C

The economics of how digital technologies impact trade

This section focuses on how new technologies are transforming international trade, creating new opportunities for a more inclusive trading system and raising new challenges. The section opens with a discussion of how digital technologies affect international trade costs. This is followed by an assessment of how digital technologies change the nature of what is traded, how we trade and who trades what. Finally, the potential impact of important trends in technological development is quantified and long-term projections on international trade are made, using the WTO Global Trade Model.

Contents

Some key facts and findings

- International trade costs declined by 15 per cent between 1996 and 2014. New technologies will help to further reduce trade costs. Our projections predict that trade could grow yearly by 1.8-2 percentage points more until 2030 as a result of the falling trade costs, amounting to a cumulated growth of 31 to 34 percentage points over 15 years.
- The wide adoption of digital technologies changes the composition of trade in services and goods and redefines intellectual property rights in trade. Trade in information technology products has tripled in the past two decades, reaching US$ 1.6 trillion in 2016.
- The importance of services in the composition of trade is expected to increase. We predict the share of services trade to grow from 21 per cent to 25 per cent by 2030.
- Digitalization has led to a decline in trade of digitizable goods (e.g. CDs, books and newspapers) from 2.7 per cent of total goods trade in 2000 to 0.8 per cent in 2016. The trend is likely to continue with the advent of 3D printing technology.
- Regulation of intellectual property rights, data flows, and privacy as well as the quality of digital infrastructure are likely to emerge as new sources of comparative advantage.
- The decline in trade costs can be especially beneficial for MSMEs and firms from developing countries, if appropriate complementary policies are put in place, and challenges related to technology diffusion and regulation are addressed. Our estimations foresee that, in such case, developing countries' share in global trade could grow from 46 per cent in 2015 to 57 per cent by 2030.

1. Lower trade costs: opportunities and challenges

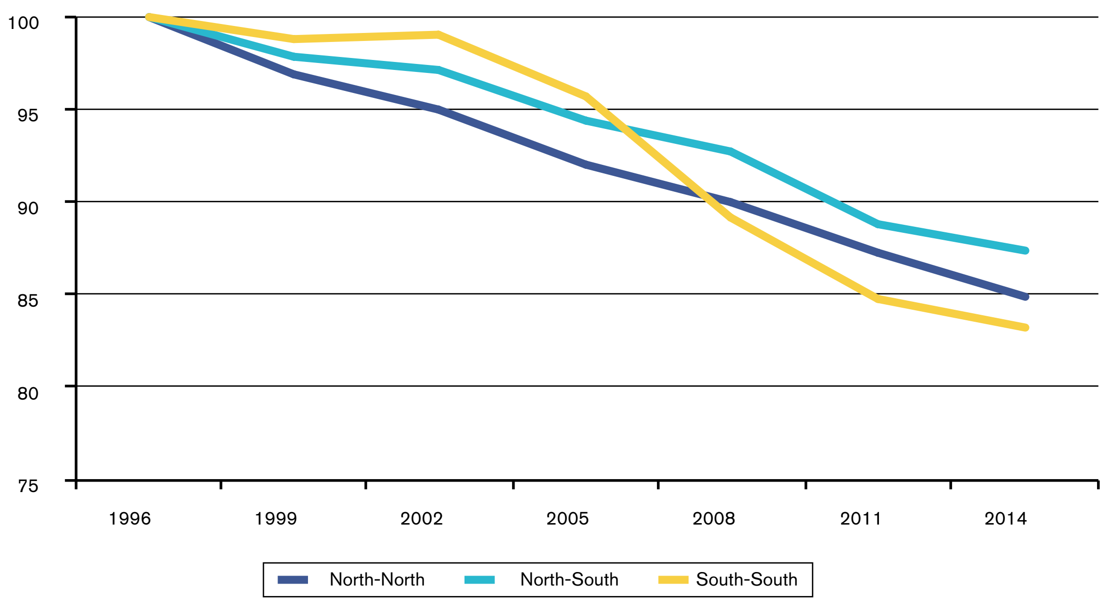
Section B discussed how digital technology is transforming economic activity, focusing purchasing habits increasingly on the internet and changing the ways in which businesses operate by enabling them to access data on consumer preferences and to adapt their product cycles and marketing strategies to this information. In this subsection, we look at the potential of digital technologies to reduce trade costs. We show that digital technologies may decrease the relevance of distance, be it geographical, linguistic or regulatory, and that they also facilitate searches for products, introduce mechanisms to verify quality and reputation, and simplify cross-border transactions.

To see how international trade costs have fallen over time, Figure C.1 plots the trend for three directions of trade flows between 1996 and 2014. The costs are calculated as a ratio between international and domestic trade. A decline in this ratio means that international trade grew faster than domestic trade, which is an indication that the world has become more globalized and that obstacles to international trade have declined. On average this decline was around 15 per cent between 1996 and 2014. The trend was similar for trade among developed ("North-North") and between developed and developing ("North-South") countries. Trade costs among developing countries ("South-South") were the slowest to decline at the beginning of the period, but their decline gained momentum after the mid-2000s, outpacing the rest.

The declining trend is in line with a recent study by Egger et al. (2018), who show that total trade costs declined both in the manufacturing and services sectors during the period between 1995 and 2011. They also show that trade costs are higher for services, mostly due to high variable costs.

Figure C.2 breaks the costs of trading goods and services down into five components: transport costs, logistics costs, the cost of crossing borders, information and transaction costs, and trade policy barriers. The first three categories capture the cost of delivering goods from suppliers to customers. They include the costs of transport, cargo loading, storage, port services and the costs of complying with customs procedures. Information and transaction costs include obstacles that firms have to overcome in order to search for trading partners, acquiring information about tastes, regulations and technical requirements, and enforcing contracts. Acquiring information about product standards in a foreign country, distribution channels and customers' preferences is costly, and

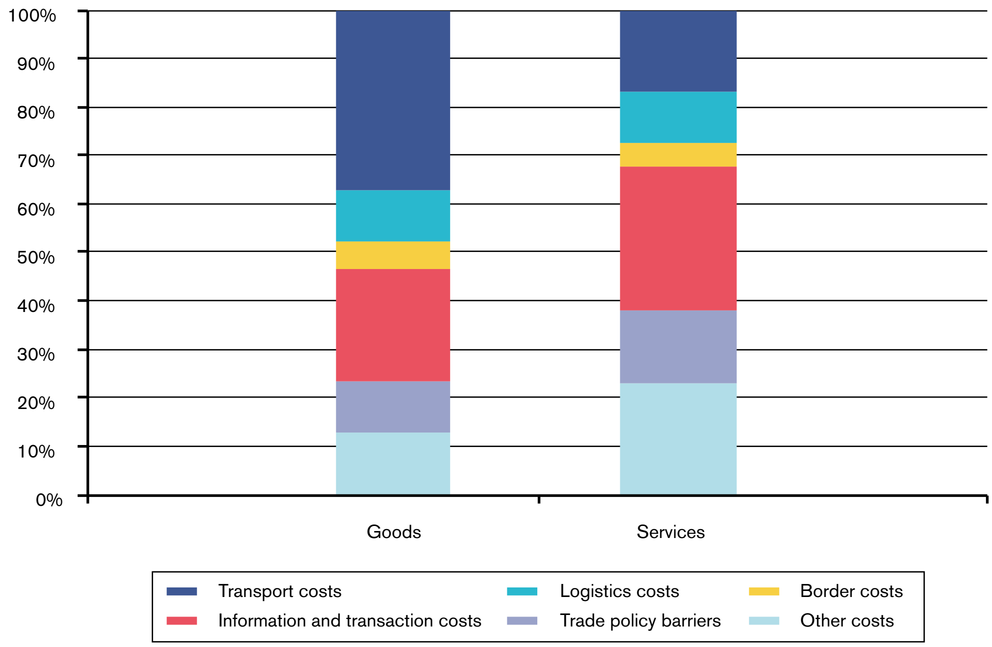
Figure C.1: Overall trade costs, 1996-2014



Source: World Bank-ESCAP database on International trade costs.

Notes: Only those country pairs for which data were consistently available for the years 1996-2014 have been included, i.e. 107 countries that were classified as developed (high-income) and developing (middle-/low-income) based on the World Bank classification for the year 2006, which is the midpoint of the time series. Each time series is standardized to 100 at the beginning of the sample period.

Figure C.2: Trade costs breakdown, based on data from 2014 (per cent)



Source: WTO calculations using World Input-Output Database (WIOD) data and methodology from Chen and Novy (2011).

Notes: The figure shows to what extent various determinants of trade costs explain the cross-country variance in trade costs. The determinants of transport costs taken into account are the effective transportation distance between countries, as constructed by Egger et al. (2018), whether or not a country is landlocked, and whether countries have a common border. Logistics costs are proxied by the Logistics Performance Index and the Liner Shipping Connectivity index. Border costs are proxied by the lead time to export. The determinants of trade policy barriers taken into account are whether countries are part of a free trade agreement, whether they are members of the European Union, and exchange rates. The determinants of information and transaction costs taken into account are whether there is a common ethnic language, a common colonizer, whether different countries were previously the same country or one was previously a colony of the other, the bilateral stock of migrants, the depth of credit information index, and the enforcing contracts indicator. Other costs are the part of the total costs variation that remains unexplained by our variables.

these costs increase with cultural and linguistic distance. Furthermore, transaction costs are high for cross-border trade because of different institutional frameworks and the need for cross-border financial transactions and currency conversions. The last category includes policy measures that make access to the domestic market relatively more difficult for foreign firms. These are tariffs, but also non-tariff barriers, such as technical regulations, product standards or licensing.

Transport costs account for the largest share of cross-country variation in overall trade costs; that is, 37 per cent for goods flows and 17 per cent for services flows.[1] Logistics costs are equally important for the trade of goods and services, accounting for 11 per cent of overall trade costs.[2] The costs of crossing a border that stem from time delays account for between 5 and 6 per cent of overall trade costs. However, since there are other administrative costs related to customs compliance for which we lack measures, these figures are likely to underestimate the importance of all border costs.

Information and transaction costs in goods flows play the second most important role after transport costs.[3] In services, information and transaction costs are the most important trade barriers, accounting for 30 per cent of the total trade costs variation. Finally, trade policy barriers also matter much more for services flows, where they account for 15 per cent, as opposed to goods flows where they account for 11 per cent.

The remaining unexplained component ("Other costs") reflects trade barriers that are not captured by the variables introduced in the estimation. These may include, for instance, taste differences that are not explained by the variables used to proxy for cultural and linguistic differences. It would also include costs of customs and regulatory compliance that go beyond time delays at the border, and those that are not affected by trade agreements. The unexplained component is considerably higher for trade costs in services than for trade costs in goods, which may also reflect poorer measures for policy barriers in trade in services. For a detailed exposition of the methodology used to estimate the decomposition, see Appendix C.1.

In conclusion, trade costs have declined in both developed and developing countries. Transport costs, together with information and transaction costs, play the most important role, and therefore their decline has the largest potential to further bring down the overall trade costs. Lower costs associated with logistics, trade policy barriers and crossing a border can also bring substantial benefits. In the next subsection, we analyse the extent to which new technologies could play a role in the declining trend and outline the possibilities for further efficiency gains. Section C.3 then builds on this analysis and provides a quantification of potential trade gains from a technology-induced decline in trade costs.

(a) Transport and logistics costs

Transport costs depend on the type of product that is transported, distance between countries, and the trade infrastructure of source, destination and transit countries. Limão and Venables (2001) emphasize that the quality of transport infrastructure significantly affects countries' ability to trade. They create an infrastructure quality index based on roads, railways and telephone lines coverage for 103 countries, and show that a country that ranks on the 75th percentile of the index faced 12 per cent higher transport costs than the median country and 28 per cent lower trade. [4] The study further focuses on the determinants of poor export performance of Sub-Saharan Africa and identifies infrastructure investment as one of the biggest bottlenecks.

Transportation costs are not limited to the price paid to move goods from origin to destination; an important part of those costs is related to time delays and uncertainty. This is due to the increasing importance of global supply chains, just-in-time inventory management and lean retailing. For exporters sourcing intermediate inputs from varied sources, the disruption of one delivery can stymie an entire production process. Hummels and Schaur (2010) quantify the costs of time delays, suggesting that each additional day in transit is equivalent to an *ad valorem* tariff of between 0.6 per cent and 2.3 per cent, and that trade in intermediate inputs is 60 per cent more time-sensitive. Similarly, according to the United Nations Conference on Trade and Development (UNCTAD) (2017b), any additional trans-shipment that lengthens shipping time is associated with a 40 per cent lower bilateral export value.

(i) Artificial intelligence and autonomous driving reduce transport costs

Many recent technological advances have had a significant impact on transportation and logistics costs. The use of GPS (i.e. Global Positioning System) for navigation and route planning has become ubiquitous in recent years. New technologies, such as artificial intelligence (AI), promise to have a similarly pervasive influence, as AI applications currently include autonomous driving capabilities and real time itinerary mapping.

For instance, one Indian start-up may potentially transform long-distance trucking across India by creating a relay network based on AI and big data. This network connects drivers to trucks so that several drivers can divide long drives into four to five hours each, rather than one driver having to cover the entire length of the journey. This system also uses machine-learning algorithms to predict precisely when trucks will arrive and leave pit-stops, and at which petrol stations drivers should refuel. This system is helping to cut down travel time by more than half, by eliminating the need for rest breaks which a single driver would require.

(ii) Cargo and shipment tracking reduce logistics costs

Cargo and shipment logistics are optimized by the combination of vehicle telematics,[5] robotization and artificial intelligence. The main benefits come from cargo and shipment tracking, because it increases operational efficiency, enables real-time adjustments and makes logistics systems more secure. Internet of Things (IoT) sensors, for example, can reduce the costs of global trade by increasing the efficiency of shipping and transport. First, they reduce the amount of goods lost in transport. Second, shipment tracking systems enable companies to optimize routes to efficiently use shipping containers. On average, shipping containers have utilization rates of only 20 per cent because companies often ship merchandise to many locations. Tracking each container using IoT technologies could improve container utilization by 10 to 25 per cent and reduce annual spending on containers by nearly US$ 13 billion by 2025 (Lund and Manyika, 2016). Globally, the total number of installed remote shipment tracking systems stood at 2.9 million units by the end of 2015, and it is expected to grow at a compounded annual growth rate of 23 per cent in the coming years (Bern Insight, 2016). In one of the largest commercial deployments of shipment tracking systems, Maersk, a Denmark-based shipping company, rolled out a system of real-time tracking for its entire fleet of some 300,000 refrigerated containers in 2015 (see Box C.1).

Decreasing hardware costs and improved battery life should further foster the adoption of cargo tracking technologies in the coming years. It is not only containers, but also each product that can now be tracked using radio-frequency identification technology. This has also proved highly effective in inventory management in global supply chains that involve many production stages, helping to reduce inventory costs by up to 70 per cent and reduce loss in transit by 11 to 14 per cent (McKinsey Global Institute, 2016).

(iii) Smart robots and AI reduce the cost of storage and inventory

Additional cost and time economies result from the automation of warehousing, trailer and container unloading, and packing. Combined with AI algorithms, the use of advanced robotics minimizes the cost of storage and speeds up distribution to final customers. Large e-commerce firms already use AI and robotics intensively to optimize their storage and distribution networks, plan the most efficient routes for delivery

Box C.1: Case study – How Maersk leverages digital technologies to optimize operations and reduce costs

Back in 2012, in response to increasing competition, Danish shipping company Maersk teamed up with Ericsson, a Swedish multinational network and telecommunications company, to develop a real-time remote container management (RCM) system across its fleet of "reefers", or refrigerated containers. Close to 300,000 reefers have been equipped with remote container devices that transmit reefer performance data 24 hours a day, seven days a week, on key parameters such as temperature, power supply and location to Maersk's private data cloud, where they can be analysed in real time at the company's headquarters.

The system, which has been operational since mid-2015, allows Maersk to track and monitor container performance at any point. According to Maersk, prior to the introduction of the RCM system, close to 60 per cent of cargo claims stemmed from malfunctioning reefer units, poor supplier handling of off-power periods and wrong temperature set points. The system can also be used to detect faults, allowing for quicker repair and cutting down on the need for manual equipment inspections. Maersk's end goal now is to use big data analytics for predictive maintenance to prevent faults.

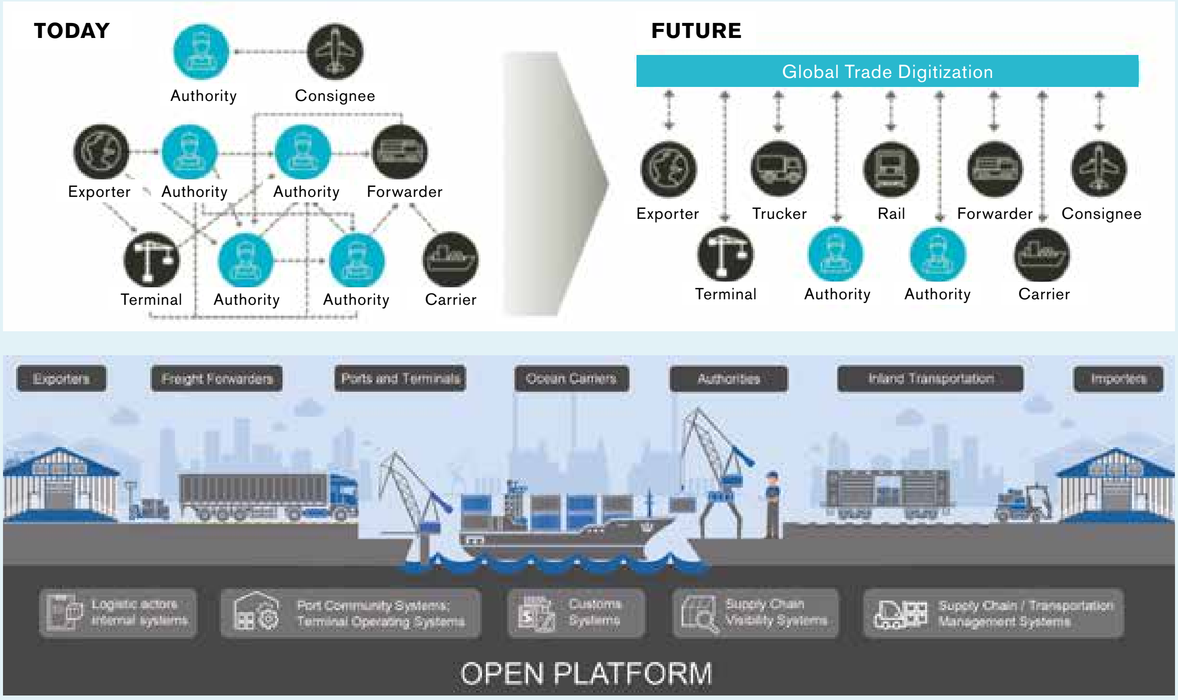
The RCM system has also allowed Maersk to speed up physical inspection processes prior to releasing containers for export. Before RCM, all containers would go through extensive and costly inspections. The use of smart sensors makes it possible to know the condition of the reefer precisely, and helps to determine the type of inspection required prior to release for export. If the reefer is running as expected, only a quick visual inspection is performed prior to release – which is now the case for around 70 per cent of reefers, meaning faster turnaround times, better asset utilization, and operational savings for Maersk (Murison, 2016). The savings generated by the RCM system have led Maersk to launch a pilot project recently to extend the monitoring system to other types of containers.

Since September 2017 customers can view the condition of their cargo in real-time. This allows for corrective actions to be taken in case the container is not operated optimally during any of the various stages of the cold chain, from the supplier's proper pre-cooling of the cargo, to the trucker ensuring that the reefer is plugged in, from accurate performance during the ocean leg, to the correct handling at destination and to final delivery to the end-customer. Should deviations occur, the shipper notifies the customer and discusses possible corrective actions. The use of smart sensors and data analytics has enabled Maersk to expand its activities, which were traditionally focused on the physical transportation of goods across the globe, to the provision of value-added advisory services to customers.

Beyond smart sensors and AI, Maersk, in cooperation with US-owned IBM, announced in January 2018 the creation of a blockchain-based global trade digitalization platform (see Figure C.3). The platform, TradeLens, was officially launched in August 2018. It aims to connect the various parties involved in international trade in order to cut the filing, verification, processing and coordination costs associated with cross-border transportation – according to Maersk, documentation and bureaucracy can represent up to one-fifth of the total cost of moving a container.

Box C.1: Case study – How Maersk leverages digital technologies to optimize operations and reduce costs *(continued)*

Figure C.3: Maersk-IBM Global Trade Platform project



Source: White (2018).

and make the best use of their warehouses. Many start-ups are developing autonomous robots that operate alongside humans and track inventory on shelves in warehouses, factories and distribution centres.

Customers on e-commerce platforms generate vast amounts of data, which AI can use to develop prediction tools to better anticipate consumer demand. A German online retailer that uses machine-learning algorithms to predict what customers are going to buy has developed a system so reliable that it can predict with 90 per cent accuracy what will be sold within the following 30 days (The Economist, 2017b). This results in better supply management by cutting down inventory, and reduces the time required for delivery.

(iv) 3D printing may render transport and logistics costs irrelevant

Additive manufacturing, or 3D printing, has the potential to reduce transport and logistics costs radically by reducing the number of parts and components that need to be traded and by favouring decentralized production close to consumers.

3D printing has two major consequences for the organization of production and global value chains (GVCs). First, it shortens the production chain. Complex and/or customized inputs are typically produced using many parts and components, each of which needs to be designed, prototyped and manufactured separately but to fit together seamlessly. 3D printing allows such complex inputs to be produced in one piece, thus lowering the number of production steps (Section C.2(c) further elaborates on this topic). Large car and airplane producers have been extensively using 3D printing to manufacture replacement materials rapidly, while experimenting with 3D printing the entire product.

Second, 3D printing favours decentralized production strategies. Decreased reliance on specific sub-components and decreased relevance of labour costs make it easier for firms to decentralize production and thus get closer to consumers. For instance, sports shoes are 3D-printed in new automated factories in Germany and the United States. These so-called "speedfactories" are supposed to shorten the time between completion of the shoe design and its delivery to shops to less than one week (The Economist, 2017a).

Such changes in the production process lead to shorter delivery times, reduced shipping and storage costs and potential elimination of import/export costs of the final products. For customized printed objects, the potential differences between the 3D printing cost and the equivalent retail price are anywhere between eight and 80 times (DHL, 2016a).

(v) Opportunities and challenges

New technologies reduce trade costs by reducing transportation and storage costs, but also by reducing both time to transport and the uncertainty of delivery time as a result of better logistics. The costs thereby reduced represent a major share of overall trade costs, as illustrated in Figure C.2, and therefore their reduction can have a large potential impact on trade flows.[6]

A decline in logistics costs allows for a greater participation of micro, small and medium-sized enterprises (MSMEs) in international trade. Small firms trade smaller quantities than big enterprises do. This suggests that fixed trade costs, such as logistics costs, often make up a greater share of the unit cost of their goods as compared to their rivals which export larger volumes. In Latin America, domestic logistics costs, including stock management, storage, transport and distribution, can add up to more than 42 per cent of total sales for MSMEs, as compared to 15 to 18 per cent for large firms (WTO, 2016a). Low reliability and high shipping costs also represent significant barriers for US-based MSMEs exporting to the European Union (USITC, 2014). Hence, cheaper and more reliable logistics services can disproportionately benefit MSMEs.

The use of shipment and goods tracking technology provides opportunities for developing-country governments to better monitor international trade. Such technology can, for example, be used to prevent the "diversion" of export goods. Exemptions from taxes and excise duties on exports often lead traders to divert goods meant for foreign markets into domestic markets and falsely claim tax benefits. A study looking at the Kenyan export market found that tracking goods shipments not only increased tax revenues for the government, but also increased efficiency for businesses because of the reduced turn-around time for trucks (Siror et al., 2010).

For developing countries, investment in basic infrastructure will be necessary if they are to make the most of the savings that new technologies offer. In Africa, potholed roads and missing rail links cause perpetual problems. Estimates suggest that a doubling of the distance between buyer and seller increases transportation costs by four to five times more in Ethiopia and Nigeria than in the United States (Atkin and Donaldson, 2015). The problem is especially acute for landlocked countries such as Malawi, Rwanda and Uganda, where transport costs can make up 50-75 per cent of the retail price of goods. For instance, shipping a car from China to Tanzania on the Indian Ocean coast costs US$ 4,000, but getting it from there to nearby Uganda can cost another US$ 5,000 (The Economist, 2013a).

(b) Costs of crossing a border

It is not just transport infrastructure and distance which affect cross-border trade. It is also what happens at the border. Layers of procedures and customs regulations can be big impediments to the flow of goods, and this is especially true of small firms. Time and resources spent in documentary compliance can sometimes be bigger impediments to trade than traditional barriers such as tariffs.

A study by Volpe Martinicus et al. (2015) analysing the export process in Uruguay found that a 10 per cent increase in customs delays resulted in a 3.8 per cent decline in exports. The study also showed that the impact of customs-driven delays is more pronounced for sales to newer buyers, of time-sensitive goods, and to countries that are harder to reach. Table C.1 gives regional information on the time and costs spent in procedural compliance for both exports and imports. A general trend is that the poorer the region, the higher is the time spent in compliance and cost of compliance at the border. Sub-Saharan Africa has the highest cost and time spent in compliance of all regions covered in the table.

(i) Basic electronic systems reduce the time spent on customs compliance

Streamlining procedures using basic information and communications technologies (ICTs) can help reduce the costs of crossing borders. The two main tools are the Electronic Data Interchange (EDI) system and the Electronic Single Window (ESW). The EDI allows trade-related documents to be transferred electronically, while the ESW is more extensive and allows trade stakeholders to submit documentation and other information through a single point of entry to complete customs procedures. Figure C.4 depicts the variation in regional adoption of EDI and ESW systems. While many countries now use EDI systems, the use of single windows lags far behind across regions.

A study on the impact of Costa Rica's adoption of an ESW system and its impact on firms' exports found that the scheme did indeed facilitate trade.

Table C.1: Border bottlenecks according to region

	Exports		Imports	
Region	**Time spent in compliance (hours)**	**Cost of compliance (US$)**	**Time spent in compliance (hours)**	**Cost of compliance (US$)**
East Asia and the Pacific	124.1	499.6	136.1	542.4
Europe and Central Asia	55.9	305.2	53.2	279.8
Latin America and Caribbean	115.8	636.9	144.3	803.5
Middle East and North Africa	136.9	708	206.8	806.9
Organisation for Economic Co-operation and Development (OECD) high-income countries	15.1	185.3	12.2	137.2
South Asia	136.4	549.3	218.5	979.6
Sub-Saharan Africa	187.9	807.2	239.4	986.9

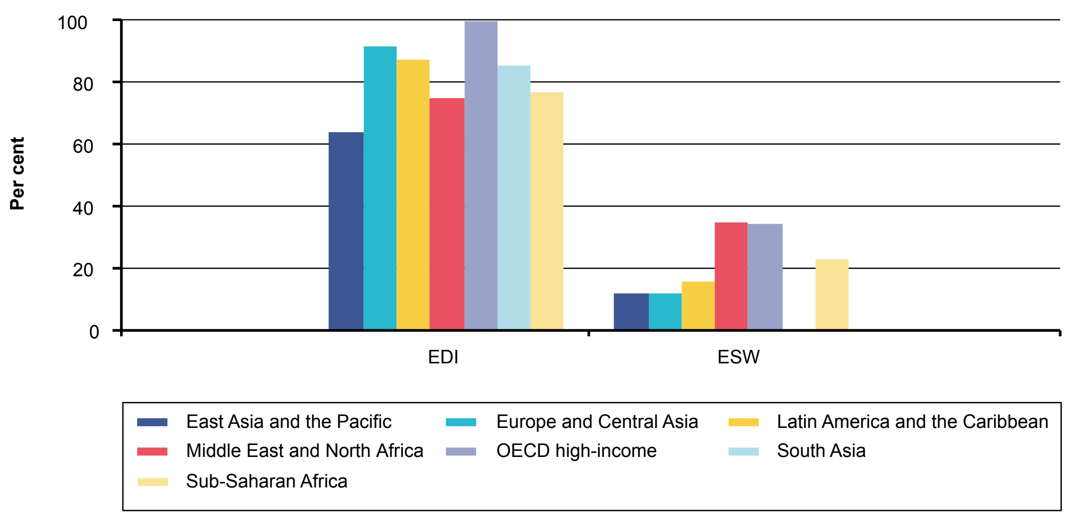
Source: World Bank Doing Business database.

Notes: Compliance includes both border and documentary compliance for a shipment of goods.

Firms whose exports were processed under ESW saw an increase of 22.4 per cent in the number of foreign buyers, and their average exports to each buyer increased by 43.5 per cent (Inter-American Development Bank, 2016). Research by the World Bank also found significant gains for economies with fully operational electronic systems for customs clearance (World Bank, 2017c). Time spent in border compliance falls by more than 70 per cent for both imports and exports when customs declarations can be submitted and processed online (see Figure C.5). This suggests that even the use of simple technologies can go a long way to reduce trading frictions and boosting the competitiveness of countries.

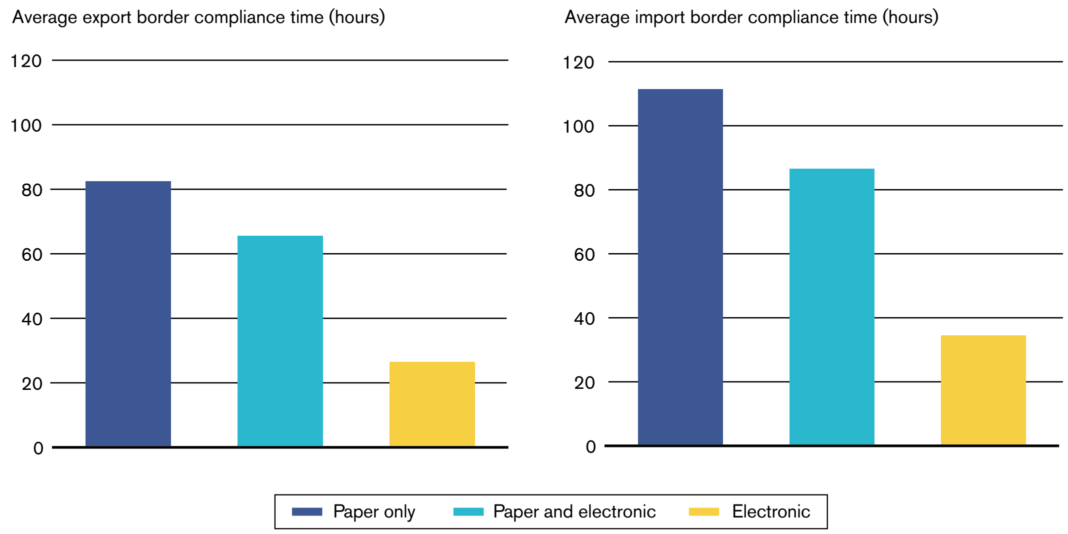
The WTO's Trade Facilitation Agreement (TFA), which came into force in 2017, aims to streamline and modernize import and export processes further by encouraging the adoption of single window systems

Figure C.4: Proportion of countries using EDI and ESW for the electronic processing of customs documents for exports in 2017, by region (per cent)



Source: Data from the World Bank Doing Business database.

