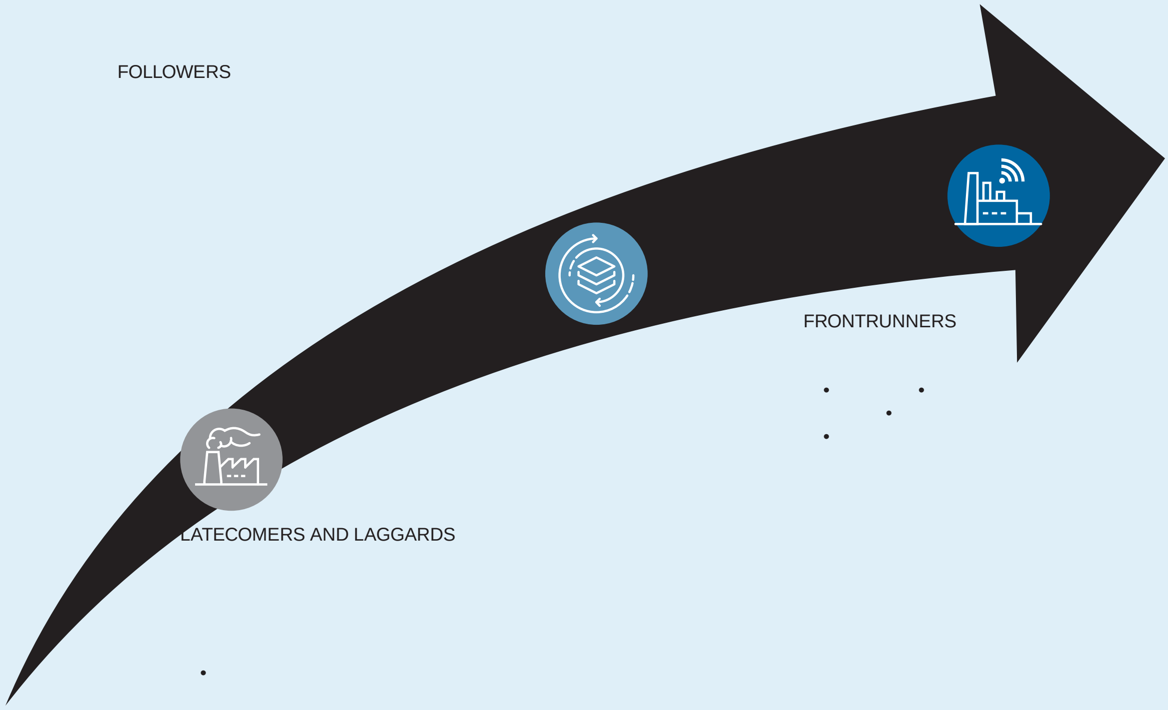
International collaboration and policy coordination can support developing countries

National strategies reflect the extent of industrialization and capability accumulation…

Strategic responses to smart manufacturing are mixed

> "Followers aspire to foster innovation-driven development

Figure 4.1
Strategic responses reflect differences in manufacturing development across countries



Source: UNIDO elaboration.

Box 4.1
Highly industrialized economies differ in their strategic stances for smart manufacturing

Source: UNIDO elaboration.

Several middle-income economies are followers

(L 2018).

> **“** Strategies for smart manufacturing could bene t from clearer pathways towards explicit desired outcomes

4

. , . , (3) (2016, - Ṅ O 2017).

.

Country strategies could benefit from better articulation of the milestones, resources and pathways

, , .O , ( ) .

…and blend different policy realms

Strategies towards ADP technologies take diverse forms

, , : , , , 4.0, , . , . , 4.0 Ṅ , 4 (, Ṅ 2018).

Among developing country strategies, the most advanced and ambitious is Made in China 2025

, 2025,

2015 (, 2015). 2025 ’ . , , .

The next tier of countries includes followers in production and use

, (, 2017). . , , , 4.0, 20- Ṅ 2017 2036 12 Ṅ 2017 2021 (2017; , 2016). , ( ) 2017/18 2019/20 ’ 4.0 (, 2017), , , 4 (, 2018). , ’ Ṅ 4.0 (4) ’ (, 2018). , , . ( ) 2015 2025, 2016, , (, O O 2016).

Other countries have a roadmap or general guidelines

O . 2016

> “ Participatory approaches are recommended for strategy development

India, an advanced follower, is leveraging efforts already in place

The model is to bind manufacturing to broader national development aspirations and plans

...and to mobilize knowledge and experiences from multiple stakeholders

Basic elements of strategy design and development

Build on multistakeholder, participatory processes

They help to gather different perspectives and build common understandings...

> “ ADP technologies require a comprehensive government response with central coordination from the highest levels

4

2017).

In Brazil, consultations were based on a triple-helix approach

2017; 2016).

2017).

2017).

Address complexity through a comprehensive government approach

Smart manufacturing requires comprehensive responses with central coordination

2016).

L 2018)

(L . 2019).

Chile built on previous learning to foster digitalization

2015 2025

Leadership in developing and implementing national strategies is generally shared

2018).

Collective thinking underpins the elaboration of roadmaps or national strategies

> "To drive ADP technologies, the private sector can become a strategic industrial development partner

Direct and active private sector involvement is essential

An additional tier reflects sectoral perspectives

Foster strategic partnerships with domestic and external agents…

The private sector provides more than investment

> Innovation with ADP technologies seems to require new forms of public policy and public–private partnerships

4

Accelerating learning curves by leveraging international collaboration

(2016).

Box 4.2
Cooperation for a new digitalization strategy for Kazakhstan

Source: UNIDO elaboration

Followers and latecomers are pursuing collaboration with frontrunners

2018). (, ,) (2018).

(4.3).

(4.2),

…but be ready to address trade-offs

Distributed leadership requires enhanced ownership and coordination

(L 2019).

> “ Indicators can help monitor and evaluate progress promoting and adopting ADP technologies, but there is no single way to do so

4

2016

, 2018,

4 .[2]

Fostering formal mechanisms and platforms modelled on the Industry 4.0 platforms

4.0

(2019,

2019).

(, 2018).

Viet Nam is developing a national response with the Prime Minister’s direct involvement

V N

4

“ Challenges imply choices about specialization in smart manufacturing —in either the use or the production of novel technologies

(L . 2018, 2018).

, ( ) , -

,

(2018). , ’

N

( ) 16

2016 25 2025 (2017).

The size of specific markets can be benchmarks

,

$8 -

2022 (, 2016)

-4.8-39.6-28 (6.5 ( ))-12.7.8 ( ) 21.9 ( )-8 ( )- 55.7 ( )11.6 ( )8.4 (2.6)-9.9

> “ Digitalization and access to broadband internet are persistent constraints for smart manufacturing

Enhance readiness for smart manufacturing with interventions, dedicated programmes and incentives

(- N O 2017):

(, 2017).

&

( )

Focus on framework conditions

Digitalization is a prerequisite for firms and countries seeking smart manufacturing

V 2018 ; , N 2018;
2017).

(& 2017; 4.1).

50

2020 (2017).

Update regulations, open the ICT sector to investment and foster broadband infrastructure

L

(4.4).

( )

[3] ,

(2017).

Enhanced digitalization improves the business environment and broadens people’s internet access

(, 2019; ,
2018),

(, 2019).

(4.5).

(3).

Search for sectoral advantages to promote in national strategies

.N

“ Strategies tend to be fairly open about the choice of either the technologies or the priority sectors to develop advanced applications

4

Follower economies target sectors where smart manufacturing already exists

A distinction between sunset and sunrise industries

> “Both frontrunner and follower economies pursue smart manufacturing as part of regional development strategies

Box 4.5
Digitalization as a prerequisite for smart manufacturing

Kazakhstan

[illegible]

Mauritius

[illegible]

[illegible]

Viet Nam

[illegible]

Source: UNIDO elaboration.

[illegible]

Capitalize on smart manufacturing as an emerging approach to regional development

[illegible]

> "Through funding for innovation, digitalization and pilot initiatives, governments can steer resources towards the development of ADP technologies

4.0 … 2017/18, 2019/20 … (4.0 2017). … 2016). … 1, 1.5 … ($111) … 2019/2020 … (2018).

Mexico and Viet Nam support regional initiatives that match national targets

… V N … (4.6). …

China's Zhejiang province promotes the adoption of cloud technologies

Fostering smart manufacturing readiness to promote ADP technologies

Is there a case for mission-oriented interventions?

… (4.7).

> “Policy interventions need to align with the requirements of firms with distinct degrees of readiness and openness to ADP technologies

4

Box 4.7
Fostering the development and adoption of cloud computing in Zhejiang province

Governance:

Capacity building:

Supply-driven interventions:

Demand-driven interventions:

Results:

Source: UNIDO elaboration.

Automation and digitalization are foundational technologies

2018).

Cater to different types of firms

2018).

> “Of particular concern is identifying the readiness, opportunities and bottlenecks for SME participation in the new technologies

(2017).

Public research infrastructure should showcase practical applications

(4.8).

Develop diagnostics, toolkits and tailor-made blueprints to assess readiness

(2016, 2016, 2017). O

4

(4.9).

Frontrunner and follower economies foster collaboration and the cross-fertilization of ideas

N 4.0 2019, N L 4.0 (N L 4.0 2019), N 4.0.

BIND 4.0 supports start-up development and growth in the Basque ecosystem

N 4.0 2016

4.0

(4.0 2017, 2019).

> "Few strategies address smart manufacturing employment

Box 4.9
Malaysia's Industry4WRD Readiness Assessments

Source: UNIDO elaboration.

150,000. 2018 524 64 40, 15 2016.

Invest heavily in human resource and research capabilities

Capacity gaps exist between generations and between women and men

2

. L -

Technology is not the only factor influencing employment

. L - (L . 2019).

Limited technological experience creates ongoing problems in demands for skills

(- 2019).

Few strategies address smart manufacturing employment

N

2017/18 2019/20

(, 2016).

(, 2018).

So, explore the potential of technical and vocational education and training

> "The DIY movements can assist governments in targeting small players, helping them acquire capabilities and generate employment

4

4.0.

( ) ,

(2019).

Incorporating new professionals in ICT

O

N

(2017).

A Basque Country–Colombia collaboration

V

Stimulate training and development to foster specific economic activities

N

2014 -

V

2016,

2019.

500

6

Expose people to learning using new technologies

( )

(4.10).

Do-it-yourself movements foster problem solving and peer-to-peer learning

(. 2019).

