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Digitalization and industrialization: friends or foes?

Abstract

Digitalization can provide new opportunities for industrialization in developing countries if these countries can leverage data on market demand for design and production decisions. The greater weight of developing countries in the global economy makes global demand patterns increasingly heterogenous and increases the value of data on developing countries' demand patterns. Digitalization facilitates translating these data into intangible assets and makes it easier and cheaper to use these data for design and production. Using the framework of value chains and drawing on insights from recent trade theory on firm and product heterogeneity, the paper discusses channels through which these mechanisms can boost industrialization. It also highlights required support from innovation, industrial and regulatory policies to promote a fair sharing of the benefits from digitalization.

Key words: digitalization, industrialization, development policies

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1. Introduction

Recent industrialization patterns are causing increasing pessimism about manufacturing as an engine of development. Peak shares of manufacturing in total employment and output in today's economies are lower and in many developing countries occur at lower levels of per capita income than in the now industrialized countries – a phenomenon known as "pre-mature" de-industrialization (e.g. Rodrik, 2016).[1] In addition, the global trade slowdown and expected prolonged structurally weak growth in developed countries are darkening prospects for traditional export-oriented industrialization strategies (UNCTAD, 2013; IMF, 2017). Moreover, international production sharing through global value chains has made different countries to adopt different modes of production in the same industrial sector, so that the productivity and employment gains from manufacturing have been determined less by sectoral specialization and more by modes of production. Finally, some argue that robotization puts at risk two-thirds of all jobs in developing countries (e.g. World Bank, 2016), and that reshoring to developed countries further jeopardizes their manufacturing activities (e.g. Boston Consulting Group, 2011).

Services are often proposed as an alternative escalator to economic development. Some see services play this role on their own, mainly in two ways: first, some services (transport, communication, finance) are found to promote productivity growth at least as much as manufacturing activities (e.g. Ghani and O'Connell, 2014; IMF, 2018a) and, second, services liberalization is seen as further increasing the potential for the unbundling of production, which together with new information technologies can allow business process outsourcing or online gig work to emerge as new export-led development strategies (e.g. Baldwin, 2016). Others argue that services can drive development as a complement to manufactures, based on two observations: first, firms increasingly augment their manufactured goods with firm-specific assets based on services in advertising, finance and after-sales care that reinforce brand loyalty (e.g. Hallward-Driemeier and Nayyar, 2017) and, second, digitalization causes a blurring of the traditional boundaries between industrial and services activities and sizably changes how the manufacturing process is undertaken and organized in value chains (e.g. De Backer and Flaig, 2017).

Two features stand out from this discussion: (i) a reduced scope for traditional export-oriented industrialization as a development strategy, implying that developing countries may need new sources of activities that allow for employment and per capita income growth; and (ii) an ambivalent role of digitalization: it may cause reshoring and oust manufacturing as an engine of development, or it may cause manufacturing and services activities to be more closely interwoven, with the ensuing servicification of manufacturing providing novel ways for industrialization to drive economic development.

Large-scale use of digital technologies is still unfolding, particularly in developing countries, and the precise impact of digitalization remains uncertain. But a clear understanding of the channels through which these technologies may affect industrialization is crucial to monitoring and influencing these effects. The paper's main contribution is to facilitate such a better understanding and to highlight what policies could make digitalization and industrialization complements, rather than substitutes, as well as allow for the benefits of digitalization to be shared widely.

The paper uses the framework of value chains and insights from recent trade theory. Much of the high value-added pre-production (research and development (R&D), and design) and post-production (marketing, logistics and distribution) segments are currently located in developed countries; developing countries specialize in the lower value-added production segment, focused on mass production (e.g. World Bank et al., 2017). Digitalization affects this pattern by allowing market-related data to be increasingly important determinants of both the design and production

[1] For critical discussion, see Haraguchi, Cheng and Smeets, 2017; and Wood, 2017.

segments of manufacturing. It also makes product innovation and design cheaper and smaller production runs economically profitable, driving an overall shift in emphasis from mass production towards more customization. This shift could imply production to be located geographically close to the designers and engineers that develop products. Insights from the recent trade literature focusing on firm and product heterogeneity (e.g. Eckel and Neary, 2010) and the role of uncertainty in shaping trade (e.g. Arkolakis, 2010) indicate under what circumstances the pre- and post-production segments might move to developing countries, instead of seeing the production segment moving to developed countries.

The next section describes the main characteristics of new digital technologies and discusses channels through which digitalization may affect the various segments of the manufacturing process and how they are organized through value chains. It interprets evidence on the greater weight of developing countries in the global economy to imply an increase in the economic value of data on their demand patterns for design and production decisions. Given that digitalization enables the translation of these data into intangible assets and that it makes both market intelligence and product design cheaper and easier accessible for developing countries, the section emphasizes the capacity to leverage data on market demand for design and production decisions as a key determinant for digitalization to provide new opportunities for industrialization in developing countries. Section 3 turns to related policy issues. It recognizes that integration of developing countries into the digital economy is contingent on their provision of digital infrastructure and skills, as well as associated institutional capabilities. But it emphasizes that a fair sharing of the benefits from digitalization will depend on ambitious policies both (i) in developing countries, especially regarding innovation and industrial policies, and (ii) by the international community that needs to adjust antitrust, competition and regulatory policies to avert the winners-take-most tendency of digitalization. Section 4 summarizes the main findings and policy conclusions, emphasizing that whether digitalization and industrialization are friends or foes is largely an outcome of policy choices.

2. Digital technologies in value chains: channels for industrialization

Digitalization gives intangibles a more prominent role in income generation, including along value chains. Intangibles refer to R&D, design, blueprints, software, market research and branding, databases etc. (e.g. Haskel and Westlake, 2018: table 2.1).[2] The data that express these intangibles and their codification through digitization drive the various new digital technologies, emphasized here (table 1).

Industrial use of these new digital technologies is at different stages of readiness. Industrial robots have experienced rapidly growing deployment, especially since 2010, even though their use remains concentrated in developed and a few developing countries at an advanced stage of industrialization (Mayer, 2018). The use of additive manufacturing has also grown rapidly. But this growth partly relates to the expiry of some core patents, so that improved accessibility of 3D-systems mainly regards technology that is somewhat dated and concerns prototyping and product development. Frontier 3D-systems allowing for decentralised batch production of final goods from multiple materials remain expensive (Ernst and Young, 2016) but are expected to be widely accessible by 2022–2025 (WEF, 2015). Big Data and cloud computing is projected to grow exponentially (Purdy and Daugherty, 2017) and to be widely accessible by 2024. Wide accessibility of artificial intelligence is expected by 2025–2026 (WEF, 2015).

[2] For discussion and empirical evidence on the greater role of intangibles in economic activities, see e.g. WIPO, 2017.

Table 1. Main digital technologies used in a digitalized manufacturing process

Technology	Attributes
Industrial robots	Industrial robots are automatically controlled, reprogrammable, multipurpose manipulators programmable in three or more axes, which may be either fixed in place or mobile for use in industrial automation applications. They largely rely on algorithms driven by software, which may be enabled to communicate with other machines through the Internet of Things and to engage in self learning and autonomous reprogramming through artificial intelligence. Industrial robots tend to substitute routine tasks in workers' occupations.
Additive manufacturing (three-dimensional (3D) printing)	3D printing builds products by adding materials in layers. Using 3D modelling software, machine equipment and layering material, additive manufacturing equipment reads data from CAD files and applies layers of liquid, powder, sheet material or other, to fabricate a 3D object. Using these techniques reduces the time, material use and number of skilled workers needed for design, prototyping and product layout and facilitates product customization.
Big data and cloud computing	Big data analytics refers to a set of techniques that allows voluminous amounts of machine-readable data to be rapidly generated, accessed, processed and analysed. These processes are often undertaken through cloud computing that substantially increases the availability and affordability of computing services by using servers, storage, databases, networking, software, analytics, etc. over the Internet (i.e. the "cloud"). Machine learning systems can employ these data and recommend product features by predicting what customers will like.
Computer-aided design and computer aided manufacturing (CAD/CAM) techniques	CAD/CAM techniques refer to software used to design and manufacture prototypes, finished products, and production runs. CAD systems allow an engineer to view a design from any angle with the push of a button and to zoom in or out for close-ups and long-distance views. In addition, the computer keeps track of design dependencies so that when the engineer changes one value, all other values that depend on it are automatically changed accordingly, first in building designs in blueprints, and then in creating or assembling physical products and parts using computer-controlled equipment.
Artificial intelligence and machine learning	Algorithms allowing computers and machines embodying or linked to computers to learn from data and to mimic and predict human behaviour.

Source: Author's elaboration.

2.1 Market-related data, product customization and heterogeneous demand

Unlike traditional technologies, technologies based on intangibles are generally not embodied in physical capital. Instead, the activities related to intangibles may be considered services. This means that, in a digital world, services increasingly permeate the goods sector and blur the traditional boundaries between goods and services in the manufacturing process.

A crucial part of the data reflecting intangibles regard sales and other market-related information.[3] The increased availability of such data and their transformation into economically meaningful knowledge, which can be used for design and production decisions, increases the role of customers (both firms and households) in the manufacturing process. It also makes a firm's ability to customize production according to such market-related information an increasingly important determinant of sales and revenue creation. Most importantly from an analytical perspective, it allows moving away from traditional value-chain concepts that focus on the production side and consider customers as an amorphous homogeneous entity (e.g. Baldwin, 2016) towards approaches that take the heterogeneity of customers and variety in the structure of their demand patterns into account.[4]

From a development perspective, the importance of approaches that give greater attention to heterogeneous demand is to allow for an examination of the manufacturing process and its organization in value chains by linking potential changes coming from digitalization with the increased weight of developing countries in the world economy and the increased importance of their firms and citizens as potential customers. The greater the weight of developing country firms and households in global demand, the larger is the economic value of data on their demand patterns for design and production decisions.

Much of the literature on the increased weight of developing countries in global demand relates to extrapolations of broad-based income convergence before the Global Financial Crisis (e.g. Popov and Jomo, 2018). The fading of some forces that were driving these developments, such as high commodity prices, may now be causing a reversal of the widened heterogeneity of global demand patterns. However, the share of developing countries in global output measured in market prices almost doubled between 2000 and 2016 (table 2) and measured in terms of purchasing power parity accounts for over half of world output; per capita income measured in purchasing power parity continues to grow in all major developing economies (table 3a); income growth in developing countries continues to exceed growth in developed countries (UNCTAD, 2018), and wealth indicators for 2017 significantly exceeded 2000-levels in the main developing country regions, except Africa, despite falling back from 2007- or 2010-peaks (table 3b). This indicates that developing countries' weight in the world economy and the purchasing power of their citizens continue to exceed levels attained at the beginning of the millennium and that, on a variety of measures, these increased shares extend beyond a small number of individual developing countries. As a result, the economic value of data on developing countries' demand patterns has increased for both firms from developed countries that export to developing countries and for firms from developing countries that aim at serving their domestic markets or increasing South-South exports, in addition to exporting to developed countries.