Figure C.5: Gains from the digitalization of customs documentation



Source: World Bank (2017).

and simplifying customs procedures. Estimates show that the full implementation of the TFA could reduce trade costs by an average of 14.3 per cent (WTO, 2015b).

(ii) Blockchain and AI can further decrease customs compliance costs

Technology increasingly has a role to play in dealing with both the breadth and complexity of rules and regulations concerning international trade. AI is being used to help businesses deal with regulatory compliance (regulatory technology is also known as "RegTech"). For instance, AI-based software can be used to continually monitor and analyse regulatory changes, and to make recommendations to clients to ensure compliance. It does this by going through millions of pages of regulations, saving both time and monetary costs.

The distributed ledger technology could allow single windows to be administered in a more efficient, transparent and secure manner. It could help streamline customs formalities further by eliminating redundant processes, accelerate customs procedures and customs clearance, reduce costs and fraud, enhance transparency and auditability, and improve coordination between the various agencies, authorities and stakeholders involved in cross-border trade. In addition, the use of smart contracts makes it possible to automate certain processes, such as the payment of duties (Ganne, 2018).

Various organizations such as the United Nations Centre for Trade Facilitation and Electronic Business, the Convention on International Trade in Endangered Species of Wild Fauna and Flora, and the World Customs Organization are investigating the potential of the technology to facilitate cross-border trade, and several proofs of concept and pilot projects have been developed.

(iii) Opportunities and challenges

Technology can save time and resources spent on customs procedures. Digitalization has proved to decrease trade costs substantially, but inefficient customs still hamper trade, especially in manufacturing products. Figure C.2 shows that these costs account for around 6 per cent of total variance in trade costs, and this is likely only to be the lower bound because the estimates are not based on data from least-developed countries (LDCs).

New technologies, such as blockchain, promise further reductions in the costs related to crossing borders. As discussed in Section C.2, the highest potential of such new technologies lies in time-sensitive goods flows such as GVC-related trade. Furthermore, since cumbersome customs procedures are especially harmful to MSMEs, their simplification would particularly foster the entry into the export market of small firms that would otherwise only sell in their domestic markets (WTO, 2016b). Finally, decreasing the cost of crossing borders has the largest potential to boost both imports and exports in developing countries where these costs are currently the highest.

While preliminary findings on blockchain are promising, more work is needed to explore fully the potential of the technology and how it can be integrated with existing customs systems. In addition, a number of technical and regulatory challenges still have to be overcome before the technology can be used to its full potential, including the lack of interoperability of various platforms, the legal status of smart contracts, and liability issues. This is discussed more fully in Section C.1(c)(v).

In spite of these challenges, the potentially significant opportunities that the use of the distributed ledger technology opens to digitalize cross-border trade and cut related costs has led key private players in the field of logistics and information technology (IT) to launch a global trade platform based on blockchain technology that has the ambition to connect all parties involved in cross-border trade and to completely digitalize and automate transactions (see Box C.1).

(c) Information and transaction costs

Long-distance trading with partners from foreign countries is difficult because it is harder than with local partners to find information about potential buyers and sellers, their products and product quality. It is also harder to ascertain reputation, verify information and enforce contracts.

When trade costs are high, firms cannot take advantage of price differences across markets. Consequently, a lack of trade is manifested in a high spatial dispersion of prices. Several economic studies use this fact to investigate the potential of technology to boost trade. They show that easier access to market information through even relatively simple technology, such as mobile phones, decreases spatial variation in prices in developing countries, and especially in agricultural markets (Bernard et al., 2007; Aker and Mbiti, 2010). In particular, a study analysing agricultural trade flows in the Philippines finds that approximately half the observed price dispersion across islands is due to search rather than transport costs (Allen, 2014). It also documents a known fact that larger farmers are better able to overcome these costs and thus are more likely to "export" to other islands. The authors then show that easier access to market information, through introduction of mobile phones, especially benefited small farmers, as more of them started to engage in inter-island trade.

Reputation and trust are crucial for success in any trade transaction and even more so in trading across borders where reliance on contract enforcement institutions may be limited. Startz (2017) shows that to overcome search and transaction costs, businessmen in Nigeria often choose to travel in order to import goods from a remote location, which makes importing very costly. Startz argues that facilitating searches for information and ensuring that contracts are respected can have a large impact on the volume of and gains from trade. This is especially important for developing countries due to weak contract enforcement institutions, limited access to IT and small firm sizes in those countries.

Selling and buying internationally also requires international financial transactions. Currently, cross-border transactions are almost exclusively handled by banks through correspondent banking, whereby local banks carry out transactions on behalf of each other, as many banks do not have local presence. Banks' share of the cross-border transactions market in business-to-business (B2B) and business-to-customer (B2C) transactions is more than 95 per cent[7] (McKinsey & Company, 2016). Large banks have a monopolistic share of this market segment because of the extensive regulatory compliance framework involved, lack of alternatives and the cost of maintaining large correspondent banking relationships. Consequently, cross-border B2B transactions can be around 10 times more expensive than domestic ones.[8]

(i) Online platforms help to overcome the lack of information and trust in cross-border transactions

As discussed in Section B, online platforms help to reduce the costs of matching buyers and sellers, of obtaining market information and of supplying information to potential consumers. Such platforms can thus help to boost participation in international trade even more than in domestic trade, and provide mechanisms such as feedback and guarantees that improve consumer trust in online sellers.

A long-standing way in which firms can provide credible information about their quality has been by developing their reputations in the form of a brand. Digital marketplaces involve thousands of small players who are often unfamiliar to potential customers. These marketplaces have thus developed alternative mechanisms to brand-based reputations to overcome asymmetric information about quality and trustworthiness that are alternatives to building a brand. The most common such mechanism is an online rating system, in which ratings from past buyers and sellers are posted for future market participants to see. Another key application is to provide information on product quality. Rather than enhance information about a particular seller, ratings can inform consumers about the best products available within a platform.

Alibaba's own research on its platform suggests that reputation plays a leading role in the performance of exporters, exceeding the impact of observable product quality. A better reputation enables exporters to achieve greater export revenues and volumes as well as a larger number of buyers and markets (Chen and Wu, 2016). Online rating platforms can also significantly affect traditional services markets. Luca (2016) shows how online restaurant reviews impact restaurant demand, particularly for independent restaurants. This suggests that online rating systems help smaller business overcome the necessity to develop a brand (in the way that restaurant chains do) as a means to establishing a reputation.

Online platforms have also ushered in the "sharing" economy and have transformed the tourism services trade. Lodging and transportation arrangements are increasingly mediated through platforms rather than through traditional channels such as travel agencies. Furthermore, sharing platforms expand services markets by allowing physical assets to be disaggregated and consumed as services. The services of apartments, cars and boats are now frequently sold by private owners directly to consumers without the use of traditional intermediaries. Online platforms' inbuilt rating and recommendation systems help establish the trust that underpins their success. Sharing platforms like California-based Airbnb have also expanded markets, such as the accommodation market, by increasing accommodation options in areas and at times where traditional accommodation services are scarce.[9]

(ii) The IoT and blockchain may simplify verification and certification procedures

New technologies offer better and cheaper ways to ensure trust through certification and verification of origin. Electronic traceability systems in supply chains that make use of the IoT and distributed ledger technology (i.e. blockchain) provide new ways for companies to prove the source and authenticity of products. Various initiatives already exist to provide supply chain transparency and prevent counterfeiting. Applications range from pharmaceuticals to luxury items and from diamonds to electronics. In the fair trade market, the UK-based social enterprise Provenance relies on distributed ledger technology, combined with smart tagging, as a means to prove the source of food products, as well as all the places they have passed through before they reach the consumer. The company has run a successful pilot project tracking the provenance of tuna in Indonesia with verified social sustainability claims.

(iii) Real-time translation and online platforms bring down language barriers

Economic literature has long identified how important communication barriers are for international trade (Harris, 1995). Based on a meta-analysis of academic studies concerning the effects of language on international trade, Egger and Lassman (2012) find that a common (official or spoken) language increases trade flows directly by 44 per cent. When trading partners are linguistically distant and their language differences are very pronounced, they are likely to trade little with each other (Isphording and Otten, 2013). In a survey of online shoppers by Eurobarometer, 42 per cent stated that they never made purchases online in a foreign language, while 56.2 per cent said that obtaining information in their own language was more important than the price. A survey by Gallup (The Gallup Organization, 2018) points towards similar preferences.

In recent years, the internet has played a prominent role in breaking down language barriers across the board. The abilities of technology are not limited to text translation anymore. The availability of software performing real-time interpretation (such as Skype Translator, which performs near real time interpretation on online calls) reduces the importance of language barriers. This opens up trade opportunities, especially for small businesses that tend to have less developed language skills. A Eurostat survey from 2017 asked companies whether the lack of knowledge of foreign languages was an obstacle to e-sales. Among medium and large enterprises, 5 per cent of those with e-sales to other EU countries and 11 per cent of those with e-sales outside the European Union replied positively. Among small enterprises, the shares were higher, reaching 6 and 14 per cent, respectively.

Another channel through which the internet has facilitated the breakdown of language and communication barriers is through e-commerce platforms. These platforms minimize the importance of language in two ways. First, they minimize the need for one-on-one interactions between buyers and sellers, making translation redundant. Second, they allow customers to search for goods in their own language, irrespective of where the seller is located. Empirical studies corroborate this impact. A study by

Brynolfsson et al. (2018b) found that the introduction of a machine translation system on eBay increased exporty by 17.5 per cent.

(iv) E-commerce platforms and mobile banking facilitate cross-border payments

E-commerce platforms have developed their own payment systems for cross border e-commerce transactions. By creating in-house payment systems, they are able to further facilitate the exchange of goods and services on their platforms. They circumvent the corresponding banking infrastructure, which results in quicker processing times and no processing fees. This also means that the efficiency of international transactions almost mirrors domestic ones. Chinese Alipay, American Amazon Pay and PayPal are a few examples of payment systems that either are or were affiliated to e-commerce giants.

Mobile banking companies target cross-border payments, especially in certain African countries, where access to traditional banking services is limited and ordinary money transfer operators charge high transaction fees. In March 2015, Kenya's main mobile phone operator partnered with its counterpart in Tanzania to launch a cross-border money transfer system, allowing customers to send and receive money at the same rate as sending money locally. While these services are essential for remittances, they also facilitate business transactions; the value of mobile payments reached 47 per cent of the Kenyan gross domestic product in 2017 (Central Bank of Kenya, 2017).

(v) Blockchain could further reduce the cost of cross-border financial services

An increasing number of start-ups are leveraging distributed ledger technology with a view to further reducing the cost of cross-border payments, in particular transaction fees, exchange rate costs and costs related to correspondent banking. A US start-up, Circle (https://www.circle.com), provides blockchain-based cross-border payment services for zero fees and a zero exchange rate mark-up. The company, which started in the United States before moving to Europe, recently entered the Chinese market with the aim of connecting Chinese consumers to the rest of the world. Another US-based company, Ripple (https://ripple.com), has ambitions to circumvent the correspondent banking model through its distributed ledger platform. It gives banks the ability to convert funds directly into different currencies in a matter of seconds and at little to no cost, without relying on correspondent banks. The company has licenses with more than 100 banks and financial institutions, but it seems that only a limited number of large operations have taken place to date. Banks are still testing the system.

Numerous start-ups, many of which are based in developing countries, are also proposing cryptocurrency-based global payments. Whether these applications will further drive down the cost of cross-border payments depends on the cryptocurrency used, as average transaction fees can vary from zero to more than US$ 7 (Ohnesorge, 2018), not to mention that most cryptocurrencies are extremely volatile. Furthermore, a disadvantage of cryptocurrency cross-border payments is the need for an internet connection, while mobile payment systems only require a mobile phone; this is an important consideration in developing countries.

Beyond the multitude of start-ups that are exploring how blockchain technology can potentially drive down the cost of financial services, including cross-border payments, an array of well-established financial institutions is investigating the potential of distributed ledger technology to streamline payments for international trade. Various consortia have been formed, the most well-known of which is R3 (https://www.r3.com). The consortium, which started in 2015 with nine financial companies and now counts over 100 banks, insurance companies, financial institutions, regulators, trade associations and technology companies as members, announced in October 2017 that it was launching a cross-border payments platform. The platform aims to provide faster and more efficient execution of cross-border payment transactions. Several multinational financial services companies are also launching or piloting their own private blockchain-based cross-border payment platforms.

Beyond initiatives to digitalize payments for international trade, distributed ledger (i.e. blockchain) technology could open new prospects to digitalize trade finance. Trade finance entails a credit or a guarantee operation, implying deferred payments. Experiments in this field aim to digitalize the movement of documents necessary for the credit and element of guarantees to proceed – and to link the financial intermediaries, the exporters and importers, and the merchandise (the collateral in many cases) together digitally (see Box C.2).

(vi) Opportunities and challenges

New technologies and online platforms help to reduce the costs of searching for trade partners and obtaining relevant market information. They also provide

Box C.2: Blockchain and trade finance

The importance of finance and external credit is higher for firms selling internationally compared to domestic retailers. This is both because of the high fixed and variable cost of selling abroad, and because international transactions are more complex and less enforceable, implying the need for credit insurance (WTO, 2016b).

Banks are currently investing significantly in distributed ledger technology with a view to digitalizing financial transactions related to trade, in particular letters of credit and supply chain finance. Regarding the latter, the objective is to digitalize the cascade of payables and receivables between buyers and suppliers within existing supply chain relations. The use of the blockchain technology could enlarge the potential scope of supply chain finance by making it easier and less risky to process B2B payments between companies that do not have a pre-established relationship. Some start-ups already offer blockchain-based, real-time 24/7 B2B payment solutions that bypass letter-of-credit processes.

In regard to letters of credit, the aim is to improve the security of transactions which involve several players (e.g. an importer, an exporter and their respective banks) and many documents (e.g. customs documents and bills of lading). Currently, the issuance, verification and endorsement of letters of credit is still a very labour- and paper-intensive process, employing a large number of people in the trade finance industry. One of the largest banks specialized in global trade transactions reviews up to 100 million trade documents per year, which are necessary to validate letters of credit. Over the past few decades, consortia of banks have invested massively in software-driven projects aimed at developing platforms to digitalize payments and information, but little has been done until recently to digitalize the transactions themselves.

Distributed ledger technology, which enables the transfer of assets in a secure manner, while increasing traceability and the potential speed of transactions, seems to open new opportunities in this respect and is viewed with hope by an industry eager to gain on processing costs, functionality and security in financial and payment transactions related to trade. Given the very large flows involved in trade finance, proofs of concepts using blockchain technology are being developed and tested in all dimensions of existing transactions. Some of them are yielding promising results in terms of increased efficiency and reduced costs.

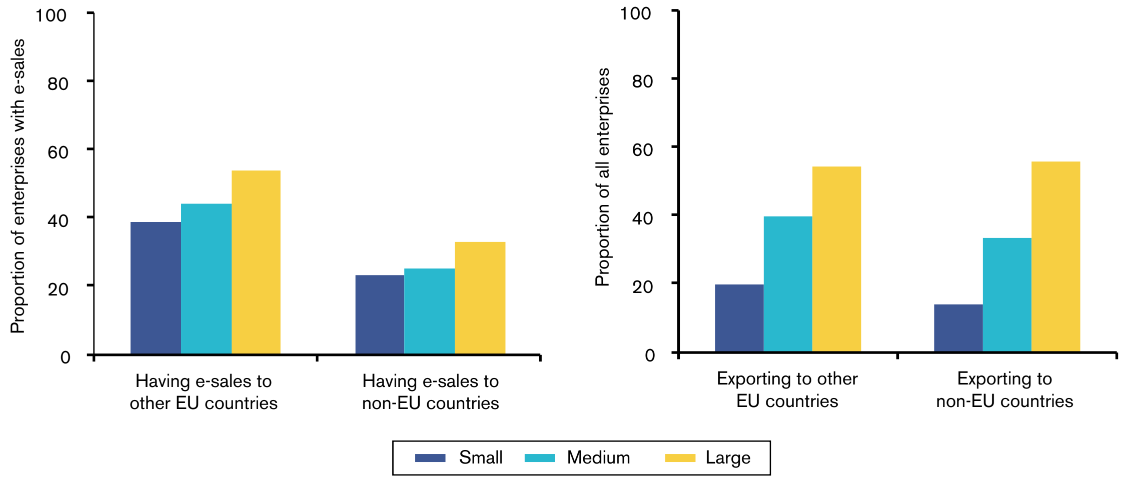
Experiments and proofs of concepts have been ongoing for several years, but doubts remain about whether the technology is best suited for trade finance transactions. Currently, compliance of documents with International Chamber of Commerce (ICC) rules – the ICC currently provides for the legal and professional rules standardizing letters of credit and other trade finance instruments internationally – leads to automatic provision of a letter of credit with legal obligor status, with the Society for Worldwide Interbank Financial Telecommunication (SWIFT) providing the payment channel to do so. By contrast, under blockchain transaction technology, there is still considerable uncertainty regarding the professional and legal standards applying to trade finance transactions, for example: who has liability at what point of the transfer of data and payment; when is obligor status confirmed; and who are the recourse authorities. Ensuring the interoperability of various blockchain platforms is another challenge. Indeed, the proliferation of blockchain projects in recent years has led to a large number of currently non-compatible blockchain platforms which apply different standards. The ICC recently created a working group to look into the "digital island problem".

Ultimately, whether blockchain will succeed in digitalizing trade finance will depend on whether current regulatory challenges are effectively tackled and whether the benefits associated with the use of the technology outweigh the costs of moving away from existing systems – which simply entail sending digital versions of documents. The current system may be costly, paper-intensive and burdensome, but it is efficient in terms of legal protection. The jury is still out.

mechanisms such as feedback and guarantees that improve consumer trust in online sellers and therefore bridge contract enforcement issues related to different legal institutions. Figure C.2 shows that information and transaction costs follow transport costs closely in their importance for the goods trade and constitute the most important trade obstacle in services trade.

Services offered by online platforms facilitate the direct participation of MSMEs in export activities. For example, Lendle et al. (2013) demonstrated that in the United States, 85 per cent of eBay sellers were merchandise exporters, while among all manufacturing firms only 18 per cent of firms exported. This point is also illustrated in Figure C.6

Figure C.6: Share of exporters among European enterprises with e-sales and overall, 2015 (per cent)

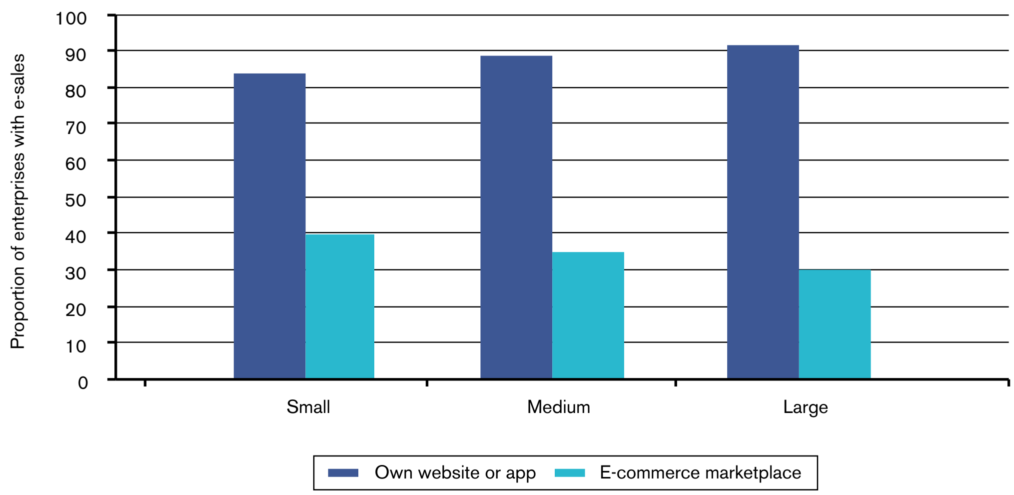


Source: Eurostat.

Notes: Data on e-sales are not available for enterprises with less than 10 employees. Small enterprises are therefore defined as those with 10-50 employees. Medium enterprises have 50-250 employees and large enterprises have more than 250 employees. E-commerce enterprises are those that received at least one e-commerce order in that year. The shares of all enterprises that export relate to merchandise exports only.

which shows that the disparity between small and large European firms in export participation is much smaller for e-sales. Finally, the importance of online platforms for smaller firms is illustrated in Figure C.7 which shows that, among firms with e-sales, the use of e-commerce marketplaces decreases with size, while the use of own website or app increases with size. Many of the services offered by online platforms have traditionally been supplied by large wholesalers and retailers, which act as export intermediaries and facilitate indirect exports for smaller firms. However, with the development of online platforms, even smaller firms can participate in international trade directly.

Figure C.7: Share of European enterprises with e-sales that use e-commerce marketplaces as opposed to their own website or app, 2015 (per cent)



Source: Eurostat.

Notes: Enterprises with e-sales are those who sell their products via their own website or app, or via an e-commerce marketplace. Data on e-sales are not available for enterprises with less than 10 employees. Small enterprises are therefore defined as those with 10-49 employees. Medium enterprises have 50-249 employees and large enterprises have more than 250 employees.

The decline in information and transaction costs holds especially large potential for firms in developing countries which tend to face higher costs for obtaining information and guaranteeing transactions. Easier verification procedures and guarantees also improve the potential for agricultural firms to enter and to upgrade within global supply chains (WTO, 2016b). New technologies enabling the electronic exchange of relevant information, such as food safety requirements, provide opportunities for producers to connect with new, high-value markets. There is also evidence that the easier access to information and the reduced need for face-to-face interactions that digital trade allows facilitate the increased participation in trade by women (see Box C.3).

The expansion of e-commerce can bring substantial benefits to small agricultural producers as well as to consumers living in remote areas. A study by Couture et al. (2018) shows that e-commerce trading access decreases prices and increases product variety for consumers in rural Chinese areas. Furthermore, it has the potential to increase business opportunities for local sellers, particularly in rural communities. For small agricultural producers in particular, e-commerce provides an opportunity to gain direct access to more consumers and renders prices more remunerative, as intermediary costs are eliminated. However, business training, access to credit, targeted online promotions and effective distribution networks are a necessary condition for these economic gains. While the study focuses on domestic e-commerce

Box C.3: How digital technologies empower women

E-commerce platforms, online work platforms and online payments are especially empowering to women's participation in trade. Given that time and mobility constraints are often greater for women, particularly those with children, technological developments like e-commerce can have an important impact on women's work. E-commerce enables women to run their businesses while managing household obligations, and to reach a much vaster market than they could offline.

In addition, digital solutions reduce searching costs between buyers and sellers and remove the need for face-to-face interactions, thus allowing more women to overcome the traditionally male-dominant trade network. Thus, digital platforms help women to work and build companies in cultures where they are expected to stay at home and where they lack men's professional networks and resources (World Bank, 2016).

There is some empirical evidence to suggest that women benefit more from digital trade than men. For example, a 2015 survey of Pacific Island exporters showed that firms that are active online have a greater concentration of female executives under 45 years of age (DiCaprio and Suominen, 2015). A survey by Etsy, an online platform for creative commerce, indicates that 86 per cent of Etsy sellers in the United Kingdom are women (Etsy UK, 2017). A survey by the International Trade Centre (ITC) also shows that the share of firms owned by women doubles when moving from traditional offline trade to cross-border e-commerce. In Africa, three out of four firms trading exclusively through e-commerce are identified as being owned by women (ITC, 2017).

In addition to e-commerce, digital payment technology has the potential to address women's preferences in new and different ways compared to traditional financial services. In Niger, evidence from the social cash transfer programme demonstrates that the greater privacy and control of mobile transfers compared to manual cash transfers shifts intra-household decision-making in favour of women (Aker et al., 2016). Technology-enabled crowdfunding platforms allow women to access trade finance. In China, the top funded industry sectors through peer-to-peer (P2P) consumer lending are in the retail and wholesale trade sectors, and 35 per cent of the fundraisers on the P2P consumer lending platforms are female (Cambridge Centre for Alternative Finance and The Australian Centre for Financial Studies, 2017).

The WTO and its various partner agencies strive to promote gender equality through development assistance programmes. For example, through a project financed by the Standards and Trade Development Facility (STDF), improvements in pest management in Uganda's flower sectors helped to raise the livelihood of the majority of women workers dependent on flower exports. The ITC also launched the "SheTrades" initiative, which seeks to connect one million women entrepreneurs to markets by 2020. Through the SheTrades app, women entrepreneurs are able to share information about their companies, increase visibility, expand their networks, connect and do business internationally.

expansion, its implications are also valid for cross-border e-commerce.

Innovations in cross-border payment systems have also had their largest impact in developing countries and for MSMEs. Starting with e-commerce platforms that ensure safe transactions, all the way to ambitious projects to circumvent traditional payment systems, these new developments bring down the transaction costs of cross-border trade, which are much more important for MSMEs than for larger firms because of their small scale, even more so in developing countries where traditional banking and financial services are available to few.

Access to finance is an acute problem for MSMEs: over half of trade finance requests by MSMEs are rejected, against just 7 per cent for multinational companies (WTO, 2016a). A survey by the United States International Trade Commission (USITC) finds that 32 per cent of US manufacturing MSMEs cite obtaining finance as a leading impediment to trade. Innovative solutions in providing trade credit are therefore essential for MSMEs to participate in international trade and underpin MSMEs' ability to benefit from all the opportunities discussed previously in this chapter.

While new technologies and big data offer many opportunities for firms to organize their production and reach consumers more efficiently, there are also challenges.

An increasingly large share of cross-border transactions does not face any international trade costs, except those caused by regulation. These include internet-enabled services such as web-search or communication services, digital intermediation services such as distributional services, travel services or P2P transactions. Measures that hinder cross-border data flows may therefore hinder the expansion of digital trade. These include, for instance, local data and server requirements, restrictions on payment methods, or requirements to give access to commercial source code or encryption keys as a prerequisite to enter a market (Ciuriak and Ptashkina, 2018a; European Parliament, 2017).

According to some estimates, blockchain technology could reduce banks' infrastructure costs attributable to cross-border payments, securities trading and regulatory compliance by between US$ 15-20 billion per annum by 2022 (Santander et al., 2015). However, if they are to be valid alternatives to the existing correspondent banking system, blockchain applications for cross-border payments will have to connect all currencies and financial institutions worldwide – "a massive undertaking" as McKinsey notes in a 2016 study (McKinsey Global Institute, 2016). Regulatory uncertainties, including liability issues and the lack of interoperability of existing platforms, remain challenges that stand in the way of widespread deployment of the technology. Until these are addressed, key players providing for legal security to a very large market of US$ 2 trillion annually will not commit (Manders, 2017). Although the technology holds interesting promises to cut a variety of costs associated with cross-border payments, its disruptive effect will only be felt if and once these challenges are addressed.

Other services, such as logistics and transport services, are also important determinants of the impact of digital technologies on goods trade. The role of digital platforms in lowering trade costs, for instance, can only go so far in markets where uncompetitive transport services result in exorbitant transport costs. Efficient services markets, therefore, are a necessary pre-condition to reaping the benefits of digital technologies.

Finally, e-commerce has engendered a rapid growth in cross-border shipments of small, low-value parcels that would previously have crossed borders in large shipments destined for local distribution centres (UNCTAD, 2017a). This may overburden customs and lead to delays at the border (see Box C.4).

(d) Trade policy and regulatory barriers

Regulatory compliance features prominently among trade policy barriers. Consumers demand assurances about basic standards and trade authorities need to ensure that imported products comply with national regulations, giving rise to a wide range of non-tariff barriers to trade. While regulatory harmonization and mutual recognition lessen the compliance burden, non-tariff barriers remain significant. Furthermore, new regulatory concerns about environmental, chemical and biosecurity standards are being reflected in international trade agreements and are translating into more regulatory requirements at the border. This compliance burden becomes multiplied in complex supply chains and, according to a survey by the USITC, affects both large firms and MSMEs (USITC, 2010). Product certification, product testing and inspection requirements represent more than half of all firms' complaints about TBT or SPS measures in developing countries (WTO, 2012c).

The adoption of electronic single window systems and electronic certificates can significantly reduce the time and resources spent in regulatory compliance. For instance, digital technologies can

Box C.4: E-commerce and the "parcellization" of trade

Cross border e-commerce accounted for 15 per cent of e-commerce merchandise sales in 2015. It is expected to grow at nearly twice the expected growth rate of domestic e-commerce, by 25 per cent annually until 2020, and account for 22 per cent of global e-commerce merchandise sales in that year (DHL, 2016b). Figure C.8 shows the growth in the number of parcels sent domestically and internationally by postal services since 2000 with the latter growing nearly threefold over the period.

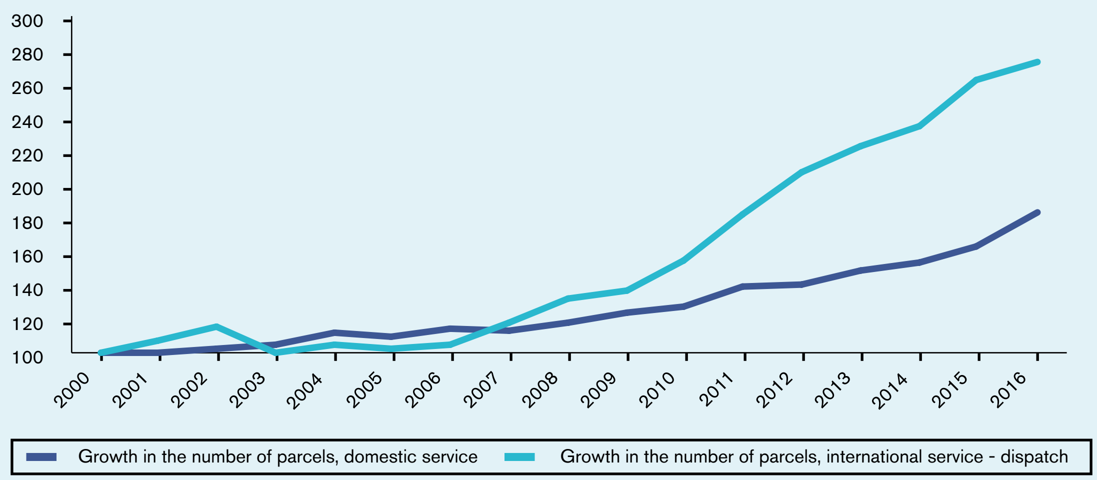
The reason behind this trend is that the number of cross-border B2C online transactions is increasing, while their average value is decreasing, generating more frequent international flows of lighter and cheaper parcels. For instance, 84 per cent of cross-border goods purchased online weighed 2kg or less, and almost 60 per cent of them cost less than EUR 50 in 2017 (IPC, 2018), while 46 per cent of respondents to the 2017 IPC Cross-Border E-commerce Shopper Survey stated that received parcels have been small enough to fit into their mailbox.