(2018).

> Objective, evidence-based debates are needed to inform decision-making for designing and implementing national strategies for smart manufacturing

Follower countries are exploring ways to reorient research infrastructure

[redacted] overarching pledge to leave [redacted] behind in the 2030 Agenda [redacted] ainable Development calls [redacted] nological solutions to [redacted] oblems accessible to all

[redacted] es to ADP reinforce the [redacted] ce of capability building

[redacted] t distinct stages of development require [redacted] ponses

( )-1 .4 (5 (5)6 ( )213-3525 ( )-321.9 ( )12.8 (

> "Mobilizing technical centres to foster academia–industry interaction is a frequently used policy tool for knowledge sharing and awareness raising around ADPs

Policy should improve understanding of ADP technologies and the conditions for their development, adoption and dissemination

Policy should assist economic agents in addressing expected challenges

Tools for assessing technologies and their possible contribution to business development

Both innovation and industrial policies are needed to advance ADP technologies

A pledge to further international collaboration

Further international collaboration is needed

> “International policy coordination and collaboration should continue to buttress efforts to leap forward

Latecomer, laggard and even follower countries may wish to diversify partnerships

L

(2017).

Boost the ability to address global development challenges

2018, N 2018, N O 2017).

Closer collaboration should be the basis of strategies

-3.5 (5 ( )1.6 2 (21))12.7 (

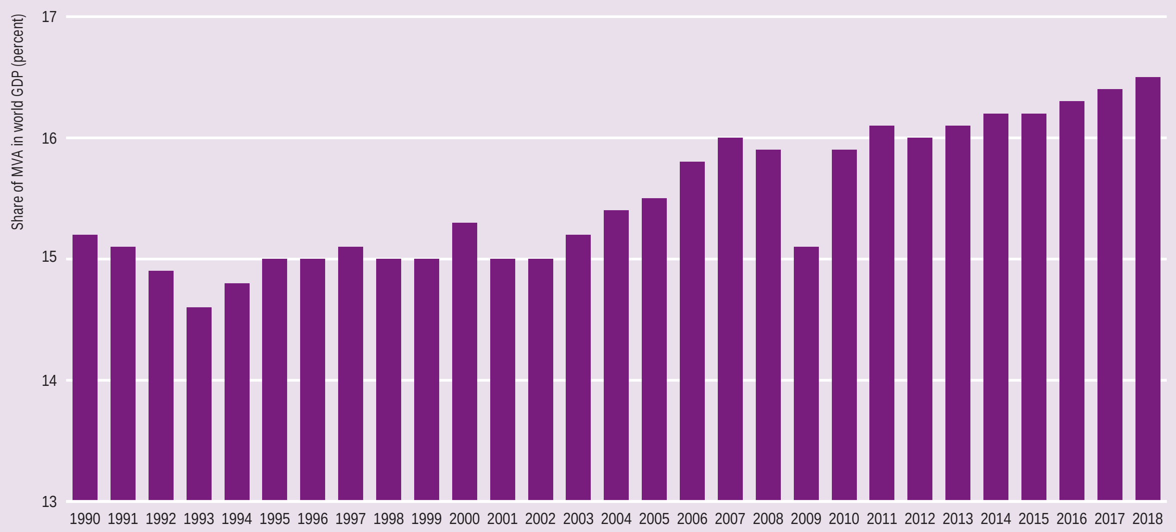
Part B

Trends in industrial development indicators

> Chinese manufacturing increased its share in world MVA from 3 percent in 1990 to 25 percent in 2018

5

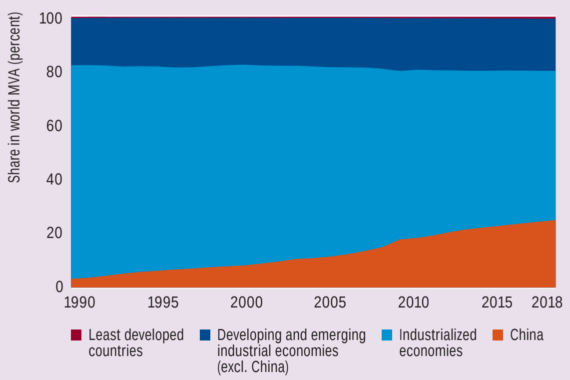
Figure 5.2
Share of MVA in world GDP



Note: GDP is gross domestic product. MVA is manufacturing value added. All values are in constant $ 2010.
Source: UNIDO elaboration based on the Manufacturing Value Added database 2019 (UNIDO 2019g).

2015, 2016 … 2015 … , … - … . … , … - V … (5.1). … , … 80 … (5.3). … , … . … V 3 1990 25 2018. … , … , … 79 … 55 … . … 20 … 1990 2018 … (L). … L … - … , … -

Figure 5.3
Share in world MVA by economy group

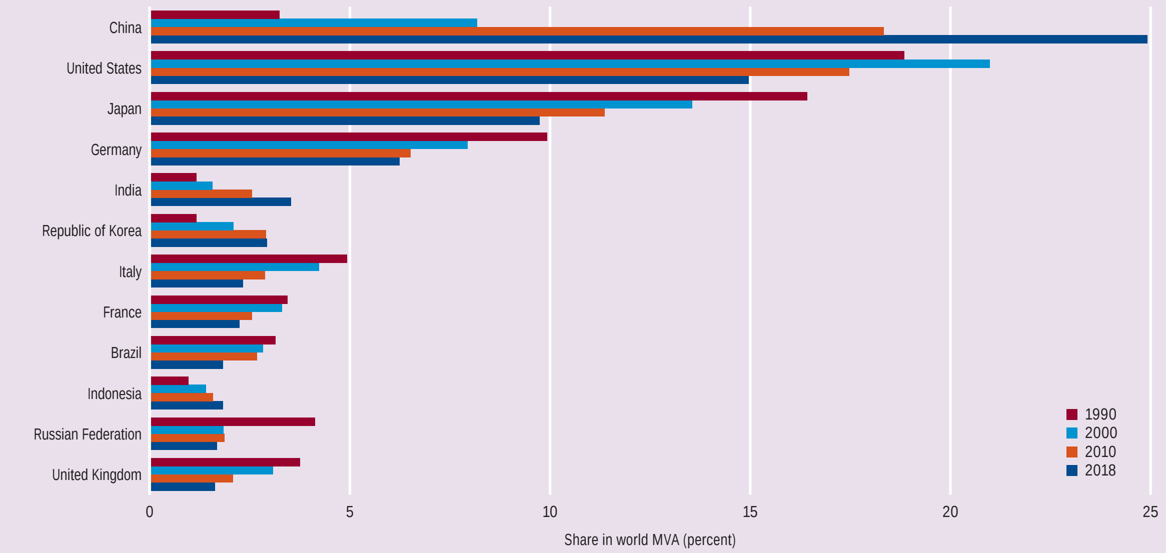


Note: MVA is manufacturing value added. All values are in constant $ 2010. Industrialization level classification is based on Annex C.1.
Source: UNIDO elaboration based on the Manufacturing Value Added database 2019 (UNIDO 2019g).

… - … . … 1990 2018 12 … - … ' … V … 71 74 (5.4). 2018, … , …

“ Enhancing export performance requires expanding manufacturing exports

Figure 5.4
Share of the 12 largest manufacturing economies in world MVA



Note: MVA is manufacturing value added. All values are in constant $ 2010.
Source: UNIDO elaboration based on the Manufacturing Value Added database 2019 (UNIDO 2019g).

Evolution of world manufacturing exports

> “ Exports of medium- and high-technology goods increase with the level of countries’ industrialization

5

Figure 5.5
World manufacturing exports growth by economy groups

Note: All values are in current $. Industrialization level classification is based on Annex C.1.
Source: UNIDO estimations based on the United Nations Comtrade database (UNSD 2019).

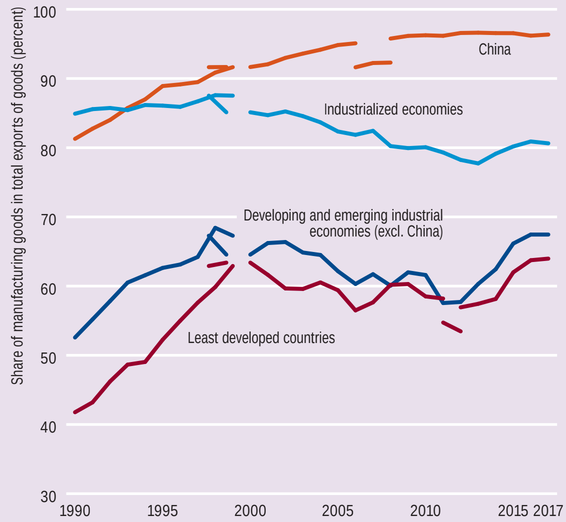
“ China’s share of manufacturing exports in its total exports steadily increased over 1990–2017

2005 2010 2015 10b

Figure 5.6
Manufacturing exports as a share of total exports by economy group

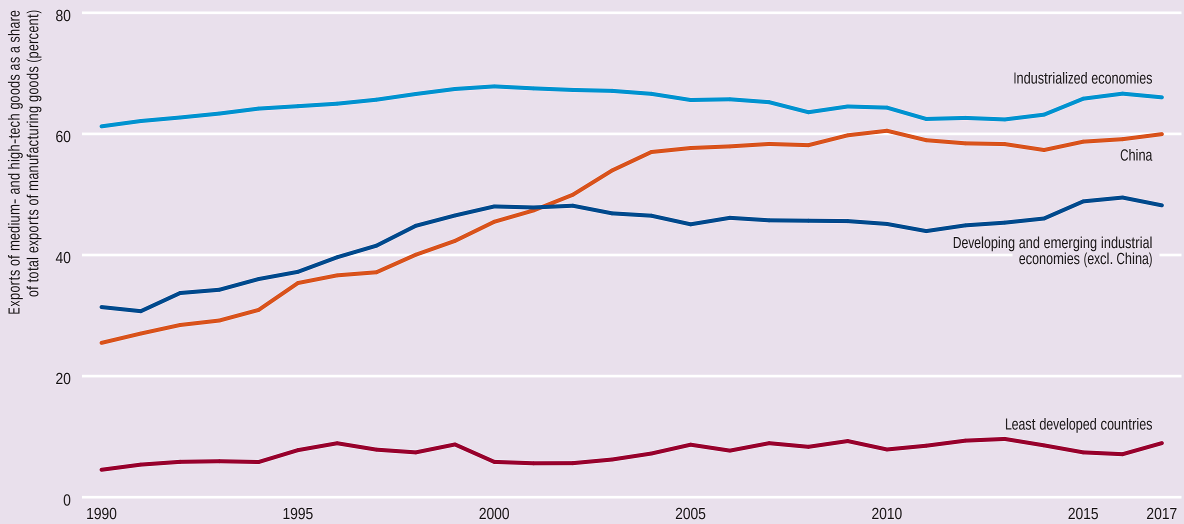
NoteAll values are in current $. Industrialization level classi cation is based on Anne
SourceUNIDO elaboration based on the United Nations Comtrade database (UNSD

Figure 5.7
Manufacturing exports as a share of total exports by economy group, with China separated



NoteAll values are in current $. Industrialization level classi cation is based on Annex C.1.
SourceUNIDO elaboration based on the United Nations Comtrade database (UNSD 2019).