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[3] Market-related information comprises personal and non-personal data. Control over personal data raises concerns about privacy and abuse which need to be addressed in country-specific manners, such as by regulation requiring citizens' agreement for the use of their personal data. It is still unclear whether Europe's digital trajectory combining an absence of large European digital firms with a lead in setting standards for regulation and privacy protection indicates a trade-off between strengthening data privacy and developing competitive firms that control data, or whether high data-protection standards will eventually provide an advantage for firms that base their data use on trust through respect for privacy and protection against abuse. The focus here is on controlling non-personal, product-specific data that would appear to raise fewer such issues, even though clearly distinguishing between these two data categories may not always be easy.

[4] Markusen, 2013, revived attention to heterogeneous demand patterns in trade theory, while this aspect has been a mainstay in development economics and structural change analyses following Chenery and Syrquin, 1975.

Table 2. Shares in global output, selected country groups, 1970–2016 (percentages)

	1970	1980	1990	2000	2005	2010	2016
Developed economies	69.7	69.6	78.8	77.2	74.2	63.8	58.9
Transition economies	13.2	8.2	3.8	1.1	2.2	3.2	2.4
Developing economies	17.1	22.2	17.4	21.7	23.6	33.0	38.7
Africa	3.2	4.6	2.4	1.9	2.4	3.0	2.8
Latin America and the Caribbean	5.3	6.3	5.0	6.7	5.8	7.9	6.8
West Asia	1.3	3.2	2.0	2.2	2.7	3.3	3.3
East, South-East and South Asia	7.3	8.1	7.9	10.8	12.6	18.8	25.7
Oceania	0.1	0.1	0.1	0.0	0.1	0.1	0.1

Source: Author's calculations, based on UNCTADstat.
Note: Shares based on market prices and market exchange rates.

Table 3a. Median wealth per adult and income per capita, selected economies and economic groupings, 2000–2017

	Median wealth per adult (*$ '000*)						Income per capita (*2011 international dollars, '000*)					
	2000	2005	2007	2010	2015	2017	2000	2005	2007	2010	2015	2017
Africa	0.5	0.7	1.0	0.9	0.7	0.4	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
South Africa	1.9	4.8	6.5	5.4	4.3	5.1	9.7	11.1	12.0	12.1	12.5	12.3
Asia-Pacific*	1.3	2.3	3.6	3.4	3.1	3.0	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
China	2.3	3.8	5.4	4.6	6.7	6.7	3.7	5.7	8.6	9.4	13.5	15.2
India	0.7	1.0	1.4	1.3	1.3	1.3	2.5	3.3	3.8	4.5	5.9	6.5
Indonesia	0.5	1.2	1.9	2.2	1.7	1.9	5.9	6.9	7.5	8.6	10.5	11.3
Rep of Korea	24.4	42.2	59.3	56.8	64.9	67.9	20.8	25.5	28.0	30.4	34.2	35.9
Taiwan Province	64.6	63.1	67.5	77.1	83.5	87.3	27.2	32.5	36.2	39.4	44.1	45.8
Thailand	0.7	1.5	1.5	2.0	1.7	3.0	9.3	11.6	12.6	13.5	15.2	16.3
Latin America & Carib.	1.1	4.0	6.1	6.3	4.8	5.2	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Brazil	2.2	3.4	5.4	7.4	3.7	4.6	11.5	12.4	13.4	14.6	14.8	14.2
Chile	5.1	8.1	12.0	13.6	17.6	20.1	14.2	17.0	18.5	19.3	22.2	22.4
Mexico	7.7	11.8	13.9	9.2	8.8	8.7	15.8	16.0	16.7	16.1	17.6	18.1
Europe	7.9	13.3	19.2	16.4	12.8	14.9	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Japan	103.0	96.7	97.6	125.1	111.6	123.7	33.9	35.7	36.8	35.9	37.9	39.0
United States	42.8	57.3	58.3	39.5	51.1	55.9	46.0	49.7	50.9	49.3	53.0	54.2
memo item												
World	1.9	2.9	4.2	3.7	3.6	3.6	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Source: Author's calculations, based on *Credit Suisse Wealth Databook*, 2017, and International Monetary Fund, *World Economic Outlook database*, April 2018.
Note: ** Including Australia, Japan and New Zealand. Wealth data based on market prices and market exchange rates; income data based on purchasing power equivalents.

Table 3b. Net household wealth as a share of world total, selected economies and economic groupings, 2000–2017

	2000	2005	2007	2010	2015	2017
	Share of world total (*per cent*)					
Africa	1.0	1.1	1.4	1.2	1.0	0.9
South Africa	0.2	0.3	0.3	0.3	0.2	0.3
Asia-Pacific**	11.3	13.3	16.4	17.5	20.7	20.3
China	4.0	5.0	6.9	7.5	10.5	10.3
India	1.0	1.2	1.6	1.7	1.7	1.8
Indonesia	0.3	0.4	0.6	0.8	0.6	0.7
Rep of Korea	1.5	2.0	2.1	0.8	2.4	2.3
Taiwan Province	1.6	1.2	1.0	1.3	1.2	1.3
Thailand	0.1	0.1	0.1	0.2	0.2	0.2
Latin America & Carib.	2.9	2.6	3.1	3.7	2.7	2.9
Brazil	0.7	0.7	0.9	1.4	0.8	0.9
Chile	0.1	0.2	0.2	0.2	0.2	0.2
Mexico	0.8	0.8	0.9	0.7	0.7	0.7
Europe	28.6	33.1	36.7	33.7	28.9	28.4
Japan	16.5	10.5	8.3	10.7	8.3	8.4
United States	36.2	34.7	29.0	27.6	33.2	33.4
memo item						
Developing countries	15.1	17.0	20.9	22.4	24.4	24.1
Developed and transition economies	84.9	83.0	79.1	77.6	75.6	75.9
	(*US dollar*)					
World	116957	172294	220834	219847	253754	280289

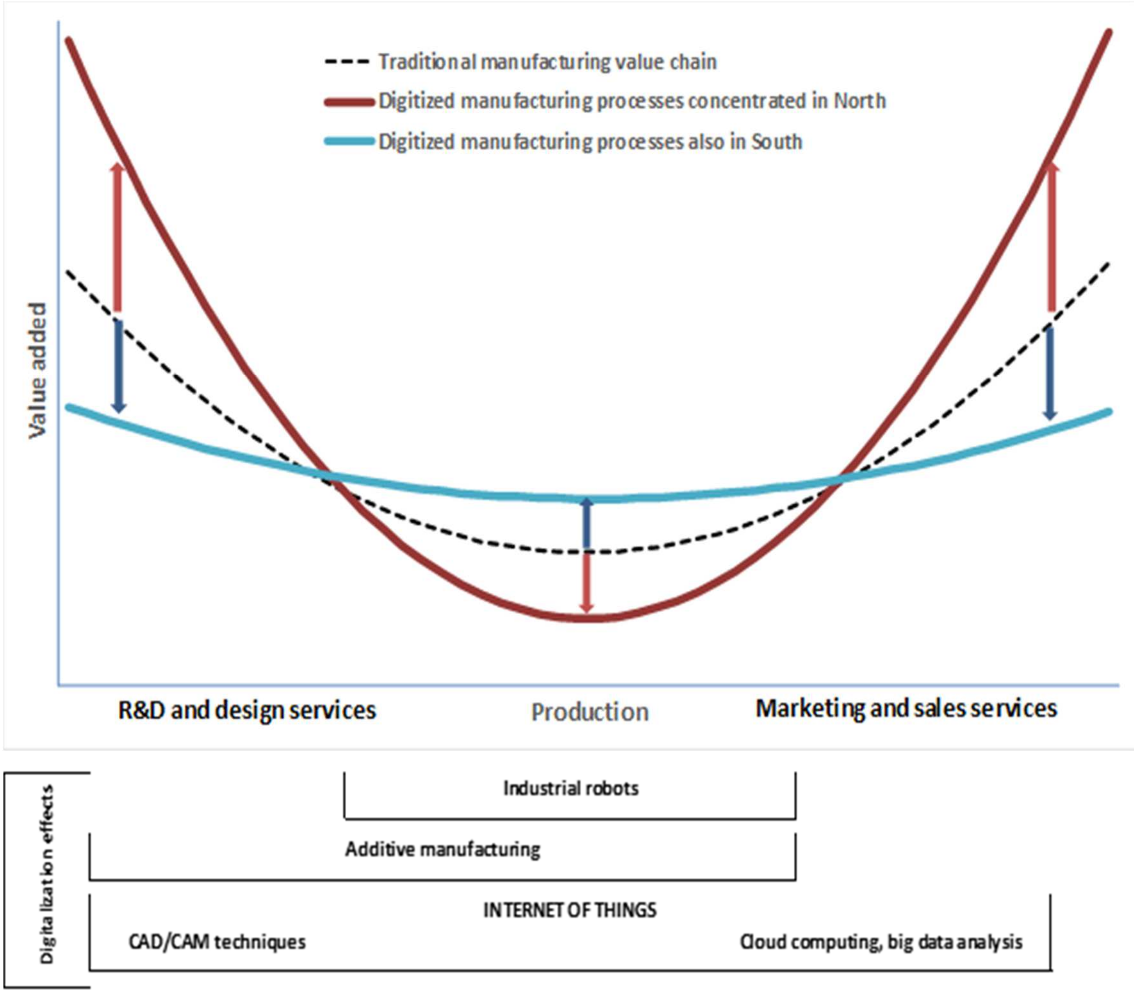
Source: Author's calculations, based on *Credit Suisse Wealth Databook*, 2016 and 2017.
Note: ** Excluding Australia, Japan and New Zealand.

The remainder of this section examines the channels through which an increased role of heterogeneous demand in the post-production segment for decisions regarding design and production in the pre-production and production segments of the manufacturing process may change income creation across the various stages along the value chain. It also examines the dynamics of governance structures in value chains. The subsequent section focuses on policies that developing countries could adopt to harness this income potential for their industrialization.