While e-commerce may provide new opportunities to export for retailers, and a wider choice and lower prices for consumers, it comes with its own set of challenges. The overwhelming quantity of e-commerce parcels is a big challenge for customs authorities. Their clearance systems are designed to tackle large container shipments, not small parcels. An increase in volume of shipments is sure to stretch customs authorities around the world, especially the ones with outdated infrastructure. Customs officials in Uzbekistan and other Central Asian states using paper-based systems have complained about the large inflows of small shipments (OECD and WTO, 2017). Time delays at the border would not just hurt e-commerce firms, whose business models revolve around fast deliveries, but also impact flows of traditional goods, as customs' resources would be thinly spread.

All other border agencies are also struggling to deal with this relatively new phenomenon, including those in charge of sanitary and phytosanitary (SPS) measures, technical barriers to trade (TBT), cultural goods, counterfeit items, drug trafficking, weapons, money laundering, endangered species or invasive alien species. For instance, the US Drug Enforcement Administration has warned that illicit drugs enter the United States on a large scale through online sales delivered by postal services (DEA, 2016).

Solutions have started emerging from both private sector and governments. The most ambitious initiative is from Alibaba, which has plans to create a network of digital free trade zones, which would enable MSMEs to sell goods across borders with zero import duties and speedy customs clearance. The first such zone opened in Malaysia in 2017, to facilitate e-commerce trade between that country and China. Logistics firms are also trying to make cross-border shipments more efficient. Another approach that has been taken by the largest companies is to set up what they call "fulfilment centres". Making use of big data analytics, they can anticipate demand for particular products, export them in the traditional way, import them and keep them in warehouses of the importing country. This way, they can very quickly ship products directly to consumers. One recent variation of this model is keeping the products in free zones and importing the small shipments after each order.

Figure C.8: Growth in the number of parcels sent by postal services, 2000-16 (per cent)



Source: Universal Postal Union data

Note: Each series is an index of the number of parcels that is standardized to 100 in the year 2000.

Box C.4: E-commerce and the "parcellization" of trade *(continued)*

Governments are making efforts to create parallel systems for customs clearance by diverting inflows of high-volume small parcels to alternate channels. One policy used to address the issue is increasing the *de minimis* value, which is the value under which shipments qualify for duty-free treatment and simplified customs clearance. While the reduction of the workload for governments is the main argument for increasing *de minimis* levels, there are challenges that this solution brings such as the increased need to manage illegal traffic. Information-sharing between customs authorities and e-commerce firms for better risk assessment is crucial to reduce the risk that harmful or counterfeit products slip by under a higher *de minimis* threshold. A survey by the World Customs Organization (WCO) found that 53 per cent of respondent countries already had such a system in place. The best solutions are not yet clear and are subject to ongoing efforts and discussions, for instance in the WCO's Working Group on E-Commerce.

play an integral part in ensuring that products meet the relevant SPS standards in export markets as they move through GVCs. Preliminary experience with SPS e-certificates indicates that transitioning to automated certification systems can reduce the time spent on processing and transmitting data, leading to increased exports and private sector savings (see Box C.5). Electronic certification can also decrease incidences of fraudulent certificates and increase transparency, strengthening trust among trading partners and connections along the value chain.

2. Changes in trade patterns

Digital technologies have transformed economic activities domestically and internationally, reducing trade costs and affecting patterns of trade. The following analysis highlights the trade dimension of digital technologies, shedding light on the changing composition of trade in goods and services, the determinants of comparative advantage and the effects of digital technologies on the international organization of production along GVCs.

(a) Changing sectoral composition of trade: what will be traded?

The wide adoption of digital technologies changes the composition of trade in different categories of goods and services, while redefining intellectual property rights (IPR) in trade. This section begins with an analysis of the impact of digital technologies on services trade, and subsequently discusses the effect on the composition of trade in goods. It also briefly touches upon the relationship between IPR and trade. In cases where digital technologies affect trade in both goods and services, the impacts will be discussed in turn.

(i) Growing importance of services trade

Services sectors are at the centre of the recent technological revolution. On the one hand, technological advances have enabled a growing array of services to be supplied digitally across borders. On the other hand, services form the rapidly evolving digital infrastructure that enables services to be supplied electronically and goods and services to be purchased online. These two facets of services, as enablers of digital trade and products supplied by means of digital technologies, have significant impacts on trade. This section illustrates how digital technologies now facilitate trade in services, either through the reduction of communication and transaction costs or by reducing the need for spatial proximity.

Contrary to the production of physical goods, the provision of services often required intensive direct communication between customer and service provider. Furthermore, some services that alter the physical condition of an object or person, such as hairdressing, required physical proximity. This requirement for spatial proximity, sometimes referred to as the bundling of labourer and labour (Baldwin, 2016), has hindered many services from being traded across borders.

Many services are delivered through communication networks. As digital technologies such as voice over internet, email and online platforms are significantly reducing international communication costs, delivering services over distances becomes cheaper, and therefore it is much easier to supply services overseas, enabling countries to specialise in sectors of their comparative advantages.

Furthermore, digital technologies have reduced the need for physical proximity by innovating the process of service provision. The WTO's General Agreement on Trade in Services (GATS) defines the services trade as spanning the following four modes of supply:

Mode 1 – Cross-border supply trade, Mode 2 – Consumption abroad, Mode 3 – Commercial presence (i.e. FDI), and Mode 4 – Presence of natural

Box C.5: E-certification and electronic traceability of agricultural products

New technologies and innovations have transformed agricultural production and the management of SPS risks within supply chains.

The Standards and Trade Development Facility (STDF)'s global partnership brings together trade, health and agriculture experts to address SPS challenges and drive forward joined-up solutions to boost safe trade, contributing to the United Nations' 2030 Global Goals for Sustainable Development. Many of these solutions draw on new technologies and digital tools. For instance, in Nigeria, the STDF is helping to develop a digital system to support pest surveillance, seed certification and traceability. In Guatemala, an STDF project developed an electronic traceability system for the honey value chain. In the Asia-Pacific region, countries are benefitting from an STDF project to strengthen information systems for pest surveillance and reporting with a view to facilitating trade.

Other ongoing STDF work is advancing the use of electronic SPS certification to facilitate safe trade and reduce transaction costs. The STDF's ePhyto project is setting up a new system for the electronic exchange of phytosanitary certificates, based on a harmonized exchange tool or "hub". Developing countries will benefit from a generic off-the-shelf system to facilitate their use of ePhyto. Following the launch of a new electronic phytosanitary certification system in Kenya in 2011, more than 892,000 ePhyto certificates were issued in the first five years, helping to increase government revenues by 75 per cent. The new system resulted in more efficient service delivery by the Kenya Plant Health Inspectorate Service (KEPHIS), and industry benefitted from time savings and better communications. Kenya's SPS reputation improved, with higher levels of trust among trading partners and greater confidence in the authenticity of Kenya's certificates.

Another STDF project is assessing the use of e-certification for trade in animals and animal products to identify how veterinary authorities in developing countries can benefit. Initial results show that transitioning to automated certification systems reduces the time spent on processing and transmitting data, leading to increased exports and private sector savings.

These experiences show how technologies can help developing countries to access lucrative regional and international markets, and can contribute to sustainable economic growth and poverty reduction, in line with the STDF's aims. They also offer valuable lessons on the benefits of expanding the use of digital technologies so that more developing countries can benefit. Giant leaps forward have been made possible by modern solutions like the IoT and blockchain. However, concerns remain about a widening inequality across countries in terms of connectivity, access to new technologies and the skills to apply them.

persons. The wide adoption of digital technologies has reduced trade costs for services and renders some services easily deliverable across borders (i.e. Mode 1), rather than via the presence of commercial entities or natural persons (i.e. Modes 3 and 4).

Finally, new developments in the field of remotely controlled robotics have opened new ways to trade in services and may continue to grow. Although such technology is relatively costly at present, lower-priced robots controlled over internet connections could have significant consequences for international trade in the future.

Reduction in trade costs increases trade in some services

Measured on a balance-of-payments (BOP) basis, trade in services now accounts for 23 per cent of total trade in goods and services, compared to 18 per cent in 1995.[10] The strong growth of trade in services is largely a result of the internet revolution. Studies have found that greater internet penetration and usage are associated with higher levels of trade in services, both in terms of exports and imports (Choi, 2010; Freund and Weinhold, 2002).

What services are digitally deliverable? Lanz et al. (2012) point out that digital technology makes those services that consist of routine codifiable tasks (e.g., performing calculations, checking a document for spelling errors) especially tradeable across borders. Looking at the phenomenon of business process offshoring, Blinder and Krueger (2013) estimate that 25 per cent of all US jobs held in 2008 could potentially be provided by workers abroad. They find that jobs in the finance, insurance and information service sectors, as well as technical and professional services, can be provided remotely.

A report by UNCTAD identifies a list of "ICT-enabled services", which is aggregated into different services sectors in Figure C.9. Consistent with what has long been observed in services trade, the services that can be delivered remotely over ICT networks are telecommunications, sales and marketing, insurance and pensions, finance, and intellectual property (IP) services. Many of these service sectors have indeed been leaders in adopting ICT technologies in the past decades.

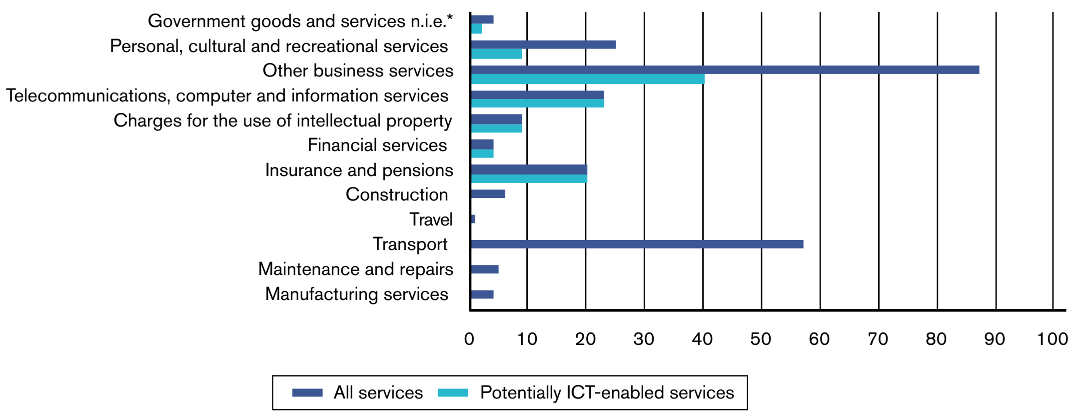
Technological advances and increased cross-border tradability have led to significant changes in the composition of trade in services. The fastest growing service exports since 2005 are digitally-enabled services such as telecommunications, computer and information services, other business services and financial services. Figure C.10 shows that trade in these service sectors is growing much faster than traditionally traded services such as travel or transport. This is not surprising, as digitally-enabled services have benefited significantly from the increased efficiency of digital networks arising from technological advances. The cross-border supply of these services offers potential for new export opportunities and for export diversification. Figure C.11 illustrates the evolution of services trade: since 2014, trade in potentially digitally-enabled services has accounted for more than half of total trade in services.

Beyond the effect of lowering communications costs, digital technology opens up new channels through which services can be delivered. Services that require more than just timely communication over the internet or phone are now tradable across borders through innovative business models that leverage digital technology.

The United Kingdom's National Health Service provides a list of online mental health services that provide access to moderated support groups and personal counselling with professional therapists directly via instant messaging or a webcam (National Health Service UK, 2018). In the field of legal services, some law firms are replacing brick-and-mortar offices with online platforms to which private clients can connect via the internet. Rocket Lawyer is an internet platform that provides free legal documents and connects lawyers to private and small enterprise customers, with the aim of reducing search costs and complexity for customers who seek legal advice (The Guardian Labs, 2017). As a consequence of the technology, clients can choose lawyers based on their qualifications rather than their geographical location.

In the education sector, digital technology has created virtual classrooms that relax geographical constraints and enable the delivery of massive open online courses (MOOCs) to students worldwide via video recorded lectures, digital slides, digital problem sets and online fora. Class Central (2017) an online catalogue of MOOCs, counts 81 million MOOC students worldwide. In comparison, around 20 million tertiary-level students are currently enrolled

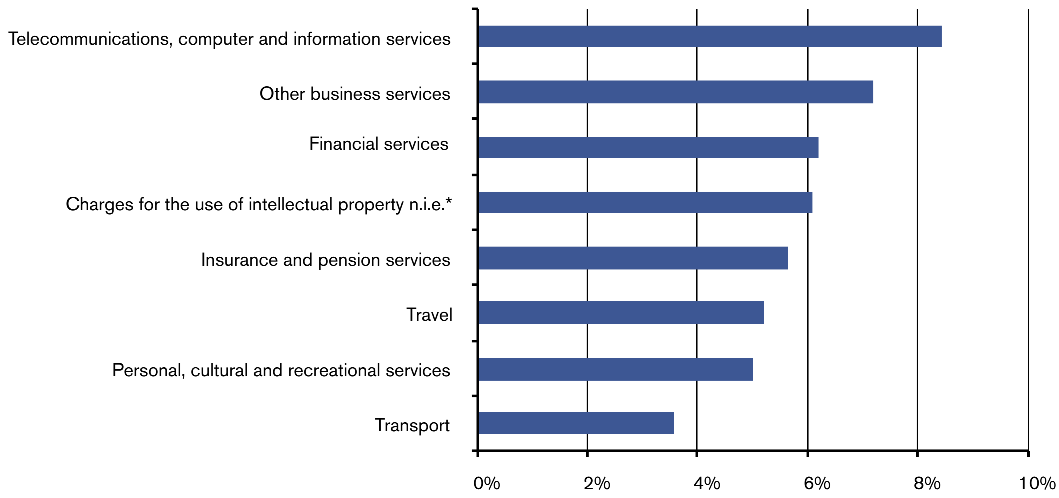
Figure C.9: Approximation of potentially ICT-enabled services by sector (per cent)



Source: Figure 1 in UNCTAD (2015), derived from UNSD "Correspondence between the EBOPS 2010 and the Central Product Classification (CPC, version 2) – Detailed version".

Notes: This figure shows the total and ICT-enabled number of CPC 2.0 (Central Product Classification) codes, grouped by EBOPS 2010 service categories (n.i.e. is "not included elsewhere").

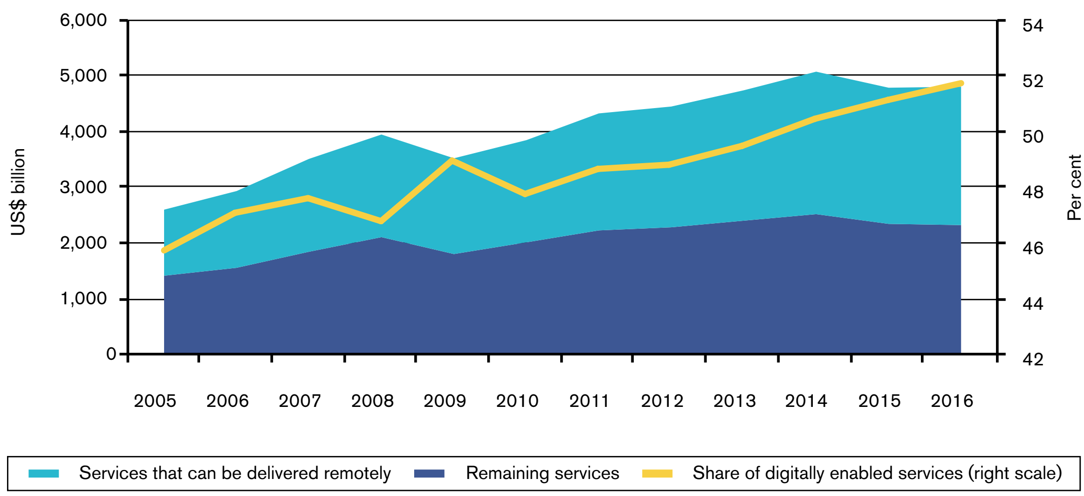
Figure C.10: Average yearly growth rates of trade in different service categories (per cent)



Source: Author's calculation based on data from the WTO Trade in Services Database (BPM6) and UNCTAD (2015).

Notes: The figure shows the compound yearly growth rates of services categories between 2005 and 2016 (n.i.e. is "not included elsewhere").

Figure C.11: Average yearly values and growth rates of trade in different service categories



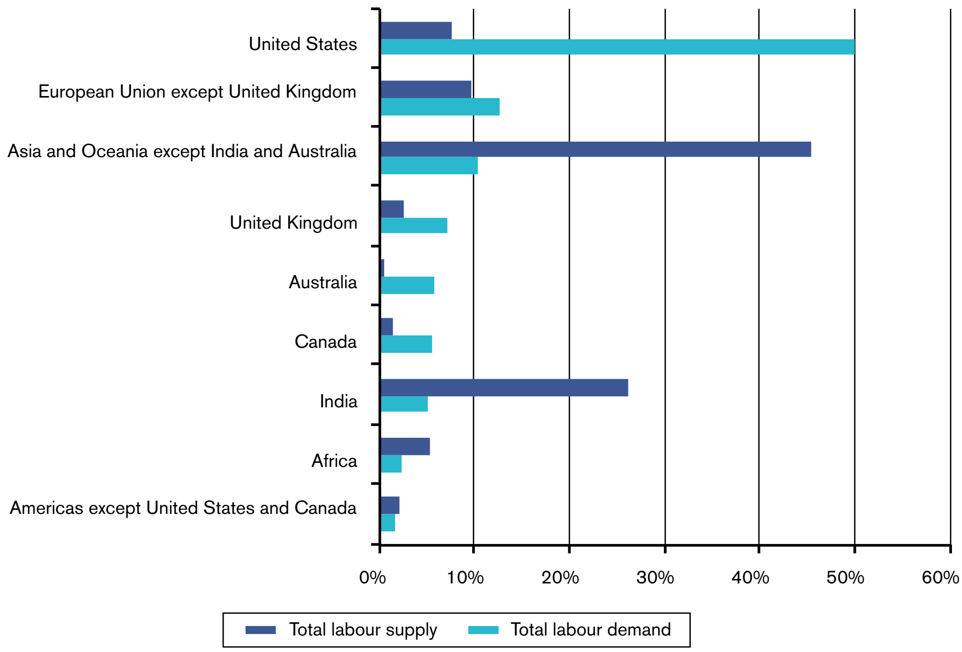
Source: Author's calculation based on data from the WTO Trade in Services Database (BPM6).

Notes: The figure shows the total world trade volume in services between 2005 and 2016, split between services that can (at least partially) be delivered remotely as defined by UNCTAD (2015) and other services.

in brick-and-mortar institutions in the European Union and the United States respectively. With the first MOOC delivered in 2008, this industry is young and still evolving. But the international element is already strong: 71 per cent of the students taking courses on HarvardX and MITx, Harvard's and MIT's online course facilities, are from outside the United States (Chuang and Ho, 2016).

For less standardized services, online labour platforms connect freelance service providers with worldwide clients, making trade in digitally delivered services such as accounting, programming or writing profitable even for small projects. Data collected by the iLabour project of the University of Oxford shows how supply and demand of such services are differently distributed over high- and

Figure C.12: Supply and demand for services on online labour platforms



Source: Authors' calculation based on data from the Online Labour Index (Kässi and Lehdonvirta, 2016).

Notes: This figure shows the share of labour offers and labour requests on the six biggest English-speaking online labour platforms for the period 16/06/2017 to 13/03/2018.

low-income countries. Figure C.12 shows that half of the employers of online labour come from the United States, while 68 per cent of the online labour offer comes from India, Bangladesh or Pakistan, and international trade in digital services is flourishing on these platforms.

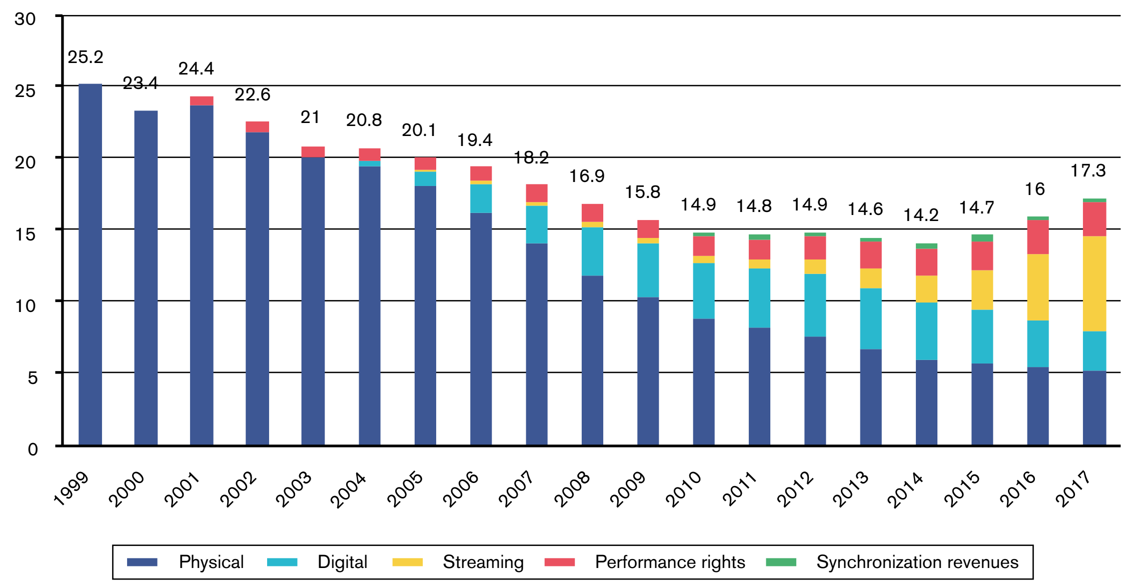
However, even though digital technologies relax some of the major constraints on cross-border trade in services, obstacles remain. As discussed in Section C.1, cultural and social differences, as well as language barriers, between workers or service providers and clients can restrict efficient communication. Furthermore, time zone differences can hinder timely communication, and geographical distance makes it difficult to build trust and social capital between business partners. Studying an applications and job posts on oDesk, a fast-growing platform for contract labour, Agrawal et al. (2016) found that employers from developed countries generally prefer to employ contractors from developed countries. However, online platforms also attempt to resolve the trust barrier by providing more information such as the contractor's education, work experience, location and the contractor's job history on the platform. The same study found that standardized information about work experience conducted on the platform and ratings of workers benefit job applicants from less-developed countries more than applicants from developed countries. As a result, digital technology can reduce information asymmetries and uncertainty, which in turn encourages trade.

Digital technologies create new ways of delivering services

Beyond facilitating trade in traditional services, digital technologies create new ways of delivering services. Take as an example the business of music streaming, which is a digital service. Figure C.13 illustrates how digitalization profoundly changed the way recorded music is consumed: while music has been bought for years in physical and later digital form, revenues from music streaming have been growing rapidly since 2014 and constituted more than one-third of recorded music industry revenues in 2017 (see also Section B and Box B.2 for a detailed analysis on how digitalization has changed the music industry).

These figures show that the recorded music industry is moving away from selling physical or digital downloads and instead relies increasingly on a

Figure C.13: Global recorded music industry revenues, 1999-2017 (US$ billion)



Source: IFPI Global Music Report (2018).

business model that provides a streaming service over the internet. As physical distance plays no role in the delivery cost of digital streaming services, a concentration of streaming service providers and an increase in cross-border streaming can be expected. This development is emblematic of a range of industries that see their physical goods becoming substituted by digital downloads, many of which are provided as a service.

On a different note, digital technology gives rise to P2P-based services, often referred to as the "sharing economy". The sharing economy is defined as the P2P-based activity of acquiring, providing or selling access to goods and services that is facilitated by a community-based online platform.

Digital technologies such as mobile applications (apps) have lowered barriers to entry in the sharing economy when it comes to building brands and scaling up quickly. Trust, convenience and a sense of community are factors that drive the adoption of the sharing economy business model. A survey shows that 19 per cent of the total US adult population has engaged in a sharing economy transaction, and nearly half of US adults are familiar with the sharing economy. Among those consumers who have tried the sharing economy, 72 per cent agree that they could see themselves being consumers in the sharing economy in the next two years (PWC, 2015a).

Connecting private service providers with private consumers for occasional transaction has often been hindered by high transaction costs. Online platforms reduce the costs of searching for business partners, communicating with them and establishing trust with them. This development makes it profitable for small entrepreneurs and private individuals to rent out durable goods such as cars, apartments or electrical appliances. One particular effect of the sharing economy is that it increases the share of traded services while possibly reducing the purchases of durable goods. The bottom line is that, by enabling the sharing economy, digitalization and the internet create new opportunities for cross-border trade in services (see Box C.6 on "Airbnb and the sharing economy").

Further revolutionary changes in the service sector may be triggered by technologies known as "telepresence" and "telerobotics". Telepresence refers to technology that enables the user to feel present or give the effect of being present in a space other than the space in which she or he really and physically is; telerobotics refers to technology that allows the user to control robots from afar. Both concepts would relax the constraints related to the regulatory barriers of services trade and costs of moving people, which inhibit trade in services that currently require face-to-face contact, such as psychological treatment or medical surgery.

Box C.6: Airbnb and the sharing economy

According to The Economist (2013b), Airbnb is a typical example of the "sharing economy". Since it was launched in 2008, more than 300 million guests have used the online platform. Airbnb currently offers 300 million different types of accommodation in 65,000 cities in over 191 countries. Consumers choose their accommodation and pay online, but this accommodation is provided by private individuals, rather than by hotel chains.

Although the business model does not appear very different from running a bed-and-breakfast, technology has reduced transaction costs, making sharing assets cheaper and easier than ever, and therefore possible on a much larger scale. The big change that digital technologies allow is to make available more data about people who may want to rent something and things (houses, flats, cars, etc.) available for renting. This allows the use of these things to be separated into smaller parts and consumed as services. Thus, platforms such as Airbnb match up owners and renters; smartphones with GPS let people see where the rentable good is and compare the locations of other similar goods; social networks provide a way to check up on both owners and renters and to build trust; and online payment systems handle the billing.

The sharing economy model is used mainly for items that are expensive to buy and are widely owned by people who do not make full use of them. Accommodation and cars are the most obvious examples, but one can also rent goods as varied as camping spaces, fields and washing machines, in most places in the world. According to Botsman and Rogers (2010), the consumer P2P market alone is worth US$ 26 billion.

Such "collaborative consumption" brings several benefits. Owners make money from under-used assets. Airbnb says that hosts in San Francisco who rent out their homes do so for an average of 58 nights a year, making up to US$ 9,300. Renters, meanwhile, pay less than they would if they turned to a traditional provider such as a hotel. It is not surprising that many sharing firms survived during the financial crisis. And there are environmental benefits, too: compared with hotels, home-sharing promotes the efficient use of existing resources, and results in reductions in energy and water use, greenhouse gas emissions and waste generation.[11]

Regulatory uncertainty remains an issue for the future of the sharing economy business model. Online platforms have so far benefited greatly from special, or lack of, legal and regulatory treatment, but this regulatory vacuum is not likely to last. Home-sharing sites are often accused of reducing the supply of affordable housing in big cities, and governments around the world are finding ways to regulate and tax the sharing economy. Many cities are creating new rules, or enforcing existing ones, on who can rent out their homes and for how long. One example is New York's move to pass a law imposing fines of up to US$ 7,500 on hosts who advertise stays of less than 30 days on Airbnb and similar sites. In Amsterdam officials are using Airbnb listings to track down unlicensed hotels. On the other hand, some argue that people who rent out rooms should not be subject to the same tight regulations as hotels. Overly strict regulations on the sharing economy could suffocate the growth of this new business model, particularly for start-up enterprises.

Source: Adapted from The Economist (2013b).

The key elements of telerobotics are the control console used by the operator, the physical robot and a stable and fast internet connection. A bipedal robot called HERMES (Highly Efficient Robotic Mechanisms and Electromechanical System), which can be remotely controlled by a human operator and will be capable of performing human-like manual activities, is currently being developed by the Massachusetts Institute of Technology (Chu, 2015). The robot is intended to be used where working conditions are too dangerous for humans, such as disaster sites. Once fully developed, it is anticipated that remotely controlled humanoid robots will be able to perform a wide range of daily manual services sector tasks, such as gardening, painting, and even complex tasks such as telesurgery (see Box C.7).

While telerobotics make it possible to undertake manual labour from afar, telepresence provides new means of digital communication in order to facilitate better intellectual collaboration. High-resolution conference call systems paired with synchronized digital whiteboards may increase productivity in meetings, while also enabling the participation of geographically distant participants. Virtual reality glasses, providing a 360-degree view of distant

Box C.7: Telesurgery

Telesurgery gives an indication of the extent to which robotics may transform the service industry. Originally developed by the United States National Aeronautics and Space Administration (NASA) and funded by the United States Defence Department, telesurgery (or remote surgery) promised to make surgery possible in places where surgeons are not present, such as on space ships or in conflict zones. The first transatlantic telesurgery took place in 2001, when a surgeon in New York, United States, removed the gall bladder of a 68-year-old woman in a hospital in Strasbourg, France, using a remotely controlled surgery robot (Wall and Marescaux, 2013).

Today, remote-controlled surgery is still unusual but is becoming more common – for example, a Canadian doctor has performed more than 20 long-distance operations by controlling a robot surgeon in an entirely different part of the country (Eveleth, 2014). Avgousti et al. (2016) review 56 medical telerobotic systems, most of them still in development, that allow surgery to be performed over long distances. They identify several challenges that need to be addressed before telesurgery can be adopted more widely. Some of the challenges are of a technical nature, involving, for example, the stability and security of networks that connect the two ends of the operation; others are legal and regulatory issues that have to be resolved. Furthermore, at present the cost of acquiring and maintaining telesurgery systems is extremely high. However, as these challenges are resolved and as the costs for technical equipment fall over time, new ways for international trade of medical treatments will open up and benefit patients worldwide.

Although telesurgery is still in its infancy, telepresence technology is already widely used in hospitals. With the help of cameras and microphones, expert surgeons can mentor other surgeons in operating theatres thousands of kilometres away. Studies find that such telementoring improves the outcomes of medical treatments (Wall and Marescaux, 2013). By detaching the expertise of a medical practitioner from her or his geographical location, digital technology can give rise to further specialization and more efficient allocation of practitioners' expertise.

locations, make it possible for specialists to remotely inspect production facilities in other countries. And telepresence robots – remotely controlled screens-on-wheels – allow workers virtually to be present in an office, attend meetings, visit a co-worker or even join co-workers for lunch. So far these technologies have mainly been used by workers who wish to check into their offices while working from home. Yet, as telecommuting technologies improve, a virtual presence might soon be enough for productive collaboration.

In a near future in which medical telerobotic systems become part of the standard equipment in hospitals, and telepresence systems make interactions over the internet deceptively real, it will probably be possible to provide certain services regardless of the supplier's geographic location. The consequences of such developments might be similar to those of digital trade in business services: workers in high-wage countries may be put in direct competition with workers from low-wage countries offering their services remotely. Ultimately, this may result in completely new ways to order the service industry as tasks are relocated across the globe, following the forces of comparative advantage. Baldwin (2016) predicts that this development will have a very large impact on the service sector, as it will enable a much wider range of services to be traded across borders than what has been traded up to now.