Figure 5.8
Exports of medium- and high-technology goods as a share of total manufacturing exports by economy group



NoteAll values are in current $. Industrialization level classi cation is based on Annex C.1. The technological classi cation of manufacturing activities is based on Annex C.2.
SourceUNIDO elaboration based on the United Nations Comtrade database (UNSD 2019).

> “Manufacturing sector employment increased 0.9 percent a year on average from 1992 to 2018

5

Evolution of world manufacturing employment

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0.9 1992 5.10. ,

2018 (5.9). , (16.1 -

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V : 14.2 , 2018.

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- 1992 2018 ,) 20

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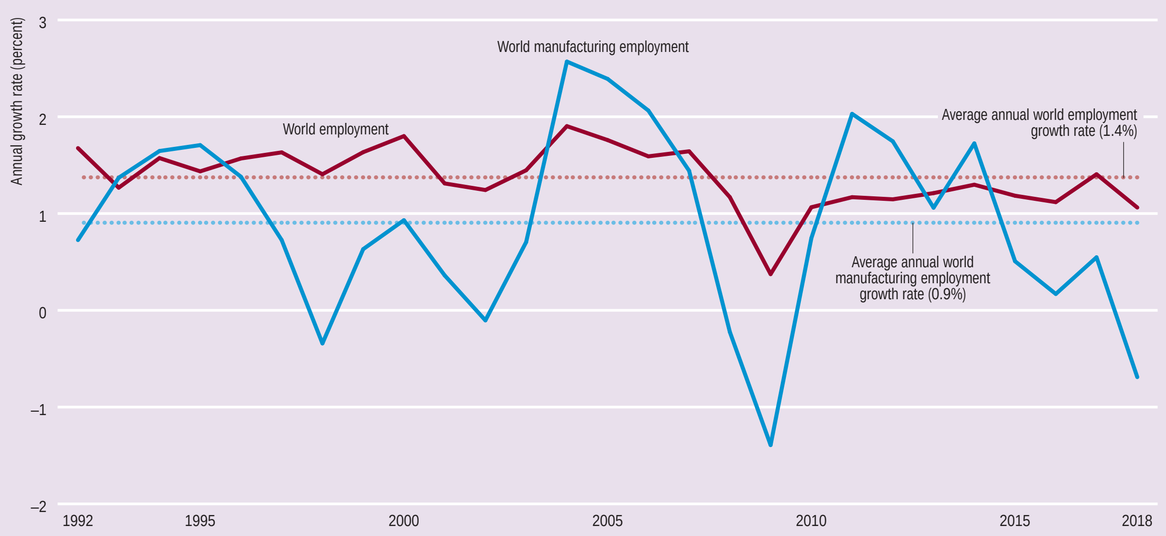
Figure 5.9
Annual growth rates of world manufacturing employment and world total employment



Source: UNIDO elaboration based on ILO (2018).

“ Most manufacturing employment growth occurred in developing and emerging industrial economies

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> **“** During 1991–2018, labour productivity in the manufacturing sector grew faster than in the total economy

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Figure 5.12
World labour productivity in manufacturing and in the entire economy

> Structural change towards technology-intensive sectors promotes the development of innovative activities

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Table 5.1
Economy group shares in manufacturing goods at different technology levels

	2005	2010	2015	2016	2017
Low-technology					
Industrialized economies	67.5	59.1	53.0	52.6	51.8
Developing and emerging industrial economies (excluding China)	24.5	26.3	26.8	26.6	26.6
Least developed countries	0.6	0.9	1.3	1.3	1.4
China	7.4	13.7	19.0	19.5	20.2
Total	100.0	100.0	100.0	100.0	100.0
Medium-low-technology					
Industrialized economies	68.4	59.3	53.5	52.9	52.8
Developing and emerging industrial economies (excluding China)	22.7	24.1	23.2	23.1	23.1
Least developed countries	0.2	0.3	0.4	0.4	0.4
China	8.6	16.3	22.9	23.6	23.7
Total	100.0	100.0	100.0	100.0	100.0
Medium-high- and high-technology					
Industrialized economies	78.7	70.7	65.3	64.1	63.2
Developing and emerging industrial economies (excluding China)	14.3	15.8	15.4	15.3	15.3
Least developed countries	0.1	0.1	0.1	0.1	0.1
China	7.0	13.5	19.2	20.5	21.4
Total	100.0	100.0	100.0	100.0	100.0

NoteEach value represents the percentage share of an economy group in the global manufacturing value added (MVA) of the sectors corresponding to a speci c technology level. See Annex C. the economy group classi cation and Annex C.2 for the technological classi cation of manufacturing activities. MVA is in constant $ 2010.
SourceUNIDO estimation based on UNIDO (2019f).

Sectoral analysis of world manufacturing value added

(N O 2013, 2015).

(2005).

“ Accelerated technical change has changed the structure of goods being produced

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2005 2017, V , 78.7 63.2 (5.1; 5.3). , V V 42.2 2005 45.6 2017 (5.2). , V 30.7 V 28.6 , 27.1 25.8 L L , , V , V

Table 5.2
Technology level of goods by economy group

	2005	2010	2015	2016	2017
Industrialized economies					
Low-technology	28.6	27.4	26.2	26.3	25.9
Medium-low-technology	25.6	24.3	23.9	23.9	23.8
Medium-high- and high-technology	45.9	48.3	49.9	49.8	50.3
Total	100.0	100.0	100.0	100.0	100.0
Developing and emerging industrial economies					
Low-technology	35.9	33.6	32.4	32.0	31.7
Medium-low-technology	31.1	30.0	29.6	29.3	28.7
Medium-high- and high-technology	33.0	36.3	37.9	38.6	39.6
Total	100.0	100.0	100.0	100.0	100.0
Least developed countries					
Low-technology	70.1	70.4	70.9	70.7	70.8
Medium-low-technology	21.6	20.5	19.7	18.9	19.2
Medium-high- and high-technology	8.3	9.1	9.4	10.4	10.0
Total	100.0	100.0	100.0	100.0	100.0
World					
Low-technology	30.7	29.8	29.0	28.9	28.6
Medium-low technology	27.1	26.3	26.2	26.1	25.8
Medium-high- and high-technology	42.2	43.9	44.8	44.9	45.6
Total	100.0	100.0	100.0	100.0	100.0

Note: Each value represents the percentage share of a speci c technology level in the total manufacturing value added (MVA) of an economy group. See Annex C.1 for the economy group classi cation and Annex C.2 for the technological classi cation of manufacturing activities. MVA is in constant $ 2010.
Source: UNIDO estimation based on UNIDO (2019f).

Chapter 6

The Competitive Industrial Performance Index

The Competitive Industrial Performance Index

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Capacity to produce and export manufactured goods.

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Technological deepening and upgrading.

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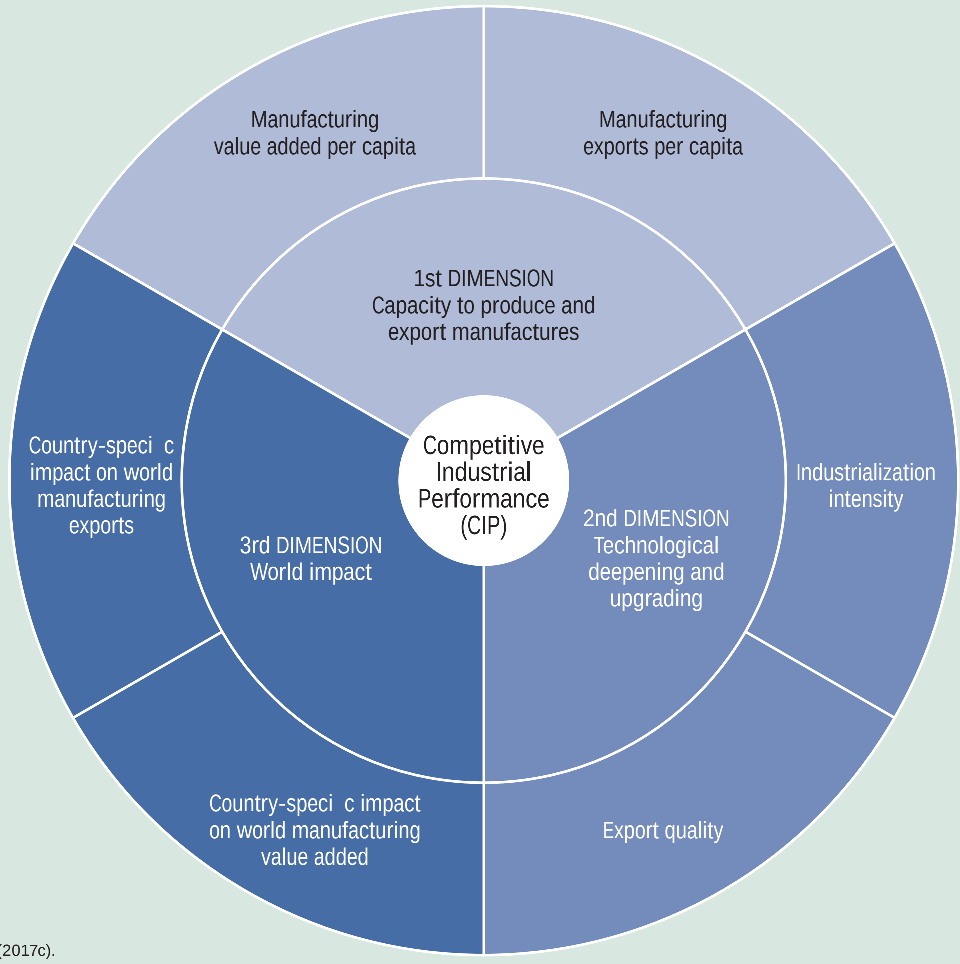
Main results

World impact. 6.1

2019 2017

> “ Industrial competitiveness is key to inclusive and sustainable industrial development

Figure 6.1
Dimensions of the CIP Index



Source: UNIDO (2017c).