2.2 The distribution of value added in value chains

Assessing how digitalization affects the manufacturing process and how its various segments become more closely interwoven may be based on what is known as the "smile curve". The smile curve conceptualizes manufacturing as a series of linked tasks, aggregated into pre-production, production and post-production segments, and highlights the distribution of value creation across these segments. While not based on a stringent theoretical framework, the smile curve has received considerable empirical support (e.g. Milberg and Winkler, 2013; World Bank et al, 2017). Its precise form varies across industries and countries but is usually U-shaped, indicating value addition to be concentrated at the beginning and end of the chain, where pre- and post-production tasks are located (figure 1).

Figure 1. Stylized potential effects from digitalization on the segments of the manufacturing process



Source: Author's elaboration, partly inspired by Eurofound (2018).

The smile curve may also be considered in terms of the international distribution of value added. Looked at from a North-South perspective, its U-shape suggests that the pre-production and post-production segments of the manufacturing process are mostly located in advanced economies and that developing countries are often left with the lower value-added activities of the production segment (Milberg and Winkler, 2013). Such an interpretation also reflects the anxieties felt in both developed and developing countries regarding the international fragmentation of manufacturing. In developed countries, the concern is de-industrialization as employment in manufacturing is being hollowed out, i.e. that low- and medium-skilled production jobs have been offshored to developing countries or, to the extent that such jobs remain in developed countries, have suffered downward pressure on wages. Developing countries worry about being stuck in low-value-added activities and unable to upgrade towards higher value-added activities in R&D and design, marketing and management, i.e. that they are trapped in "thin industrialization".

Methodologies allowing for the decomposition of value added into labour and profit shares propose some explanation for the smile curve's U-shape and the sharing of value addition between developed and developing countries. Following de Vries, Miroudot and Timmer (2018), total value added can be disaggregated into the contributions by the four functions that characterize labour activities in the manufacturing process, i.e. management, marketing, R&D and fabrication, with the capital share as a residual. Taking global output of the highly fragmented automotive sector for the period 2000–2014 as an example indicates an increase in the capital share and suggests that the declining share of production activities drove the overall decline in the labour share in total value added (table 4a). Both these features point to a deepening of the smile curve's U-shape.

Related data on the domestic shares in value added in global output of the automotive sector (table 4b) indicate a decline in the overall share, reflecting the increased international fragmentation of automotive production. The data also indicate that the capital share increased and that the decrease in production activities drove the decline in the labour share, i.e. two features already noted for total global value added. To the extent that developing countries have been engaged mainly in production activities, these features point to a deepening of the U-shape also in terms of a North-South interpretation of the smile curve.

Table 4a. Automotive sector: value-added shares in total global output, 2000–2014

	2014 (*per cent*)	Difference 2014-2000 (*percentage points*)
Capital	47.4	5.4
Labour	52.6	-5.4
Headquarter functions	31.8	-0.9
Management	7.6	-0.7
Marketing	15.5	-0.1
R&D	8.7	-0.1
Production activities	20.8	-4.5
Memo item:		
Total output ($ mn)	3.0	1.8

Table 4b. Automotive sector: domestic value-added shares in total global output, 2000–2014

	2014 (*per cent*)	Difference 2014-2000 (*percentage points*)
Total	72.5	-4.3
Capital	33.7	2.4
Labour	38.8	-6.7
Headquarter functions	23.0	-2.2
Management	5.4	-0.9
Marketing	11.2	-0.8
R&D	6.4	-0.6
Production activities	15.8	-4.5

Source: Author's calculations, based on de Vries, 2018.

One explanation of the unequal distribution of value added between developed and developing countries may relate to wages per worker. These tend to be higher in developed countries because workers are better skilled, live in countries with higher aggregate levels of productivity and hence higher real wages, and/or undertake more skill-intensive activities because they are engaged predominantly in non-production activities. Post-production activities will need to be located near customers, and so in developed countries as long as firms see their typical customers to reside in developed countries. Pre-production activities may locate in developed countries partly for the same reason, as a result of the feedback loop from marketing to design.

But the distribution of value added between developed and developing is probably less an issue of differences in wage rates than one of the high profit rates of mainly Northern firms that reflect rents arising from intellectual property and/or barriers to entry. Legally enforced property on standards, technologies and brands, combined with network externalities from coordinating information and communication across the value chain, tend to increase the value-added shares of non-production activities (e.g. Durand and Milberg, 2018).

The critical question is whether and how the digital technologies listed in table 1 might change the shape of the smile curve and address the anxieties of policymakers. The bottom panel of figure 1 indicates what new digital technology may affect what segment of the manufacturing process. Policymakers in developed countries aiming at reshoring manufacturing activities (indicated by the red arrow regarding production in figure 1) could do so by using robots in production to compensate developing countries' labour-cost advantages. This would tend to reduce the value added by workers in the production stage and the share of value added accruing in developing countries. Combined with the possibility that digitalization might remain largely confined to developed countries, it would make the smile curve deeper and further increase developed countries' share in high value added (indicated by the red arrows regarding the pre- and post-production segments in figure 1).

How digital technologies could affect the distribution of value added in the manufacturing process such that they foster higher value-added activities in developing countries (indicated by the blue arrows in figure 1) is the focus of the remainder of this section.

2.3 Digitalization: potential impacts on the manufacturing process

(i) Potential impacts on income generation

The post-production segment

The new digital technologies and especially ICTs associated with the Internet of Things – such as cloud computing and big-data analysis – significantly raise the importance of the post-production segment for the entire manufacturing process, mainly in three ways. One is that these ICTs can optimize business operations by increasing the efficiency of production schedules, logistics, inventory management and equipment maintenance, and especially by integrating the data emanating from separate systems into a coherent picture. Another is that access to sales data enables the provision of better after-sales services, perhaps even provided remotely, so that manufactures can broaden their activities to include services.

More important from a development perspective, cloud computing and big-data analysis reduces the need for hard digital infrastructure, as well as the cost of computing and using software. Cloud computing and big-data analysis also allows for a drastic increase in the number of interactions between firms and customers which, in turn, facilitates more personalized advertising and distribution campaigns that go beyond traditional marketing, targeted at certain groups such as readers of certain publications or residents of certain neighbourhoods. This may drastically reduce marketing costs while reaching out to more potential customers. It may also sizably increase the effectiveness of expenditure used to build brand names and other reputational assets. All of this has to potential to make both access to market-related information and its analysis more easily affordable for developing countries.

Analyzing market-related data helps designers and producers to uncover the functionalities and features that customers particularly value, thereby identifying or even anticipating demand for specific products. Such use of market-related data for product design and development can help firms to enter sectors that they would otherwise not know whether they would provide profitable sales opportunities. Firms that control these data and possess the required analytical capabilities can identify the heterogeneity of demand patterns both between and across developed and developing country markets and, thus, can customize their products accordingly. These mechanisms equally apply to developed and developing country firms. But the increased weight of developing countries in global demand makes data on their markets and demand patterns particularly valuable, and the greater facility of accessing such data and the reduced cost of analysing them provide space for developing country firms to undertake such activities.[5]

The pre-production segment

The new digital technologies tend to make design more flexible and reduce its cost. While requiring digital capabilities, digital design simulation reduces the number of work hours required to create new goods. It may also reduce the expertise needed to design goods. The latter may arise particularly to the extent that digitalization allows for the codification of tacit knowledge, i.e. the kind of know-how that comes from experience regarding, for example, how to best design and interlink product definition, detailed design, design for manufacturability, component design and eventual manufacture. Codification of tacit knowledge might result from machine learning that identifies correlations based on voluminous data. Machine learning may eventually even be superior to experience-based knowledge accumulation because it can easily identify correlations that humans would not have deliberately looked for.

The rise in flexibility and the decline in cost of pre-production activities may be further enhanced by additive manufacturing. This technology can be used for rapid and less-costly simulation-based iterative prototyping and the production of specialized machinery. It compresses the development cycle of products that may subsequently be mass-produced based on traditional technology and infrastructure (e.g. Sturgeon, 2017), or be taken for more customized production based on digital technologies.

Taken together, using digital technologies in the pre-production phase would most likely help compensate part of the lack of skilled designers and an established machinery industry in developing countries.[6] As a result, the pre-production segment of the manufacturing process may become decentralized and could, at least in part, move to developing countries. This move could accelerate if the pre- and the post-production segments are integrated, i.e. if developing country firms can use data on their own markets' demand patterns for product design, as well as if data on the availability, cost and quality of critical inputs could help firms to optimize their sourcing and investment decisions.

[5] As further discussed below, the availability of such space requires policies that regulate the control and use of domestic market data.
[6] Recent evidence for the United States indicates that such moves are happening, arguably driven by a shortage in software and IT-related human capital in the United States (Branstetter, Glennon and Jensen, 2018).

The production segment

Most of the debate on digitalization has focussed on the use of industrial robots in the production segment of the manufacturing process. In the context of value chains, industrial robots may mainly have two effects. First, countries that produce within already robotized value chains may need to robotize their production as well. This may apply especially for the inputs from their firms to meet the quality and product standards that the lead firm in that value chain sets in accordance to the needs of the lead firm's customers in developed countries. The relatively high robot density of countries in Central Europe, such as Czechia, Slovakia and Slovenia, which are closely integrated in automotive value chains led by firms in Western Europe, and the related positive association between these countries' change in robot use and their change in output, provides some supportive evidence for this mechanism (Mayer, 2018).

Second, industrial robots may adversely affect developing countries' employment and income opportunities by the reshoring of manufacturing activities back to developed countries. However, while offshoring might have slowed down, there is no systematic evidence that would point to large-scale reshoring from developing to developed countries (ILO, 2018). Nevertheless, the economic case for reshoring may be strong particularly where firms produce for developed-country markets and expect that geographic co-location of production and R&D positively affects innovation (see also De Backer et al., 2018).[7] Building a dense network of intra- and cross-sectoral forward and backward linkages and complementarities in developing countries could stem the risk of reshoring. Building such linkages through increased digital content of pre- and post-production activities could help to reduce incentives for reshoring even as the cost of operating robotics systems further declines, and their dexterity increases, to also affect traditional labour-intensive sectors.