It is crucial to this scenario that the costs of telerobotics and telepresence systems fall while demand for these services remains stable. However, as robotic technology advances, so does AI. Vacuum-cleaning robots or self-driving cars are compelling because of their labour-substituting technology. Ultimately, in the future, the issue of whether manual services will be performed by telecommuting workers or by AI may depend on the importance of human judgement involved in the task. Therefore, the nature and substitutability of the tasks involved in the provision of services will determine the extent to which services will be sourced from abroad by means of digital technology.

To summarize the preceding subsection, it is conceivable that the relevance of trade in services will increase as digital technologies reduce trade costs and generate new means of delivering services across borders. Furthermore, technological advancements in the foreseeable future have the potential to render most services traded across borders. Such developments may have revolutionary effects on the international trade system, national economies and labour markets. The global production of services could be entirely reorganized along the lines of countries' comparative advantages.

(ii) New technologies affect the composition of trade in goods

New technologies have the potential to transform how and where goods such as electronics, auto parts, machinery and medical instruments are produced. With the increasing penetration of digital technology, international trade in some goods may rise while trade in other products may decline or even disappear in the coming decades.

Trade in information technology goods has expanded

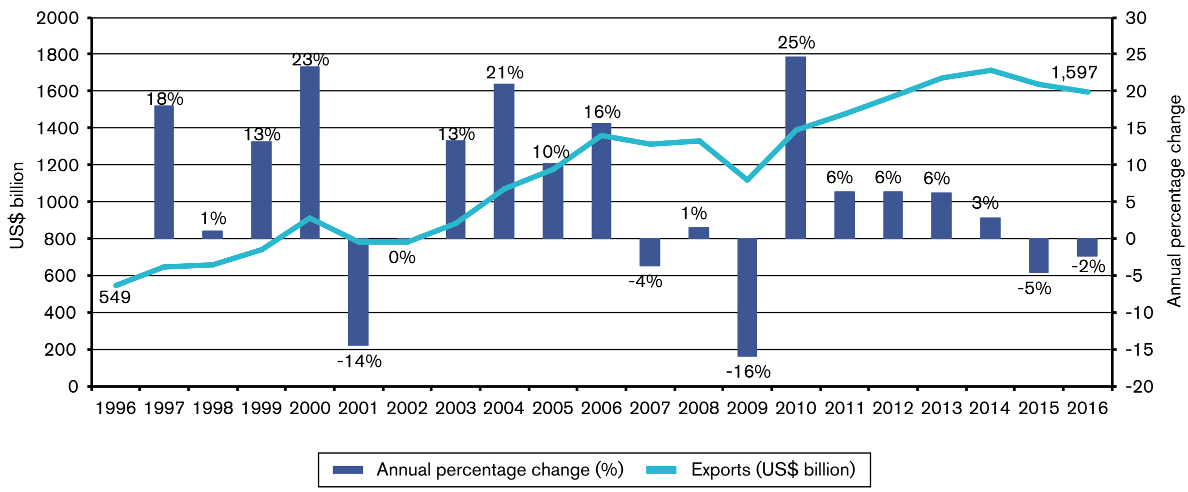
The trade flow of information technology goods has increased exponentially in the past decades. The WTO Information Technology Agreement (ITA) – originally signed in 1996 and expanded in 2015 – covers a large number of high-technology products, including computers, telecommunication equipment, semiconductors, semiconductor manufacturing and testing equipment, software, and scientific instruments, as well as most of the parts and accessories of these products.

The information technology sector has been one of the fastest growing sectors in world trade. Products covered under the ITA accounted for an estimated US$ 1.6 trillion in 2016, almost three times as much as when it was signed in 1996 (see Figure C.14). Today, trade in these products accounts for approximately 15 per cent of global merchandise exports.[12]

There have been profound changes in the type of ITA products that are being traded, partly driven by technological advancements and variations in consumer preference. Figure C.15 compares the share of ITA product categories between 1996 and 2015. In 1996, "semiconductors" and "computers and calculating machines" represented the categories with the highest shares of IT product export; 20 years later "semiconductors" remained the product category with the highest trade share and the share of "telecommunication equipment" increased from 9 per cent in 1996 to 21 per cent in 2015. This increase is largely explained by the increasing popularity of mobile phones, including smartphones (WTO, 2017a).

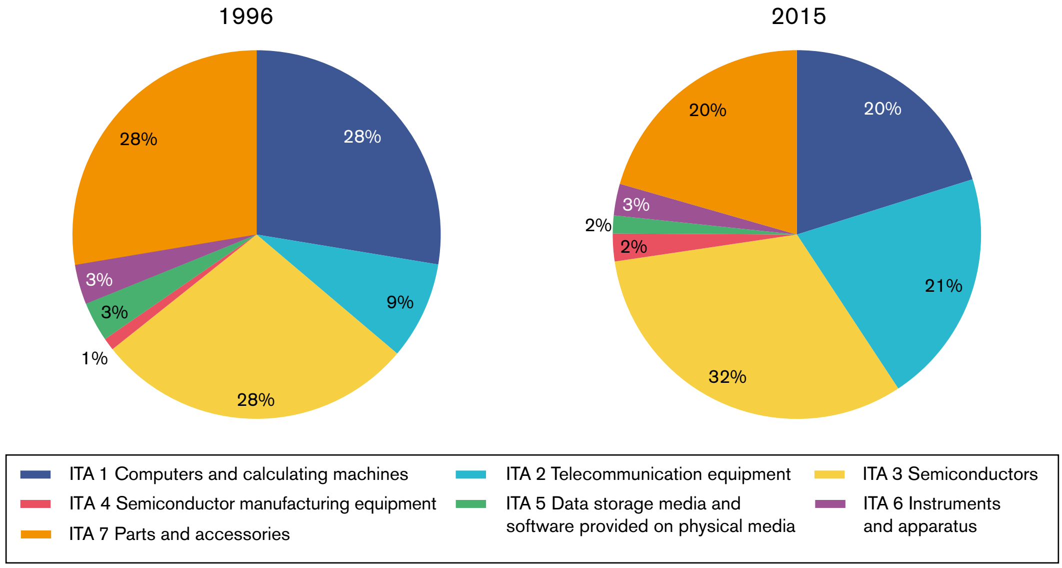
The expansion of trade in ITA products provides the basic infrastructure that enables information processing and communication, playing a vital role in promoting the adoption and use of digital technology. The lower cost and greater availability of computers and mobile phones has resulted in increased access to the internet and the growth of the digital economy, also creating new opportunities for trade. The expansion of trade in IT products is likely to continue with the increasing penetration of digital technologies and the invention of new products.

Figure C.14: World exports of ITA products, 1996-2016



Source: WTO Secretariat based on UN Comtrade (reported data, complemented by mirror estimates).

Figure C.15: World exports of ITA products, by product category (percentage share)



Source: WTO Secretariat, based on UN Comtrade.

Reduction in trade costs affects sectors differently

Digital technology changes the economics of doing business across borders, bringing down the cost of cross-border communications and transactions (see Section C.1). The reduction of trade costs has enabled an expansion of trade in some goods that were previously more costly to trade.

The extent to which products can benefit from a reduction in trade costs depends on the structure of trade costs and the amount of digitally-induced cost reduction. Freund and Weinhold (2004) provide suggestive evidence that the internet increased trade in physical goods due to a reduction in the cost of international communication. In the same vein, Fink et al. (2005) and Tang (2006) show that the decline of cross-border communication costs has had a significant influence on bilateral trade flows, particularly in sectors that exhibit a greater extent of product differentiation or low international transport costs.

Empirical research comparing trade through online platforms with offline trade offers interesting insights on the nature of digital trade. Based on data from Alibaba's international B2B e-commerce platform from five Asian LDCs – Bangladesh, Cambodia, Lao People's Democratic Republic, Myanmar and Nepal – ITC (2017) finds that products that trade particularly well off-line also feature prominently in e-commerce. For the five Asian LDCs in the study, apparel and textile products, along with agricultural products, were the largest export categories in both offline and online trade. In addition, e-commerce specifically facilitates trade for processed consumer goods. Product lines in which MSMEs dominate, such as gifts and craftwork, attract a greater share of total demand in online trade. E-commerce also provides opportunities to expand and diversify exports in terms of both products and markets. Apparel and clothing accessories account for around 86 per cent of Bangladesh's total exports, for example, but only 47 per cent of online demand. Agriculture, food and beverages, and consumer electronic products fill the gap.

The increasing use of digital technologies could give rise to trade in goods that have traditionally incurred higher costs in transportation, regulatory compliance, information and transaction. Time-sensitive goods, certification-intensive goods and contract-intensive goods are among these that are likely to benefit from a reduction in trade costs.

Time-sensitive goods

The growing use of digital technologies allows companies to manage complex supply chains and speed up delivery of products. Although digitalization cannot shorten the physical distance between countries, new technologies such as the IoT and AI afford companies up-to-the-minute visibility into complex supply chains and enable them to coordinate global vendors in real time.

Digital technologies also reduce the time and cost of delivery. Hema, a retail grocery concept developed by Alibaba, can deliver groceries to a consumer within 30 minutes of the order being placed. The company has managed to achieve speedy delivery by combining a mobile payment system with physical stores in high-density areas in major Chinese cities. Users of the New Retail-driven mobile app who live within a three-kilometre radius of a store can still get round-the-clock delivery service. Aside from regular fresh produce such as fruits and vegetables, the online retailer also delivers live fish and other seafood products (Wang, 2017).

A number of academic studies explore the time-sensitivity of different goods. For example, Hummels and Schaur (2013) investigate the probability of air transport being chosen as a means of transportation compared with ocean freight for different manufacturing industries. They find that the most time-sensitive trade flows involve the parts and components trade, which has a time sensitivity 60 per cent higher than other goods, as the presence of multi-stage global supply chains may magnify time costs, and so the absence of key components due to late arrival or quality defects can interrupt work in an entire assembly plant. An earlier draft of the paper (Hummels, 2001) also found the most time-sensitive manufacturing industries are in office equipment, electric power machinery and photographic equipment. Djankov et al. (2010) estimate the cost of time delay in trade. They find that each additional day of delay reduces trade by at least 1 per cent. Delays have an even greater impact on developing country exports of time-sensitive products. In particular, a day's delay reduces a country's relative exports of time-sensitive to time-insensitive agricultural goods by 7 per cent.[13]

Since speed to market matters more than ever in a digital world, many companies are re-evaluating the merits of lengthy and complex supply chains. According to a recent UPS survey, approximately one-third of high-tech companies are moving their manufacturing or assembly closer to end-user markets (UPS, 2015). Section C.2(c) discusses digital technologies' impact on value chains in more detail.

As a result of lower costs of transportation and logistics, trade in time-sensitive products may increase in the future. Digital technologies have the potential to reduce transportation costs further and to enable firms to optimize supply chains. As systems are getting better at routing items efficiently and predicting their arrival, integrating AI into the complex web of production and distribution could mean big potential gains for trade in time-sensitive products such as perishable food products, fast fashion items, life-saving medical supplies and intermediate inputs in supply chains (The Economist, 2018a).

Certification-intensive goods

Products that require certification and labelling may see a rise in trade volume as digital technologies enable a reduction of costs in verification and regulatory compliance.

The economic justification for certification requirements rests on the theory that the flow of information among market participants plays a critical role in the efficient operation of markets (Akerlof, 1970; Stiglitz, 1996). By making the information initially held by the firm also available to consumers, certifications remove information asymmetry and reduce search costs. Increasingly, firms in developing countries voluntarily obtain certifications that signal the quality of their products in order to enter international markets (Hudson and Jones, 2013; Auriol and Schilizzi, 2015). Complying with certification requirements, however, can be costly for companies, particularly for small enterprises in developing countries (Maskus et al., 2005).

Digital technologies remove some information asymmetries by making product attributes and processes more transparent, so that markets function more efficiently. This can result in a reduction of certification costs.

What types of goods may be affected? Certifications are often required for food and agricultural products, to verify that the product meets food safety, animal and plant health standards. For industrial goods, the top sectors using quality management standards include basic metal and fabricated metal products, electrical and optical equipment, and machinery and equipment, according to a survey of the International Organization for Standardization (ISO, 2017).

The question of whether a product can benefit from a reduction of certification costs depends on whether a credible link can be established between online and offline events. Analyzing the use of blockchain, Catalini and Gans (2016) point out that, while it is relatively cheap to verify the transaction of goods with offline attributes that are easy to capture and difficult to falsify (e.g. diamonds), in many cases, maintaining a robust link between online events and distributed ledgers is still expensive, and therefore asymmetric information and moral hazard continue to be an issue. In this context, IoT devices may be instrumental, because they can be used to record real-world information through sensors, GPS devices, etc.

By lowering the cost of obtaining certifications and by increasing transparency in the supply chain, digital technologies may lead to a rise of trade in products that entail high certification costs. The likely technology-induced reduction in certification costs varies according to the sector; products that are likely to benefit the most include luxury items, consumer electronics and food products.

Contract-intensive goods

International trade requires large amounts of paperwork, from contracts to cargo documents and bills of lading. The complication involved in drafting and executing an international trade contract can discourage entrepreneurs – especially small enterprises – from participating in trade.

Empirical research finds that transactions costs associated with insecure exchange resulting from corruption or imperfect contract enforcement significantly deters international trade (Anderson and Marcouiller, 2002). Traders in countries with weak institutions often need to rely on costly intermediaries and networks (Rauch, 1999) or bias their trade towards partners they trust (Guiso et al., 2009).

As discussed in the previous section, digital technologies can significantly reduce information and transaction costs in trade, most notably through online platforms which match buyers and sellers and rating systems that reduce information asymmetries. Emerging technologies are expected to further reduce the costs associated with cross-border transactions by removing the need for third parties to manage transactions and keep records. blockchain-based smart contracts, for example, may provide an efficient and reliable way to release payment for a supply of goods automatically following a secure and transparent confirmation of the execution of the contract (Weernink et al., 2017).

As a result of lower transaction costs, goods that require more relationship-specific investments are likely see a rise in trade. Nunn (2007) constructs a measure of "contract intensity" of industries by measuring, for each good, the proportion of its intermediate inputs that require relationship-specific investments.[14] According to his calculation, the manufacture of transport equipment, professional and scientific equipment and other machinery relies heavily on contracts. Since the inputs in these manufacturing industries are not standardized, buyers and sellers need to establish mutual trust by drafting and enforcing contracts. Studying the use of Electronic Data Interchange (EDI) in the Czech Republic, Vrbová et al. (2016) find that industries with a high ratio of EDI use include auto parts, electronics, engineering, plastics, retailing and textiles. These are sectors associated with well-organized value chains. A technology-induced reduction of transaction costs is therefore likely to affect trade of both final and intermediate goods in these sectors.

New technologies affect the composition of trade through mass customization

Technological advancements drive the shift towards mass customization, creating virtually infinite amounts of varieties fitting individual needs (see Section B.1(d)). This trend could be an important factor that stimulates trade.

Several technological developments are behind the trend towards mass customization. Data collection technologies can precisely gauge consumers' needs and tastes, enabling more individualized product design. Technologies such as online interactive configuration can assemble customers' preferences and enable shoppers to envision the final product. Developments in 3D scanning make it easier to measure real-world objects, for example a human body, with a view to tailoring individualized products to fit that object. Social media and crowdsourcing (i.e. obtaining goods and services from a large, relatively open and often rapidly-evolving group of internet users) also allow companies to analyse components of both real or virtual products, paving the way for better customization.

In manufacturing, flexible production systems are essential to making small batch production for mass customization. In the automotive industry, for example, Ford and General Motors have invested in dynamically programmable robotics with interchangeable tooling that can switch agilely between models and variants with no loss of efficiency. Companies from other industries are adapting these technologies. Caterpillar's production system, for example, cuts out shoe parts according to customers' measurements with an automated, computer-guided cutter (Gandhi et al., 2013).

Mass customization is expected to find applications in a wide variety of sectors, particularly in industries where customization would serve a functional or aesthetic purpose, usually based on preferences dictated by biology or taste, such as apparel, food, health care, consumer electronics and the automotive industry.

Some clothing brands already offer consumers the option of configuring products with different colours and different elements. One California-based website, for example, allows its users to configure custom-made shoes. Users choose the shoe type and the design of the toe, back and heel, as well as any decorations, with each click automatically updating a preview. In the future, 3D scanning technology and flexible manufacturing systems may allow companies to make customized clothing to fit individual body measurements.

Food and beverage companies allow users to choose different toppings or flavours, while collecting data that would allow them to measure the popularity of particular ingredients and flavours.[15] With increasing amounts of data available on consumers' tastes and nutritional needs, food companies in the future may offer personalized food and vitamins based on individuals' tastes and nutritional needs.

In the healthcare industry, it is possible that, in the future, pharmaceutical companies may offer DNA-based personalized medicines. Gene-based information should help doctors prescribe more effective, accurate doses, and predict whether a person will benefit from a particular medicine or suffer serious side effects (Adams, 2008).

In consumer electronics, companies have already developed online configurators that allow consumers to configure products according to their preference. Advances in product visualization and the increased speed and adaptiveness of configuration software make product configuration an engaging experience. Technological developments could further enable companies to produce highly customized electronics with individualized colours and graphics.

Likewise, the automotive industry is expected to customize vehicles with personalized colours, artwork and designs that suit individual preferences. Technological advancements in 3D scanning, which analyses a real-world object to collect data on its shape and appearance, could facilitate the manufacturing of individualized components such as car seats and interior accessories designed to fit specific body shapes.

Various empirical studies show that technology-induced mass customization expands product variety and leads to welfare gains. For instance, Broda and Weinstein (2006) find the impact of increased choices to be statistically and economically significant and estimate that the value of US consumers of the expanded import varieties to be about 2.6 per cent of GDP. Brynjolfsson et al. (2003) show that increased product variety made available through electronic markets can be a significant source of economic welfare for consumers.

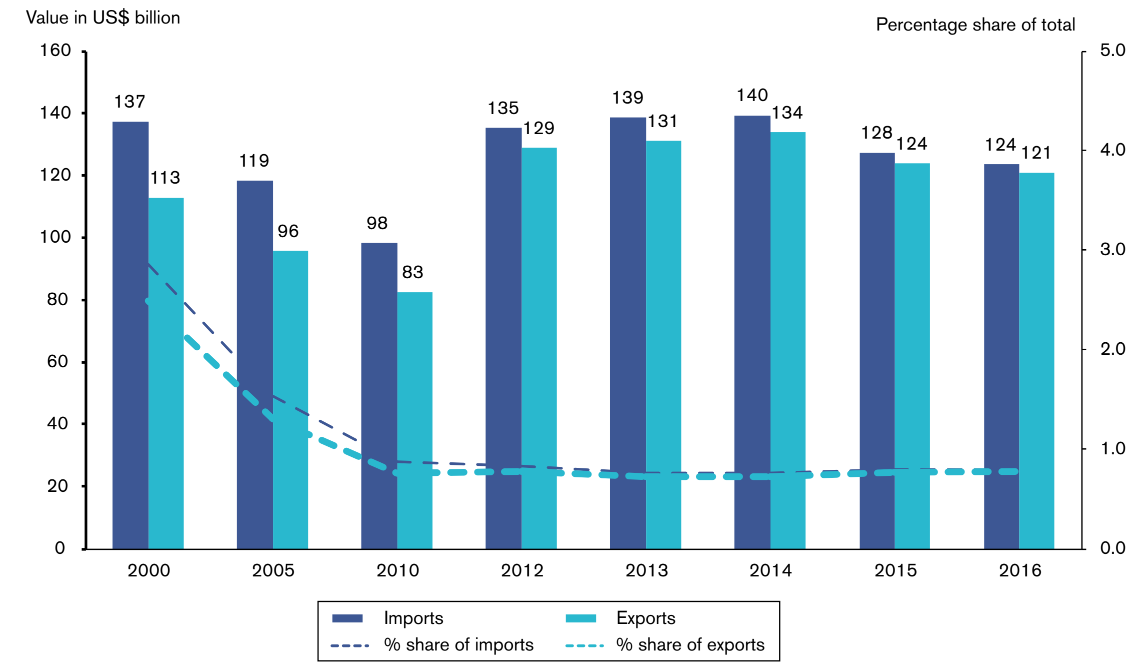
Mass customization could lead to an increase in international trade. The seminal work by Paul Krugman (1979; 1980) posits that consumers' love of variety, coupled with economies of scale in production, explains trade in similar products between similar countries. Empirical studies have also shown that the internet has expanded trade in sectors where products are easily differentiated. For example, Lendle et al. (2016) compare offline international trade flows with cross-border transactions on eBay and find that distance matters less online, especially when products are more differentiated and thus information frictions are high. As firms located in different countries increasingly specialize in customized production and as technologies enable online purchases at lower costs, this type of mass customization could lead to an increase of trade in similar yet highly differentiated products that meet different consumer preferences. On the other hand, mass customization could also allow production to be located closer to customers, thus reducing cross-border trade in some products.

Trade in digitizable goods is likely to continue falling

Over the past decades, digitalization has dramatically reduced the cost of copying, creating, accessing and diffusing creative work such as text, image and music, bringing about a decline in the trade of physical products embodying the work. Books, newspapers, video cassettes/DVDs and music records/CDs now gradually replaced by e-books, news apps and media content streaming or download services. Digitalization has transformed the industries concerned. As the cost of 3D printing declines, this trend of digitization could expand to new categories of goods — for instance, three-dimensional objects that currently exist in only physical form.

Conventionally defined digitizable goods (physical goods that can be digitalized) include cinematograph film; traditionally printed matter such as books, pamphlets, maps, newspapers, journals, periodicals, postcards and personal greeting message or announcement cards; video games; computer software; and recorded media such as musical records, tapes and other sound or similar recordings.[16] The share of trade in these products has been gradually falling. The current value of imports of digitizable goods by WTO members, not accounting for intra-EU trade, is around 0.8 per cent of total imports. In 2000, by contrast, total imports of digitizable goods were at 2.86 per cent of total imports (see Figure C.16).

Figure C.16: Trade of digitizable goods, value and as per cent share of total trade



Source: WTO Secretariat calculations based on UN COMTRADE data.

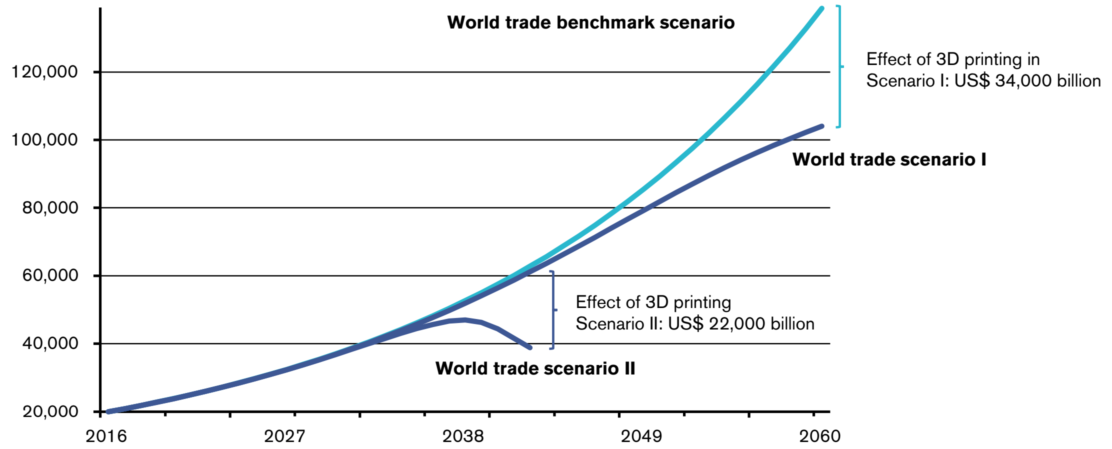
The advent of 3D printing technology could expand the reach of digitalization to a new category of products. By making a three-dimensional solid object from a digital model, 3D printing makes it possible to produce physical objects locally based on data files downloaded from the internet. This could reduce the need for international trade in commodities, intermediate and finished goods, while increasing trade in the materials used in 3D printing, such as plastics and resins. As discussed earlier, 3D printing has successfully moved from being a nascent technology to enjoying a high level of investment. Although the amount of goods produced with 3D printers and the value of related services currently only account for a fraction of total worldwide production, the annual growth rate for investment in 3D printing has been 29 per cent over the five-year period between 2012 and 2016 (Wohlers Associates, 2017), compared to an average of 9.7 per cent for global investment growth in traditional machines (ING, 2017). This growing trend of 3D printing implies that goods will increasingly be digitally transmitted and locally produced.

According to some industry estimates, 3D printing could lead to a significant reduction of trade in goods. ING (2017) estimates in a scenario analysis that if the current growth differential between investments in 3D printers and investments in traditional capital goods continues, 3D printers will print half of all manufacturing goods produced in 2060. Alternatively, if the growth rate of 3D printed production doubles after five years, this break-even point would be reached in 2040. These two scenarios are indicated in Figure C.17. In scenario I, total world trade in manufactured products will be 19 per cent lower than would be the case without the rise of 3D printing because these goods are made locally with 3D printers. In scenario II, it is calculated that two-fifths of world trade in goods will be lost by 2040.

3D printing could also affect trade in services. While some manufacturing-related services such as trade finance, transport and logistics may decline, other 3D printer-related services like installation, repair, design, software and education could increase.

The five industries that are the largest buyers of 3D printers and related services are the industrial machinery, aerospace, automotive, medical/dental devices and consumer products (electronics, etc.) industries. They are responsible for 75 per cent of all investment in 3D printing (see Table C.2). These five frontrunner industries make up 43 per cent of world trade, and their 3D activities will have the greatest impact on international trade.

Figure C.17: Scenarios comparing the effects of 3D printing on world trade (goods and services) (US$ billion)



Source: ING (2017); Wohlers Associates (2017).

Notes: This scenario analysis is based on the following assumptions:

(1) The global annual real GDP will grow on average at the same rate as during the past 30 years (2.9 per cent) and that world inflation will be half the rate of 5.1 per cent that it has been. This holds both for scenario I and scenario II.

(2) The benchmark trade growth (without 3D printing) is calculated by assuming that world trade in volumes will grow on average at 1.2 times the rate of world real GDP growth until 2060, so real world trade will grow 3.5 per cent per year.

(3) World trade prices will grow at only half the rate of the past two decades at 1 per cent per year.

(4) The share of manufacturing in world GDP will keep on declining so that it will make up 10 per cent of world GDP in 2060 (12.5 per cent in 2040), instead of the current 15 per cent.

(5) Since half of manufacturing production will then be made with 3D printers, traditionally produced goods (that are subject to exporting) will worth US$ 37,500 billion. If, as currently, half of this is exported, manufacturing exports will be US$ 18,750 billion.

(6) World trade is measured on the basis of national export turnover statistics, subject to double counting. According to the World Input-Output Database, export values are on average 1.4 times as high as the value-added of exports. Multiplying this production value by 1.4 times to translate the production figures to export figures results in remaining worldwide exports of traditionally manufactured goods of US$ 26,250 billion.

Table C.2: Fields of application and the consequences of 3D printing, 2016

Field of application	Share in sales of 3D printers	Examples of application	Effects of 3D production
Industrial machinery	19%	Production of tools like jigs and fixtures.	Less time-consuming/cheaper to produce (shorter lead time).
Aerospace	18%	Small quantities of geometrically complex and lightweight parts.	Fewer stocks and sometimes faster (and cheaper) to produce.
Automotive	15%	Functional prototypes, small and complex parts for luxury and antique cars. Mainly non-mass production of specific tools and parts and for prototyping.	Reduce or even eliminate tooling, welding and entire assembling lines. Design and manufacturing tools become dispensable.
Consumer products (e.g. electronics)	13%	Micro-electromechanical systems, microwave circuits fabricated on paper substrates, radio-frequency identification devices inside solid metallic objects (radio-frequency identification technology), polymer-based three-dimensional grippers.	Easier adaption to domain specific development processes, acceleration of design process, functional integration of a number of different electronic devices in just one product, functional prototypes, spare parts produced on demand.
Medical and dental devices	11%	Digital prostheses, dental aligners and invisible dental braces, dental restoration.	Reduced processing times, digitalization of manufacturing process, easy reproducing of production properties.
Others	24%		

Source: ING (2017); European Parliament (2015b); Wohlers Associates (2017).

Notes: Based on responses from 61 producers of 3D printers who were asked what their customers use the printers for. Respondents were from North America, Europe and Asia, and South Africa.

The possibility of digitalizing physical objects incorporating creative work highlights the importance of IPR protection. As digital technology allows households to manufacture goods based on designs downloaded from the internet, it is challenging for IP owners to identify whether and how they can enforce their rights in this sector. While anecdotal evidence suggests that 3D printing companies are enforcing patents in industrial 3D printing (Bechtold, 2015), the personal 3D printing sector could pose significant challenges to the protection of IPR. Infringement could be difficult to detect as it would often take place at home. The possibility of copying and modifying objects which are wholly or in part IP-protected might raise new challenges (OECD, 2017e).

The "sharing economy" is also likely to affect trade through its impact on the demand for durable goods

New business models like the "sharing economy" are also likely to affect trade through their impact on the demand for durable goods. The sharing economy offers the possibility to monetize underutilized assets or to forgo buying those assets altogether, which has dramatically altered consumer purchase behaviour, particularly when it comes to expensive items such as automobiles and houses.

In addition to generating new services trade flows (see the previous section), the sharing economy model could affect the demand for durable consumer goods. Some factors point to an increased demand for these goods, while others may lead to a reduced demand. How digital technology is likely to affect demand for durable goods depends in part on the way digitalization might affect: (1) the services provided in conjunction with such products (for example car-sharing services), which might ultimately increase the efficient use of the product; and (2) the content of these products, in particular the relationship between the digital (service) part and the manufactured part. Box C.8 focuses on the automotive industry and discusses the impact of digitalization on the demand for these durable goods.

Durable goods are also trade-intensive. The slowdown of global trade in recent years has led to research about its causes and possible consequences. Auboin and Borino (2017) have estimated the standard import equation for 38 advanced and developing economies using an import intensity-adjusted measure of aggregate demand. They found that the prolonged weakness of aggregated demand since the end of the global crisis, particularly in the most trade-intensive components (investment and consumer goods), has been the primary restraint on trade growth, accounting for up to three-quarters of the overall slowdown. Therefore, the evolving demand for durable goods could have implications for the composition of trade.

Whereas digital technologies have expanded trade in certain goods, the trade flow in some other goods has gradually declined, giving rise to trade in services and data flows. This section has analysed the impact of digital technologies on the trade of goods. Trade in IT products has seen a steady increase in the past decades with the development and increasing adoption of digital technologies. Digital technologies can enable a further reduction in trade costs, thus giving rise to trade in notably time-

Box C.8: The impact of digital technology on automotive demand

By making the use of cars more efficient, digital car-sharing services reduce transport costs for the consumer and help to increase the cross-border ordering of that service (e.g. a person ordering a car-sharing transport service online to transfer them from the airport). The fall in the cost of individual transport services linked to digital applications has certainly increased the demand for them, which more than offsets the fall in demand for existing substitutes (e.g. taxis). The sharing economy business model enables the optimization of the use of existing vehicles, which could contribute to reducing the overall number of cars needed for transportation. On the other hand, new functionalities brought about by digital technologies could create a new order of preferences that would make the purchase of new vehicles more attractive. The literature covers a rather wide spectrum of scenarios.