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> "The top quintile of the CIP Index consists almost entirely of industrialized economies; Germany, with the highest composite score, ranks rst

Industrialized economies · Emerging industrial economies · Other developing economies · Least developed countries

Quintile	Rank 2017	Country	Score 2017	Rank 2015	Change in rank, 2015–2017
Top quintile	1	Germany	0.5146	1	
	2	Japan	0.4043	2	
	3	China	0.3687	3	
	4	Republic of Korea	0.3646	5	▲
	5	United States of America	0.3551	4	▼
	6	Ireland	0.3237	7	▲
	7	Switzerland	0.3119	6	▼
	8	Belgium	0.2716	8	
	9	Italy	0.2690	9	
	10	Netherlands	0.2687	11	▲
	11	France	0.2605	10	▼
	12	Singapore	0.2563	12	
	13	Taiwan Province of China	0.2394	13	
	14	Austria	0.2242	14	
	15	Czech Republic	0.2153	18	▲
	16	Sweden	0.2076	17	▲
	17	United Kingdom	0.2070	15	▼
	18	Canada	0.2038	16	▼
	19	Spain	0.2009	19	
	20	Denmark	0.1754	21	▲
	21	Malaysia	0.1664	22	▲
	22	Mexico	0.1662	20	▼
	23	Poland	0.1649	23	
	24	Slovakia	0.1589	25	▲
	25	Finland	0.1481	26	▲
	26	Hungary	0.1459	27	▲
	27	Thailand	0.1458	24	▼
	28	Turkey	0.1343	28	
	29	Israel	0.1243	29	
	30	Australia	0.1152	30	
Upper middle quintile	31	Russian Federation	0.1086	31	
	32	Romania	0.1084	33	▲
	33	Slovenia	0.1066	35	▲
	34	Portugal	0.1020	34	
	35	Brazil	0.0975	36	▲
	36	Norway			

> “ Ranking second through fth are Japan, China, the Republic of Korea and the United States

“ Asia and Paci c includes three of the top four countries on the CIP ranking

Table 6.1 (continued)
2019 CIP Index

Quintile	Rank 2017	Country	Score 2017	Rank 2015	Change in rank, 2015–2017
Middle quintile	81	Eswatini	0.0256	81	
	82	Jordan	0.0250	80	▼
	83	Pakistan	0.0240	83	
	84	Lebanon	0.0226	91	▲
	85	Brunei Darussalam	0.0220	87	▲
	86	Mauritius	0.0214	88	▲
	87	Hong Kong SAR, China	0.0207	85	▼
	88	Botswana	0.0205	86	▼
	89	Cambodia	0.0203	90	▲
	90	Myanmar	0.0202	97	▲
Lower middle quintile	91	Ecuador	0.0193	89	▼
	92	Cyprus	0.0165	95	▲
	93	Honduras	0.0158	93	
	94	Georgia	0.0154	96	▲
	95	Algeria	0.0153	94	▼
	96	Côte d’Ivoire	0.0149	101	▲
	97	Namibia	0.0146	92	▼
	98	Paraguay	0.0138	98	
	99	Armenia	0.0133	104	▲
	100	Plurinational State of Bolivia	0.0130	99	▼
	101	Jamaica	0.0119	100	▼
	102	Nigeria	0.0114	84	▼
	103	Lao People’s Democratic Rep	0.0110	105	▲
	104	Congo	0.0105	114	▲
	105	Suriname	0.0100	106	▲
	106	Republic of Moldova	0.0098	111	▲
	107	Mongolia	0.0097	102	▼
	108	Barbados	0.0097	108	
	109	Albania	0.0096	109	
	110	Senegal	0.0093	113	▲
	111	State of Palestine	0.0093	110	▼
	112	Kenya	0.0093	107	▼
	113	Gabon	0.0092	112	▼
	114	Fiji	0.0092	116	▲
	115	Azerbaijan	0.0090	103	▼
	116	Syrian Arab Republic	0.0087	115	▼
	117	Cameroon	0.0083	117	
	118	Kyrgyzstan	0.0075	121	▲
	119	Bahamas	0.0072	120	▲
	120	Montenegro	0.0067	124	▲

(continued)

> " The CIP dimensions are path-dependent, so a country must make a continuous effort to move up in the rankings

Table 6.1 (continued)
2019 CIP Index

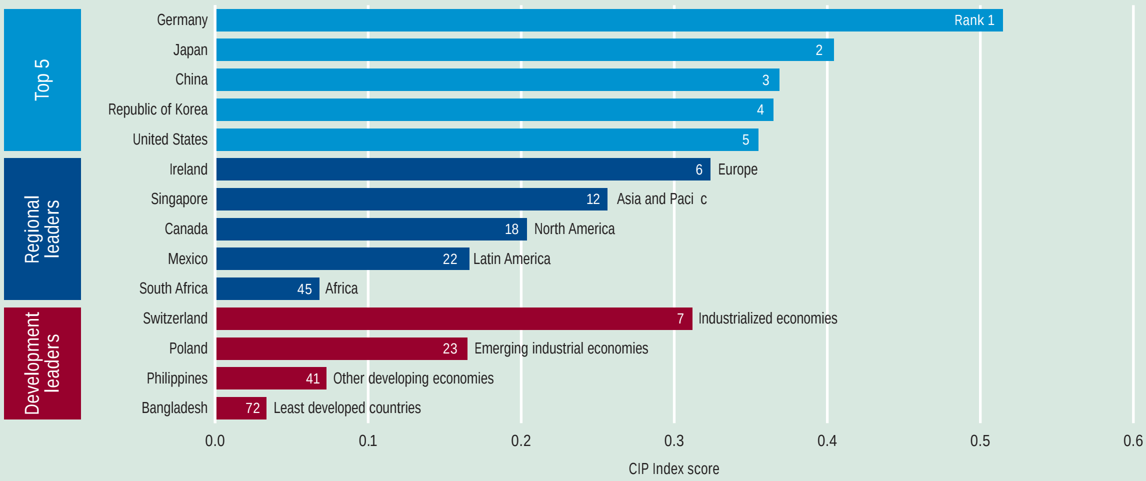
Quintile	Rank 2017	Country	Score 2017	Rank 2015	Change in rank, 2015–2017
Bottom quintile	121	Zambia	0.0066	118	▼
	122	Papua New Guinea	0.0061	123	▲
	123	Ghana	0.0058	122	▼
	124	Zimbabwe	0.0054	125	▲
	125	Belize	0.0053	127	▲
	126	Madagascar	0.0052	126	
	127	United Republic of Tanzania	0.0047	119	▼
	128	Central African Republic	0.0046	131	▲
	129	Tajikistan	0.0041	130	▲
	130	Uganda	0.0041	128	▼
	131	Angola	0.0036	133	▲
	132	Nepal	0.0036	132	
	133	Mozambique	0.0035	129	▼
	134	Saint Lucia	0.0031	136	▲
	135	Cabo Verde	0.0031	138	▲
	136	Bermuda	0.0029	139	▲
	137	Haiti	0.0028	135	▼
	138	Malawi	0.0023	134	▼
	139	Rwanda	0.0022	141	▲
	140	Yemen	0.0017	140	
	141	Ethiopia	0.0016	148	▲
	142	Maldives	0.0016	144	▲
	143	Afghanistan	0.0012	143	
	144	Niger	0.0009	137	▼
	145	Macao SAR, China	0.0008	145	
	146	Iraq	0.0006	142	▼
	147	Gambia	0.0004	146	▼
	148	Burundi	0.0000	147	▼
	149	Eritrea	0.0000	149	
	150	Tonga	0.0000	150	

Source: UNIDO elaboration based on the Competitive Industrial Performance Index 2019 database (UNIDO 2019c).

Results by geographical region and development stage

> “ Changes in yearly observations may provide policymakers timely insights into the effectiveness of current strategies

Figure 6.2
Scores and ranks of the top CIP performing economies in 2017



NoteCIP is Competitive Industrial Performance. “Regional leaders” and “development leaders” are runners-up if the top country in the region or development stage already appears among
Annex C.1 for the economy group classi cation.
SourceUNIDO elaboration based on the Competitive Industrial Performance Index 2019 database (UNIDO 2019c).

(6.2).[2] ( ). 2017, 37 : Ɲ 49 . O 52 Ɲ 54 Ɲ L Ɲ . L , L L .

> “The level of industrialization is central to SDG 9

Economy groups	Capacity to

Sustainable Development Goal 9

SDG 9.2.1 Manufacturing value added as a proportion of GDP and MVA per capita

> “Micro, small and medium-sized enterprises are the major sources of employment in developing economies

SDG 9.3.1 Proportion of small-scale industries in total industry value added

SDG 9.2.2 Manufacturing employment as a proportion of total employment

SDG 9.3.2 Proportion of small-scale industries with a loan or line of credit

6

> "Sustainable industrialization requires global cooperation and integration

SDG 9.4.1 Carbon dioxide emissions per unit of value added

SDG 9.b.1 Proportion of medium- and high-tech industry value added in total value added

Notes

1. 2018 (N O 2019).