The production segment may also be affected by additive manufacturing. It combines 3D-printers with computer-aided design and manufacturing or any other 3D-software that creates digital models. Once cost reductions in 3D printing and improved complementarity with cloud computing and CAD/CAM-techniques make it widely available for industrial use, direct digital manufacturing through the fabrication of tools and spare parts, or the seamless adding of parts made of different materials, can reduce the number of assembly stages in the production process. Moreover, additive manufacturing can increase the modularity of value chains by printing goods whose design and building patterns are transmitted in digital form, including across borders, thereby allowing remote firms to be integrated into the world economy.[8] Remote and smaller firms could also benefit from global digital platforms if they succeed in customizing their product to serve well-defined niche markets. Perhaps most importantly, additive manufacturing reduces the number of production runs where manufacturing becomes economically profitable, allowing for increased flexibility and customization of production. This means that once the industrial use of additive manufacturing becomes firmly established, it can be used to manufacture complex

[7] E-commerce may counter geographic co-location of the various manufacturing segments. In 2017, e-retail sales accounted for 10.2 percent of all retail sales worldwide, with this share expected to reach 17.5 percent in 2021 (https://www.statista.com/statistics/534123/e-commerce-share-of-retail-sales-worldwide/). There is limited evidence on the economic consequences of e-commerce trading in developing countries. Findings for rural markets in China indicate positive effects to be concentrated in remote areas and to accrue mainly to consumers, while there is no evidence for significant effects on the production side of the local economy (Couture et al., 2018). This points to the risk, further addressed below, that large e-commerce platforms could assume an increasingly important role in the control of digital data and use these data to organize and mediate transactions between the various actors in the manufacturing process, with limited benefits for domestic income generation.

[8] However, these narrow technological benefits would need to be weighted against the possibility that 3D-printed components might require a rethink of the architecture of the product for which this component is used which, in addition, might involve a reorganization of the entire value chain.

parts and products and do so in an economically profitable way even at low-volume production runs and in an increasingly customized manner.

Findings of recent trade theory on firm and product heterogeneity indicate that domestic firms and those foreign firms whose knowledge of local market preferences is high may well be better placed than other firms to provide customized products and meet heterogeneous demand structures (see box 1).

Box 1: Some insights from recent trade theory on firm and product heterogeneity

One emphasis of the recent trade literature on heterogenous firms regards sunk costs which firms need to incur to start exporting and which trigger changes in the number and variety of products sold by multi-product firms. An important conclusion is that a firm's decision what product to offer on what market depends on combinations of firm, product and market characteristics: firms may locate production close to their customers to avoid trade costs and only the firm with the lowest market-specific component of the fixed cost related to market entry and/or with the highest market-specific component of demand can sustain its entry into a market (e.g. Melitz and Redding, 2014).

One part of this literature focuses on uncertainty and tries to explain trade statistics suggesting that new exporters often start by selling only small quantities and that only a small number of new trade relationships extend beyond one year and grow in importance. Firm-specific uncertainty about export profitability and about persistent demand components on a potential export market make new exporters incur search costs and, therefore, start by exporting varieties that they have previously been selling on their domestic market (e.g. Iavocone and Javorcik, 2010). Uncertainty and the related fixed cost of market entry tend to be lower for producers of homogenous goods, for which global reference prices and quality standards are available. By contrast, attempts by producers of heterogenous goods to reduce such uncertainty and reach more, and different, customers may cause substantial costs of market intelligence and marketing (Arkolakis, 2010). Firms adjust the intensity of market intelligence by using acquired information to update their beliefs on the profitability of their exports (Eaton et al., 2014). Bernard, Redding and Schott (2010) also show that only the most productive firms manufacture a wide range of products, as it is only them that can cover the fixed costs associated with multiple products. A multi-product firm decides to drop or add products depending on interactions of shocks to its overall profitability coming from changes in its productivity and the attractiveness of its products to consumers vis-à-vis other producers of the same product.

Local firms are generally presumed to have better knowledge about local circumstances, preferences and needs, so that the heterogeneity of demand across countries may also be a demand-side explanation for the frequently observed positive correlation between an economy's production and consumption structure, i.e. what has been called "home bias" (e.g. Markusen, 2013). However, foreign firms that can leverage large amounts of market data, including from extensive e-commerce activities, could reduce their uncertainty and fixed market-entry cost, and compensate such advantages of local firms. This means that an economic rationale for digital platforms or multinational enterprises to strive for control over foreign market data may be to compensate for the sunk costs that they incur in obtaining intangible assets, such as data stemming from market intelligence regarding customers that differ from these enterprises' traditional core clientele. Controlling such data would reduce their uncertainty, and related sunk costs of market entry, as to whether they can reach customers on foreign markets that demand product features and functionalities that differ from those on their traditional markets (see also Diez, Mora and Spearot, 2018). In doing so, global firms could widen the scope of varieties that they export and move beyond current patterns where their export growth appears to be driven mainly by more sales of existing varieties (e.g. Lawless, Siedschlag and Studnicka, 2018).

Another part of this literature relates differences across firms to the supply side and explains adjustments in the range of goods produced by a multi-product firm based on its core competence. Assuming that (i) a multi-product firm's costs of production differ across products, (ii) these differences operate at the level of the firm rather than being specific to particular markets, and (iii) all of a firm's products are differentiated from its rivals' products as well as from each other, this approach shows that products closer to a firm's core competence have lower costs and that multi-product firms adjust to shocks that increase both the size of the potential market and the extent of competition by dropping some of their marginal products while trying to expand sales of their core products (Eckel and Neary, 2010). In doing so, the firm would increase its average productivity and avoid product cannibalization, i.e. that rising demand for its marginal product varieties would cause decreasing demand for its core variety. One source of such a shock to a multi-product firm from a developed country might be an increase in developing countries' purchasing power sufficiently strong to provide a potential new market for one of the firm's marginal varieties, combined with increased competition from the rise of a local firm whose core-competence technology produces the variety of that product whose functionalities and price matches best the potential new customers' desires.

Eckel at al. (2015) combine these demand and cost aspects by extending the core-competence model to allow for investment in advertising and marketing (such as in Arkolakis, 2010) to enhance the perceived quality of their products. They show that quality-based competence is higher for firms in heterogenous goods sectors than in homogenous goods sectors, both on the domestic and on export markets.

Similar research suggests that firms producing different varieties of goods, such as similar goods but at different quality, experience diseconomies of scope in producing many varieties, and that the extent of these diseconomies increases with growing distance from the firm's core variety (Arkoladis, Ganapati and Muendler, 2016). One element of such diseconomies is higher market-access cost on an exporter's minor varieties, for example because of additional cost in access to data on consumer preferences and tastes regarding the additional products further away from a firm's core competency.

Taken together, this literature may be linked to the digitalization debate as it suggests that control over market-related data may determine what kind of product what firm offers on what market, as well as that a local firm whose core-competence product matches the pattern of domestic demand may have an advantage over foreign firms.

To sum, using the new digital technologies with a view to harnessing market intelligence on the functionalities and features of goods and services that appeal to customers for design and production decisions may allow developing countries to engage in the higher value-added activities in the value chain and benefit from the income-generating potential of digitalization. This potential will increase with the weight of developing countries in global demand and control over market-related data. Crucially important regarding macroeconomic sustainability in developing countries, the income generating effects from such use of digital technologies would help to generate the purchasing power that developing country customers will need to expand acquisitions of the customized goods without incurring debt. Such capability to flexibly respond to developing country customers may be particularly important for those developing countries whose export opportunities have been dented by the declining dynamism of developed country imports, but whose domestic markets and potential for South-South trade are relatively large.

(ii) Potential impacts on governance structures

Digitalization might also alter the governance structure of value chains. The governance structure determines how lead firms guide production patterns and how transactions are made between the parties, thereby ultimately shaping the scope and magnitude of value distribution within a value chain.

Governance structures were initially analysed in terms of the dichotomous categories of buyer-driven and supplier-driven commodity chains. The recent value chain literature distinguishes five more elaborate types of relationships – arm's length contracting, modular, relational, captive, hierarchy – whereby increasing complexity of transactions, decreasing ability to codify relevant information and knowledge, and diminishing capabilities in the supply base require higher levels of coordination and a type of governance further away from arm's length and closer towards hierarchy. Sectoral specificities in production technology further contribute to variation in the type of governance across industrial sectors and products. And combined with lead firms' decisions on appropriate modularization, quality control and institutional oversight, they determine cross-sectoral differences in the generation and diffusion of the knowledge-based assets that underlie value creation through innovation or industrial upgrading (Gereffi, Humphrey and Sturgeon, 2005). Depending on the sectoral structure of a country's involvement in GVCs, such cross-sectoral variation also influences country-specific benefits from GVCs. Cross-country variation in such benefits are also influenced by the effectiveness of countries' innovation systems in enabling the transfer of knowledge through inter-firm linkages in GVCs (e.g. Pietrobelli and Rabelotti, 2011).

Digitalization enables firms to adopt new business models with potential ensuing changes in the governance structure of value chains. These changes may occur separately in specific industrial sectors and be enacted by incumbent firms. For example, increasing supplier capabilities, such as through improved digital infrastructure and skills, including the capability to access and analyse relevant data from the post-production segment, may reduce intervention and control by lead firms and shift relationships away from captive towards more relational and modular types of governance. This shift may be enhanced by increased codification and by increased complexity of codified information and knowledge, such as in the form of design templates that suppliers can flexibly accommodate and use in accordance to their analysis of data from the post-production segment.

Moreover, digitalization increases the possibilities for product customization and could move the control of value chains towards customers whose specific desires regarding the functionality and features of products may guide design and production patterns. As a result, digitized manufacturing processes could benefit producers that master customer personalization in the form of higher profits, or they could benefit customers through improved products and/or reduced prices. But reaping these benefits crucially depends on a supplier's digital and managerial capabilities. This is because digitalization also satisfies demands for more granular financial and managerial control and contributes to greater flexibility for lead firms in choosing among an increased number of suppliers. This could increase the risk for producers that lack digital capabilities to be marginalized or excluded (e.g. Foster et al., 2018).

The above perspective looks at the manufacturing process as a "pipeline" that creates value by controlling a linear series of activities where inputs enter at one end of the chain and undergo a series of steps that transform them into more valuable products that exit as outputs at the other end of the chain. This perspective may not suit digitized manufacturing processes. There, the main asset is controlling and knowing how to use digitized data to organize and mediate transactions between the various actors in the process, combined with the capability of expanding the size of such ecosystems in a circular, feedback-driven process (e.g. van Alstyne, Parker and Choudary, 2016). The actors that make up such ecosystems can comprise customers, innovators, designers, suppliers, producers, services providers, advertisers, and – through the Internet of Things – even physical objects. As a result, the structure of digital ecosystems is based on data control and management, including the reuse or sharing of data for more products or more functions within the manufacturing process. This means that a digital ecosystem's primary source of value is the size of the ecosystem itself. It also means that digitized value chains may be governed by platforms that are new to a specific value chain.