On one side of the spectrum, Barclays Bank (2016) forecasts that shared driverless cars entering the market could cut total US auto sales by 40 per cent in the next 25 years. As a result, auto-makers would need to shrink to survive (Naughton, 2015). Under this scenario, automated vehicles would significantly reduce the operational costs (no driver costs for example) for ride-sharing and vehicle-sharing services, and the demand for such mobility services would increase. The model of vehicles wholly owned by households would gradually change. Urban residents would eventually try to avoid the fixed costs of owning a car. As shared automated vehicles are utilized more intensively than conventional cars, however, shared automated vehicles would wear out faster and would need to be replaced more frequently (Milakis et al., 2017).

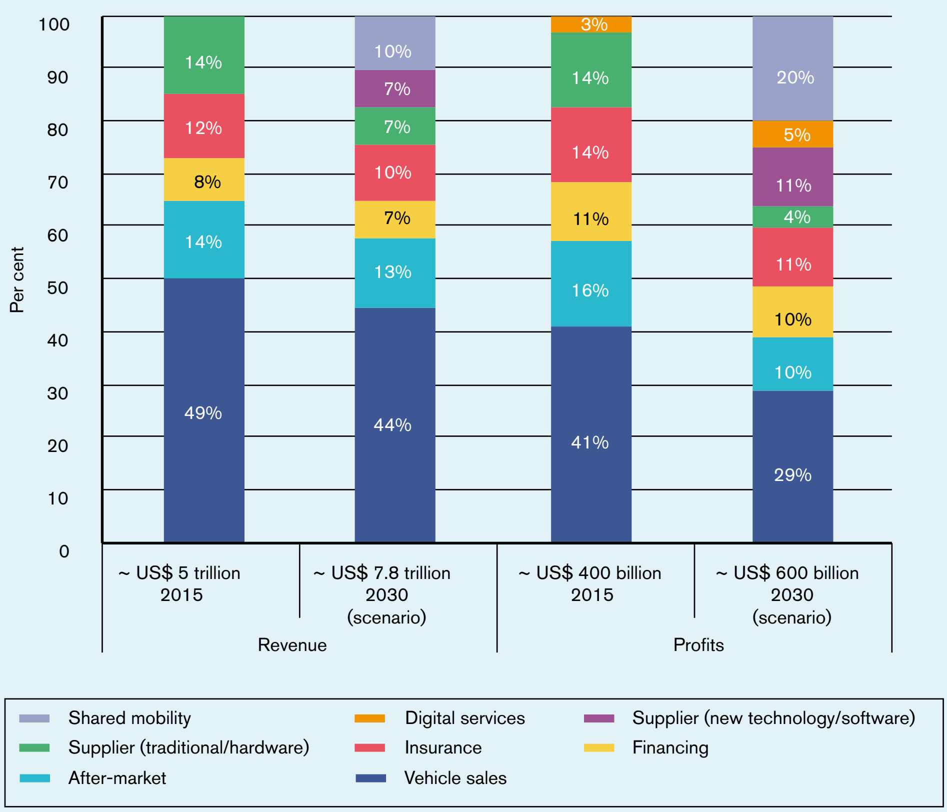
Box C.8: The impact of digital technology on automotive demand *(continued)*

On the other side of the spectrum, several scenarios for the automotive industry foresee a continued increase in the demand for vehicles, although with limited growth in "mature" markets (the United States and Europe), and a continued expansion in emerging markets. These scenarios also take into account the digitalization of car functions and the increased expectations of customers regarding technological developments. Most customers would expect their vehicles to incorporate digital technologies that could operate autonomously during driving, to have fewer accidents, and have self-learning and communication capabilities. The baseline scenario in the latest PWC 2016 connected car report forecasts a relatively regular increase in the demand for vehicles and in the automotive industry's revenue by 2030, from US$ 5 trillion currently to US$ 7.8 trillion, mainly due to the increase in demand in developing countries (PWC, 2016).

Here the main variable is falling profits for car-makers despite increased volumes, as increased entrants' market shares relative to traditional car-makers, and shifts in the value of car parts in favour of share mobility and digital services (see Figure C.18) would erode margins. The idea that connectivity will trigger a redistribution of revenue pools from the car industry is widely shared in these scenarios (McKinsey & Company, 2014).

A relevant question is whether the integration of an increased set of digital technologies, creating new functionalities, would affect the overall price of vehicles. The software value of a car is expected to increase in line with the new functionalities provided by digital technologies (e.g. functionalities available in connected cars, such as software assistance with key mechanical functionalities). However, several observers argue that the automotive industry already has a long history of leveraging cross-cutting advantage in design and production (see Deloitte, 2015c). Customers have become accustomed to having music and other

Figure C.18: Scenario for value shifts in the auto industry, 2015-30 (per cent)



Source: PWC (2016).

Box C.8: The impact of digital technology on automotive demand *(continued)*

entertainment, often for free, and "have been resisting paying extra for those services in their cars" (Kaiser, 2013). While nearly all observers predict a race between software and traditional automotive companies to capture the rent from increased connectivity, that rent may be falling in line with the falling price of technology and customers' reluctance to pay for more expensive cars. The solution would be for car-makers to aim for shorter design and production cycles. According to Deloitte (2015c), several auto-makers have started to re-design the product-development process with a view to increasing production flexibility, reducing time-to-market and decreasing production costs.

For the time being, the literature on the (connected) car industry is inconclusive, as it is unclear whether the final global demand for vehicles will increase or decrease. The demand for capital goods to produce durable goods can, in the short run, be expected to increase (more robots in factories), and the integration of more connected software will require more data centres, hence a greater demand for servers and other hardware.

sensitive goods, certification-intensive goods and contract-intensive goods. Technologies have also enabled mass customization, creating virtually infinite varieties to meet individual consumer needs. On the other hand, digitalization has led to a decline in the trade of certain digitizable goods – such as CDs, books and newspapers – and the trend is likely to continue with the advent of 3D printing technology. In this context, IPR have a pivotal role to play in the future of trade. The "sharing economy" business model could possibly affect trade in some durable consumer goods. Taking the automotive industry as an example, the sharing economy could lead to a decline in demand as households have less incentive to purchase new cars. Meanwhile, new car models integrating software and hardware could create new demand, particularly in emerging markets.

(iii) Intellectual property in trade

The evolution of digital technologies has radically transformed the linkages between IP and international trade. Conventionally, IPR were seen as a component of the added-value embedded in traded goods and services. Trade in music, film, books, journals, newspapers, and even consumer software, used to be essentially conducted through the exchange of physical carrier media. The transformation of the internet, especially from the early 1990s, from a largely scientific and academic network into a platform for social, cultural and commercial exchanges, has led to fundamental shifts in these industries.

Part of the transformational impact of this development has been that the linkages between IP and trade have become more evident. Transactions for products such as books, music and software in the digital environment are not generally defined by the transfer of ownership of a physical medium from a seller to a buyer; and ownership or control of a physical copy is no longer a proxy for the bundle of rights required to use the embedded content. Instead, the online "purchase" of an e-book, an app, a music download or a 3D printer design is typically defined in legal terms by contract and as a limited licence to use IPR and may also be structured by technological protection measures that constrain the effective uses of the licenced material. As one widespread content platform clearly states it: "Apps made available through the App Store are licensed, not sold" (Apple Inc., 2018). Such B2C licenses of IP are generally reserved for certain private, non-commercial uses, imposing significant constraints on further downstream use.

Alongside this burgeoning trade of products with important IP components and international licensing transactions, the international transfer of ownership of IP rights is growing in diversity. Increasingly, the acquisition of firms may be undertaken essentially to enable the transfer of ownership of strategic IP portfolios. A WIPO report on renewable energies charted how the rapid rise of emerging economy firms as leading owners of wind technology patent portfolios "can be attributed in large part to their strategic pursuit of knowledge acquisition through a strategy of licensing and M&A" (Helm et al., 2014).

Analysing the economics of copyright and the internet, Wunsch-Vincent (2013) points out that a few important factors brought about by digital technologies fundamentally change the way in which content is created and accessed, and potentially changes how copyrights are administered.

First, the internet and the increased availability of digital technologies have significantly lowered the cost of creating and distributing creative works on a global scale. While the distribution costs of content have plummeted, many content sectors have experienced increased costs due to production in the digital context. At the same time, the same tools used to distribute creative works facilitate piracy of the same works, as the variable cost of copying and disseminating unauthorized copies is reduced to close to zero.

Second, the rise of the internet as a new distribution channel has introduced a change in the ways in which works are made accessible and revenues generated and shared. Value chains and business models – and associated revenue opportunities and incentives – have changed, and the impact on the supply of and the access to creative works is uncertain. This is not to say that the revenues of content creators, the content industry or others need be negatively affected. If the overall pie of revenues increases, original creators potentially stand to benefit. Whether revenues for creators have increased or decreased due to the digital transformation is ultimately an empirical question.

The emergence of such diverse forms of trade which necessarily involve IP has immediate implications not merely for trade policy, but even for how we understand the very character of "trade" – the growth of digital platforms has enabled hundreds of billions of valuable transactions across the globe that are, in legal terms, B2C licences, defined by reference to IP rights. It is not clear to what extent these transactions are recorded in current trade statistics, but their value is now a major component of revenues in the content industries, and a share of these earnings is redistributed to app developers, musicians, authors and other creators internationally. A clearer picture of these sizeable revenue flows would improve our understanding of the pattern of international trade in these sectors, and could lead to a more accurate understanding of how economies benefit from this form of international trade, as internet platforms serve to connect content developers across the globe with consumers in multiple jurisdictions. The scale of international transactions involved is illustrated by the example of one firm, Apple, which reported in June 2017 that it had been the channel for payments totalling over US$ 70 billion to its "global developer community" since its App Store was opened in 2008, as over 180 billion applications had been downloaded since then (Apple Inc., 2017).

(b) Who trades what? Trade patterns in the digital age

What will determine the trade patterns of the future? As the previous sections have shown, digital technologies create new products, change the characteristics of traditional products, lower trade costs, and shift the sectoral composition of production. These developments affect trade patterns by changing the relative importance of their underlying determinants (e.g. labour endowments, productivity differences) and by establishing completely new determinants (e.g. digital infrastructure). To answer the question of who trades what in the digital age, this section examines which traditional determinants of trade patterns are likely to become more important and outlines which new determinants of trade patterns may arise in the digital age.

Determinants of trade patterns are typically country characteristics that interact with product or sectoral characteristics to give a country a relative cost advantage in the production of these products vis-à-vis its trade partners. They are commonly referred to as sources of comparative advantage. Classical examples of such country characteristics are differences in relative productivity or in factor endowments, such as capital, natural resources or labour. Countries abundant in capital tend, for instance, to specialize in the production and export of goods that are capital-intensive, while labour-abundant countries export labour-intensive goods.

In addition to these canonical determinants of trade patterns, researchers have shown that differences in regulation, market size and infrastructure influence what countries trade. For instance, Nunn (2007) finds that countries with strong legal institutions have a comparative advantage in products that are contract-intensive. Helpman and Krugman (1985) suggest that countries with large domestic markets export in scale-intensive sectors. Beck (2003) and Manova (2013) show that financial institutions matter for comparative advantage since sectors differ in their dependence on external capital. Cuñat and Melitz (2012) and Tang (2012) provide evidence that labour market regulations also have an impact on comparative advantage in sectors that exhibit high volatility in sales or depend on sector-specific skills. Kowalski (2011) establishes the availability and affordability of energy as source of comparative advantage, since sectors differ considerably in the amount of energy they require for production.

With digital technology changing the determinants of trade patterns, opportunities will arise for both developing and developed countries. For instance, as digitalization raises the complexity of tasks performed by workers, developed economies can strengthen their comparative advantage in skill-intensive sectors. Similarly, as new technologies diminish the importance of physical infrastructure, developing economies will be able to gain comparative advantage in sectors that are most affected by the shift from physical to digitalized trade. Moreover, as developed economies increasingly specialize in high-tech production, developing economies should be able to diversify their export portfolio and move into new sectors that have been freed up. Digital technologies can thus increase the gains from trade in countries across all income levels.[17]

In order to determine how the advent of digital technologies causes the determinants that matter for trade to change, sectors need to be classified according to their use of these technologies. Section B has demonstrated that sectors differ significantly in their dependence on digital technologies, and has provided rankings of sectors according to their digital intensity. These rankings show that services sectors, with the exception of construction and transport, tend to use digital technology more intensively than manufacturing and agriculture sectors. Within manufacturing, the transport equipment and electronics sectors stand out as digital-intensive, which is mirrored in data from the International Federation of Robots, which show that the automotive industry uses a significant number of robots and is likely to benefit from progress in smart robotics. Sectors such as textiles and paper, on the other hand, are ranked low based on robot and digital-intensity data.

Classifying the data in this manner will eventually allow researchers to examine digital comparative advantage but, not least due to data issues, currently research in this area is still limited. Deardorff (2017) shows that the concept of comparative advantage remains relevant in explaining trade in the digital age. Goldfarb and Trefler (2018a) point out that digital technologies like AI have special characteristics that make an assessment of trade patterns in the digital age complex. They highlight in particular the following aspects: economies of scale, economies of scope, and knowledge externalities. Evaluating how country characteristics interact with these three aspects can facilitate such an assessment.

Economies of scale exist because creating and maintaining local AI expertise is expensive and has a substantial fixed cost component. In addition, the quality of most new technologies increases exponentially with scale; for example, map applications are more reliable the more users provide data on traffic flows, while Google's search suggestions improve with every search undertaken by the user. Economies of scope are the outcome of many digital firms providing different services that each benefit from each other. Both characteristics suggest that the factors that attract digital technology firms should also benefit comparative advantage, since economies of scale and scope provide natural barriers to entry. Digital technologies are also likely to exhibit knowledge externalities, that is they benefit a wider set of actors than just the producer who does not take these benefits into account, since progress in this area is typically shared through publications or open source software. Goldfarb and Trefler (2018a) argue that policies that support comparative advantage in digital-intensive sectors can only be effective when knowledge externalities remain local. Whether this is the case is an open empirical question.

It is important to point out at this stage that a comparative advantage in one sector implies by definition a comparative disadvantage in another sector. Trade tends to raise incomes and welfare in all countries independent of where their comparative advantages lie. Moreover, many determinants of trade patterns are outside the reach of policy (e.g. geography) or the outcome of region-specific preferences (e.g. towards privacy). Hence, even if regulation can influence comparative advantage, it is not optimal to strive for a comparative advantage in a particular sector but rather to take comparative advantage as given and create an environment where this advantage can thrive.

With this qualification in mind, the first part of this subsection examines the impact of new technologies on the importance of traditional sources of comparative advantage for trade patterns. The second part discusses new determinants that have the potential to shape future trade flows such as digital infrastructure or data regulation. The third section concludes with a careful assessment of what this means for the future of trade patterns across developed and developing countries.

(i) New technologies, same old sources of comparative advantage?

Will the role of traditional sources of comparative advantage for trade patterns change in the digital age and what are the implications for countries at different stages of development? Traditionally, trade flows have been shaped by differences across countries in terms of labour and capital endowments, relative productivity differences, geography, infrastructure or institutional factors. New technologies have the potential to turn around such established trade patterns as robots affect the available labour supply or as the digitalization of trade renders geography and infrastructure less, or potentially more, relevant. Countries will therefore see their export baskets develop and reflect these changes.

Starting with factor endowments, countries that have a high supply both of skilled labour and of capital are likely to exhibit a comparative advantage in certain digital-intensive sectors. A common theme of the economic literature is biased technological change, which was reviewed in the 2017 *World Trade Report*

(WTO, 2017d). The current evidence points to the fact that technological change has been mainly routine-biased, which means it reduces the demand for employment in routine activities. Manual and complex tasks, on the other hand, have benefitted from innovation. However, the evidence collected in WTO (2017d) also points to the fact that digital technologies increasingly touch upon a wider set of activities and push demand towards high-skilled labour. In addition, by substituting labour to some extent, digital technologies are also considered to be capital-biased, as the discussion surrounding the falling labour income share in the 2017 report shows. As a result, high-skilled digital-intensive products are mainly exported by economies that have high levels of capital and educational attainment.

In a more extreme and futuristic scenario, advanced AI, additive manufacturing and robotics may come to exclude labour endowments as a determinant of trade patterns. As technologies develop and become cheaper, they might be able to substitute for workers of all skill levels, and since the supply of smart robots and 3D printers can potentially become unlimited, this would lead to an equalization of labour endowments across the globe. At the same time, robots do not generate additional demand. As a result, trade flows driven by differences in labour endowments could potentially run dry with considerable consequences for current trade patterns. On the path to this extreme outcome, it is likely that trade patterns will evolve with the skills and adoption of additive manufacturing and robots in production across sectors. Figure B.20 suggests in this regard that the automotive trade will be affected first, followed by electronics and metals.

The effect of digital technologies on the relevance of the second canonical source of comparative advantage, differences in technology, is less clear. Such differences are often linked to research and development (R&D) expenditure and policy (Costinot et al., 2012; Griffith et al., 2004; Goldfarb and Trefler, 2018a). The central question emphasized by Goldfarb and Trefler (2018a) in this regard is whether knowledge externalities and R&D spillovers in digital technologies are confined within borders or extend beyond. That is, how easy is it in an age of GVCs and high-skilled migration to keep research insights and know-how within innovating countries? Knowledge externalities that extend beyond borders would facilitate potential technological leapfrogging of developing countries and blur out differences in technology. If digital knowledge externalities are, however, confined within borders, the existing advantages of high-income economies in innovation are likely to persist and provide these economies with a lasting comparative advantage in digital-intensive sectors.

A source of comparative advantage whose role is likely to increase for comparative advantage in digital-intensive sectors is energy infrastructure. The server farms that are necessary to support digital technologies depend on storage devices, power supplies, and cooling systems that consume vast amounts of energies. Van Heddeghem et al. (2014) estimate that communication networks, personal computers and data centres were responsible for about 5 per cent of global electricity consumption in 2012, a number that had increased by around 20 per cent since 2007. Based on Facebook's 2013 sustainability report, Burrington (2015) shows that its data centres alone consumed as much energy as Burkina Faso and, as Section B.1(b) found, the Bitcoin network uses as much electricity as a country the size of Ireland.

Another factor that will become more important for trade patterns in the digital age is market size. This is due to the extraordinary economies of scale and scope that exist in digital-intensive sectors. As pointed out above, Goldfarb and Trefler (2018a) explain how firms relying on digital technologies, and in particular AI, benefit from having access to large amounts of information. As a consequence, when such firms from larger domestic markets enter export markets, they will be more competitive than competitors coming from smaller markets that have less access to information prior to entering foreign markets. This can partly explain the dominance of Chinese and US firms in digital-intensive sectors, and it also suggests that there is potential for large developing economies to enter digital-intensive sectors.

In contrast, border processes, geographical factors and physical infrastructure with the exception of telecommunications and energy infrastructure, may become less relevant for remote or landlocked countries, as well as countries whose physical infrastructure and customs procedures are underdeveloped and which wish to enter new markets. As products are increasingly supplied digitally and GVCs possibly become shorter (see Section C.2(c)), trade will rely less and less on roads, ports, airports or railways, and this would counteract some of the competitiveness gains of high-income countries in digital-intensive sectors and tasks. However, Section C.2(c) also discusses a scenario in which GVCs become longer. New technologies make logistics and transport more efficient, consumers prefer higher degrees of customization, and e-commerce brings markets closer together, leading to a parcellization of trade (see Box C.4). Thus, infrastructure and geographical factors will remain important for digital intensive products that are still traded physically.

The digitalization of trade can be expected to magnify the importance of formal and informal institutional factors for comparative advantage. The role of legal institutions that measure the ability of countries to enforce contracts will increase insofar as they interact with other policy fields. For instance, data privacy or IPR regulations rely on credible enforcement. As a consequence, their effectiveness will be ultimately determined by the strength of legal institutions in affected countries. The same holds true for financial institutions which can facilitate access to capital and therefore investments in the necessary infrastructure and equipment. Labour market regulation, in contrast, could become less important, as robots and 3D printers will be less protected by labour rights. Finally, informal institutions have been shown to play their part as well. Amongst others, Lanz et al. (2018) show that migrant networks can substitute for formal institutions in enforcing contracts and bridging information asymmetries.

At the same time, new technologies can reduce the role of institutions and facilitate the trade of countries with weak institutions. As discussed in Section C.1, technologies such as blockchain can circumvent intermediaries in trade and lower demand for contract enforcement institutions. There is also evidence that standardized information provided by digital technologies can reduce the importance of trust and reputation in online transactions (Agrawal et al., 2016). They find that this can in particular boost the exports of digitizable products from developing economies.

(ii) New determinants of trade patterns in the digital age

Beyond changing the role of traditional determinants, digital technologies also create new determinants of trade patterns. As, for instance, the role of physical infrastructure decreases for some sectors, digital infrastructure will increasingly become central for digital trade. Similarly, as labour market regulation might become less important for comparative advantage, the regulation of data flows will become more important. The importance of regulation is reflected in recent trade agreements or trade policy announcements that include substantive chapters on IP protection and e-commerce, and these will be discussed in Section D. How these new areas will affect comparative advantage in digital intensive tasks and sectors will determine trade patterns in these activities in the future.

Privacy, personal data protection and web content restriction policies will play an important role in this regard. From an economic perspective, limitations on firms' abilities to collect and assign data to individual users can restrict the development of economies of scale and scope and hamper competitiveness in digital-intensive sectors. For example, Goldfarb and Tucker (2010) show that the tightening of European privacy laws in 2004 decreased the effectiveness of online advertising in Europe by 65 per cent relative to the United States. Related to this, Miller and Tucker (2011) find that variations in US state medical privacy laws can explain differences in neo-natal mortality rates because strict laws prevent access to electronic medical records.

The same logic applies to web content restrictions that have been enacted by certain countries. By blocking certain websites or content on certain websites, countries limit firms' abilities to understand consumers' preferences. More importantly, blocking content can reduce incentives to invest in and produce digital-intensive products. Zhang and Zhu (2011) provide evidence that the blocking of the Chinese-language Wikipedia in mainland China reduced the contributions of non-blocked Chinese-speaking contributors in Chinese Tapei, Hong Kong (China), Singapore, and other regions in the world considerably, since the rewards, in this case the social benefits of adding content, were reduced.

The evidence presented above thus suggests that privacy, personal data protection and web content restriction regulation can affect comparative advantage in digital-intensive sectors. In other policy fields, such as environmental regulation or tax policy, such insights have led to the discussion of regulatory race-to-the-bottom developments. However, empirical support for such an outcome in these fields is limited (Mendoza and Tesar, 2005; Copeland, 2013). An exception is the area of labour regulation where Olney (2013) and Davies and Vadlamannati (2013) find that reductions of labour standards in one country can trigger similar changes in countries nearby. Consequently, weakening privacy and personal data protection in one country to gain competitiveness in digital sectors may lead other countries to follow suit.

On the other hand, the Porter hypothesis (Porter and van der Linde, 1995) argues that, with respect to environmental regulations, strict standards can in fact raise productivity and innovation and thus be a source of comparative advantage. A mechanism behind the Porter hypothesis could be selection effects whereby regulation shifts resources to the most innovative and productive firms by driving less productive firms out of the market (Qiu et al., 2017). While empirical evidence in this area is inconclusive (Ambec et al., 2013), such a mechanism could allow countries to combine strict regulation with comparative advantage in digital-intensive sectors.

Since data protection and privacy regulation are still in their infancy in many countries, it is difficult to predict the impact on trade patterns that will arise from differences in this area. Anecdotal evidence suggests that the European Union has a relatively high degree of data protection and privacy standards, with Spain and Germany standing out as particularly stringent. Singapore and the Republic of Korea have also passed regulations protecting privacy, and several South American states have passed privacy laws in order to comply with European regulations. In contrast, the laws in Australia and the United States are considered to be less strict (Gustke, 2013). Section D will discuss this evidence in more detail.

Unlike privacy, personal data protection and web content restriction regulation, Goldfarb and Trefler (2018a) emphasize that data localization and government data access policies tend to impose costs primarily on foreign firms. These policies typically restrict the transfer of individual-level data across borders or limit access to publicly collected data to domestic firms. That is, in case privacy laws allow for data collection, this data can only be used and accessed domestically. As a result, strict data localization laws and restricted access to government data limit economies of scale of foreign firms and might necessitate the setting up of foreign affiliates and local servers. If knowledge spillovers in digital technologies are local, this can boost the competitiveness of the home market in digital-intensive sectors. However, Ferracane and van der Marel (2018) and Ferracane et al. (2018) provide evidence that data flow restrictions, such as data localization regulation, lead to lower levels of services traded over the internet and lower productivity, which hurts competitiveness.

The importance of IPR regulation is also bound to increase in the digital age because many digital products are replicable at zero cost and are of a non-rival nature. This means that they can be consumed by an indefinite amount of people at the same time without a loss of utility. To ensure profitable prices for producers, strict and enforceable IPR are central and can increase the attractiveness of a country for digital firms. Goldfarb and Tucker (2017) review evidence that shows that weak copyright enforcement has led to a reduction of revenues in the music, film and publishing industries (see Box B.2). However, Goldfarb and Tucker (2017) also discuss literature which shows that strict IPR policies could constrain the creation and quality of digital products by limiting access or raising royalty costs. Whether IPR regulations increase or reduce competitiveness in digital sectors is therefore ultimately an empirical question. Preliminary evidence presented in Appendix C.2 suggests that more stringent IPR boosts exports of IP-intensive industries, especially in countries with relatively less stringent IP protection.

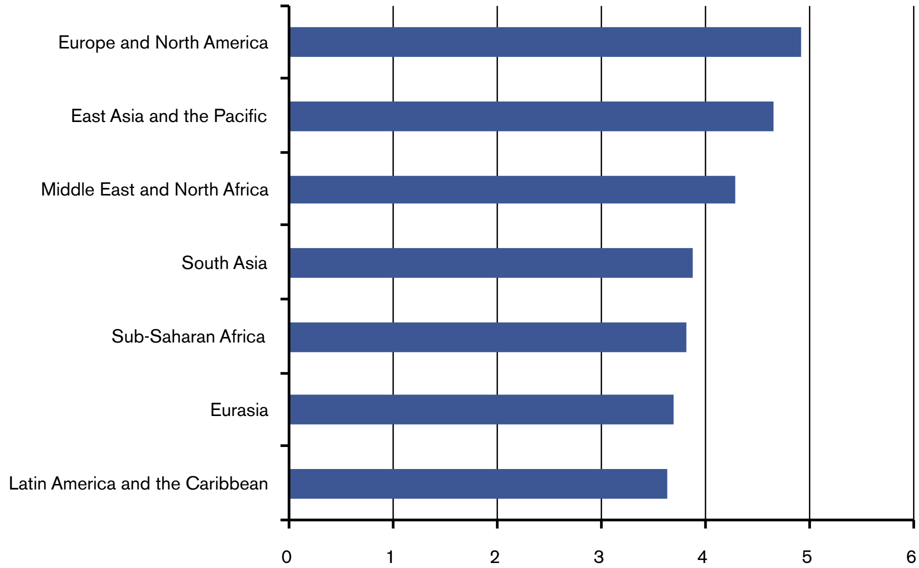
Turning to differences in IPR laws across countries, Park (2008) provides a patent right index for 122 economies from 1960 to 2005. The index combines information on coverage (i.e. sectors excluded from patenting); membership in international treaties; duration of protection; enforcement mechanisms; and restrictions on IPR. According to this index, the most stringent IPR in 2005 were among OECD members, but Bulgaria, the Philippines, Singapore and South Africa also exhibited high values. The United States topped the list, which has a maximum value of 5, with a value of 4.88.

More recent data is available from the World Economic Forum (WEF) in its Global Competitiveness Report database, which is updated annually and currently extends to 2018. In contrast to Park (2008), the database is survey-based. In 2017, Switzerland exhibited the highest score, ahead of Finland, Luxembourg and Singapore. Overall, Figure C.19 shows that European and North American as well as East Asian and Pacific economies have stringent IPR policies while the index reports low values for Latin America and the Caribbean. However, regional aggregations tend to hide significant heterogeneity within regions. To give an example, Chile, Colombia, Costa Rica and Panama all have stronger IPR than the median country in the sample.

Turning from policy to infrastructure, a reliable, comprehensive and affordable high-speed broadband network will become a central factor for competitiveness in the digital age. For instance, the amount of data that is required for the IoT will demand large investments in digital infrastructure. As the digital content of manufacturing increases, high-quality broadband access will become a necessity for competitiveness in all sectors that heavily rely on digital technologies (see also Box B.1 on the pivotal role of the telecommunications sector). Yi (2013) finds for 21 OECD countries that better broadband access provides for a comparative advantage in less routine sectors. She argues that ICT complements workers when they perform non-routine tasks, and can therefore increase competitiveness in these tasks. Given that digital technologies tend to involve many non-routine tasks, broadband access will become ever more important.

To understand how good broadband access is in different regions, it is possible to look at indicators of

Figure C.19: Intellectual property protection index



Source: WEF, the Global Competitiveness Index Historical.

Notes: IP protection as measured by the 2016/2017 WEF Executive Opinion Survey.

broadband subscriptions and broadband speed split into fixed and mobile access; these data are available from the International Telecommunications Union (ITU) and the website www.speedtest.net. Combining these four indicators into a single index shows that cross-country broadband access is highly correlated with income, as shown in Figure C.20. Figure C.21 also indicates, from a regional perspective, that North America is best prepared for the digital age, while South Asia, Sub-Saharan Africa, and Latin America and the Caribbean are lagging behind and would benefit from additional investments into their broadband networks when it comes to comparative advantage in digital-intensive activities.

(iii) Adding it all up: comparative advantage in the digital age

The advance of digital technologies brings about opportunities and challenges for developing and developed countries alike. Digital technologies have quickly become an integral part of many sectors but to varying degrees. This means that established trade patterns will change considerably as the importance of traditional sources of comparative advantage changes and new sources arise. An assessment of how these different forces will play out jointly and determine future trade patterns in digital-intensive sectors is inherently difficult. Rigorous empirical evidence on the relative strength of the individual factors for comparative advantage that have been discussed here is not available because many new technologies, such as self-driving cars or the IoT, have not been widely adopted yet. A rough evaluation is possible but should only be taken as indicative, in particular since these new forces pull at times in different directions and it is not certain which effects are going to dominate in the future.

Such a preliminary evaluation suggests that several new sources of comparative advantage could allow high-income economies to become net exporters of digital-intensive tasks and sectors and therefore reinforce existing trade patterns. High-tech activities would continue to be performed in developed economies and be a major part of their export baskets. These economies typically have a large capital stock and pool of skilled workers at their disposal. In addition, internet content restrictions are rare and the broadband infrastructure is usually well advanced. Combining this with strong formal and informal institutions should make for a comparative advantage in digital-intensive sectors, a conclusion that is reflected in the discussion on the digital divide in Section B.1(d) or in assessments like the *Readiness for the Future of Production* by the WEF, which almost exclusively lists high-income economies as leading countries (WEF, 2018b).