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Annexes

Annex A.1

Producing the landscape of production and use of ADP technologies (Chapter 1)

Measuring the creation and diffusion of ADP technologies using patent and trade data

A

Technology	Harmonized System codes included
Additive manufacturing	847710 (Inje737 Td13.8 153 k6017 Tc[a)-223.8 (z58.-) (e)-moul5 (.)2d3.2 (i)ng0.015 9.1 (l)15 (d)1.2 (ta)113.2 (i)na lTJ0c -0.0146w

Constructing the groups of economies

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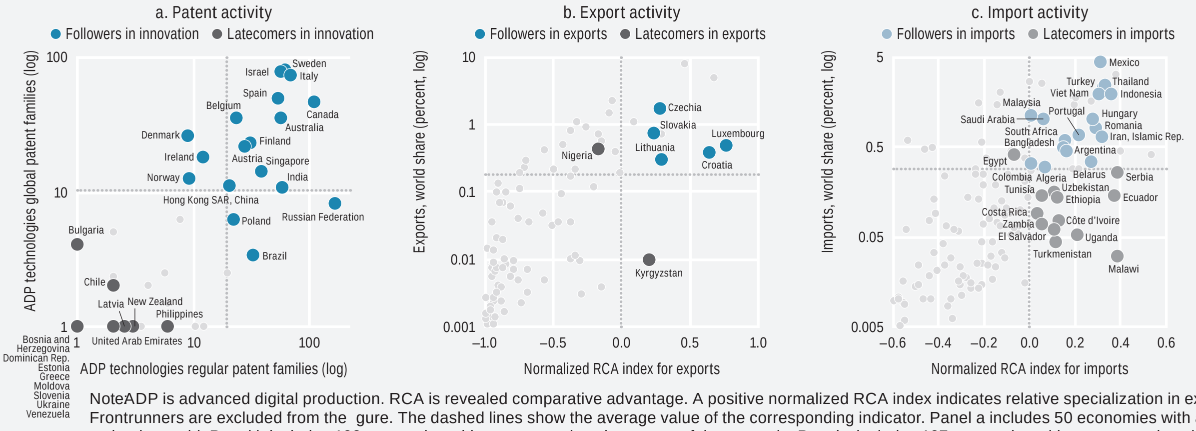
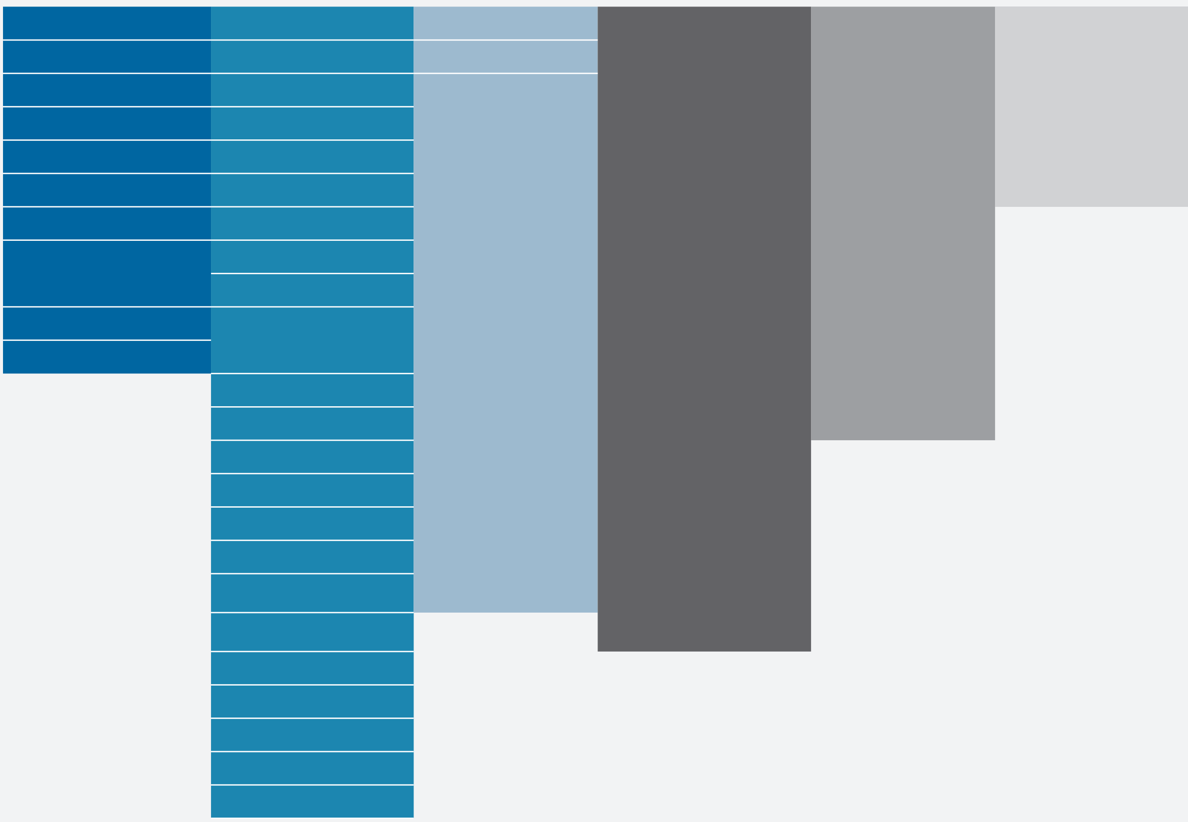
Figure A1
Characterization of economies: followers and latecomers



Note: ADP is advanced digital production. RCA is revealed comparative advantage. A positive normalized RCA index indicates relative specialization in exporting (importing) ADP
Frontrunners are excluded from the figure. The dashed lines show the average value of the corresponding indicator. Panel a includes 50 economies with at least one patent family
technology field. Panel b includes 160 economies with non-zero values in exports of these goods. Panel c includes 167 economies with non-zero values in the imports of these go
Economies are included in the maximum category to which they belong.
Source: UNIDO elaboration based on dataset by Foster-McGregor et al. (2019) derived from Worldwide Patent Statistical Database 2018 Autumn Edition (EPO 2018) and BACI In
Trade Database (Gaulier and Zignago 2010).

Table A2
Countries and economies by level of engagement with ADP technologies applied to manufacturing



Annex A.2

Knowledge-intensive business services and robots (Chapter 2)

Measuring knowledge-intensive business services

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(2018, . 29).

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Annex A.3

Surveys of the adoption of digital production technologies by industrial firms (Chapter 3)

Sample and coverage

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Table 3A.2
Final sample composition by firm size and industry

Country	Size	Sector: TDI industries	Sector: Other sectors	Total
Argentina	Large	22	16	38
	Small	58	75	133
	Total	80	91	171
Brazil	Large	193	135	328
	Small	—	—	—
	Total	193	135	328
Ghana	Large	—	59	59
	Small	—	138	138
	Total	—	197	197
Thailand	Large	69	36	105
	Small	45	50	95
	Total	114	86	200
Viet Nam	Large	73	84	157
	Small	49	55	104
	Total	122	139	261
Total		509	649	1,157

Note: Large firms have 100 or more employees. Small firms have fewer than 100 employees. TDI is technology- and digital-intensive. TDI industries include automotive and auto parts and electronics. Other sectors include food and beverages; textiles, leather and footwear; plastic and rubber; metal products; wood products; and furniture.
Source: UNIDO elaboration based on data collected by the UNIDO firm-level surveys "Adoption of digital production technologies by industrial firms" and on Kupfer et al. (2019).

Table 3A.3
Topic coverage by individual country

Topics	Argentina	Brazil	Ghana	Thailand	Viet Nam
Current and expected use of digital production technologies	●	●	●	●	●
Employment and skills	●		●	●	●
Location of production and trade			●	●	●
Energy and sustainability			●	●	●

Source: UNIDO elaboration based on data collected by the UNIDO firm-level surveys "Adoption of digital production technologies by industrial firms."

(3.4).

Measures for adoption of technological generations and readiness

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(4.0), 1 (1.20).

($Firm_c$); 5 10 ($Firm_e$); ($Firm_a$).

Table A.4
Digital technology generations and business functions

Generation of digital technologies		Business function: Supplier relationship	Business function: Product development	Business function: Production management	Business function: Client relationship	Business function: Business management
G 4.0	Fourth generation: smart production	Real time web-based relation	Virtual development systems (such as virtual manufacturing)	Machine-to-machine system, cobots, augmented reality, additive manufacturing	Client relationship based online monitoring product use (such as artificial intelligence in customer services)	Business management supported by big data analytics
G 3.0	Third generation: integrated production	Digital system for processing orders, stocks and payments	Integrated data product system (such as product data management and/or product lifecycle management)	Computerized process execution system	Internet based support for sales and after services (such as mobile app, customer data analytics)	Integrated platform to support decision making (such as advanced enterprise resource planning)
G 2.0	Second generation: lean production	Automated electronic transmission of orders (such as email)	Computer-aided design and computer-integrated manufacturing, computer-aided engineering, computer-aided process planning	Partially or fully integrated computer-aided manufacturing	Automated devices to support sales (such as customer relationship management)	Enterprise resource management in few areas (such as enterprise resource planning)
G 1.0	First generation: rigid production	Manual electronic transmission of orders (such as email)	Stand-alone computer aided design	Stand-alone automation	Electronic contact (such as spreadsheet registry, email)	Information systems by area/department
G 0.0	Zero generation: analog production	Manual transmission of orders (such as personal contact, telephone)	Manual generation of designs (such as 2D/3D drawings in 2D space)	Non-micro-electronic based machinery	Manual handling of contacts (such as personal contact, telephone)	No software support to business management

Note: The technical solutions identi ed in correspondence of each technological generation and each business function have been speci ed with the support of specialized engineers (IEL 20
Generation 0.0 was included only in the survey questionnaires collected in Ghana, Thailand and Viet Nam.
Source: UNIDO elaboration based on Indústria 2027 Survey (IEL 2018) and on Kupfer et al. (2019).

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Currently adopted ($Firm_c$) and expected ($Firm_e$) technological generation

f_i,

0 (0.0) 4 (4.0)

f_i,

Sum_c ( ) Sum_e ( ) f_i (Sum_e):

$$(1)\ Sum_c = \sum_{i=1}^{4} f_i\ c \ldots f_i\ c,\ where\ 4 \le Sum_c \le 16$$

($Firm_c$, $Firm_e = 0,1,2,3,4$)

($Firm_e$):

$$(2)\ Firm_c = \begin{cases} 0 & generation\ 0.0\ if\ 0 \le Sum_c < 4 \\ 1 & generation\ 1.0\ if\ 4 \le Sum_c \le 6 \\ 2 & generation\ 2.0\ if\ 7 \le Sum_c \le 9 \\ 3 & generation\ 3.0\ if\ 10 \le Sum_c \le 12 \\ 4 & generation\ 4.0\ if\ 0 \le Sum_c \le 16 \end{cases}$$

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Plans and actions to reach the projected generation ($Firm_a$)

- $(Firm_a)$.

f_i,

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f_i.