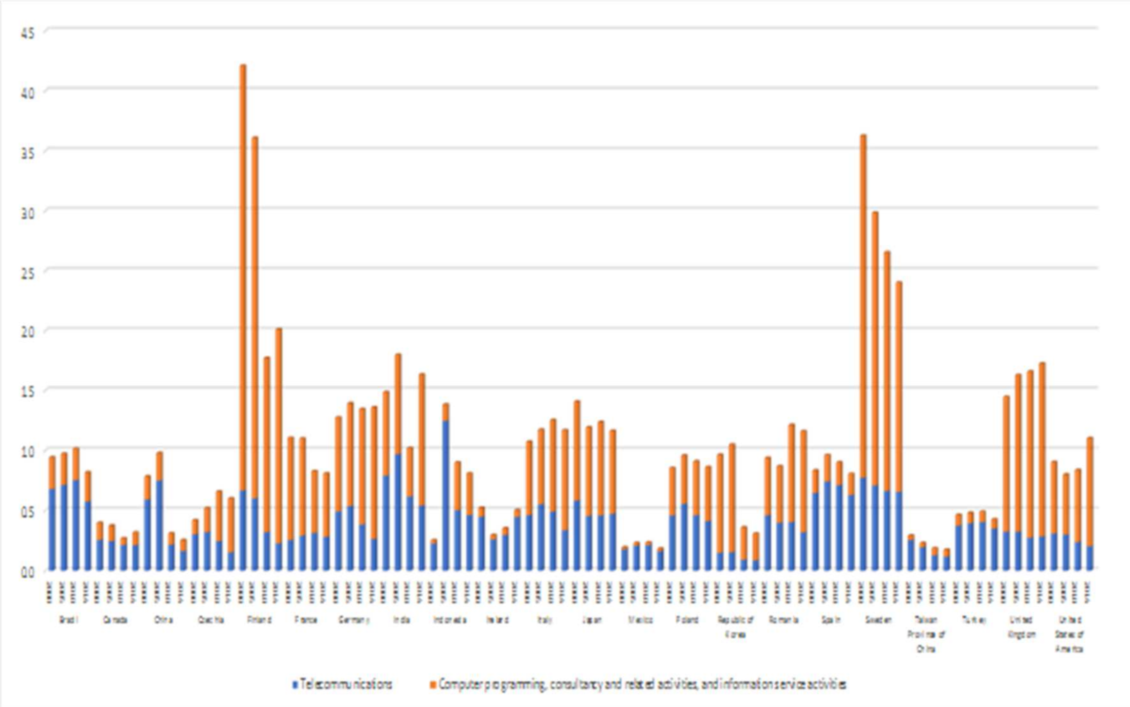
The easy scalability of data through digital ecosystems may give rise to network effects and potential anti-competitive practices, especially when this scalability combines with market concentration regarding data control and capabilities for digital data analysis.[9] On the other hand, newcomers that have access to data and the capability to translate them into economically meaningful knowledge can target potentially overlapping customer bases with distinctive new offerings – such as links to local innovators, designers or producers that may provide better customized products – and create effective competition to an established ecosystem. The degree of such competition depends on legal and policy frameworks that determine the extent to which lead firms in digital ecosystems must share some of their data or of the value that accrues from controlling data. More generally, the capacity of agents internal to a value chain to appropriate the generated value is circumscribed by rules and regulations from agents external to the chain, mainly national governments and supranational institutions.[10] Such rules and regulations can mediate value sharing between customers and platforms that control data, on the one hand, and incumbent platforms and competitor platforms, on the other hand, as further discussed below.

(iii) Digitization of the manufacturing process: some evidence

To assess the digitization of the manufacturing process, the evolution of telecommunications, computer programming and information service activities as a share of total intermediate consumption in manufacturing may be a useful gauge.[11] Cross-country evidence for the period 2000–2014 (figure 2) indicates that this share remains low and accounts for less than 1 per cent for most countries. It also shows wide variation across countries. Sweden and Finland record the largest shares while a few developing countries show very low shares, even though there is no clear divide between developed and developing countries. Among developing countries, it is perhaps surprising that for 2014 the share in India ranks fourth, while that of China remains among the smallest of all countries and even declined by more than half between 2005 and 2014. Regarding composition, computer programming and information service activities as a share of total intermediate consumption is of significantly greater importance than telecommunications for most countries, even though there is no clear pattern either across countries or over time.

[9] See UNCTAD (2018) for detailed discussion.
[10] Although its final legal outcome is uncertain, the European Union's landmark antitrust fining of Google in July 2018 illustrates such rules and regulations. See Richard Waters, "Brussels takes aim at Google's mobile strategy", *Financial Times*, 18 July 2018; https://www.ft.com/content/8ddd8b86-8aa9-11e8-bf9e-8771d5404543.
[11] This measure most likely underestimates the inputs from the digital sector to manufacturing. Some parts of the digital sector are probably classified in other categories than in ISIC Revision 4 divisions J61–J63. Only data referring to these divisions are used here because available data do not allow for disaggregation of data in divisions that may cover more than digital services that affect manufacturing.

Figure 2. Selected ICT services as a share of total intermediate consumption in manufacturing, selected economies, 2000–2014 (*percentages*)



Source: Author's calculations, based on World Input–Output Database (WIOD), University of Groningen, *National Supply-Use Tables*, 2016 release.

Note: ICT services refer to divisions J61–J63 of the International Standard Industrial Classification (ISIC) Revision 4 and distinguish telecommunications (J61) from computer programming, consultancy and related activities, and information service activities (J62 and J63). Manufacturing refers to ISIC Revision 4 divisions C5–C23. Shares calculated from weighted averages in national currency.

Several factors may explain the apparent low importance of ICT-services in manufacturing.[12] The small shares across all economies could indicate that digitalization is little more than a media hype. But these small numbers may also be a result of the slack in global demand following the global financial crisis that has been a key factor holding back productive investment. The finding could also reflect a new form of the Solow paradox[13] – you can see the computer age everywhere but in the productivity statistics – in that digitization can be seen everywhere except in the national accounts statistics (Brynjolfsson, Eggers and Gannamaneni, 2018). One reason for this could be that many digital services come free of charge in monetary terms. Accurate measurement of intangibles such as ICT-services is difficult. But estimating them as a residual, their importance appears to be large and increasing and to account for about one third of total production value (WIPO, 2017). Measurement issues could play an important role particularly in indicators based on input-output data, mainly for two reasons. First, firms may prefer producing most intangibles in-house, due to concerns regarding intellectual property protection. Intangibles sourced in-house

[12] According to IMF (2018b: 1, 7): “Available evidence suggests that the digital sector is still less than 10 percent of most economies if measured by value added, income or employment”, even though “Estimates of the size of the digital sector can be sensitive to the choice of definition.” It should also be noted that the database used here is the only one available for assessing the role of digital services in manufacturing but that its country sample covers only 43 individual economies with the remainder comprised in a rest-of-the-world aggregate.

[13] While Robert Solow expressed this paradox in 1987, subsequent research (e.g. Oliner and Sichel, 2000) affirms that the paradox has been resolved as the bulk of the productivity increase in the US-economy during the 1990s could be explained by the sizable increase in the use of information technology. While United States productivity growth indeed recovered between 1995 and 2005, it has subsequently dropped even below its 1973–1995 average (Furman and Orszag, 2018).

are not reflected in input-output tables, which rely on purchased inputs. The surprisingly small shares for China in chart 2 could also reflect such measurement issues, as China may have a particularly large degree of vertical integration as a result of the country's relatively small services sector. Moreover, the shares shown in chart 2 are based on current prices. Given the rapid quality improvements in ICT-services, hedonic price deflators may lead to different numbers when based on volume data. This issue may also explain the somewhat surprising declining trend in the share shown in the chart.

3. Adapting economic policies to a digital world

The previous section examined the channels through which the new digital technologies may support industrialization in developing countries. This section focusses on the policies that may be required to unlock this potential. It recognizes that experiencing benefits from moving towards a digital world is contingent on the presence of appropriate digital infrastructure and digital capabilities, and that engaging in digital trade could encourage the provision of hard and soft digital infrastructure and, thus, be a promising first step. But the section focusses on ensuring broad distribution and a fair sharing of these benefits, which requires adapting additional policy frameworks and regulations.

3.1 Ensuring an equitable sharing of the benefits from a digital economy

(i) Innovation policy

For a long time, the dominant discourse on innovation and technology was that innovation was costly, risky and path-dependent and that ground-breaking innovation was highly concentrated in a few firms in developed countries. Assuming that, in addition to licensing technology, the main sources of innovation are technologies embodied in machinery and equipment, technical information and specialized inputs from suppliers of inputs and components, as well as that foreign technologies are easy to diffuse and to adopt, it would therefore be most efficient for developing countries to use their meagre innovation and technological capacities to acquire technologies created abroad and adapt them to local circumstances.

To speed up and support this process, developing countries were advised to ensure appropriate absorptive capacity, including in terms of the skill level of the labour force and institutional setups around technology and related transfer mechanisms. Pro-active innovation policy was largely perceived as pertinent only for developed countries and to mark an outcome of economic development, rather than a means to it (see, e.g. Zanello et al., 2016).[14]

More recently, pro-active innovation policy has found a more prominent place on the agenda of developing country policymakers. One reason is that several developing countries have progressed on certain innovation variables, even though significant divides remain (e.g. Cornell University, INSEAD, and WIPO, 2017). Another reason is mounting evidence of little technology transfer and few spill-over effects of foreign direct investment on the local firms (Fu, Pietrobelli and Soete, 2011; De Marchi, Giuliani and Rabellotti, 2017). A third reason is increased spending power in a range of developing countries, as discussed above. Given that the preferences and tastes of these customers may differ from those in developed countries, this rise in spending power

[14] UNCTAD has long deviated from this dominant discourse and encouraged developing countries to pursue pro-active innovation policies.

is creating a new market segment and additional potential for innovation, particularly innovation aimed at goods and services customized to developing country firms and consumers. Such pro-active innovation contests the dominant technology-push perspective, proposed by Schumpeter, and instead features demand pulling innovations from suppliers (Schmookler, 1966) and steering innovators to work on certain problems (Rosenberg, 1969).

One form of pro-active innovation is related to the idea of frugal innovation, which may denote 'new functionality at lower cost', achieved by "(re)designing products, services, systems, and business models in order to reduce complexity and total lifecycle costs, and enhance functionality, while providing high user value and affordable solutions for relatively low-income customers" (Leliveld and Knorringa, 2018: 1; see also Zeschky, Winterhalter and Gassmann, 2014).