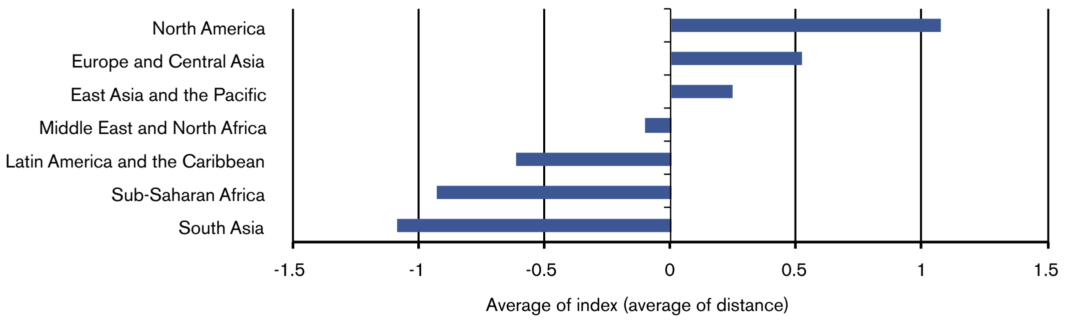
However, several developing countries might equally be able to gain market shares in these activities. Traditional sources of comparative advantage in which

Figure C.20: Broadband access index, countries grouped by income

Source: Calculations by authors, data from ITU World Telecommunication/ICT Indicators and speedtest.net.

Notes: The index combines four indicators capturing proliferation and speed of fixed and mobile broadband internet connections, defined by the ITU as networks that provide download speeds of at least 256 kbit/s. It is the average of the distances between a country's value and the mean of the respective indicator, normalized by the mean. A positive index value indicates above average broadband access. Income groups as defined by the World Bank.

Figure C.21: Broadband access index, countries grouped by geography



Source: Calculations by authors, data from ITU World Telecommunication/ICT Indicators and speedtest.net

Notes: The index combines four indicators capturing proliferation and speed of fixed and mobile broadband internet connections, defined by the ITU as networks that provide download speeds of at least 256 kbit/s. It is the average of the distances between a country's value and the mean of the respective indicator, normalized by the mean. A positive index value indicates above average broadband access. Geographic groups as defined by the World Bank.

developing economies might lag behind are likely to become less important for certain types of products. When trade becomes digitalized, underdeveloped infrastructure and ineffective border procedures might become less burdensome. Along the same lines, advances in technologies like blockchain can overcome weak contract enforcement abilities. Another central aspect of digital technologies is that they will amplify economies of scale and scope. Large developing economies could be the main beneficiaries of this development. Market size itself will create competitiveness in selected sectors and can counterbalance underperformance in other areas of relevance. Finally, knowledge externalities that spread beyond borders can facilitate technological leapfrogging, as has already been the case of financial technology ("fintech") in Kenya (see the opinion piece by Wim Naudé, Maastricht University, UNU-MERIT, and IZA Institute of Labor Economics, on page 46).

Evidence that digital technologies already help developing countries to export digital-intensive products has recently been provided by Loungani et al. (2017). They find that while developed countries are responsible for the majority of exports in (potentially) digitally-enabled services, exports of these services have been growing the most in developing countries. Some developing countries have built up strong positions as exporters of ICT services. India, for example, is the leading exporter of computer services, exporting computer services worth an estimated US$ 53 billion in 2016, while the Philippines exported ICT services worth US$ 5 billion, making it a global top 20 exporter of ICT services.

In sum, new technologies have the potential to benefit trade in countries across all stages of development. Innovation will continue to shape trade patterns and, therefore, offers vast opportunities for developing and developed countries alike. This certainly requires minimum levels of factors such as skilled labour or capital, digital infrastructure and institutional quality, but as long as such minimum levels are ensured, countries will be able to participate in the new gains from trade that will arise.

(c) Digital technologies and GVCs: an uncertain outlook

In GVCs, intermediate products are outsourced and production becomes fragmented across borders. The GVCs phenomenon began in the 1970s[18] and thrived from the mid-1990s to the late 2000s.[19] During the 2000s, both the value of GVCs' trade flows and their complexity increased (see Figure C.22). The global financial crisis of 2008 caused a collapse in international trade, which was moderately amplified by GVCs.[20] While value chain trade rebounded after the crisis, the last few years have witnessed a further slowdown in GVCs (this can be seen in the last two data points of Figure C.22).

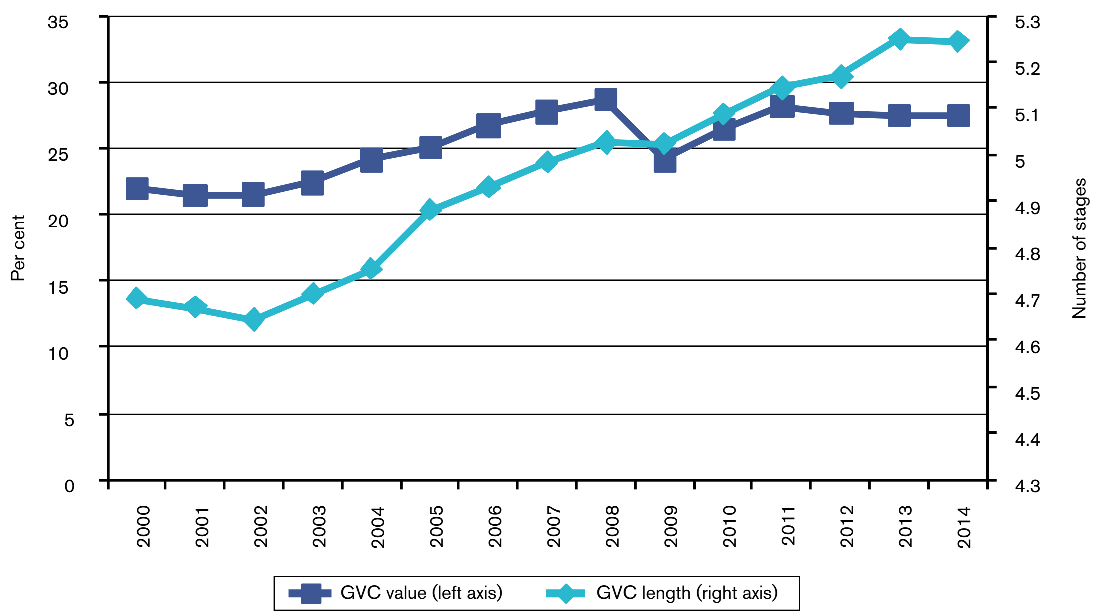
The objective of this section is to assess the role of technology in driving GVCs. In particular, insights are provided on how the digital technologies that are the focus of this report can contribute to explain the patterns described above, and on whether the current slowdown in GVCs might persist in the future, or further GVC expansion might be expected.

(i) Technology is a key driving factor of GVCs

Technology is a key factor driving international fragmentation of production in GVCs.[21] As explained by Amador and Cabral (2016), adequate technology is required to combine parts and components produced in different locations in sophisticated final products, and more generally to coordinate and manage dispersed production activities. Such coordination and management is carried out by technology-intensive services. Management and IT services synchronize the worldwide production process; transportation services move parts and components between production facilities; and marketing and sales services make sure that products are sold in the most suitable way on different national markets.

Accordingly, theoretical analyses of GVCs highlight the role of technology, and the services enabled

Figure C.22: GVC value and GVC length, 2000-14 (per cent and number of stages)



Source: Timmer et al. (2016), Degain et al. (2017).

Notes: GVC values are proxied by global import intensity, computed as the ratio of "GVC imports" (imports needed in any stage of production of a final good or service) to the value of the final product (Timmer et al., 2016). GVC length is the average number of stages in the production process of "complex" GVCs – defined as domestic value-added that is embodied in intermediate exports and used by a partner country to produce exports (intermediate or final) for other countries (Degain et al., 2017).

by technology, in their development. The spatial unbundling of production and consumption (the "first unbundling" in Baldwin's 2006 terminology) which occurred at the end of the 19th century was made possible not only by the great reductions in transport costs which resulted from steam power (Baldwin, 2006), but also by the fall in communication costs which came about due to the telegraph (Juhász and Steinwender, 2018).[22] The spatial unbundling of production stages previously clustered in factories and offices (the "second unbundling") which occurred in the 1990s, is largely due to sharp falls in communication and coordination costs, or in the "cost of moving ideas", in Baldwin's term, originated by the ICT revolution. As communication and coordination costs fell below the expected cost advantages through specialization, economies of scale and differences in labour costs, companies found it more attractive to organize their production processes on an international scale (De Backer and Flaig, 2017).

The work by Baldwin and Venables (2013) further shows how technology fundamentally shapes the way in which different stages of production are linked. Production processes in which multiple parts and components are assembled in no particular order (which the authors call "spiders") differ from production processes where goods move in a sequential way from upstream to downstream stages in value chains (which the author call "snakes") because of intrinsic engineering (i.e. technological) requirements.[23]

(ii) Digital technologies will affect GVCs in opposing ways

Digital technologies do, and will in the future, have ambiguous effects on GVC trade. This subsection reviews the mechanisms through which various digital technologies can increase or decrease supply chain trade, starting with those mechanisms which point to a positive link between digital technologies and supply chain trade.

How can digital technologies increase supply-chain trade?

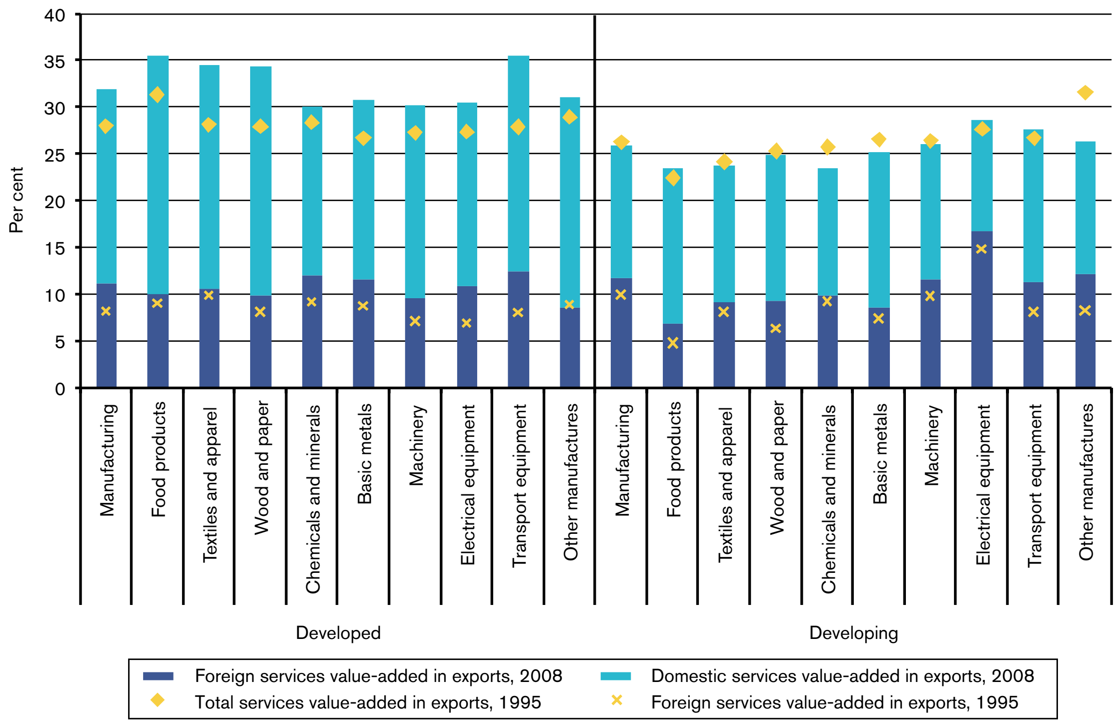
There are two ways in which digital technologies can lead to more GVC trade. First, as argued in Section C.1, the adoption of digital technologies can reduce costs that negatively affect GVCs. Second, digital technologies can also lead to more GVC trade when they increase the quality and availability of services that act as enablers of value chains or that are used as inputs to the production of goods.

GVC trade is particularly sensitive to communication costs, transportation and logistics costs, and to matching and verification costs. This is because the higher these costs, the harder it is to coordinate geographically dispersed tasks. Technologies that reduce these costs, therefore, are particularly likely to favour GVC trade. Improved broadband applications, the spread of smartphones and tele-, video- and virtual-conferencing make it easier to operate longer and more complex GVCs by lowering communication costs.[24] Technologies that make it cheaper and easier to track and monitor components as they move through the supply chain, such as radio-frequency identification technology, reduce inventory management costs[25] and simplify logistics (see Section C.1a). Blockchain technology has the potential to reduce verification costs greatly. This is likely to increase transparency and expand trade along value chains. Another potential impact of blockchain technology on value chains works through its effects on matching costs between upstream suppliers and downstream buyers. Such costs often arise due to a lack of trust, which is not an issue in blockchain-based transactions. Accordingly, sourcing along value chains could become more diversified.[26]

The trade cost-reducing impact of some digital technologies is particularly relevant within value chains, relative to trade in final goods and services, because trade costs tend to cumulate along value chains, as was first argued by Yi (2003). When supply chains require semi-finished goods to cross international borders more than once, the effect of a marginal variation in trade costs everywhere in the supply chain is much larger than would be the case if there were a single international transaction. Ferrantino (2012) shows that when trade costs apply in proportion to the value of a good, the total cost of delivering the product through the supply chain down to the final consumer increases exponentially with the number of production stages. In practice, the accumulation effect, while still relevant, may be lower than what a simple exponential formula suggests, because of two mitigation forces: the topology of the supply chain (there is less accumulation in "spiders" than in "snakes"), and the fact that trade costs have to be significantly reduced before GVCs start expanding (Diakantoni et al., 2017).[27]

The second way in which digital technologies can lead to more GVC trade is through their impact on services. Digital technologies increase the quality and availability of a wide range of intermediate services (domestic or imported) that act as enablers of GVCs, for example, computer, R&D, advertising, telecommunications, financial and professional services.[28] Moreover, as argued in Section C.2.(b), services provide significant inputs to the production of goods. Figure C.23 portrays the services value-

Figure C.23: Service value-added content of manufacturing industry exports, 1995 and 2008 (per cent)



Source: Lanz and Maurer (2015).

Notes: Figures are divided by provenience of value-added.

added content of exports of manufacturing industries for developed and developing countries in 1995 and in 2008. Services account for close to one-third of manufacturing exports in developed countries and 26 per cent in developing countries, with the share of foreign services value-added (i.e., value-added coming from imported services) being above 11 per cent for both country groups (Lanz and Maurer, 2015). Recent studies estimate that up to half of the value-added in manufacturing exports is contributed by external and internal (i.e. in-house provided) services (Miroudot and Cadestin, 2017).[29]

New technologies will magnify such estimates because they will further increase the share of services in the value of goods. The value of self-driving cars, for instance, will be increasingly determined by the software steering the wheel. Smart fridges will be priced more according to the relevant software development costs than the costs of their physical parts and components. The combination of rising shares of value-added in manufacturing exports and of the greater ease of supplying services remotely (discussed in Section C.2(a)) will lead, all other things being equal, to more value chains trade in the future.

Do digital technologies trigger reshoring?

The recent slowdown in GVC activities (both in value and in length) documented above is consistent with three explanations (Degain et al., 2017):

(i) the rising tide of protection around the globe after the global financial crisis (Georgiadis and Gräb, 2016);

(ii) substitution of imported intermediate inputs with domestically produced intermediate inputs in major emerging economies, such as China;[30] and

(iii) reshoring, i.e. firms' relocation of production or other business functions from abroad to the domestic country of the firm.

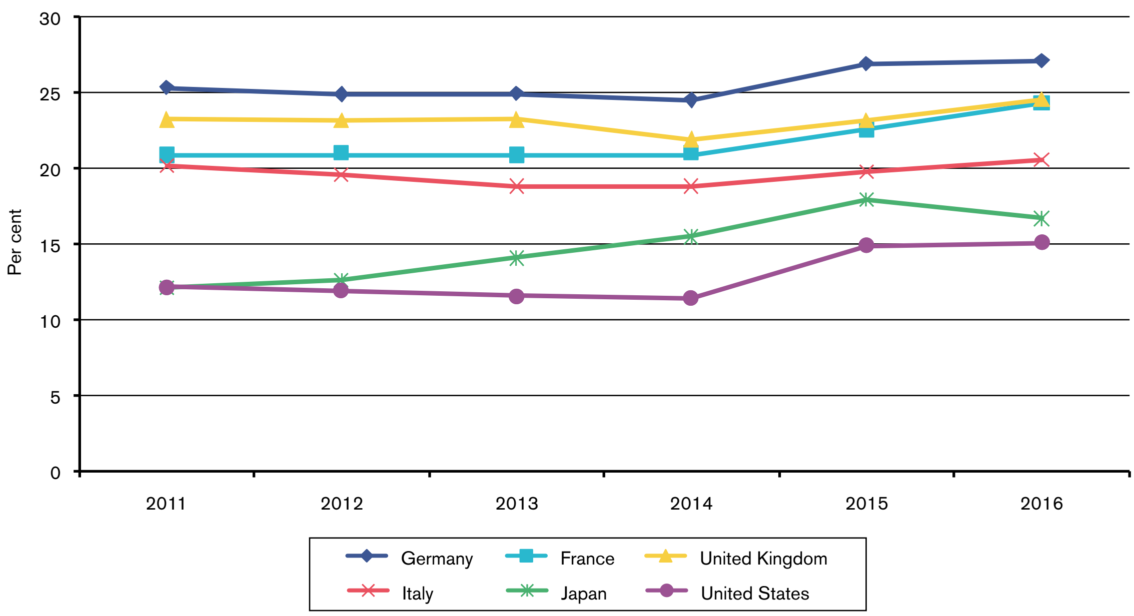
In what follows, the focus is on reshoring, and in particular on how digital technologies may affect this phenomenon.[31]

Anecdotal evidence of reshoring is not difficult to find. Dachs et al. (2017) provide the example of an Austrian producer of metal parts. One of the core production processes of this firm is smoothing and polishing large metal parts. This time-consuming task, requiring between 100 and 150 working hours per part, was initially offshored to Hungary. Recently, the firm automated this production step, installing a robot. The robot works 24/7 and only requires 20 hours to smoothe and polish one metal part. Such enormous productivity advantages largely compensate any wage gap that motivated the offshoring decision. Therefore, the investment in robots allowed the firm to relocate the task back to Austria, re-concentrating production in one place. Since transport of metal parts between the two countries is not needed anymore, the firm is also able to take orders that were not possible before because of the time needed for transport between the production facilities (Dachs et al., 2017). In the United States, companies such as General Electric, Master Lock, Caterpillar, Whirlpool and Ford have moved parts of production of some of their products back from abroad (Oldenski, 2015). A.T. Kearney (2015) reports 16 cases of reshoring to the United States in 2010, 64 in 2011, 104 in 2012, 210 in 2013, and 208 in 2014.

All systematic evidence, however, shows that reshoring has been so far a limited phenomenon, and has exhibited no significant trend. In a sample of 2,120 manufacturing firms from Austria, Germany and Switzerland, each with at least 20 employees, from the European Manufacturing Survey, Dachs et al. (2017) find that the share of firms that reshored production in 2013 or 2014 was only 3.8 per cent, increasing to 10 per cent if only firms with production activities abroad were considered. If all countries covered by the European Manufacturing Survey were considered (Austria, Denmark, France, Germany, Hungary, the Netherlands, Portugal, Slovenia, Spain, Sweden and Switzerland), again only around 4 per cent of firms moved production activities back home between 2010 and mid-2012 (De Backer et al., 2016). In the case of the United Kingdom, the Manufacturers' Organisation (EEF)[32] (2014) reported that approximately 15 per cent of manufacturing firms engaged in reshoring (whether bringing production back in-house or to a UK supplier from abroad) in 2013. For the United States, Oldenski (2015) considers, as inverse proxies of reshoring, imports of US-based multinational corporations, using data from the US Bureau of Economic Analysis. Both imports from affiliates (intra-firm trade) and imports from non-affiliates (arm's-length trade) exhibited an upward trend between 1999 and 2012. This is evidence of offshoring, rather than reshoring.[33]

Further confirmation that there has been no significant reshoring trend is conveyed by Figure C.24, which displays the evolution between 2011 and

Figure C.24: Share of foreign value-added in domestic final demand, 2011-16 (per cent)



Source: Asian Development Bank's Inter-Country Input-Output table.

Notes: Foreign value-added as a share of domestic final demand reveals the share of foreign value-added present in final goods or services purchased by households, government, non-profit institutions serving households or as investments. It shows how industries abroad (upstream in a value-chain) are connected to consumers at home, even where no direct trade relationship exists, and can be interpreted as “imports of value-added”. Note that the share of foreign value-added in domestic final demand is equal to one minus the share of domestic value added in domestic final demand.

2016 of the share of foreign value-added embodied in domestic final demand in selected advanced economies. Reshoring would be associated with a decrease in the share of foreign value-added in domestic final demand and a corresponding increase in the share of domestic value-added, as reshoring firms source more value-added domestically. For the United States, with the exception of the 2008-09 dip (corresponding to the Great Recession), the trend is slightly negative between 2011 and 2014, but positive afterwards, in line with Oldenski's (2015) finding that the available evidence for the United States is in favour of more offshoring rather than reshoring. Similar results also apply to the largest European economies, namely France, Germany, Italy and the United Kingdom. The only large advanced economy in which the share of foreign value-added in domestic final demand recently declined is Japan. However, the decrease between 2015 and 2016 did not overturn an overall positive trend since 2011.

Various factors can explain the slow pace of reshoring (UNCTAD, 2016b). First, relatively weak aggregate demand, and investment in particular. Second, developed countries may lack the supplier networks that some developing countries have built to complement assembly activities. Finally, as indicated by the fact that offshoring continues to take place, labour-cost differentials are not the only factor in the decision of firms on where to locate production. Demand factors such as the size and growth of local markets are becoming increasingly important determinants. Therefore, production of labour-intensive manufactures destined for rapidly growing markets in large developing countries that have domestic production linkages is unlikely to be reshored (UNCTAD, 2016b).

The evidence against an existing reshoring trend does not imply that, in the future, sourcing patters of multinational firms will not change. The example of the Austrian producer of metal parts illustrates how automation technologies can lead to reshoring. Automation reduces the share of labour costs in total costs. Since labour cost differentials are the main determinants of offshoring, smaller labour cost differentials will lead, other things equal, to more reshoring. Automation does not need to be smart for this mechanism to work. However, smart automation provides additional reasons to reshore. Smart robots not only can work in "dark factories" like traditional robots.[34] They can also perform a wider range of relatively complex manual tasks and adapt to changing conditions (De Backer and Flaig, 2017). In sectors like consumer electronics, traditional robots may not be flexible enough to adapt production to the short life cycle of products (with the consequence that production is often manual), but smart robots may. The incentives to reshore production closer to larger and richer markets would therefore increase.[35]

Against this theoretical background, there is quite limited empirical evidence that digital technologies can trigger reshoring. De Backer et al. (2018) find a negative association between robotics investment and the growth of offshoring for developed economies in the period 2010-2014. This begs the question of whether investments in robots will lead to the actual reshoring of activities to developed economies. The evidence in De Backer et al. (2018) points to a negative answer, leading the authors to conclude that the use of robots does not (yet) trigger reshoring of activities to developed economies. Conversely, in a survey of 2,120 manufacturing firms from Austria, Germany and Switzerland with at least 20 employees, Dachs et al. (2017) find a positive relation between reshoring and an index of "Industry 4.0 readiness".[36]

As will be further discussed in Section C.3, simulations conducted using the WTO Global Trade Model produce mixed results on the effect of digital technologies (as measured by changes in the degree of digitalization and robotization across sectors and countries) on reshoring. In particular, when the share of intermediate imports in gross output is used as a measure of reshoring, there is indication of future reshoring. On the contrary, when foreign value added in exports is used as a measure of reshoring, there is hardly any change from the baseline scenario. This would indicate that the reorganization of tasks in production due to changing degrees of digitalization and robotization will not necessarily lead to a change in the organization of GVCs.

Future scenarios matter

It has been argued so far that digital technologies will have ambiguous effects on GVCs. On the one hand, those technologies that help to coordinate geographically dispersed tasks will likely lead to longer and more complex value chains in the future. On the other hand, those technologies that reduce the relative costs of domestic production to offshore production could lead to less GVC trade.

The outlook is uncertain not only because different digital technologies have different effects, but also because the same technology could increase or decrease GVC trade, depending on future scenarios regarding its adoption. This is most notably the case of 3D printing. Along value chains, most 3D printing is concentrated in upstream activities like prototyping, product development and R&D.[37] In a scenario in which 3D printing continues to be used mostly for upstream activities in GVCs, it is likely that traditional production methods and 3D printing will complement each other rather than compete (WTO, 2013c).

In the longer run, however, 3D printing may to some extent substitute traditional manufacturing methods. By making it possible to produce final consumption goods at the point of sales, the need for outsourced production and assembly might be reduced, thus lowering the number of production steps (De Backer and Flaig, 2017; Moradlou et al., 2017; Strange and Zucchella, 2017). Value chains in a world of pervasive 3D printing might overwhelmingly be based on the cross-border exchange of digitally-transmitted designs, blueprints and software, rather than on the cross-border exchange of material goods (PWC, 2014; Kommerskollegium, 2016).

A radical shift in the organization of production, from mass production to mass customization, would also have radical implications for value chain trade. Long and complex GVCs emerged as an efficient way of organizing production of standardized products, exploiting economies of scale and gains from specialization. In a world where supply shifts away from mass production towards mass customization, long and complex value chains do not provide the necessary flexibility to adapt to changing demand conditions. According to some commentators (Standard Chartered, 2016; De Backer and Flaig, 2017), value chains may become shorter in response to such shifts, with production centres emerging near every large customer base (Baldwin, 2013) or near centres of innovation (Spence, 2018).

To conclude, while it is undisputed that digital technologies will deeply affect the nature, complexity and length of value chains in the future, the question of whether the net effect of digital technologies will be a reduction or an increase in GVC trade is an open one.

3. Quantitative analysis of the impact of new technologies on trade

In this section, the qualitative analysis undertaken earlier, which identified the ways in which new technologies and digitalization can affect international trade, is complemented with quantitative projections on changes in the size and patterns of international trade. To this end, the Global Trade Model, a recursive dynamic computable general equilibrium (CGE) model is employed, featuring multiple sectors, multiple production factors, intermediate linkages, capital accumulation, a global transport sector and a host of taxes.[38] The model is based on the facelift version of the GTAP-model (Version 7) with the following additional features. The model is recursive dynamic, allowing for endogenous capital accumulation, features endogenous factor supply, contains different options to allocate global savings, and is flexible in its trade structure allowing to switch between the Armington perfect competition, Ethier-Krugman monopolistic competition, and Melitz-structures firm heterogeneity structures. More details on the model are provided in Appendix C.3.

Quantitative analysis serves three important goals. First, it disciplines the qualitative predictions, as it forces analysts to translate the storylines into quantitative shocks in a micro-founded economic model, which is based on agents' optimizing behaviour. Second, the use of a consistent general equilibrium model (that is, within a set up where all markets and their interactions are taken into account) implies that indirect effects of shocks across countries and sectors are all taken into account. Third, the fact that the model is computable makes it possible to go beyond qualitative predictions and provide actual numbers on the expected effects of new technologies on international trade. As a caveat, it should be emphasized that some of the expected changes are inherently difficult to predict. Quantitative predictions should therefore be interpreted with care.

In particular, the impact of the following three trends on the size and patterns of international trade is explored. First, the impact of digitalization, robotization, and artificial intelligence (AI) on the allocation of tasks between labour and capital is studied. These trends will reallocate more tasks in the economy away from labour towards capital (defined in a broad way) and at the same time raise productivity. The task-based approach in Acemoglu and Restrepo (2016), discussed further below, is employed to model this phenomenon. AI can be a form of automation which, rather than substituting machine power for manual labour, substitutes the computing ability of machines for human intelligence and expertise. As such labour is substituted by capital (broadly defined, the capital intensity of production rises).

In the quantitative analysis, changes in the capital intensity of production are projected conservatively, based on historical empirical trends and productivity growth varying by sector and region, based on various studies and indicators on the differential productivity impact of these phenomena.

Second, changes in the production structure leading to a more intensive use of ICT-services by other sectors in the economy, defined as servicification, are explored. New technologies are expected to lead to a more intensive use of ICT services inputs in other sectors. Conservatively, the change in ICT-services over the next 15 years is projected based on changes in the last 15 years visible in global input-output data from the World Input-Output Database (WIOD).

Third, the impact of new technologies on trade costs is examined. Along various channels, digital technologies are expected to reduce trade costs. In particular, the improvement of customs procedures, the rising efficiency of logistics, falling communication costs associated with different languages, and falling contract enforcement costs due to the development of blockchain are taken into account. The expected reductions in trade costs are inferred by employing empirical estimates of the impact of the mentioned channels on the size of trade costs.

Before exploring the impact of new technologies and digitalization, a baseline scenario for the world economy needs to be constructed. The baseline scenario projects the development of the world economy until 2030 without technological changes as a result of digitalization, robotization and AI. The baseline is constructed using 2011 base data from GTAP 9.2 and macroeconomic projections from IMF, OECD, and CEPII and WTO calculations on structural change. To keep the model and presentation of results tractable the base data are aggregated to 14 regions, 16 sectors, and five factors of production. Further details on the construction of the baseline are provided in Appendix C.3.

(d) The impact of new technologies on trade

To study the impact of digitalization on global trade, the effects of three trends are explored quantitatively: (i) a reallocation of tasks in production because of robotization and digitalization; (ii) the servicification of the production process with a rising share of the use of ICT services in the rest of the economy; and (iii) falling trade costs as a result of technological changes. The three trends are translated into quantitative shocks to the baseline projections, which are the business-as-usual projections of the economy without technological changes. For each of the three shocks, a core scenario and a convergence scenario are developed, where the latter foresees an acceleration of the three trends in developing countries.

Since technological developments are highly uncertain, the trends modelled are an indication of the direction global trade is projected to take. The size of the effects of different trends is based on econometric work together with scenario building (for falling trade costs), on predictions from the literature (for the productivity part of digitalization and robotization) and on trends in the past (for rising capital income shares and servicification).[39] This subsection discusses the way the shocks are introduced in our model. The next subsection compares the outcomes of the implementation of these shocks in terms of the most relevant variables in the baseline, core and convergence scenarios.

(i) Description of the three trends

Digitalization, robotization and reallocation of tasks

The expected technological changes as a result of digitalization, robotization and AI are described extensively in Section B. Technological changes as a result of robotization and artificial intelligence are modelled here following the approach in Aghion et al. (2017).