$(Firm_a = 1,2,3,4)$

:

$$(3)\ Firm_a \begin{cases} 1 & \text{no action if } 4 \quad Sum_a \quad 6 \\ 2 & \text{initial studies if } 7 \quad Sum_a \quad 9 \\ 3 & \text{plan available but not yet implemented if } 10 \quad Sum_a \quad 12 \\ 4 & \text{plan in execution if } 13 \quad Sum_a \quad 16 \end{cases}$$

UNIDO digitalization readiness index

N O ( )

$Firm_c, Firm_e$

$Firm_a$

:

$$(4)\ DRI \quad Firm_c + (Firm_e \quad Firm_c) *$$

:

$$(5) \begin{cases} 0 & \text{if } Firm_a \quad 1 \text{ (no action)} \\ 0.33 & \text{if } Firm_a \quad 2 \text{ (initial studies)} \\ 0.66 & \text{if } Firm_a \quad 3 \text{ (plan available but not yet implemented)} \\ 1 & \text{if } Firm_a \quad 1 \text{ (plan in execution)} \end{cases}$$

:

$$(6)\ \text{Firm readiness category} \begin{cases} 1 & \text{lagging behind if} \quad 2 \\ 2 & \text{catching up if } 2 < \quad < 4 \\ 3 & \text{forging ahead if } 4 \leq \end{cases}$$

3.5 - $Firm_c$, $Firm_e$ $Firm_a$.

Table 3.5
Firm readiness categories

$Firm_c$	$Firm_e$	$Firm_a$ 1	2	3	4
0 or 1	0 or 1	1	1	1	1
	2	1	1	1	1
	3	1	1	2	2
	4	1	1	2	2
2	2	1	1	1	1
	3	1	1	2	2
	4	1	1	2	3
3	3	2	2	2	2
	4	2	2	3	3
4	4	3	3	3	3

Note: A firm is not allowed to advance three generations even if there are plans in execution (for example, a firm that is currently in generation 1.0 and is expecting to be in generation 4.0 in 5 to 10 years). In this case, the firm is assigned $Firm_a$ = 1. A firm is excluded if the expected technology generation in future is lower than current one.
Source: Kupfer et al. 2019.

Annex A.4

Summary of strategic responses to ADP technologies in 11 countries (Chapter 4)

Table A.1
Strategic responses to ADP technologies in selected economies, by geographical region

	Strategy name	Timeline	Responsible agency	Strategic objectives	Strategic sectors	Policy instruments	Performance indicators
Latin America and the Caribbean							
Argentina	Working group/ mechanism set up to develop a strategy	N/A	Ministry of Science, Technology and Productive Innovation, National Institute of Industrial Technology	N/A	Diagnostic studies ongoing or to be carried out in: • Biotechnology • Franchising • Software • Electric vehicles • Textiles • Health technologies • Computers • Aeronautics and aerospace • Shoes • Robotics • 3D printing	N/A	N/A
Brazil	Plano de CT&I para Manufatura Avançada no Brasil	N/A	Ministry of Science, Technology, Innovation and Communication	Provide Brazilian firms with conditions to access and adopt smart manufacturing ecosystems, with support from science, technology and innovation. Ultimately, this should assist the development of strategic value chains, and promising economic sectors capable of addressing local demands.	• Aerospace and defence • Agriculture • Health-related industries • Basic chemicals • Biodiversity-based industries • Digital industries • Petroleum and gas • Renewable energies	From Innovation Law (Law no. 13.243 / 2016), several possible instruments are considered: • Direct subsidies • Direct capital injection/strategic partnerships • Technology vouchers • Strategic procurement, notably of specific technologies • Tax breaks • Grants and scholarships • Investment funds • Financial securities, either encouraged or not • Investment in research and development within public service concessions or sectoral contracts	Document provides substantive evidence of scientific and technological production in Brazil and of technological adoption by firms.

Table A.1 (continued)
Strategic responses to ADP technologies in selected economies, by geographical region

	Strategy name	Timeline	Responsible agency	Strategic objectives	Strategic sectors	Policy instruments	Performance indicators
Chile	Strategic Programme Smart Industries (PEII) 2015–2025	2015–2017 (short-term), 2018–2020 (medium-term) and 2020–2025 (long-term)	Chilean Economic Development Agency (CORFO)	• Develop an enabling digital ecosystem to underpin industrial transformation • Facilitate coordination between industrial supply and demand • Develop a mechanism to identify and select priority sectors • Contribute to productivity and value addition in domestic industry	• Mining (particularly copper) • Agriculture and food • Smart cities • Other sectors to be identified in the future	Public–private partnerships	• Increased available speed for national broadband • Penetration of high-speed internet • Reduced deficit of human resources in ICTs • Private sector participation in PEII implementation • Number of industries involved in the programme • Interoperability in mining • Interoperability and introduction of sensor technologies in agriculture • Urban areas with smart city–enabling infrastructure
Mexico	Roadmap	2030	Ministry of Economy	• Increase the value content of Mexican manufactured exports • Enhance industry–academia collaboration as the basis for innovation • Become a dynamic market for IoT within a decade of adoption of the roadmap	Automotive, aerospace and chemicals as case studies of the country’s manufacturing paradigms. Other sectors will be designed based on findings from other thematic roadmaps	• Pilot programmes • Boost digitization and access to internet services in the country	• In 2019 and 2021, two regional clusters should be set in place with a mandate to develop Industry 4.0 hyper-flexible manufacturing operating systems, which will be the platform for systems integration and application development • By 2022, the value of the domestic market for IoT should amount to about $8 billion

Table A.1 (continued)
Strategic responses to ADP technologies in selected economies, by geographical region

	Strategy name	Timeline	Responsible agency	Strategic objectives	Strategic sectors	Policy instruments	Performance indicators
Asia and Paci c							
China	Made in China 2025	2025, with milestones for 2020	Ministry of Industry and Information Technology (MIIT) is the lead agency, but responsibilities for implementation are shared by other agencies at different levels	To facilitate the country's evolution from a large manufacturing country to a "manufacturing power" strong in innovation and manufacturing	• High-grade computer numerical control machine tools and robots • Aerospace equipment, marine engineering equipment, high-tech ships • Advanced rail transit equipment • Energy-saving and new energy vehicles • Electric power equipment • Agricultural machinery and equipment • New material • Biomedicine and high performance medical devices	• Public–private partnership • Value added tax reform to take R&D into deduction • Perfecting the multi-level talent training system	• R&D/revenue • Patents/revenue • Competitiveness Index* • Value added ratio increase • Labour productivity growth rate • Broadband penetration rate • Digital R&D and design tools penetration rate • Computer numerical control of key processes • Reduction in energy consumption per MVA • Reduction in CO_2 emission per MVA • Reduction in water consumption per MVA • Industrial solid waste comprehensive use rate
Malaysia	Industry4wrd	2025	Ministry of International Trade and Investment	• Attract stakeholders to smart manufacturing technologies and processes. Increase Malaysia's attractiveness as a preferred manufacturing location • Create the right ecosystem for smart manufacturing in line with existing and future development initiatives • Transform domestic industry capabilities	• Electrical and electronics • Machinery and equipment • Chemicals, aerospace and medical devices • Automotive • Textiles • Transport • Pharmaceuticals • Metal • Food processing • Services	• Funding and outcome-based incentives (tax incentives) • Enabling ecosystem and digital infrastructure (digital connectivity between different stakeholders, notably government, firms and education organizations) • Regulatory frameworks (creating a dedicated smart manufacturing platform, several issues around data generation, storage and use) • Dedicated training and upskilling programmes • Access to smart technologies and standards (through public–private partnerships)	• Increase by 30 percent productivity per person, from about $25,000 • Increase the absolute contribution of manufacturing to the national economy from about $60.7 billion to $93.7 billion • Climb from 35th place to the top 30 in the Global Innovation Index ranking • Augment from 18 percent to 35 percent the share of high-skilled workers in manufacturing

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	Strategy name	Timeline	Responsible agency	Strategic objectives	Strategic sectors	Policy instruments	Performance indicators
Thailand	Thailand 4.0 20-Year National Strategy (2017–2036) 12th National						

Table A.1 (continued)
Strategic responses to ADP technologies in selected economies, by geographical region

	Strategy name	Timeline	Responsible agency	Strategic objectives	Strategic sectors	Policy instruments	Performance indicators
Europe							
Turkey	Smart Manufacturing Systems Technology Roadmap	N/A	Higher Council of Science & Technology, the Scientific and Technological Research Council of Turkey	To be determined	• Digitalization: emphasis on big data and cloud computing, virtualization and cyber-security • Connectivity: emphasis on IoT and sensor technologies • Future factories: additive manufacturing, advanced robotic systems and automation and control systems	• To be determined	• To be determined
Middle East							
Saudi Arabia	National Transformation Program. Delivery Plan 2018–2020 Vision 2030—Industry 4.0	2030	N/A	• Increasing competitiveness of industries within sectors of the National Industrial Development and Logistics Program • Expand existing value chains and develop new ones • Mitigate impact of reforms in energy, natural gas and labour markets • Develop environmental system for smart manufacturing technologies • Create new high-skill jobs to attract national labour force	• Chemicals and pharmaceuticals • Basic materials • Food and beverage • Textiles • Advanced industries • Basic industries/ materials	• Establishment of capacity-building centres for pilot testing, demonstrating technologies, training and capacity development	• Improvements in annual operating income of existing assets of firms endorsing smart manufacturing • Total required technological cost

* Comprehensive index consisting of 12 indicators, developed by AQSIQ, the General Administration of Quality Supervision, Inspection and Quarantine.
Note: MVA is manufacturing value added. IoT is Internet of Things. R&D is research and development. ICT is information and communications technology.
Source: UNIDO elaboration.

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Notes

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3. , L (2017).
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6. (N) . 2 - N 2008 (N 2008)/ N 2010 (2010) .
7. , N O . (2019).
8. - N O , V N N O - . (2019).
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11. - , N O . (2019).