This definition leaves open whether developing country citizens are included as producers or as consumers, or both, and whether innovations are conceived and developed in developed or developing countries. In some cases, frugal innovations emanate from developed country firms as re-engineered versions of existing products and services that had been conceived for developed country consumers, but whose reduced functionalities and features make them cost-effective solutions for low- and middle-income citizens in developing countries. These cases see inclusiveness on the consumer side and relate to top-down innovation practices by transnational corporations that develop stripped-down versions of existing products and services to expand their markets beyond developed country customers, as well as beyond the top-income earners in developing countries whose purchasing power, tastes and preferences differ little from developed country markets. This strategy closely relates to what has sometimes been called "glocalization", i.e. the development of products that are initially destined for developed country markets but are then distributed worldwide with some adaptation to local conditions.

Viewed from a development perspective, frugal innovation relates to developing country citizens both as consumers and producers, by focussing on the geographical location of innovation, production and consumption in developing countries. Unconstrained by developed country demands, developing country firms can benefit from local cost advantages, better local sourcing conditions and better knowledge about local circumstances, preferences and needs. They can use these elements to design goods and services with entirely new functionalities and features that are customized for local firms and for local low-income or middle-class consumers. Such local innovation also helps to reduce balance-of-payments constraints on growth by matching domestic demand through customized domestically produced goods, as well as to generate the income that developing country customers will need to purchase the customized goods without incurring debt.

Looked at from this perspective, digitalization may provide specific opportunities for frugal innovation by developing country firms because they tend to reduce the cost of innovation and therefore can better address local resource constraints. As discussed in the previous section, whereas in the past laboratories, staff and expensive hardware equipment were needed, nowadays one person can use a computer and software to design and develop innovation products and services, with much lower fixed costs and investments involved. This potential to reduce the cost of innovation, combined with allowing for customization, may lead digitalization to make innovation less path-dependent and allow for technological leapfrogging.

Frugal innovations initially launched in a developing country may not be limited to local markets, but later be introduced also in developed countries, i.e. a feature comprised in "reverse innovation".[15] Similarly to frugal innovation, reverse innovation is not necessarily targeted at very low-income groups or destined to be of low quality, but rather to arise from changed contexts. As such, reverse innovation may originate in affiliates of developed country firms that face sluggish demand on their lead firm's home markets and, caused by growing distributional inequality, a shift in the composition of this demand towards simpler and cheaper products. It can also regard

[15] Examples of reverse innovation created by developing country firms include small tractors and trucks created in India and mobile phones and electric scooters created in China. For further discussion and examples see, for example, Immelt, Govindarajan and Trimble, 2009; von Zedtwitz et al., 2015; Hadengue, de Marcellis-Warin and Warin, 2017.

sophisticated and expensive offerings, such as when developed country firms locate R&D labs in developing countries to take advantage of labour cost differences.

But reverse innovation may also be part of the internationalization strategy of local firms in some large developing countries that initially aim at responding to growing domestic demand, but later attempt tapping into lower-income segments of developed-country markets. The economic significance of reverse innovation, as compared to frugal innovation, regards the economies of scale accruing to developing country firms that succeed in selling their locally developed products also on developed country markets. This means that reverse innovation tends to achieve both economies of scale and scope by enabling customized production for both domestic and foreign markets.

Crucial for success of pro-active innovation designed to develop new cost-effective products with functionalities customized to their target markets is interaction between all the actors that contribute to innovation (e.g. Foster and Heeks, 2014). As a result, innovation policy must go beyond its traditional focus on supply-side conditions and capabilities and reinforce the attention given to demand-side instruments. A possible starting point of such a shift in emphasis is fostering the "articulation of needs" (Edler, 2016: 100). While this articulation can be based on foresight techniques, new digital technologies may also play an important role. Big data analytics and other digital technologies can significantly ease interaction between innovators, producers and consumers. The availability of data on required innovative product functionalities and features and on expected market developments, combined with the capacity of analysing such voluminous data for design and production decisions, would significantly ease the flow of information from consumers to innovators and producers. And product-specific marketing and distribution based on digital media would help customers in their spending decisions. Using these digital devices might be particularly important in developing countries where they would allow shortening, or even removing, the long chains of intermediation that often characterize user-producer interactions in the innovation systems of developing countries (e.g. Foster and Heeks, 2014).

But given that pro-active innovation in whatever form aims at generating customized goods and services, those innovative firms – whether they are foreign or local – that control data on local demand patterns and are capable of analyzing these data through big data analytics are likely to have crucial advantages in designing, producing and marketing goods and services that result from frugal innovation.

Embarking on less path-dependent innovation and attempting technological leapfrogging towards more demand-driven innovation models further increases the challenges that developing countries face for their innovation policies. Given that both frugal and reverse innovation are relatively recent concepts, much of their accounts and identification of criteria that may be required for success remains based on examples with little systematic evidence (e.g. Hadengue, de Marcellis-Warin and Warin, 2017).

One example of successful active innovation policy is the Chinese company Huawei that for developing its smartphone business outcompeted main incumbent firms not simply through low-cost advantage but by relying on recent scientific knowledge and the integration of ensuing new technologies in its innovation strategies (Joo, Oh and Lee, 2016). Starting by producing low-end phones for the domestic market, its continued focus on local R&D and reverse engineering of foreign technology allowed it to become a global leader in telecommunications networks by 2012 (Kang, 2015). Another example is the Republic of Korea’s Samsung that, in 1996, decided to build in-house design competencies rather than continue to import such knowledge. This shift towards in-house design, combined with associated changes in management and business models, laid the basis for the firm’s global success in the smartphone, tablet and television sectors (Yoo and Kim, 2015).

These examples illustrate that it has been possible to overcome obstacles that intellectual property rights (IPR) protection may pose to active innovation strategies and design development in developing countries.[16] And cross-industry surveys have led some observers to conclude that design-related IPRs are relatively ineffective, as also illustrated by firms' often significant additional investment in brand image and other reputational assets intended to increase value capture from their designs (Filitz, Henkel and Tether, 2015). IPR protection has generally taken the form of registered patents and industrial designs, or unregistered IPR protection, such as copyrights and trade secrets. Given that patent rights are costly, especially when obtained across multiple jurisdictions, developed-country firms often seek patent coverage only in jurisdictions covering large economies. This means that there is relatively little design-related patent protection in developing countries other than China (WIPO, 2017).

IPR protection may be incomplete even where designs are patent protected. The use of some patented design features may not be exclusive to a specific product but span a range of product groups, implying difficulty in determining what a patent covers, as illustrated by the law suit between Apple and Samsung that was first ruled in 2012 but is still ongoing.[17] Designs can also be protected by industrial design rights. But while industrial design rights may cover appearance, they usually do not extend to functionality and ease of use (WIPO, 2017). Moreover, 3D equipment can scan a non-patented physical object and create a CAD-file that will reproduce the object (Osborn, 2016). The CAD-file can subsequently be used as a starting point for creating objects that have new functionalities or other novel characteristics. Given that digitalization may bring about entirely new products, as well as enable new functionalities and ways of use, it would appear that existing IPR protection leaves scope for active design-oriented innovation policy in developing countries. Nevertheless, maintaining this scope will also require containing practices such as interlocking patents and patent trolls, which have become important features of competition mainly in the smartphone and pharmaceutical industries.

Moving towards a digital world may also broaden the scope for developing-country firms to engage in cross-licensing arrangements with developed-country firms. At least some of these firms may privilege protecting their designs through trade secrets but be interested in licensing, and thereby disclosing, their designs to developing countries. They could wish to do so in exchange for innovative design features regarding functionalities and ease of use that developing countries have developed for their domestic customers but that may appeal also to the lower income segments of a developed-country firm's customers. IPR owners may also wish to create new revenue streams by commercializing template CAD files or software that purchasers can subsequently customize.

In addition to a sizable increase in R&D spending and the size of in-house design departments, enhanced skilled labour migration in the form of both intellectual returnees and skilled expatriates from developed countries could provide substantial support to developing countries' more active innovation policy. While skilled returnees appear to have played a crucial role for example in the development of China's photovoltaic industry (Luo, Lovely and Popp, 2017), skilled expatriates from developed countries have been instrumental in creating the designs for automobile production in developing countries such as Brazil, India and Morocco, as well as in Romania. There, designers have focused on the functionalities and price ranges that would appeal to customers in developing countries, as well as to relatively low-income customers in developed countries (Midler, Jullien and Lung, 2017).

To sum, while the specific form of innovation policy will differ across countries and be subject to experimentation, it may be difficult to ensure an equitable sharing of the benefits from

[16] For a succinct discussion of how Intellectual property law affects 3D printing, see, for example Elsa Malaty and Guilda Rostama, "3D printing and IP law", *WIPO Magazine*, February 2017, http://www.wipo.int/wipo_magazine/en/2017/01/article_0006.html. For more detailed discussion see, for example, Osborn, 2016 who concludes: "perhaps the innovations most impacted by 3D printing should be removed from certain IP protections altogether. This argument is perhaps strongest in patent law, where the utilitarian nature of the inventions urges their introduction into the public domain" (270).

[17] See Tim Bradshaw, "Apple and Samsung return to court in "Groundhog Day" spat", Financial Times, 13 May 2018, https://www.ft.com/content/a411ed46-556d-11e8-b3ee-41e0209208ec.

digitization if developing countries do not embark on more pro-active innovation trajectories. Crucial support for such policies could come from the creation of favourable demand conditions, as discussed in the next section.

(ii) Industrial policy

Theoretical insights, historical evidence and recent experiences all point to the importance of proactive industrial policies. By contrast, how to harness such policies in development strategies and what lessons can be learned and transferred from success stories remains extensively debated (e.g. Chang and Andreoni, 2016).

As discussed above, bridging digital divides and developing digital capabilities facilitate integration into the digital economy from the supply side and pro-active innovation policies can raise productivity and increase the responsiveness of design and product development to demand-side signals. These policies may need to be complemented by industrial policies that affect the incentives for designers and producers to provide the customized products that meet their customers' desires. This would imply that, as innovation policies, industrial policy would need to be adapted to a digital world by moving away from its traditional supply-side focus.

More demand-side oriented industrial policy starts from a potential buyer and emphasizes the interplay between innovation and demand-driven policy instruments that focusses on customers' disposable income and varying preference systems. These are key determinants for the creation of demand for domestic innovation and the potential creation of entirely new sectors (see also Saviotti and Pyka, 2013; Santiago and Weiss, 2018). A government can do this in several ways: (i) as a direct costumer, it can act through government procurement; (ii) as a regulator, it can affect competition, and hence the level of demand enjoyed by individual firms, by determining the number of licenses for certain activities or by imposing certain industry standards, and it can steer the direction of innovation by pushing firms to form research consortia in certain areas or by taking the lead in undertaking itself certain innovation activities; (iii) as a knowledge broker, it can link innovators, producers and consumers; and (iv) as an active promoter of private demand, e.g. through tax incentives and subsidies, that stimulates innovations from domestic firms (for more detailed discussion, see, for example, Edler, 2013; and Chang and Andreoni, 2016).