In this set-up, a continuum of tasks has to be completed in order to produce. Robotization will reallocate tasks from labour to capital, which has two effects: first, it will raise the capital income share, and second, it will raise productivity. The second effect occurs if the initial allocation of tasks is not optimal, as pointed out by Acemoglu and Restrepo (2016).[40] Since the extent of reallocation of tasks cannot be observed, the base scenario will be disciplined by changes in two observable variables, the capital income share and productivity growth, varying across countries and sectors. Appendix C.2 describes how average projected changes in capital income share and productivity are calculated and how they then vary across sectors and countries. The variations in changes in the capital income share and in productivity growth are assumed to be identical.[41] With respect to variation across countries, two scenarios are developed for productivity growth and rising capital income shares as a result of robotization: a base scenario and a convergence scenario with developing countries catching up in comparison to the base.[42]

Servicification of the production process

Digitalization will affect the sectoral structure of production, generating a process of servicification. In particular, the use of information and communication technology services by other sectors of the economy will rise. To infer the extent of servicification, the change in the share of ICT services in the World Input-Output Database (WIOD) from 2000 to 2016 (more specifically the share of sectors J62 –

"Computer programming, consultancy and related activities" – and J63 – "Information service activities") were computed. The data show that the average share of sectors J62 and J63 in the total intermediate demand by all sectors has doubled in 15 years from about 2.5 per cent to 5 per cent.

Based on these changes in the last 15 years, two scenarios are developed in this report, a core scenario and a convergence scenario. In the core scenario the share of ICT services used by other sectors grows at a constant rate for all regions. In the convergence scenario, the share grows more in countries that started with a lower share in the 2000-2016 period than the region with the highest share.

Falling trade costs

New technologies are expected to lead to a reduction of trade costs in a number of areas. First, digitalization will improve the handling of customs procedures. Second, logistics efficiency is expected to rise. Third, the negative impact of language differences may have less impact with the development of new technologies. And fourth, the emergence of blockchain and other digital forms of finance may reduce the effects of bad contract and credit environments. A detailed description of how falling trade costs are modelled can be found in Appendix C.3.

(ii) The impact of new technologies on trade

This section presents the impact of the three trends described above in the core, and convergence scenarios on the following outcomes: (i) annual trade growth; (ii) the share of developing countries in global exports; (iii) changes in the sectoral and geographical distribution of production; (iv) changes in the global value chain measures imported intermediates in gross output and foreign value-added; and (v) the share of imported services in manufacturing output. For comparison the values in the baseline are also presented. Table C.3 displays an overview of the three trends modelled in the different scenarios.

Four main results are obtained. First, technological changes are expected to raise trade growth, as a result of both falling trade costs and the more intensive use of ICT services. Second, the trend of a rising share of developing countries in global trade can be weakened if developing countries do not manage to catch up in terms of all three phenomena modelled: technology growth associated with new technologies, reductions in trade costs, and increased ICT services in the production process. Third, the trend of a rising share of services exports in total exports is reinforced for most countries by the modelled technological developments. Fourth, the impact of these developments on the organization of value chains as measured by foreign value added in exports or imported intermediates in gross export is limited. Nevertheless, we find that the rising share of services imports in manufacturing gross output becomes much stronger with technological changes, both as a result of servicification and falling trade costs for services.

Table C.3: Overview of trends modelled in the two scenarios

	Scenarios	
Trends	**Core**	**Convergence**
Digitalization and robotization	Differential productivity growth by sector and region as a function of, respectively, scope for technological change and digital readiness.	Differential productivity growth across sectors in the same way as in the core scenario, with lagging regions catching up to 25% best performing regions in terms of productivity growth.
Servicification	Doubling of the share of ICT services and consultancy used by all other sectors. Constant growth in the share across regions.	Doubling of the share of ICT services and consultancy used by other sectors. Larger growth in the share in lagging regions.
Falling trade costs	Reductions in iceberg trade costs* as a result of new technologies along four channels. Identical reductions across different regions.	Reductions in iceberg trade costs as a result of new technologies along four channels. Trade costs in high-trade cost pairs converging to trade costs in 25% lowest-trade cost pairs.

* Iceberg trade costs (first modelled by Samuelson, 1954) are the costs of transporting a good when that transport uses up some fraction of the good itself, rather than other resources. Iceberg trade costs are called this way in an analogy with floating icebergs, part of which melt while floating.

Table C.4 contains the first main message of the analysis: technological changes are expected to raise trade growth. This is the result of both falling trade costs and the more intensive use of ICT services. The figure compares the annual trade growth in the baseline, the core scenario, and the convergence scenario. It is clear from the figure that the additional trends raise trade growth considerably in the different regions. The impact is bigger in regions displaying smaller trade growth in the baseline scenario. As expected, the lower-income regions display stronger trade growth in the convergence scenario. Globally trade grows by 1.8 to 2 percentage points more in

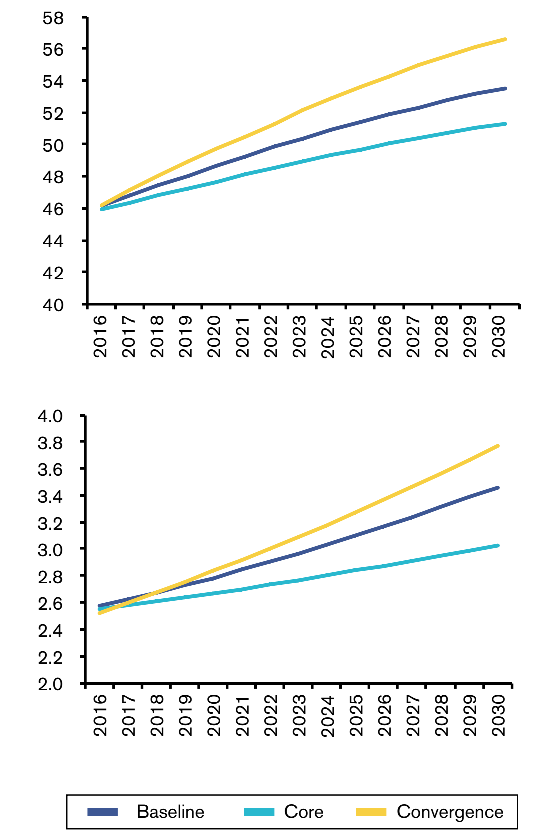
Table C.4: The average annual real trade growth between 2016 and 2030 (%)

Region	Baseline	Core	Convergence
ASEAN	5.47	7.60	7.99
Brazil	1.69	4.86	4.66
China	6.62	8.72	8.66
European Union (28)	1.51	3.20	3.27
India	7.46	9.33	9.61
Japan	1.54	2.96	2.98
Latin America and Caribbean	3.37	5.44	5.68
Middle East and North Africa	3.66	5.76	6.22
Nigeria	5.72	7.13	7.93
Other Asian countries	3.96	6.12	6.51
Other developed countries	2.46	4.35	4.27
Rest of the world	2.61	4.65	5.25
Sub-Saharan Africa	5.27	7.05	8.25
United States	2.40	3.85	3.47
Global	3.29	5.17	5.32

Source: Authors' own calculations with WTO Global Trade Model.

Notes: The figure displays annual real trade growth in the different regions and globally (trade weighted average). Details on the aggregation are in Appendix Table C.3. ASEAN is Association of Southeast Asian Nations.

Figure C.25: The share of developing (upper panel) and least-developed (lower panel) countries in global exports (per cent)



Source: Own calculations with WTO Global Trade Model.

Notes: The figure displays the share of developing countries' (upper panel) and LDCs' (lower panel) exports in global exports (including intra-regional international trade).

the different regions in the core and convergence scenarios compared to the baseline. This corresponds with a 31 to 34 percentage points larger trade growth in the core and convergence scenarios over 15 years.

Figure C.25 displays the second main message of the analysis: the trend of a rising share of developing countries in global trade can be weakened if developing countries do not manage to catch up in terms of all three phenomena modelled, i.e. technology growth associated with new technologies, reductions in trade costs, and the rise of ICT services in the production process. The figure shows that the export share of developing countries (upper panel) rises over time, but much less so in the core scenario. The share of developing countries in global exports rises from 46 per cent in 2015 to 57 per cent in the convergence scenario, whereas it rises only to 51 per cent in the core scenario without catch-up. A similar positive trend holds for the share of LDCs (lower panel).

The third main message of the analysis is that the trend of a rising share of services exports in total exports is reinforced for most countries by the modelled technological developments, as shown in Table C.5. This is due to the fact that trade costs fall more for the services sectors and that the servicification trend leads to a rising importance of services in the economy and thus also of trade. Globally, the share of services trade in total trade rises from 21 per cent in 2016 to 25 per cent in the two scenarios, whereas it is projected to stay at 22 per cent in the baseline scenario (see the last row of Table C.5).

Examining the results of the separate servicification shock indicates that global export shares of the affected ICT-services are reallocated away from the traditionally strong exporters of these goods.[43] The reason is that the largest producers of ICT services will demand the largest increase in demand for these services in terms of values. Therefore, they will produce more for the domestic market and also attract more imports from other countries. Hence,

Table C.5: The share of services exports in total exports per region in 2016 and in the baseline, core and convergence combined scenarios in 2030 (per cent)

Region	2016	Baseline 2030	Core 2030	Convergence 2030
ASEAN	20.14	21.03	22.33	21.99
Brazil	15.04	15.65	17.57	18.58
China	8.37	9.12	10.21	10.56
European Union (28)	28.30	33.20	35.71	36.17
India	30.73	33.45	39.35	39.60
Japan	15.04	20.16	22.75	23.67
Latin America and Caribbean	12.49	13.06	14.65	16.23
Middle East and North Africa	13.66	13.48	16.59	17.15
Nigeria	3.37	3.04	4.17	4.39
Other Asian countries	26.36	28.54	29.35	26.80
Other developed countries	19.63	21.09	23.95	26.14
Rest of the world	14.49	15.53	18.44	20.71
Sub-Saharan Africa	12.44	11.91	14.83	13.02
United States	24.76	27.68	31.62	33.26
Global	20.95	21.08	24.70	25.03

Source: Authors' own calculations with WTO Global Trade Model.

Notes: The figure displays the share of services exports in total exports in 2016 and in 2030 in the baseline, core and convergence scenarios (including intra-regional international trade).

Table C.6: The share of imported intermediates in gross output in 2016 and in the baseline, core and convergence combined scenarios in 2030 (per cent)

Region	2016	Baseline 2030	Core 2030	Convergence 2030
ASEAN	18.03	18.10	18.64	18.67
Brazil	5.38	5.53	5.68	5.68
China	8.00	7.54	8.20	7.90
European Union (28)	15.25	14.80	14.42	14.48
India	11.49	12.09	11.87	11.83
Japan	6.60	6.98	6.83	6.80
Latin America and Caribbean	9.62	9.12	9.58	9.45
Middle East and North Africa	11.65	10.96	11.46	11.65
Nigeria	5.16	5.53	5.52	5.57
Other Asian countries	17.25	17.52	17.82	18.21
Other developed countries	9.55	9.09	9.19	9.09
Rest of the world	7.94	7.80	8.35	8.82
Sub-Saharan Africa	11.83	11.52	11.78	12.27
United States	6.04	6.09	6.34	5.98
Global	10.33	10.07	10.32	10.29

Source: Own calculations with WTO Global Trade Model.

Notes: The figure displays the share of imported intermediates in gross output in 2016 and in 2030 in the baseline, core and convergence scenarios (including intra-regional international trade).

comparative advantage export patterns of ICT services will become less pronounced as a result of the demand-driven shock.[44]

Fourth, the impact of the three trends on the organization of value chains is limited. Table C.6 displays the share of foreign value-added in imported intermediates, showing that for most regions, except for the European Union, the share of imported intermediates in gross output rises in both the combined core and convergence scenario. This is again due to the fact that trade costs are falling, thus making it more attractive to employ imported intermediates in production.

Nevertheless the rising share of services imports in manufacturing gross output becomes much stronger with the technological changes, as is clear from Table C.7. This is caused by the combination of falling trade costs, especially for services, and the servicification leading to more imports of ICT services.

Finally, it is found that the reallocation of tasks leading to a rising capital income share will not lead to a fall in foreign value-added or imported intermediates in gross output. Hence, there seems to be no support for the idea that rising capital shares in developed economies would lead to reshoring of manufacturing activity and thus reduced imports of foreign intermediates. This result is in line with other findings in the literature as discussed in Section C.2(c).[45]

Table C.8 displays the share of foreign value-added in output to illustrate this point. The separate task reallocation shock also generates other interesting results. In particular, it is predicted to reduce the

Table C.7: The share of imported services in manufacturing (gross) output in 2016 and in the baseline, core and convergence combined scenarios in 2030 (per cent)

Region	2016	Baseline 2030	Core 2030	Convergence 2030
ASEAN	0.99	1.08	1.32	1.39
Brazil	0.58	0.74	0.83	0.86
China	0.49	0.43	0.52	0.49
European Union (28)	2.76	3.22	4.00	4.00
India	1.21	1.17	1.47	1.60
Japan	0.37	0.41	0.51	0.50
Latin America and Caribbean	0.70	0.78	0.91	0.94
Middle East and North Africa	1.31	1.47	1.71	1.83
Nigeria	0.49	0.65	0.68	0.74
Other Asian countries	0.94	1.03	1.30	1.40
Other developed countries	1.34	1.55	1.90	1.85
Rest of the world	0.72	0.79	0.94	1.05
Sub-Saharan Africa	1.39	1.46	1.71	1.86
United States	0.39	0.45	0.58	0.53

Source: Own calculations with WTO Global Trade Model.

Notes: The figure displays the share of imported services intermediates in manufacturing gross output in 2016 and in 2030 in the baseline, core and convergence scenarios (including intra-regional international trade).

Table C.8: The share of foreign value-added in exports in 2030 as a result of digitalization and robotization (per cent)

Region	Baseline	Core	Convergence
ASEAN	23.75	23.75	23.73
Brazil	9.97	9.68	9.81
China	18.75	18.51	18.50
European Union (28)	17.68	17.44	17.45
India	23.68	23.22	23.23
Japan	16.05	15.95	15.95
Latin America and Caribbean	12.63	13.21	13.24
Middle East and North Africa	6.98	7.00	6.98
Nigeria	2.24	2.33	2.30
Other Asian countries	28.71	28.48	28.57
Other developed countries	15.55	15.66	15.75
Rest of the world	6.98	6.95	6.93
Sub-Saharan Africa	11.95	12.09	11.97
United States	14.58	14.65	14.70

Source: Authors' own calculations with WTO Global Trade Model.

Notes: The figure displays the share of foreign value-added in exports (as defined in Koopman et al., 2014) in 2030 in the baseline, core and convergence scenarios (excluding intra-regional international trade).

export share of the United States in global exports. The United States is projected to display the largest technological changes, which in turn leads to a stronger orientation of the United States on its domestic economy

(iii) Comparison with other studies

The quantitative projections in this section on the impact of new technologies on trade are comparable to a number of studies in the literature. First, De Backer and Flaig (2017) conduct quantitative simulations on the future of global value chains modelling various trends of which one is digitalization. They predict that this trend will lead to some reshoring of economic activity, as measured by a reduction of imported intermediates in production. The current study predicts instead a positive small increase in the share of imported intermediates in production, especially for the share of imported services intermediates. The difference in findings can be explained with the modelled shocks. Whereas De Backer and Flaig (2017) model a standard increase in total factor productivity varying by sector, the current study models productivity increases in the framework of a reallocation of tasks between labour and capital to capture *both* digitalization and robotization. Furthermore, the current study includes also falling trade costs and servicification to capture the effects of new technologies. These trends lead to an increase in trade and also an increase in imported intermediates in gross output.[46]

De Backer and Flaig (2017) also construct a combined scenario including different shocks, which also generates a falling share of intermediate inputs in gross output. This result is hence contrasting the findings in this report, suggesting an increase in the share of intermediate inputs in gross output. The reason for this difference is threefold. First, as discussed above, the digitalization shock is implemented more broadly in this report as a reallocation of tasks. Second, this report models a fall in trade costs as a result of new technologies, whereas De Backer and Flaig (2017) include rising trade costs in their combined scenario (reflecting rising energy prices). Third, other shocks are different. This report incorporates rising servicification, leading to a rising share of imported (services) intermediates in gross output, while De Backer and Flaig (2017) incorporate a growing labour force, rising wages and rising consumption in emerging countries. The latter three trends are already part of the baseline in this report.

Second, several studies have conducted simulations projecting the future of the world economy and global trade, for example the *World Trade Report 2013* (WTO, 2013c). Compared to the current study, the *World Trade Report 2013* attempted to make general projections about the future of global trade, whereas this report focuses on the impact of new digital technologies on the future of global trade. To show how the current projections on the future of global trade differ from earlier work by the WTO-secretariat, In Appendix C.3, outlining the baseline projections, differences and similarities between the simulations in the *World Trade Report 2013* and the current simulations are further addressed.

4. Conclusions

Understanding the factors that will be shaping trade as digital trade evolves is essential to maximize the gains from trade and address the challenges. This section aims to identify the mechanisms by which digital technologies will affect trade as well as opportunities and challenges. The section identifies five key messages.

First, digital technologies have lowered and will continue to lower traditional trade costs. As described in Section C.1, several recent technological advances have had a large impact on transportation and logistics costs. The use of GPS for navigation and autonomous driving capabilities or real time itinerary mapping reduce costs, enable real-time adjustments and make delivery more secure. Online platforms help reduce the costs of matching buyers and sellers, of obtaining market information and supplying information to potential consumers. Such platforms can help boost participation in international trade even more than domestic trade and provide mechanisms such as feedback and guarantees that improve consumer trust in online sellers.

Second, digital technologies provide new opportunities for MSMEs and developing countries to benefit from trade, but they also raise new challenges. One the one hand, many innovative and productive small firms now have the potential to become successful international traders as well. Moreover, since distance matters less in online trade, trade provides opportunities for remote countries and remote areas.

On the other hand, these innovations may be impeded by challenges, such as the lack of digital connectivity in some parts of the world. Progress in terms of mobile/cellular, fixed broadband, and internet penetration is not yet uniform, and this causes difficulties for some smaller businesses. Other challenges include inadequate regulatory frameworks, institutional weaknesses, insufficient private investment and underdeveloped infrastructures (including not only ICT infrastructure, but also payment mechanisms, for example). "Winner-takes-all" dynamics and new forms of barriers (such as to data flows) will also determine how gains from this new technology revolution will be distributed.

Third, new technologies will affect the composition of trade, increasing its services component of trade and fostering trade in certain type of goods. Technological developments in digital infrastructure services have enhanced the cross-border tradability of services, in turn expanding export opportunities and changing the structure of international trade in services (increasing importance of Mode 1 services – i.e. cross border trade – and of sectors other than travel and transport). Services sectors that can more readily be supplied electronically have experienced strong growth. The participation of developing countries in trade is strong in sectors such as computer services and back-office services.

The services component of trade has increased not only because of the greater ease of supplying services digitally, but also because new ways of delivering services emerge and replace trade in goods (like in the case of music streaming versus trade of CDs), and because international production networks increase the services content of manufacturing goods. These phenomena can be expected to continue, and so will the importance of services in the composition of trade. This will increase the relative importance of barriers to trade in services.

As regards the composition of trade in goods, we should expect the reduction of trade costs induced by digital technologies to foster trade in time-sensitive goods, certification-intensive goods and contract-intensive goods. By the same token, we should also expect an increase in trade in customizable goods. The decreasing trend in the trade of certain digitizable goods – such as CDs, books and newspapers – is likely to continue with the advent of 3D printing technology. Finally, the "sharing economy" business model could affect trade in durable consumer goods.

Fourth, digital technologies will deeply affect the nature, complexity and length of value chains in the future. However, it is hard to predict whether digital technologies will reduce or increase GVC trade. In combination with innovations in logistics, the reduction of transaction costs through the internet has led to an enormous expansion of GVCs. Yet, new technologies can also bring a reversal of this process: reshoring.

Fifth, new technologies will affect the role that capital, labour and institutions play to determine the patters of trade. There is the impact of AI on capital, of 3D printing on the role that port infrastructure play, and potential of blockchain technologies to affect the role that institutions play. Other factors will however also shape patterns of trade in the future. These are regulations and digital infrastructure endowment. These factors will be key determinants of the extent to which developing countries will be able to participate in the new global e-markets.

In order to get a sense of the potential quantitative impacts of these changes, in this section we also simulate the impact of some of the changes that new technologies may bring on international trade by 2030. Using a computable general equilibrium model, we examine the impact of three trends: the reallocation of tasks between labour and capital related to robotization and digitalization, the servicification of the production process, and the fall in trade costs. Our simulations show that future technological changes are expected to increase trade growth, especially trade in services, compared to the baseline-standard projections of the world economy until 2030. Global trade is projected to grow by around 2 percentage points more as a result of these trends compared to the baseline, and the share of services trade is projected to grow from 21 per cent to 25 per cent. Developing countries are likely to gain an increasing share of global trade, but the quantitative effects will depend on their ability to catch up on the adoption of digital technologies. With that catching-up, developing and least-developed countries' share in global trade is predicted to grow to 57 per cent by 2030 from 46 per cent in 2015. The organization of global production is projected to change through a rising share of imported intermediate services in manufacturing.

Appendix C.1: Trade costs decomposition

As proposed by Head and Ries (2001), bilateral iceberg trade costs can be expressed as a ratio of intra-national trade flows to domestic trade flows. Mathematically, this translates to

$$t_{ij}^{k} \cdot t_{ji}^{k} = \left(\frac{x_{ii}^{k} \cdot x_{jj}^{k}}{x_{ij}^{k} \cdot x_{ji}^{k}}\right)^{\frac{1}{\sigma_k - 1}},$$

where t_{ij}^{k} are trade costs faced by imports from country i's industry k to country j, x_{ii}^{k} is domestic trade of country i, x_{ij}^{k} are bilateral imports from country i's industry k to country j, and σ_k is industry-specific elasticity of substitution. This structure allows a calculation of bilateral trade costs using the observed bilateral and domestic trade flows.

Since the above-defined trade costs are non-directional at the bilateral level (see Chen and Novy, 2011 for more details), a geometric average is used by taking the square root of the above expression. The average bilateral trade costs (θ_{ij}^{k}) can then be expressed as

$$\theta_{ij}^{k} = \left(\frac{x_{ii}^{k} \cdot x_{jj}^{k}}{x_{ij}^{k} \cdot x_{ji}^{k}}\right)^{\frac{1}{2(\sigma_k - 1)}}.$$

The more two countries trade with each other (i.e., the higher is $x_{ij}^{k} \cdot x_{ji}^{k}$), the lower is the measure of relative trade frictions *ceteris paribus* (i.e. all else being equal). Conversely, if the domestic trade increases in either of the two countries (i.e. the higher is $x_{ii}^{k} \cdot x_{jj}^{k}$), the higher is the measure of relative trade frictions *ceteris paribus*. In the subsequent analysis, we identify the factors which explain θ_{ij}^{k}, run a regression analysis and use the results to decompose the variation in θ_{ij}^{k} into different types of trade costs.

To construct the dependent variable θ_{ij},[47] we use the international and domestic trade data from the World Input-Output Database (WIOD) and, following Chen and Novy (2011), σ is assumed to be the same across sectors and take the value of eight.

The estimated equation is

$$\ln(\theta_{ij}) = \alpha + \beta \cdot Transport_{ij} + \gamma \cdot Logistics_{ij} + \delta \cdot Border\ costs_{ij} + \varphi \cdot Information\ and\ transaction\ costs_{ij} + \rho \cdot Trade\ policy_{ij} + \epsilon_{ij}.$$ [48]

- To capture the impact of transportation costs on total trade frictions, the set of variables in $Transport_{ij}$ includes the geometric average of the effective transportation distance as in Egger et al. (2018), being landlocked and having a common border (Mayer and Zignago, 2011).

- To capture the impact of logistics costs, $Logistics_{ij}$ includes the log of the geometric average of the Liner Shipping Connectivity Index[49] and the log of the geometric average of five out of six sub-components of the Logistics Performance Index – the quality of trade and transport infrastructure; the ease of arranging competitively priced shipments; the competence and quality of logistics services such as trucking, forwarding, and customs brokerage; the ability to track and trace consignments; and the frequency with which shipments reach consignees within scheduled or expected delivery times.[50]

- To capture the impact of time delays related to customs procedures, $Border\ costs_{ij}$ is the geometric average of the lead to time to export.[51]

- To capture the impact of information and transaction costs, the set of variables in $Information\ and\ transaction\ costs_{ij}$ includes common ethnic language, common coloniser, previous colony, previously the same country (Mayer and Zignago, 2011), the log of geometric average of the bilateral stock of migrants,[52] the log of geometric average of the depth of credit information index and the log of geometric average of the enforcing contracts indicator.[53]

- Trade policy barriers ($Trade\ policy_{ij}$) are captured by dummies for having a free trade agreement and being part of the European Union (Egger and Larch, 2008). They also include the log of geometric average of the two countries exchange rates.[54]

The regression is run on data from 2014 and includes 36 countries, which is the largest sample for which all variables are available. Cyprus, Luxembourg and Malta are excluded due to their small sizes.

The regression coefficients are then used to identify the contribution of different trade costs categories to the variance in trade costs across countries. For instance, the contribution of border costs to the trade costs variance is calculated as:

$$\hat{\delta} * \frac{Covariance(\ln(\theta_{ij}), Border\ costs_{ij})}{Variance(\ln(\theta_{ij}))}$$

where $\hat{\delta}$ is the estimated coefficient associated with the *Border costs* variable. The coefficient is multiplied by the covariance between the dependent variable and the *Border costs* variable, and divided by the variance of the dependent variable. Contributions of trade costs categories that consist of several variables are calculated as a sum of the individual contributions. The contributions of all the explanatory variables sum to the R-squared of the regression. The unexplained component then reflects any frictions that are not captured by the variables included in the regression.

Appendix C.2: IP protection and comparative advantage in IP-intensive industries

Digital assets and technologies play an increasingly important role in the production process. Because digital products are sensitive to IP protection, strong IP protection might have a productivity-enhancing effect on industries that rely on a digitalized production process.

In light of this, strong IP protection might be a source of comparative advantage because it raises the relative productivity of IP-intensive industries in countries that have strong IP protection compared to other countries.

Nevertheless, very strong IP protection can also impede productivity growth as it reduces the availability of more efficient production technologies and might slow down innovation. Therefore, the effect of strong IP protection is in principle ambiguous.

This appendix gives an empirical assessment of the relationship between the level of IP protection in a country and exports from industries that require relatively more IP protection.

To examine whether countries with high IP protection have a comparative advantage in IP-intensive industries, the following econometric specification was estimated by ordinary least squares (OLS).

$$\ln(Trade_{gij})=\alpha_i+\alpha_{gj}+\beta(ipi_g{*}IPP_i)+\theta(ipi_g{*}GDPpc_i)+\sum_a \delta^a(z_g^a * Q_i^a) + \boldsymbol{X}_{ij}\boldsymbol{\gamma} + \varepsilon_{gij}$$

Chor (2010) derives this specification from a sectoral Eaton and Kortum (2002) model. The dependent variable is the natural logarithm of exports from country *i* to country *j* produced by industry *g* denominated in US$. The main explanatory variable of interest is the interaction term between the use of IP protection in industry *g* (ipi_g) and the strength of IP protection in the exporting country i (IPP_i). All further terms in the specification control for confounding factors.[55]

The use of IP protection by industry is measured as the number of filed patents divided by the number of employees in that industry. This information is available for 82 manufacturing industries from a report by the European Patent Office and the European Union Intellectual Property Office (EPO and EUIPO, 2016). The level of IP protection is based on a survey-based measure of IP protection from the WEF's Global Competitiveness Index (Schwab and Sala-i-Martín, 2014).[56] The results are reported in Appendix Table C.1.

Column 1 in Appendix Table C.1 shows that the coefficient on the IP interaction term is statistically significant and positive. This result suggests that IP-intensive industries export significantly more from countries that have strong IP protection mechanisms. This effect persists even when controlling for the interaction of industry IP intensity and GDP per capita ($ipi_g{*}GDPpc_i$), which controls for the level of economic development (column 2) and accounting for traditional sources of comparative advantage: human capital ($z_g^{HC} * Q_i^{HC}$) and physical capital ($z_g^{PC} * Q_i^{PC}$) (column 3).[57]

Heterogeneous effects across countries with different levels of IP protection are further investigated. To this end, the interaction of industry IP intensity and GDP per capita ($ipi_g{*}GDPpc_i$) is in turn interacted with an indicator variable D_i that is 1 if the IP protection index in exporting country i is above the global median of the index. This specification allows for the separation of the comparative advantage effect for countries with high IP protection and countries with lower IP protection. The results are reported in Appendix Table C.2. As before, the coefficient on the IP interaction is positive and statistically significant. However, the triple interaction term is significant and negative. The two effects have the same absolute size. This result indicates that the positive effect of IP protection on IP-intensive exports holds as long as a country's strength of IP protection is below the median level of protection. Once a country is positioned in the upper half of the IP protection index, further strengthening IP protection has no effect on exports from IP-intensive industries.

To summarize, it is found that, on average, strong IP protection is a source of comparative advantage in IP-intensive industries. Furthermore, once a country's strength of IP protection is above a certain threshold, a further increase in IP protection does not increase comparative advantage in IP-intensive industries.

Appendix Table C.1: Intellectual property protection as a comparative advantage

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable	ln($Trade_{gij}$)	ln($Trade_{gij}$)	ln($Trade_{gij}$)	$Trade_{gij}$	$Trade_{gij}$	$Trade_{gij}$
$ipi_g{*}IPP_i$	0.0211*** (0.000599)	0.00524*** (0.00103)	0.00477*** (0.00101)	0.0281*** (0.00299)	0.00514 (0.00356)	0.00820* (0.00384)
$ipi_g{*}GDPpc_i$		0.0105*** (0.00544)	0.0078*** (0.00053)		0.0142*** (0.00162)	0.0155*** (0.00150)
$z_g^{HC} * Q_i^{HC}$			2.614*** (0.0774)			-1.444*** (0.336)
$z_g^{PC} * Q_i^{PC}$			-0.0794*** (0.00978)			0.0037*** (0.00038)
Observations	366429	365241	364697	861186	852825	836103
Adjusted R-squared	0.588	0.588	0.591			
Exporting countries	103	102	100	100	100	100
Importing countries	103	103	103	103	103	103
Number of industries	82	82	82	82	82	82
Trade volume (US$ billion)	10197.6	10196.1	10195.9	10195.9	10195.9	10195.9

Source: WTO Secretariat estimates.

Notes: The table reports coefficients (and standard errors clustered by country pair in parentheses) from OLS (columns 1-3) and Poisson pseudo-maximum likelihood (PPML) (columns 4-6) estimations that regress $Trade_{gij}$ (or the log of it) on the interaction term $ipi_g{*}IPP_i$ and further covariates.

Trade data is from the CEPII's world trade database, BACI (Gaulier and Zignago, 2010); ipi_g is the number of filed patents divided by the number of employees in ISIC industry g; IPP_i is the WEF's Global Competitiveness Index for country i (Schwab and Sala-i-Martín, 2014); and D_i is a dummy being 1 if $IPP_i > median(IPP)$ and 0 otherwise.