Annex B.1

Rankings on the three dimensions of the Competitive Industrial Performance Index, by geographical regions

Table B.1
European economies' ranking on the three dimensions of industrial competitiveness

	Capacity to produce and export manufactures (1st dimension)		Technological deepening and upgrading (2nd dimension)		World impact (3rd dimension)		CIP rank	
Economy	2015	2017	2015	2017	2015	2017	2015	2017
Germany	5	5	6	5	3	3	1	1
Ireland	1	1	4	3	24	24	7	6
Switzerland	2	2	13	13	18	19	6	7
Belgium	4	4	21	21	17	17	8	8
Italy	19	18	24	24	7	6	9	9
Netherlands	7	7	27	30	14	13	11	10
France	22	21	22	22	6	7	10	11
Austria	6	6	16	16	25	25	14	14
Czechia	12	11	9	7	29	27	18	15
Sweden	9	10	18	19	26	26	17	16
United Kingdom	30	30	33	34	9	9	15	17
Spain	27	26	32	33	12	11	19	19
Denmark	10	9	26	20	33	33	21	20
Poland	39	36	25	26	22	22	23	23
Slovakia	14	14	10	9	41	39	25	24
Finland	13	13	30	27	39	38	26	25
Hungary	23	22	8	10	36	36	27	26
Turkey	48	48	37	37	20	20	28	28
Russian Federation	57	58	69	66	13	14	31	31
Romania	42	41	15	15	37	37	33	32
Slovenia	16	15	19	18	59	57	35	33
Portugal	35	34	49	48	42	42	34	34
Norway	18	20	59	67	43	46	32	36
Lithuania	26	25	36	39	60	59	40	40
Luxembourg	8	8	67	69	74	75	42	44
Belarus	49	50	23	23	56	55	45	46
Estonia	25	24	39	42	71	73	49	48
Greece	50	47	71	72	53	50	52	50
Croatia	45	43	43	46	67	63	56	54
Bulgaria	54	51	51	51	62	60	58	55
Latvia	41	40	55	55	77	76	59	57
Serbia	65	62	44	44	69	69	65	62
Malta	32	28	48	41	100	98	66	64
Ukraine	92	91	56	57	54	53	69	67
Iceland	24	27	87	89	104	107	71	73
North Macedonia	61	57	35	36	93	91	79	74

Economy	Capacity to produce and export manufactures (1st dimension)		Technological deepening and upgrading (2nd dimension)		World impact (3rd dimension)		CIP rank	
	2015	2017	2015	2017	2015	2017	2015	2017
Bosnia and Herzegovina	68	64	65	65	87	87	82	

Table B3 (continued)
Asia and Paci c economies' ranking on the three dimensions of industrial competitiveness

Economy	Capacity to produce and export manufactures (1st dimension) 2015	2017	Technological deepening and upgrading (2nd dimension) 2015	2017	World impact (3rd dimension) 2015	2017	CIP rank 2015	2017
Indonesia	80	80	42	43	19	18	38	38
India	110	108	34	32	8	8	39	39
Philippines	81	81	11	11	31	32	43	41
United Arab Emirates	38	38	119	111	44	44	41	42
Viet Nam	79	77	31	29	32	31	46	43
New Zealand	37	37	94	92	57	56	48	47
Islamic Republic of Iran	77	75	62	60	35	34	53	49
Qatar	29	29	84	87	63	61	50	53
Bahrain	28	32	70	68	75	77	55	56
Kuwait	40	44	106	112	61	64	54	59
Kazakhstan	69	68	99	107	58	58	68	66
Oman	51	54	92	96	70	71	63	68
Bangladesh	114	113	63	58	45	43	73	72
Sri Lanka	86	86	75	76	65	62	78	77
Jordan	82	84	47	50	79	81	80	82
Pakistan	119	120	64	64	50	49	83	83
Lebanon	90	78	79	86	90	86	91	84
Brunei Darussalam	43	42	81	88	121	116	87	85
Hong Kong SAR, China	78	82	86	105	83	84	85	87
Cambodia	102	103	76	73	82	78	90	89
Myanmar	118	114	113	75	76	68	97	90
Armenia	95	89	110	104	114	110	104	99
Lao People's Dem. Rep.	111	110	101	103	107	105	105	103
Mongolia	88	95	136	142	109	112	102	107
State of Palestine	112	112	98	93	115	119	110	111
Fiji	87	88	102	94	134	131	116	114
Azerbaijan	107	116	135	133	95	102	103	115
Syrian Arab Republic	126	123	117	116	94	93	115	116
Kyrgyzstan	121	117	96	99	127	124	121	118
Papua New Guinea	122	122	141	135	119	120	123	122
Tajikistan	135	135	104	101	131	129	130	129
Nepal	141	139	114	115	126	125	132	132
Yemen	145	144	120	129	133	133	140	140
Maldives	120	119	148	147	146	144	144	142
Afghanistan	146	145	143	146	130	135	143	143
Macao SAR, China	124	129	149	149	144	145	145	145
Iraq	143	143	147	150	125	128	142	146
Tonga	131	130	138	131	150	150	150	150
Asia and Pacific (average)	81	81	80	80	74	73	76	76

Source: UNIDO elaboration based on the Competitive Industrial Performance Index 2019 database (UNIDO 2019c).

Table B4
Latin American and Caribbean economies' ranking on the three dimensions of industrial competitiveness

	Capacity to produce and export manufactures (1st dimension)		Technological deepening and upgrading (2nd dimension)		World impact (3rd dimension)		CIP rank	
Economy	2015	2017	2015	2017	2015	2017	2015	2017
Mexico	47	49	17	17	10	10	20	22
Brazil	70	69	53	52	16	15	36	35
Argentina	63	66	60	61	40	41	47	51
Chile	53	53	89	91	46	45	51	52
Trinidad and Tobago	36	39	45	45	80	82	57	58
Peru	76	72	93	90	51	48	61	60
Costa Rica	55	55	57	59	72	72	67	65
Bolivarian Republic of Venezuela	71	76	128	122	49	52	64	69
Colombia	89	92	78	80	52	51	70	70
El Salvador	72	71	50	49	81	79	76	75
Guatemala	83	85	54	54	68	70	75	76
Panama	56	61	97	102	78	80	74	78
Uruguay	58	60	90	98	84	85	77	79
Ecuador	93	94	126	127	73	74	89	91
Honduras	103	104	72	79	91	90	93	93
Paraguay	101	102	115	110	98	94	98	98
Plurinational State of Bolivia	106	106	140	128	89	89	99	100
Jamaica	94	98	85	84	113	115	100	101
Suriname	67	73	130	124	132	130	106	105
Barbados	73	74	58	56	137	139	108	108
Bahamas	91	90	77	71	140	140	120	119
Belize	100	99	124	108	141	141	127	125
Saint Lucia	104	101	123	118	147	146	136	134
Haiti	142	140	100	100	135	132	135	137
Latin America and the Caribbean (average)	79	80	86	84	84	84	83	83

Source: UNIDO elaboration based on the Competitive Industrial Performance Index 2019 database (UNIDO 2019c).

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Table B5
African economies' ranking on the three dimensions of industrial competitiveness

Economy	Capacity to produce and export manufactures (1st dimension)		Technological deepening and upgrading (2nd dimension)		World impact (3rd dimension)		CIP rank	
	2015	2017	2015	2017	2015	2017	2015	2017
South Africa	64	65	52	53	34	35	44	45
Morocco	84	83	41	40	55	54	60	61
Tunisia	66	70	40	35	64	65	62	63
Egypt	105	105	61	63	48	47	72	71
Eswatini	60	59	38	38	103	101	81	81
Mauritius	59	56	83	82	105	104	88	86
Botswana	62	63	112	114	92	92	86	88
Algeria	108	109	146	144	66	66	94	95
Côte d'Ivoire	116	115	108	83	86	83	101	96
Namibia	75	79	118	121	101	106	92	97
Nigeria	115	132	116	119	47	67	84	102
Republic of Congo	109	107	129	123	112	108	114	104
Senegal	123	121	82	81	102	100	113	110
Kenya	128	128	95	106	85	88	107	112
Gabon	85	87	145	143	116	118	112	113
Cameroon	125	124	121	120	96	95	117	117
Zambia	127	125	133	130	106	109	118	121
Ghana	129	127	144	145	97	96	122	123
Zimbabwe	132	131	105	113	117	121	125	124
Madagascar	134	134	127	126	111	111	126	126
United Republic of Tanzania	133	136	132	139	88	99	119	127
Central African Republic	136	133	20	25	139	137	131	128
Uganda	138	138	122	125	110	113	128	130
Angola	130	126	150	148	99	97	133	131
Mozambique	137	137	137	140	120	122	129	133
Cabo Verde	117	118	107	85	143	143	138	135
Malawi	139	142	109	117	129	134	134	138
Rwanda	140	141	134	137	136	136	141	139
Ethiopia	149	146	139	136	122	126	148	141
Niger	147	148	88	97	128	127	137	144
Gambia	144	147	103	138	145	149	146	147
Burundi	148	149	125	134	142	142	147	148
Eritrea	150	150	142	141	148	147	149	149
Africa (average)	116	116	106	107	103	104	112	113

Source: UNIDO elaboration based on the Competitive Industrial Performance Index 2019 database (UNIDO 2019c).

Annex B.2

Sustainable Development Goals and the Competitive Industrial Performance Index

Economy	Proportion of medium- and high-tech industry value added in total manufacturing value added (percent)	Manufacturing value added per capita (2010 $)	Manufacturing value added as a proportion of GDP (percent)
	2017	2017	2017
Germany	61.68	10,064	21.33
Japan	56.77	10,191	21.14
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Economy	Proportion of medium- and high-tech industry value added in total manufacturing value added (percent) 2017	Manufacturing value added per capita (2010 $) 2017	Manufacturing value added as a proportion of GDP (percent) 2017
Saudi Arabia	39.22	2,576	12.44
Indonesia	35.35	888	21.50
India	42.87	330	16.86
Lithuania	24.89	3,065	18.64
Philippines	43.32	651	22.49
United Arab Emirates	35.92	3,434	8.45
Viet Nam	38.68	309	16.84
Luxembourg	20.02	5,574	5.03
South Africa	24.43	927	12.37
Belarus	38.83	1,468	22.96
New Zealand	18.53	3,696	9.77
Estonia	27.48	2,799	14.68
Islamic Republic of Iran	46.02	868	12.46
Greece	20.03	1,829	8.24
Argentina	26.00	1,487	14.29
Chile	20.96	1,461	9.67
Qatar	47.86	5,961	9.21
Croatia	27.77	1,852	12.38
Bulgaria	29.21	1,113	13.41
Bahrain	22.17	3,315	15.01
Latvia	20.60	1,719	11.11
Trinidad and Tobago	39.60	2,428	15.41
Kuwait	32.87	1,544	4.62
Peru	15.13	795	12.91
Morocco	27.75	534	15.29
Serbia	26.75	728	15.20
Tunisia	28.87	665	15.65
Malta	37.97	2,202	7.65
Costa Rica	16.69	1,273	12.82
Kazakhstan	13.35	1,099	10.10
Ukraine	29.17	305	10.61
Oman	20.64	1,537	9.73
Bolivarian Republic of Venezuela	34.28	1,168	13.13
Colombia	23.33	835	10.99
Egypt	18.38	410	14.87
Bangladesh	9.76	222	20.47
Iceland	13.90	6,281	12.40
North Macedonia	29.61	709	13.51
El Salvador	19.13	749	19.35