The extent to which governments can effectively influence the demand for manufactures through such measures will be determined, inter alia, by the size of a country's domestic market and the level of purchasing power of its citizens, domestic firm's ability to leverage and analyse the data generated from increased market demand for design and production decisions, as well as the strength of their innovation and manufacturing capabilities to react to the signals.

From a more general perspective, an important issue regarding the impact of digitalization on the effectiveness of industrial policies is whether these policies can be adapted to the digital world in an incremental way, such as by mainstreaming digitalization across all policy areas, or whether the very nature and ambition of industrial policies need to change. Often taking the United States as an example, some observers argue that "it is a primary duty of the state to provide direction for technological development and innovation in order to satisfy state needs (e.g. defence, security) and citizen needs (health, education, etc.), take risks and help to create the kinds of markets that are societally preferable … Thus, policy support incentivises actors to invest in knowledge and innovation production in targeted areas with a specific need in mind" (Edler et al., 2016: 6; see also Mazzucato, 2011).

A case for such a more ambitious shift towards "mission-oriented" industrial policies could be made for digitalization. This stems from the need to use these technologies for transformational purposes in the form of product innovation that creates and shapes new products and new markets, including to compensate for the job destruction that these technologies' process innovation may cause. Such a more ambitious shift would, for example, involve institutional changes, including in the nature of private-public partnerships. They could allow public organizations to participate more in the rewards that commercial success of its policies brings, including to cover the losses that experimentation and discovery of policy making may entail. It would also involve using more dynamic metrics in policy evaluation to assess the degree to which public investment has opened and transformed sectoral and technological landscapes.

But the most important impact of moving towards a mission-oriented industrial policy in a digital world may concern the structure of finance for investment. Contrary to tangible assets – such as buildings, machines or particular plots of land – intangible assets, such as data, software, market analysis, organisational design, patents, copyrights and the like, tend to be unique or most valuable within narrowly defined specific contexts. Therefore, they are difficult to sell or value as collateral. This makes it cumbersome to finance investment in intangibles from traditional sources, such as bank loans and marketable bonds, and, in addition to private equity finance, increases the role of retained profits as a source of finance for investment. As a result, supporting investment in intangibles may well imply policy measures designed to strengthen the profit-investment nexus, such as by changing financial reporting requirements or imposing restrictions on share buybacks and dividend payments when investment is low or preferential fiscal treatment of reinvested profits, as well as by increasing role of development banks.

Moreover, governments could engage in more than just help funding new technology. They could become investors of first resort regarding digital innovation by investing in corporate equity (Mazzucato, 2017). One way of doing so would be for governments to acquire stakes in the commercialisation of successful new technologies by establishing professionally managed public funds, which would take equity stakes in new technologies, financed through bond issues in financial markets, and which would share its profits with citizens in the form of a social innovation dividend (Rodrik, 2015). In this way, the fruits of high productivity growth from technological change could spread more widely and fuel aggregate demand also for output from lower productivity sectors, thereby increasing employment and average productivity at the same time. Empirical evidence suggests that companies with blockholders (i.e. large shareholders), such as publicly held companies, tend to invest more in innovation than companies with dispersed equity ownership (Edmans, 2014). This is because such shareholders typically base buying and selling decisions on the company's long-term prospects, including those built on intangible capital. And by investing large enough blockholding funds, for example through sovereign wealth funds, such investment could ensure long-term thinking across the digital ecosystem and enable benefits from the spillovers and synergies that intangible assets may generate across companies (Haskel and Westlake, 2018).

(iii) Regulatory policy

The digital economy creates significantly new regulatory policy challenges because the network effects associated with digitalization can cause market concentration and barriers to market entry. First-mover advantages regarding the benefits from controlling and scaling large volumes of data tend to create a few highly profitable large firms and "winners-take-most" issues. First-mover advantages can also become self-reinforcing, as data gleaned from one market can facilitate entering new markets or even new business lines. Resulting increases in market concentration may sizably augment the financial power of a few leading firms and cause increased rent seeking, anticompetitive practices and attempts to block actual or potential competitors.[18] As a result, certain established competition and antitrust policies may be unsuited to the digital economy.[19]

[18] UNCTAD (2018) provides detailed discussion of market concentration from expanding digital platforms.

[19] For detailed discussion, see the literature on "two-sided markets". There is no accepted definition of "two-sided markets", but digital platforms are generally considered as such (e.g. Rysman, 2009) as they have two distinct user groups that offer each other network benefits.

Anticompetitive practices have traditionally been addressed by antitrust and competition policies. But the goal of these policies has increasingly shifted from a concern with market structure and market behaviour to an emphasis on maximizing consumer welfare.[20] Recent concerns have emphasized consumer welfare related to data privacy[21], internet security, and the functioning of societies.

The extraction of economic rent receives much less attention. One form of rent extraction is aggressive tax optimization by locating a firm's tax base in low-tax jurisdictions (e.g. Beer, de Mooij and Liu, 2018). The digital economy may exacerbate tax base erosion because global firms can easily transfer their intangible assets (e.g. data; intellectual property) across tax jurisdictions. The OECD's Base Erosion and Profit Shifting (BEPS) initiative has taken some useful steps towards safeguarding fiscal revenues. But critics are calling for wider and more inclusive discussion and argue that the reform proposals "have failed to ensure that profits are taxed where activities take place …, in favour of where the companies that receive income are based", mainly because "the revisions to transfer pricing rules continue to cling to the underlying fiction that a MNE consists of separate independent entities transacting with each other at arm's length" (ICRICT, 2018: 5).

Taxing where activities are done rather than where firms declare as being headquartered redistributes rents and can help build the tax bases of developing countries. But it does not tackle the anticompetitive features that make these rents arise. Price-based measures of competition may well prove inadequate in a digital world where control and use of data is of paramount importance, where competition strategies and pricing decisions may be determined by the algorithms of machine learning, and where consumers often receive services in exchange for data, at zero nominal prices.[22] Established competition policy assumes that actors pursue a strategy focused on profit maximization whereby unjustifiably high prices are judged as harming consumer welfare. In a digital economy, by contrast, actors tend to privilege scale and market-share strategies. This may involve slashing prices, even to the extent of being willing to sustain losses, and/or increasing spending to expand capacity, including by acquiring other firms and expanding into multiple business lines.

One way of addressing anti-competitive practices in a digital world would be through tighter regulation of restrictive business practices, with strong monitoring and administration at the international level.[23] Breaking up the large firms responsible for market concentration would be a policy that takes literally the often-made comparison between oil in the analogue and data in the digital economy, in that Standard Oil was broken up in 1911 and required by law to split into multiple pieces. Forcing firms into joint ventures with certain majority rules could avoid market concentration to arise and might be a feasible option for economies with nascent digitalization, including many developing countries. Closer monitoring of vertical integration, including by adding the scope and scale of data at stake as criteria for merger control, would be another policy strengthening competition.

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[20] Lynn, 2017, provides an account of this shift in the United States, with a divergent view in Atkinson and Lind, 2018. For more general discussion see, e.g. Coyle, 2018; Khan, 2017; and Vezzoso, 2016.

[21] See, for example, the Human Rights Council HRC Resolution 34/7 adopted on 23 March 2017, https://documents-dds-ny.un.org/doc/UNDOC/GEN/G17/086/31/PDF/G1708631.pdf?OpenElement; and the European Union's General Data Protection Regulation (https://www.eugdpr.org/), which entered into force on 25 May 2018, requiring firms to give customers more control over their online information.

[22] One policy problem that this business model poses is difficulty in identifying when a market price is below cost, i.e. a criterium required to establish a case of predatory pricing on which established competition policy could act.

[23] A starting point for any such policies might be the Set of Multilaterally Agreed Equitable Principles and Rules for the Control of Restrictive Business Practices adopted by the United Nations General Assembly in 1980.

An alternative would be accepting a digital world's tendency towards market concentration but regulate these tendencies with a view to limiting a firm's ability to exploit its dominance. Given that a country's data may have public utility features, one option could be regulating large firms as a public utility with direct public provision of the digitized service. This means that the digital economy would be considered similarly to traditional essential network industries, such as water and energy.[24]

In addition to scaling data and chasing market share, patent trolls and interlocking patens are widely used forms that can favour rent seeking and act as barriers to market entry. Moving towards a digital economy might mean that the right balance between stimulating innovation and ensuring technology diffusion implies weakening, rather than strengthening, the rules governing intellectual property rights (see also Haskel and Westlake, 2018), including to bolster technology diffusion to developing countries. Given the cross-border character of the digital economy, international cooperation will be key.

Developing countries face even greater regulatory challenges. Contrary to many developed countries in both the earlier and current phases of digitalization (Bauer, Ferracane and van der Marel, 2016), most developing countries do not have policies regarding the control and use of data.[25] The absence of well-defined policies in this area risks causing their data to be controlled by whoever gathers and stores data and then has exclusive and unlimited rights on data. National data policies should address four core questions: who can own data; how it can be collected; who can use it and under what terms; under what conditions can data cross borders and whose country's law governs transferred data. The latter question is also affected by the compatibility of data localization frameworks across countries.

3.2 Economic policy frameworks for the digital economy

Compared to the excitement in much of the media and business literature about the imminence and disruptive impact of digitalization, policymakers are lagging in deploying policies that would help to determine its course and distributional effects. A recent review of policy initiatives regarding the digital economy undertaken in a group of selected countries[26] concludes that even "in pioneering countries such as Germany …, concrete policy initiatives around … [the digital economy] remain, at best, at initial stages of implementation" and that "middle-income countries are yet to define strategic policy agendas around … [the digital economy]. National plans or concrete policy strategies are either non-existent, or at initial stages of discussion, consultation and planning. Even the few advanced cases … show that the strategies are insufficiently articulated regarding milestones, resources and pathways towards desired outcomes" (Santiago, 2018: 40, 20).

[24] However, treating the digital economy as a public utility regime may need to overcome the currently wide-spread unfavourable assessment of any rise in state regulation.