Q_i^{HC} is an index of human capital per person, proxied by years of schooling and returns to education and Q_i^{PC} is capital stock at current PPPs (in trillion 2011 US$); both measures are from the Penn World Table version 9 (Feenstra et al., 2015).

$GDPpc_i$ is GDP per capita in country i from the CEPII gravity base (Head et al., 2010; Head and Mayer, 2014).

z_g^{HC} and z_g^{PC} are human capital intensity and physical capital intensity, equivalent to z_2 and k_3 in Romalis (2004), calculated using North American Industry Classification System (NAICS) industry-level data from National Bureau of Economic Research/the US Census Bureau's Center for Economic Studies (NBER-CES) that is mapped to the International Standard Industrial Classification of All Economic Activities (ISIC) classification using the NAICS 2002 to ISIC REV. 3.1 correspondence from EUROSTAT's Reference And Management Of Nomenclatures (RAMON) metadata server.

All specifications include exporter fixed effects, importer-industry fixed effects and the following controls for country-pair characteristics: bilateral distance, common language, common colonial history, shared border, common regional trade agreement membership and common WTO membership; these indicators are from the CEPII gravity base (Head et al., 2010; Head and Mayer, 2014). All data are for the year 2015, except for Q_i^{HC} and Q_i^{PC} (average 2008-2009), z_g^{HC} and z_g^{PC} (2011) and ipi_g (average 2011-2013).

Appendix Table C.2: Intellectual property protection as a comparative advantage. Heterogeneity across countries

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable	ln($Trade_{gij}$)	ln($Trade_{gij}$)	ln($Trade_{gij}$)	$Trade_{gij}$	$Trade_{gij}$	$Trade_{gij}$
$ipi_g{*}IPP_i$	0.0405*** (0.00324)	0.0316*** (0.00327)	0.0301*** (0.00321)	0.120*** (0.0172)	0.0864*** (0.0165)	0.108*** (0.0192)
$ipi_g{*}IPP_i{*}D_i$	-0.0177*** (0.00339)	-0.0296*** (0.00327)	-0.0263*** (0.00321)	-0.0943*** (0.0177)	-0.0882*** (0.0165)	-0.107*** (0.0192)
$ipi_g{*}D_i$	0.0484*** (0.0118)	0.0981*** (0.0114)	0.0832*** (0.0112)	0.334*** (0.0633)	0.329*** (0.0591)	0.400*** (0.0689)
$ipi_g{*}GDPpc_i$		0.0110*** (0.00056)	0.00799*** (0.000543)		0.0149*** (0.00171)	0.0163*** (0.00162)
$z_g^{HC} * Q_i^{HC}$			2.609*** (0.0776)			-1.484*** (0.326)
$z_g^{PC} * Q_i^{PC}$			-0.0793*** (0.00977)			0.369*** (0.0383)
Observations	366429	365241	364697	861186	852825	836103
Adjusted R-squared	0.588	0.588	0.591			
Exporting countries	103	102	100	100	100	100
Importing countries	103	103	103	103	103	103
Number of industries	82	82	82	82	82	82
Trade volume (US$ billion)	10197.6	10196.1	10195.9	10195.9	10195.9	10195.9

Source: WTO Secretariat estimates.
Notes: See notes to Appendix Table C.1.

Appendix C.3: Details on the quantitative analysis using the Global Trade Model (GTM)

(a) Global trade model and baseline projections

The WTO Global Trade Model (GTM) is a recursive dynamic CGE model, based on the facelift version of Purdue University's Global Trade Analysis Project (GTAP) model (Version 7). This means that the model features multiple sectors, multiple factors of production, intermediate linkages, multiple types of demand (private demand, government demand, investment demand and intermediate demand by firms), non-homothetic preferences for private households,[58] a host of taxes, and a global transport sector. Each region features a representative agent collecting factor income and tax revenues and spending this under utility maximization on private consumption, government consumption and savings. Firms display profit-maximizing behaviour, choosing the optimal mix of factor inputs and intermediate inputs. Savings are allocated to investment in different regions. The model is calibrated to the current GTAP database, which has 141 regions and 57 sectors, implying that baseline shares are equal to actual shares.[59]

The starting point is a baseline projection of the world economy until 2030. For the simulations described in Section C.3, an aggregation with 16 sectors, 14 regions, and 5 factors of production is used, as displayed in Appendix Table C.3. The sectoral aggregation includes the sectors of interest related to digitalization of the economy, such as telecommunications, business services, and electronic equipment. In order to shed light on the question how some of the newly emerging countries are affected by digitalization, countries like Brazil and Nigeria are included in the aggregation.

The simulations start from 2011 based on the latest release of GTAP 9, GTAP 9.2. Following standard approaches, projections on growth in GDP per capita growth, population, labour force and skills are used to discipline the trajectory of the world economy until 2030. The growth in population, labour force and skills are imposed on the projections, and GDP per capita growth is targeted by endogenizing labour productivity growth, while allowing for endogenous capital accumulation based on recursive dynamics. GDP per capita growth is based on actual International Monetary Fund (IMF) data and projections with the IMF Global Projection Model until 2014 (Carabenciov et al., 2013). From 2015, the

Appendix Table C.3: Overview of regions, sectors and production factors

Regions	Sectors	Production factors
Japan	Agriculture	Land
China	Mining and extraction	Unskilled labour
India	Processed food	Skilled labour
ASEAN	Chemicals and petrochemicals	Capital
United States	Other goods	Natural resources
Brazil	Metals	
Latin America and the Caribbean	Electronic equipment	
European Union (28)	Other machinery and motor vehicles	
Middle East and North Africa	Utilities and construction	
Nigeria	Trade	
Sub-Saharan Africa	Transport	
Other developed countries*	Communication	
Other Asian countries**	ICT services and consultancy	
Rest of world***	Other business services	
	Financial services and insurance	
	Other services	

Source: Authors' own aggregation based on regions, sectors, and production factors from GTAP 9.

* Australia, New Zealand, Canada, Norway, Switzerland.

** All other Asian countries.

*** All other GTAP regions.

OECD Shared Socioeconomic Pathways projections, SSP2, are used (Dellink et al., 2017). Population and labour force growth come from the United Nations population projections, medium variant for 2015 (UN DESA, 2015). Changes in the number of skilled and unskilled workers are inferred from projections on education levels by the International Institute for Applied Systems Analysis (IIASA) (KC and Lutz, 2017). In particular, the changes in the share of tertiary educated are used as a proxy for changes in the share of skilled workers. To allow for changes in the amount of land and natural resources employed, supply functions with supply elasticities equal to 1 are used. All the other parameters are set at standard values provided by the GTAP 9.2 database.

Besides these standard sources two other elements are incorporated in the model. First, to account for structural change (a rising share of services output in total output and falling shares of agriculture and manufacturing), we allow for differential productivity growth across sectors based on historical data. Second, the domestic savings rates are targeted to the projections of the CEPII macroeconomic model MaGE (i.e. (Macroeconometrics of the Global Economy) (Fouré et al., 2013). In this model, saving rates are determined by demographic developments in a life-cycle framework. Savings rates stay virtually constant in the basic model with savings a Cobb-Douglas share of national expenditures.

The results of the baseline simulations are similar to the results of the analysis on the future of world trade in the *World Trade Report 2013* (WTO, 2013c), so the results will be described only briefly. The baseline simulations display three main characteristics. First, the included structural change has a considerable impact, with production shares of services rising and production shares of manufacturing and agriculture falling. The extraction sector also displays growth, because there is limited scope for productivity growth in this sector which is mainly using natural resources. Second, the geographic distribution of trade is changing with developing countries taking over the dominant position in global trade from the developed countries. The LDCs also raise their market share in global trade, although it remains small in 2030. Third, the sectoral distribution of trade follows the production pattern driven by structural change, featuring a rising share of services trade at the expense of manufacturing trade.

Although some of the predictions of the simulations are similar, the current simulations differ both in setup and in focus from the simulations in the *World Trade Report 2013*. There are two main differences in set-up. First, in the current simulations, the baseline does not contain an autonomous reduction in trade costs to generate an increase in the trade-to-income ratio based on observed trade growth in the past, as in the *World Trade Report 2013*. This choice is made for two reasons. First, the experiments contain reductions in trade costs as a result of new technologies, which generate additional trade growth. Second, trade growth has largely followed income growth in the first half of the current decade (from 2011 to 2016) with a ratio of trade growth to GDP growth close to 1.

A second difference with the simulations in the *World Trade Report 2013* is that macroeconomic projections from different international agencies (such as the UN for population projections and the IMF and World Bank for growth projections) were employed to generate baseline projections in the current report. In the *World Trade Report 2013* the macroeconomic projections were based on one macroeconomic model, MaGE.

In terms of results, the current report comes to similar findings as the World Trade Report 2013. Geographically, both reports predict rising shares of developing countries in global trade and sectorally, both reports predict rising shares of services in global trade. However, the focus of the current report is different. Whereas the World Trade Report 2013 intended to make general projections on the trajectory of the global economy in general and trade in particular, the simulations in the current report focus on the impact of new technologies on global trade.

(b) Modelling technological change as a result of digitalization and robotization

Consider first the size of the average change in the capital income share. Changing capital income shares are modelled based on historical trends. Data from the Organisation for Economic Co-operation and Development's STructural ANalysis Database (OECD-STAN) and data collected by Karabarbounis and Neiman (2013) show that there is a long-run downward trend in the labour income share. The data show, moreover, that the downward trend is a phenomenon exclusively taking place in developed economies. Since it is hard to predict how large the impact of robotization on the labour income share will be until 2030, we take as a benchmark the historical decline in the labour income share. Bekkers and Francois (2018) display the change in the global labour income share over time, both globally based on the data collected by Karabarbounis and Neiman (2013) and in OECD countries only, based on data from OECD-STAN. The analysis shows that the labour share fell from 0.54 in 1980 to 0.48 in 2010, a decline of about 0.002 per year. Phrased differently, this corresponds to a reduction of 2 percentage points in the labour income share per decade (0.2 percentage points annually).

Second, the size of the average productivity growth is discussed. Several studies have attempted to come up with projections on productivity growth as a result of robotization and digitalization. Information on the average size of productivity growth and on the distribution across sectors and countries is needed. For the size of the shock, two studies are employed, Bauer and Horváth (2015) and Boston Consulting Group (2017). The former study projects productivity growth in six sectors until 2025 in Germany as a result of "Industry 4.0", predicting average yearly growth of 1.27 per cent until 2025. The latter study examines the impact of robotization on productivity across sectors and countries, predicting an average cost reduction of 16 per cent up until 2025 (from 2015). Based on these studies, the average yearly productivity growth is assumed to be 1.25 per cent.

Third, consider the variation in the degree of digitalization across sectors. Four studies on variation across sectors in the degree of digitalization and robotization are used (Bauer and Horváth, 2015; Boston Consulting Group, 2017; Booz and Company, 2011; McKinsey Global Institute, 2015). These studies display to a large extent a uniform picture on which sectors mostly benefit from digitalization. The rankings of sectors in each of these studies were added up. This leads to the sectoral scaling factors as displayed in the first two columns of Appendix Table C.4.

Fourth, projections of the variation across countries in terms of digital readiness for the changes provoked by robotization and digitalization are needed. This variation is based on the Network Readiness Index (NRI) of the WEF (Baller et al., 2018), which is based on 53 sub-indices classifying countries in terms of regulatory and business environments related to ICT, usage of ICT, readiness (infrastructure, affordability and skills), and economic and social impact. The NRI is available for 139 countries and was aggregated using GDP-weighted averages. This leads to the country scaling factors displayed in the last two columns of Appendix Table C.4. For the convergence scenario, it is assumed that the regions lagging behind are catching up to the 75th percentile best performing country in terms of the NRI and thus also in terms of scaling.

Appendix Table C.4: Scaling factors for countries and sectors of digitalization shock

Sectors		Regions	
Metals	0.64	Nigeria	0.71
Processed food	0.65	Sub-Saharan Africa	0.77
Agriculture	0.65	India	0.84
Other services	0.66	Latin America and the Caribbean	0.86
Transport	0.73	Brazil	0.89
Extraction	0.86	China	0.93
Utilities	0.87	ASEAN	0.97
Other goods	0.87	Middle East and North Africa	0.97
Chemicals	0.99	Rest of the world	0.99
Other business services	1.05	Other Asia	1.14
Trade	1.07	European Union (28)	1.16
ICT and consultancy	1.22	Japan	1.24
Communication	1.23	Other developed economies	1.25
Finance and insurance	1.30	United States	1.29
Other machinery and motor vehicles	1.56		
Electrical machinery	1.64		

Source: Authors' own calculations.

(c) Modelling falling trade costs

To gauge the impact of technological change on trade costs, proxies for iceberg trade costs were regressed on variables associated with these developments. Using the approach originally proposed by Head and Ries (2001) and applied, among others, by Novy (2013), (symmetric) iceberg trade costs can be written as the ratio of international relative to intra-national trade flows in trade models with constant elasticity of substitution preferences such as the Armington or Krugman models (see Appendix C.1).

Employing the same methodology and data described in Appendix C.1, the equation for iceberg trade costs is estimated for the three aggregate sectors primary (agriculture and extraction), secondary (manufacturing), and tertiary (services) employing data from WIOD for 2014. Controlling for variables such as transport costs, the existence of a free trade agreement and a dummy for EU-membership, the following variables were included to determine the

Appendix Table C.5: Annual *ad valorem* equivalent trade cost reductions as a result of technological change, averages across importing regions and across sectors

Regions	Total	Common language	Lead time to export	Liner shipping connectivity index	Credit and contracts
Sub-Saharan Africa	-1.30	-0.34	-0.22	-0.21	-0.54
Rest of the World	-1.05	-0.42	-0.23	-0.34	-0.08
Middle East and North Africa	-0.91	-0.35	-0.19	-0.16	-0.21
Nigeria	-0.87	-0.30	-0.35	-0.12	-0.10
Other Asia	-0.85	-0.33	-0.09	-0.13	-0.30
ASEAN	-0.78	-0.35	-0.07	-0.15	-0.22
European Union (28)	-0.78	-0.41	-0.08	-0.14	-0.15
Brazil	-0.76	-0.43	-0.14	-0.06	-0.12
Latin America and the Caribbean	-0.66	-0.21	-0.18	-0.12	-0.15
Other developed economies	-0.63	-0.33	-0.04	-0.20	-0.06
India	-0.60	-0.26	-0.10	-0.06	-0.18
Japan	-0.59	-0.39	-0.10	-0.03	-0.08
China	-0.56	-0.35	-0.10	0.00	-0.12
United States	-0.43	-0.25	-0.11	-0.01	-0.06
Commodities					
Transport	-1.27	-0.68	-0.21	-0.30	-0.09
Communication	-1.25	-0.68	-0.20	-0.30	-0.09
ICT and consultancy	-1.24	-0.63	-0.21	-0.28	-0.12
Other business services	-1.23	-0.69	-0.19	-0.27	-0.09
Trade	-1.21	-0.70	-0.19	-0.24	-0.09
Processed food	-1.17	-0.48	-0.18	-0.19	-0.34
Other services	-1.16	-0.64	-0.23	-0.23	-0.07
Finance and insurance	-1.14	-0.66	-0.19	-0.22	-0.08
Utilities	-1.10	-0.55	-0.20	-0.30	-0.06
Chemicals	-0.79	-0.33	-0.13	-0.11	-0.22
Agriculture	-0.75	-0.48	0.00	-0.12	-0.15
Metals	-0.62	-0.26	-0.10	-0.09	-0.18
Other goods	-0.60	-0.27	-0.10	-0.07	-0.16
Other machinery	-0.59	-0.27	-0.10	-0.07	-0.16
Electrical machinery	-0.48	-0.22	-0.08	-0.04	-0.15
Extraction	-0.36	-0.22	0.00	-0.06	-0.08

Source: Authors' own calculations.

expected impact of technological change on trade costs: (i) lead time to export as a measure of customs procedures; (ii) the liner shipping connectivity index as a measure of logistics efficiency; (iii) the depth of credit information index and the enforcing contracts indicator as a measure of the contract and credit environment; and (iv) the existence of a common language as a measure of the importance of language differences. The first three variables are from the World Bank Doing Business project and the last variable from CEPII. The country-specific variables are bilateralized by taking geometric averages.

Based on the estimated coefficients, like for the other trends, a core scenario and a convergence scenario were developed for the reduction in trade costs. In the convergence scenario it is assumed that countries with poor performance in terms of the different measures converge partially to the level of the country with the 75th percentile best performance. In particular, we assume that laggard countries close half of the gap with the 75th percentile best performing country.[60] The *ad valorem* equivalents of these changes are calculated for all the countries available in the World Bank and CEPII database and are aggregated up to the level of the aggregate regions using bilateral trade weighted averages per sector. Given the lack of information on the impact of technological changes on trade costs, we develop a core scenario with identical trade cost reductions across regions in the different sectors, in such a way that the trade-weighted average reduction in trade costs is identical to the one in the convergence scenario.

The *ad valorem* equivalents are mapped to yearly changes in such a way that trade costs fall as predicted by the empirical estimates and the convergence scenario over the course of 15 years. Appendix Table C.5 displays the trade-weighted annual reductions in trade costs varying across regions (employed in the core and convergence scenario) and across importing regions (employed in the convergence scenario). As is clear from the table, the average yearly reduction in trade costs is about 1 per cent and the reduction is strongest in the convergence scenario for the least-developed regions.

Endnotes

1 Transport costs are important for modes of supply that involve travel, such as consumption abroad (for instance, tourism) and the presence of a natural person (for instance, providing personal services abroad). They may also be important when cross-border supply requires some face-to-face communication and thus business travel.

2 Both transport and logistics costs may matter for services because they also matter for the goods trade. Recent empirical findings suggest that the exports of many business, financial and transport services are tied to exports of goods, and therefore to the extent that some barriers hamper flows of goods that tend to be exported together with a service, these barriers thereby also have consequences for services flows (Ariu et al., 2018).

3 One of the proxies for information costs is the number of migrants from the trade partner's country. While it has been shown in the literature that migrant networks make it easier to search for and enforce contracts with trade partners, the variable may also capture their impact on consumer taste similarity because migrants tend to keep consumption preferences of their country of origin (Rauch, 2001; Rauch and Trindade, 2002; Felbermayr et al., 2015; Parsons and Vézina, 2018).

4 If there were 100 economies in the sample, the 75th percentile would correspond to the 75th ranking and the median would correspond to the 50th ranking.

5 These include the use of telecommunications, vehicular technologies, electrical engineering and computer science for vehicle, container and trailer tracking and for fleet management.

6 Even if transportation costs go to zero, distance will probably continue to matter. This is because it proxies for taste similarity. As demonstrated by Blum and Goldfarb (2006), internet surfing behaviour follows the well-established empirical finding in the trade literature that bilateral trade decreases with distance. In other words, even for a product with zero shipping costs, people are more likely to visit websites from nearby countries than from faraway countries. This relationship between distance and website visits is driven by taste-dependent categories of products such as music or games, but does not matter in non-taste-dependent categories such as software.

7 This is in contrast with consumer-to-consumer transactions, where the market share of banks is 60 per cent.

8 More specifically, the banks' revenue margin on cross-border transactions is 20 per cent as compared to 2 per cent on domestic transactions. The revenue calculations include transaction fees, float income and foreign exchange fees (McKinsey & Company, 2016).

9 According to Zervas et al. (2017), 70 per cent of Airbnb offerings are outside central hotel districts.

10 BOP statistics do not capture trade in services through a commercial presence (Mode 3), which is estimated to account for the bulk of world trade in services. Excluding "travel", most BOP statistics on services trade relate to Mode 1.

11 According to a report by Cleantech Group, a home-sharing guest uses an estimated 63 per cent to 71 per cent less energy than a hotel guest in North America. In the European Union, a home-sharing guest uses 78 per cent to 84 per cent less energy than a hotel guest.

12 It is worth noting that not all products covered under the ITA are "ICT products", as originally defined by the OECD and then adapted by UNCTAD in collaboration with the UNSD (United Nations Statistics Division). See the OECD Guide on Measuring the Information Society 2011: http://www.oecd.org/sti/ieconomy/oecdguidetomeasuring theinformationsociety2011.htm However, the expanded ITA includes as much as 80 per cent of all product codes included in the ICT goods definition, and ICT goods still represent the bulk of ITA goods imports (UNCTAD, 2015).

13 The authors defined time-sensitive agricultural goods as products with a minimum storage life of two weeks or less, for example apricots, beans, currants and mushrooms. In comparison, time-insensitive agricultural goods are defined as those with a minimum storage life of 4 weeks or longer, for example apples, cranberries and potatoes.

14 Nunn (2007) defines an input as "relationship-specific" if it is not sold on an organized exchange or reference priced in trade publications.

15 For example, a website called "Totally Chocolate" allows users to design and order customized chocolate bars, helping consumers to configure their own bars from four base chocolates and 100 different toppings.

16 See Appendix 1 of WTO official document JOB/GC/114 (available via the "Documents Online" function of https://www.wto.org/) for a full list of digitizable goods and their Standard International Trade Classification codes.

17 A relevant concern in this regard is the potential reshoring of low- and medium-skilled activities, which is discussed in Section C.2(c).

18 Chen et al. (2005) find that trade in those intermediate goods that are imported and used to make goods that are later exported (i.e., "vertical specialization trade" as defined by Hummels et al., 2001) increased between the late 1960s and the late 1990s in the ten OECD countries in their sample (Australia, Canada, Denmark, France, Germany, Italy, Japan, the Netherlands, the United Kingdom and the United States).

19 Los et al. (2015) find evidence of international fragmentation of production (higher foreign shares in the value of final products) in a sample of 35 industries in 40 countries between 1995 and 2008. In particular, foreign value-added shares increased on average by about 20 per cent (see also Timmer et al., 2014). Johnson and Noguera (2012) and Baldwin and López-González (2015) also show evidence that supply chains fragmented across the board between 1995 and 2009.

20 Bems et al. (2011) show that between the first quarter of 2008 and the first quarter of 2009, real world trade fell by 15 per cent, a figure roughly four times larger than the fall in real GDP (3.7 per cent). According to these authors, vertical specialization trade (the difference between gross trade and value-added trade) fell by 12.9 per cent, while value-added trade fell by slightly less, 10.3 per cent. Therefore, vertical specialization played a moderate role in amplifying the trade collapse.

21 A comprehensive review of all the factors determining GVC integration is beyond the scope of this report. The interested reader is referred to the survey by Amador and Cabral (2016).

22 Juhász and Steinwender (2018), focusing on the cotton textile industry, show that that connection to the global telegraph network (the first ICT) disproportionately increased trade in intermediate goods relative to final goods. This was due to differences in codifiability, i.e. the extent to which product specifications could be communicated at a distance using only words (and thus by sending telegrams) as opposed to inspecting a sample of the product.

23 "Spiders" and "snakes" are theoretical benchmarks. Fragmented production processes normally include a combination of the two forms, as argued by Diakantoni et al. (2017).

24 Teleconferencing is the conduct of a conference with several individuals who are in different locations, as opposed to just one place at the same time. Videoconferencing adds the ability to see, and not only hear, all the participants. Virtual conferencing allows remote participants to enjoy a virtual experience, making them feel they can move around in the room.

25 The Economist (2018a), citing IHL research, reports that in 2015 the cost to companies of overstocking was around US$ 470 billion, and that of understocking US$ 630 billion worldwide.

26 See Korpela et al. (2017) for a discussion of how supply chain integration through the use of blockchain technology can help transform digital supply chains and networks.

27 For empirical estimates of trade cost accumulation effects, see Rouzet and Miroudot (2013) and Muradov (2017).

28 More than 70 per cent of world services imports are intermediate services (De Backer and Miroudot, 2014). It should be noted that when the production process of a final service is fragmented, value is often created not along linear, sequential value chains, but rather by linking consumers (the so-called "value network", as in insurance or banking services) or by solving customer problems (the so-called "value shop", as in professional services). See Miroudot and Cadestin (2017).

29 This finding echoes the "smile curve", i.e. the higher contribution to value added provided by pre- and post-production services than the contribution provided by the actual fabrication process of goods (Baldwin, 2016). WIPO (2017) argues that "smile curves" reflect the growing importance of "intangible capital" – in the form of technology, design and brand value as well as workers' skills and managerial know-how. Since a large fraction of such capital depends on IP protection, licensed IP rights can be seen as a mechanism allocating "intangible" production inputs into GVCs, in the form of embedded technologies, manufacturing know-how, product design, or branding. See also the discussion in Section C.2(b) on the role of IPR protection for comparative advantage.

30 When the domestic division of labour deepens in emerging economies, more intermediate inputs are produced domestically. With the domestic value chain lengthening, cross-border production-sharing activities may decline.

31 A comprehensive review of all the factors (including those unrelated to technological developments) that may lead to lower GVC trade and reshoring in the future is beyond the scope of this report. The interested reader is referred to De Backer et al. (2016); Standard Chartered (2016); and De Backer and Flaig (2017).

32 Formerly called the Engineering Employers' Federation.

33 The upward trend in multinational corporation imports is also apparent when weighting imports by sales. Using slightly different offshoring proxies from the US Census Related Party Trade database, Oldenski (2015) shows that the increasing trend in multinational corporation imports continued from 2012 to 2014.

34 Dark factories are literally factories that run with the lights out because they require no human presence on-site. Very few factories currently operate without humans (and not at all times), making the concept of dark factories a theoretical benchmark for the time being. Note that fully robotized factories not only need no lights, but also no heating. To give an idea of the enormous contrast with "traditional" factories with humans, consider that (human) workers' productivity depends on appropriate heating (in cold climates) and cooling (in hot climates). Moreover, it depends not only on the working environment being properly lightened, but also on the quality of installed lights. The move from standard fluorescent lighting to LED lighting greatly improves working conditions and productivity in factories in Bangalore (India), due to the lower heat emissions produced by LED lighting (Adhvaryu et al., 2018).

35 Markoff (2012) reports the case of the Philips shaver factory in Drachten (The Netherlands). Instead of moving the high-end of their shaver product line to China, Philips opened this factory with 128 robots, capable of moving at two-second intervals and producing about 15 million shavers a year. The type of tasks performed by these robots is described by the author as "dexterous".

36 Dachs et al. (2017) measure reshoring (which they call "backshoring") as a dummy variable equal to 1 if the firm backshored production in 2013 or 2014, and 0 otherwise. The main explanatory variable, readiness to Industry 4.0, is an index ranging from 0 to 5, constructed using information on whether the firm adopted digital management systems, wireless human-machine communication and cyber-physical-systems (CPS) technology. The data are from the European Manufacturing Survey 2015.

37 In a survey of 114 industrial manufacturers in the United States conducted in 2014 (PWC, 2014), among the 37.7 per cent of respondents who indicated that their company was currently using 3D printing technology, a large majority (24.6 per cent) claimed that the use of 3D printing technology only concerned prototyping; 9.6 per cent claimed that the use of 3D printing technology concerned a combination of prototyping and production; and only 3.5 per cent indicated that the use of 3D printing technology concerned production of final goods, components or products that could not be made from traditional methods. Similarly, De Backer and Flaig (2017) report that only 15 per cent of the 3D printing output currently concerns goods (final but especially intermediate parts), with the majority being models, tools and prototypes.

38 The GTM has been developed by a team of Purdue University's Global Trade Analysis Project (GTAP) in cooperation with the Economic Research and Statistics Division at the WTO.

39 Basing trends on the past is a conservative approach for rising capital income shares, given that technological changes leading to rising capital shares such as robotization and AI are expected to accelerate. Also, for servicification, the use of trends in the past is probably a conservative approach, given the trends described earlier in this report, such as digitalization and AI.

40 If the initial allocation of tasks is optimal, a reallocation will not have an impact on productivity, an application of the envelope theorem.

41 This assumption can be rationalized based on the theoretical framework of a reallocation of tasks, although also other combinations (stronger variation in productivity growth than in capital income shares for example) can also be motivated.

42 The approach in this section is partially inspired by De Backer and Flaig (2017). Based on the German study by Bauer and Horváth (2015) on Industry 4.0, De Backer and Flaig also define scenarios for the differential impact of digitalization on productivity growth across sectors and countries, leading to sectoral productivity growth rates and scaling factors for countries like in our study.

43 Simulation results are available upon request.

44 Servicification is also predicted to raise the skill premium, because ICT services are relatively high-skill-intensive.

45 The result is also found when only the reallocation of tasks is modelled.

46 Neither De Backer and Flaig (2017) nor the current study take into account the effects of a potentially disruptive technology, additive manufacturing. As discussed elsewhere in the report, this technology could drastically reduce international trade in goods. Since there is not sufficient information about this technology and its development is highly uncertain, it is not included in the quantitative simulations.

47 We run the analysis separately for goods and services and therefore in what follows we omit the industry superscript k.

48 Letters in bold indicate vectors of multiple coefficients.

49 If a country is landlocked, an average of the neighbours of the landlocked country is taken. The variable comes from UNCTAD (http://unctadstat.unctad.org/wds/TableViewer/tableView.aspx?ReportId=92).

50 Source: World Bank (https://lpi.worldbank.org/).

51 Source: World Bank (https://data.worldbank.org/indicator/LP.EXP.DURS.MD?view=chart).

52 Source: World Bank (http://www.worldbank.org/en/topic/migrationremittancesdiasporaissues/brief/migration-remittances-data).

53 Both variables come from World Bank's Doing Business project (https://data.worldbank.org/indicator/IC.CRD.INFO.XQ?view=chart and http://www.doingbusiness.org/data/exploretopics/enforcing-contracts).

54 Source: World Bank (https://data.worldbank.org/indicator/PA.NUS.FCRF).

55 α_i are exporter fixed effects, α_{gj} are importer-sector fixed effects, $(ipi_g * GDPpc_i)$ is an interaction of industry IP intensity and GDP per capita, $\delta^a(z_g^a * Q_i^a)$ are measures of comparative advantage for human capital (a=HC), and physical capital (a=PC), X_{ij} is a vector of controls for country-pair characteristics: bilateral distance, common language, common colonial history, shared border, common regional trade agreement membership and common WTO membership. The combined use of exporter and importer-sector fixed effects is standard in the related literature – see for instance Chor (2010) and Nunn and Trefler (2014).

56 The results are robust to alternatively using an index comparing the strength of patent protection across countries for the year 2005 from Park (2008).

57 Because OLS estimates could be inconsistent and biased due to heteroskedastic (i.e. non equally dispersed) error terms and the omission of zero trade flows, we estimate the same specification in exponential form, using the Poisson pseudo-maximum likelihood (PPML) estimator, as proposed by Santos Silva and Tenreyro (2006). The PPML results (Appendix Tables C.1 and C.2, columns 4 to 6) confirm the findings of the OLS specification in most cases.

58 Non-homothetic preferences display non-unitary income elasticities and are thus able to capture changing budget shares as countries grow.

59 Bekkers and Francois (2018) describe differences between the GTM and the GTAP-model.

60 In line with this approach, the negative impact of not having a common language on trade costs is assumed to fall by half.