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Table B.1 (continued)
Sustainable Development Goal 9 targets included in the CIP Index

Economy	Proportion of medium- and high-tech industry value added in total manufacturing value added (percent) 2017	Manufacturing value added per capita (2010 $) 2017	Manufacturing value added as a proportion of GDP (percent) 2017
Guatemala	22.40	567	18.15
Sri Lanka	8.87	608	15.41
Panama	6.40	577	5.07
Uruguay	15.29	1,742	12.15
Bosnia and Herzegovina	17.29	672	12.08
Eswatini	2.23	1,361	34.01
Jordan	23.66	504	15.58
Pakistan	24.62	156	13.02
Lebanon	15.57	361	5.09
Brunei Darussalam	3.32	4,697	14.94
Mauritius	5.24	1,252	12.30
Hong Kong SAR, China	37.38	498	1.31
Botswana	5.79	474	6.30
Cambodia	0.26	194	17.08
Myanmar	7.62	292	23.46
Ecuador	13.57	638	12.22
Cyprus	23.68	867	4.06
Honduras	7.16	356	16.17
Georgia	8.58	466	11.44
Algeria	2.69	207	4.31
Côte d’Ivoire	14.99	237	14.41
Namibia	7.35	600	10.22
Paraguay	21.83	439	10.81
Armenia	4.62	435	9.68
Plurinational State of Bolivia	9.70	277	11.00
Jamaica	18.77	362	7.52
Nigeria	33.44	223	9.26
Lao People’s Dem. Rep.	3.77	193	10.89
Republic of Congo	2.42	102	3.76
Suriname	11.62	1,416	17.29
Republic of Moldova	19.51	220	11.61
Mongolia	5.37	215	5.34
Barbados	38.11	777	4.91
Albania	4.47	280	5.86
Senegal	21.65	112	9.88
State of Palestine	2.52	268	11.28
Kenya	14.98	116	9.92
Gabon	5.39	403	4.70
Fiji	7.09	479	11.16

Economy	Proportion of medium- and high-tech industry value added in total manufacturing value added (percent)	Manufacturing value added per capita (2010 $)	Manufacturing value added as a proportion of GDP (percent)
	2017	2017	2017
Azerbaijan	19.05	323	5.59
Syrian Arab Republic	21.52	55	3.30
Cameroon	7.61	212	14.03
Kyrgyzstan	2.71	147	13.54
Bahamas	27.77	599	2.34
Montenegro	14.86	315	4.08
Zambia	9.73	131	8.03
Papua New Guinea	12.61	54	2.3
Ghana	0.80	91	5.05
Zimbabwe	21.82	76	8.21
Be54			

Annex C.1

Country and economy groups

Table C1
Countries and economies by industrialization level and geographical region

INDUSTRIALIZED ECONOMIES				
Asia and Paci c				
Australia[a,b,c]	Hong Kong SAR, China[a]	Kuwait	New Zealand[a,c]	United Arab Emirates
Bahrain	Israel[a]	Macao SAR, China	Qatar	
French Polynesia	Japan[a,b,c]	Malaysia[a]	Singapore[a,c]	
Guam	Korea, Republic of[a,b,c]	New Caledonia	Taiwan Province of China[b]	
Europe				
Andorra	Estonia[a,b,c]	Ireland[b]	Monaco	Slovakia[a,b,c]
Austria[a,b,c]	Finland[a,b,c]	Italy[a,b,c]	Netherlands[a,b,c]	Slovenia[a,b,c]
Belarus	France[a,b,c]	Liechtenstein	Norway[a,b,c]	Spain[a,b,c]
Belgium[a,b,c]	Germany[a,b,c]	Lithuania[a,b,c]	Portugal[a,b,c]	Sweden[a,b,c]
Czechia[a,b,c]	Hungary[a,b,c]	Luxembourg[b]	Russian Federation a[b]	Switzerland[b]
Denmark[a,b,c]	Iceland[a]	Malta[a,b]	San Marino	United Kingdom[a,b,c]
Latin America and the Caribbean				
Aruba	Cayman Islands	French Guiana	Trinidad and Tobago	
British Virgin Islands	Curaçao	Puerto Rico	United States Virgin Islands	
North America				
Bermuda	Canada[a,b,c]	Greenland	United States[a,b,c]	
EMERGING INDUSTRIAL ECONOMIES				
Africa				
Egypt	Mauritius	South Africa[a]	Tunisia[a]	
Asia and Paci c				
Brunei Darussalam	India[a,b]	Iran, Islamic Republic of	Oman	Thailand[a]
China[a,b,c]	Indonesia[a,b]	Kazakhstan[a]	Saudi Arabia[a]	
Europe				
Bulgaria[a,b]	Greece[a,b,c]	Poland[a,b,c]	Turkey[a,b,c]	
Croatia[a,b]	Latvia[a,b]	Romania[a,b,c]	Ukraine	
Cyprus[a,b]	North Macedonia	Serbia		
Latin America and the Caribbean				
Argentina[a,c]	Chile[a,c]	Costa Rica[a]	Peru[a]	Uruguay
Brazil[a,b]	Colombia[a]	Mexico[a,b,c]	Suriname	Venezuela, Bolivarian Republic of
OTHER DEVELOPING ECONOMIES				
Africa				
Algeria	Congo, Republic of the	Gabon	Morocco[a]	Seychelles
Botswana	Côte d’Ivoire	Ghana	Namibia	Zimbabwe
Cabo Verde	Equatorial Guinea	Kenya	Nigeria	
Cameroon	Eswatini, Kingdom of	Libya	Réunion	

Table C1 (continued)
Countries and economies by industrialization level and geographical region

OTHER DEVELOPING ECONOMIES				
Asia and Paci c				
Armenia	Korea, Democratic People’s Republic of	Mongolia	Samoa	Uzbekistan
Azerbaijan	Kyrgyzstan	Pakistan	Sri Lanka	Viet Nam
Cook Islands	Lebanon	Palau	Syrian Arab Republic	
Fiji	Maldives	Palestine, State of	Tajikistan	
Iraq	Marshall Islands	Papua New Guinea	Tonga	
Jordan	Micronesia, Federated States of	Philippines[a]	Turkmenistan	
Europe				
Albania	Bosnia and Herzegovina	Georgia	Moldova, Republic of	Montenegro
Latin America and the Caribbean				
Anguilla	Bolivia, Plurinational State of	El Salvador	Honduras	Panama
Antigua and Barbuda	Cuba	Grenada	Jamaica	Paraguay
Bahamas	Dominica	Guadeloupe	Martinique	Saint Kitts and Nevis
Barbados	Dominican Republic	Guatemala	Montserrat	Saint Lucia
Belize	Ecuador	Guyana	Nicaragua	Saint Vincent and the Grenadines
LEAST DEVELOPED COUNTRIES				
Africa				
Angola	Congo, Democratic Republic of the	Lesotho	Niger	Sudan
Benin	Djibouti	Liberia	Rwanda	Tanzania, United Republic of
Burkina Faso	Eritrea	Madagascar	São Tomé and Príncipe	Togo
Burundi	Ethiopia	Malawi	Senegal	Uganda
Central African Republic	Gambia	Mali	Sierra Leone	Zambia
Chad	Guinea	Mauritania	Somalia	
Comoros	Guinea-Bissau	Mozambique	South Sudan	
Asia and Paci c				
Afghanistan	Cambodia	Myanmar	Timor-Leste	Yemen
Bangladesh	Kiribati	Nepal	Tuvalu	
Bhutan	Lao People’s Democratic Republic	Solomon Islands	Vanuatu	
Latin America and the Caribbean				
Haiti				

a. Included in OECD Inter-Country Input-Output (ICIO) tables (OECD 2016,2018b).
b. Included in World Input-Output Database (WIOD) (Timmer et al. 2015).
c. Included in the Analytical Business Enterprise R&D database (OECD 2018a).
NoteIndustrialized economies include economies with adjusted manufacturing value added (MVA) per capita higher than $2,500 (international PPP) or a gross domestic product higher thar
Emerging industrial economies include economies with adjusted MVA per capita ranging between $1,000 (international PPP) and $2,500 or whose share of the world MVA is higher than 0.
list of least developed countries is based on decisions of the United Nations General Assembly. All remaining economies are included in the group “other developing economies.”
SourceUNIDO elaboration based on UNIDO (2019f).

Annex C.2

Classification of manufacturing sectors by technology groups

Table C.1
Definition of medium- and high-technology manufacturing exports

Standard International Trade Classification Rev. 3 codes of medium- and high-technology exports
266t267
512t513, 525, 533, 541t542, 553t554, 562, 571t575, 579, 581t583, 591, 593, 597, 598
653, 671t672, 678
711t714, 716, 718, 721t728, 731, 733, 735, 737, 741t749, 751t752, 759, 761t764, 771t776, 778, 781t786, 791t793
811t813, 871t874, 881t882, 884t885, 891

Source: UNIDO elaboration based on UNIDO (2017c).

Table C.2
Technology classification of industrial activities

International Standard Industrial Classification Rev. 4	Description	Technology group
10	Manufacture of food products	Low
11	Manufacture of beverages	Low
12	Manufacture of tobacco products	Low
13	Manufacture of textiles	Low
14	Manufacture of wearing apparel	Low
15	Manufacture of leather and related products	Low
16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	Low
17	Manufacture of paper and paper products	Low
18	Printing and reproduction of recorded media	Low
19	Manufacture of coke and refined petroleum products	Medium-low
20	Manufacture of chemicals and chemical products	Medium-high and high
21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	Medium-high and high
22	Manufacture of rubber and plastics products	Medium-low
23	Manufacture of other non-metallic mineral products	Medium-low
24	Manufacture of basic metals	Medium-low
25	Manufacture of fabricated metal products, except machinery and equipment	Medium-low
26	Manufacture of computer, electronic and optical products	Medium-high and high
27	Manufacture of electrical equipment	Medium-high and high
28	Manufacture of machinery and equipment not elsewhere classified	Medium-high and high
29	Manufacture of motor vehicles, trailers and semi-trailers	Medium-high and high
30	Manufacture of other transport equipment	Medium-high and high
31	Manufacture of furniture	Low
32	Other manufacturing	Low

Source: UNIDO elaboration based on OECD (2011), adapted from ISIC rev. 3 to ISIC rev. 4.

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