[25] One exception is the National Data Revolution Policy of Rwanda, which maintains national data sovereignty and allows Rwanda to retain exclusive rights and control over its national data (http://statistics.gov.rw/publication/rwanda-national-data-revolution-and-big-data). Others include Vietnam's Law on Cybersecurity (https://vietnam-business-law.info/blog/2018/7/30/vietnams-new-cybersecurity-law), Chile's Data Protection Law (https://iclg.com/practice-areas/data-protection-laws-and-regulations/chile), the Data Privacy Act of the Philippines (https://sprout.ph/blog/data-privacy-act/), Indonesia's draft Data Protection Law (https://www.lexology.com/library/detail.aspx?g=499916e4-0b16-42e1-95e2-4a077402ecf5), and India's Draft Personal Data Protection Bill (http://meity.gov.in/writereaddata/files/Personal_Data_Protection_Bill,2018.pdf).

[26] This group includes the member States on the European Union, as well as Argentina, Brazil, Chile, Mexico, India, Malaysia, Thailand, Viet Nam, Ethiopia, Kenya, South Africa, Egypt, Morocco, Kazakhstan, and Turkey. It should be noted that this list is not exhaustive and most notably does not include China whose Made in China 2025 initiative is probably the most clearly defined strategic policy agendas around the digital economy.

One reason for this apparent lack of policy initiatives regarding the digital economy may be the highly contextual character that such initiatives will invariantly imply and therefore the experimental approach that policymakers are required to take. Each country's specific policy mix will necessarily be influenced by a range of country-specific factors. Most importantly, a country's overall policy strategy will be key in determining whether broad policy objectives aim at strengthening industrial sectors or at developing and scaling-up potential future development engines. This choice will reflect the stage of a country's digital infrastructure and capabilities, but also be determined by the size of its domestic market and the strength of its manufacturing and innovation structure. The issues around demand heterogeneity discussed above may be particularly important for deciding the role of domestic demand in this context.

Keeping these country-specific factors in mind, the discussion above, nonetheless, suggests a few general elements that may help policymakers in developing countries to define a strategic policy framework designed to allow their economies integrate into a digital world and experience an equitable share of the benefits from digitalization. Table 5 reflects the various elements that such a framework may comprise. It should be noted that the given framework considers only those policy areas that were discussed above, and therefore should not be considered as exhaustive. Moreover, any such national policy framework will need to be supported and complemented by international rules and regulations, as well as regional and international policy collaboration.

Table 5. **An economic policy framework for the digital economy**

Policy area	Policy objectives	Strategic questions	Policy options
General policy stance	Provide digital infrastructure and capabilities to integrate into the digital economy and adopt additional policy measures to ensure equitable sharing of its benefits	Can current policies be adjusted, or is new big vision and general policy overhaul required? How to ensure coherence across policy areas and with broader development strategy?	Whole-of-government approach
Assessment criteria	Adequately measure, monitor and evaluate policy implementation and outcomes	What new indicators does a digital economy require?	Support international cooperation for elaboration of indicators and harmonize domestic with international indicators
Digital infra-structure and capabilities	Build network infrastructure, digital capabilities, cloud computing infrastructure, and data infrastructure to enhance integration into the digital economy	1) How to ensure adequate finance for and investment in digital infrastructure? 2) How to ensure adequacy of skills and training systems?	1) Mix of (i) public investment, (ii) public-private partnerships, and (iii) incentives for technology transfer 2) Support digitally-oriented curricula, life-long learning and firm-level training 3) Encourage digital trading as first step (not as end in itself)
Innovation policy	Raise productivity and increase responsiveness of domestic design and product development to demand-side signals	How to ensure equitable sharing of benefits from digitalization through innovation as a driver of economic progress?	1) Ensure that innovation policies match digital capabilities of firms and implementation capacity of government 2) Optimize interaction between various actors of innovation system
Use of new digital tech-nologies	Deploy key ICTs	How to support investment in the new digital technologies?	Government as investor of first resort; increased role of development banks

	Support effective market intelligence	1) What is the optimal degree of enabling reuse, sharing and linkage of data? 2) How can emerging market trends be better anticipated to target allocation of research funds and other resources?	Foresight services and market intelligence
	Leverage domestic data through big-data analytics	1) How to address potential trade-off between maximizing welfare effects and more equal distribution of these gains? 2) How to secure responsible use of personal data and how to optimize data privacy?	1) Monitoring data localization and access to domestic market data (e.g. joint ventures) 2) Data security rules
	Expand and strengthen capabilities and use of design and prototyping tools (CAD/CAM)	1) What prevents greater domestic use of CAD/CAM? 2) How can issues of intellectual property regarding CAD be addressed?	1) Encourage return of digitally skilled diaspora 2) Provide conducive regulatory environment and fiscal framework; increase digital capabilities
	Turn big-data analytics and design into production activities	What role do standards play for interdependence of industrial sectors and for support to individual industries?	1) Increase R&D investment 2) Adapt standard setting to digital economy
Science and R&D policies	Identify priorities for government-funded research and initiatives, while encouraging private investment and ensuring complementarity of private and public investment	1) How can funding match best growing multidisciplinary nature of research and complexity of manufacturing? 2) How can impact be measured best given increasingly blurred boundaries among research domains? 3) How can public-private partnerships and government linkages with other stakeholders be optimized?	1) Increase public investment in priority areas and provide support to crowd in private investment 2) Consider fiscal and non-financial measures that support frontier firms while avoiding winners-take-most tendencies
Demand-side industrial policy	Raise information and awareness regarding domestic products	How to ensure equitable sharing of benefits from digitalization through enhanced incentives for designers and producers to provide customized products?	Awareness campaigns, national brands, voluntary labelling
	Boost consumption of intermediate & final domestic products		Fiscal incentives, prizes and mandatory standards and labels fostering mission-focused innovation
	Boost demand for domestic products		Public procurement
Financing investment	Structure of finance for investment	How to finance investment for adequate provision of digital infrastructure and capabilities, as well as in intangible assets?	Government as investor of first resort; role of national and multilateral development banks
Regulation	Adopt fairer taxation	How to minimize tax avoidance and evasion?	Support international collaboration on reform of international tax rules and adjust domestic legislation accordingly

	Reduce monopolistic tendencies and anti-competitive practices	How to minimize winners-take-most tendencies and abuse of market power?	Adapt competition and anti-trust policies to a digital world
	Boost demand for domestic products	How to provide assurances about safety and functionality of new products?	Set minimum mandated standards
	Ensure adequate control over domestic market-related data and its use	Who can own data? How can it be collected? Who can use it and under what terms? Under what conditions can data cross borders, and whose country's law governs transferred data?	1) National localization policies 2) International rules and regulations governing the digital economy
Macro-economic policies	Ensure macroeconomic stability and support fair sharing of benefits from digitalization	How can income and purchasing power of citizens, as well as profits of firms by supported to ensure adequate supply and demand in digitized manufacturing process?	1) Provide institutional structure that allows average economy-wide wage growth commensurate with average economy-wide productivity growth 2) Support reinvestment of enterprise profits
Social policies	Support displaced workers and promote inclusiveness during transition to digital economy	How can sustainable and adequate protection of citizens during periods of work-place disruption be ensured?	1) Adapt curricula to develop digital skills and learning opportunities 2) Ensure revenue-raising capacity and improve efficiency and progressivity of tax system to allow adequate funding of social protection

Source: Author's elaboration.

4. Conclusions

Moving towards a digital economy may hold greater potential for industrialization in developing countries than often thought. This is because many existing studies overestimate the potential adverse effects of robots. But it is also because of the manifold opportunities that digitalization may provide for developing countries to locate in their economies high value-added and job-creating activities in all segments of the manufacturing process. Whether digitalization and industrialization are friends or foes is largely the outcome of policy choices.

However, the rapid pace of digitalization risks leaving many policymakers unprepared. Depending on a country's level of development, unpreparedness can take several forms – from skills and infrastructure deficits to inexistent or fragmented policy adjustment – and can have numerous consequences, including wider digital divides, growing concentration of the benefits of digitalization among a few large firms, and stalled economic catch-up or even marginalization of developing countries from the global economy. Policymakers from all countries need to be aware about the key importance of data in a digital world. While engaging in digitized manufacturing may seem a remote possibility for some, first-mover advantages from controlling data will be difficult to undo.

Realizing the opportunities from a digital world will be difficult. It requires ambitious policies in a wide range of areas and in a coherent way. Engaging in digital trade is a promising first step and will spur institution building and the provision of hard and soft digital infrastructure, which are basic requirements for people and enterprises to engage successfully in the digital economy. But digital trade should not be an end itself. Narratives of the benefits of digital trade often take a consumer perspective, coached in dollar terms. But digitized exchanges are generally paid for in data, i.e. goods and services are delivered, often free of charge in dollar terms, in exchange of the customers' data. Looked at from a development perspective, merely increasing connectivity might empower already more productive firms and sharpen the exclusion of other firms. And providing customer data to international platforms tends to result in concentration of corporate power that may make it difficult for developing countries to control and use data from their economies for their own economic development.

This means that policy changes in a wide range of areas should accompany increased digital connectivity. Access to, control over and capabilities to analyse and transform data into economically meaningful knowledge will be central to reaping the benefits from a digital world. While ensuring that data governance frameworks appropriately address privacy and digital security considerations, policies should also encourage investment in data that have synergies both within and across industries.

Regarding competition and antitrust policies, exploring what policies on standards, public participation in long-term finance, public procurement, etc. may be necessary to increase the benefit of developing countries in a digital world. Also required are bold demand policies, as developing countries can make such benefits sustainable only if their firms and consumers have the income required to turn their preferences into effective demand without incurring debt. In this sense, establishing a virtuous circle between the new digital technologies' greater emphasis on customized demand on the one hand, and greater involvement of developing countries in manufacturing processes that satisfy such demand on the other, will require the adoption of more expansionary macroeconomic policies and reconnecting wage and productivity growth.

Given that large-scale use of digital technologies is still unfolding and that related impacts are still not fully understood, international cooperation to fill data gaps and develop comparable metrics needs to accompany policy efforts at the national level. More inclusive and ambitious efforts towards addressing aggressive tax optimization of global firms are also needed. Moreover, the international community is just beginning a dialogue on what rules and regulations can harness the productivity and developmental potential of the digital economy. Agreement needs to be reached on what part of the issues around the digital economy are in the realm of the WTO and what should be dealt with elsewhere. There remains a wide variation of views on these issues. Some hold that rapid adoption of negotiated rules in the multilateral trading regime may prevent regulations from arising through practices that may be unduly shaped by the narrow business interests of firms that are already ahead in the digital economy. Others consider that it may be premature to commit to trade and investment rules in this rapidly evolving area without a clear understanding of how digitalization can support industrialization and of how the longer-term impacts of rulemaking in this area could go against countries' specific own digital needs. Yet, both positions indicate the need for constructive dialogue as the existing institutional setup of international trade and investment relationships may be ill-equipped to deal with issues arising from digitalization.

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