Digital Technologies and Globalization: A Survey of Research and Policy Applications

Integration and Trade Sector

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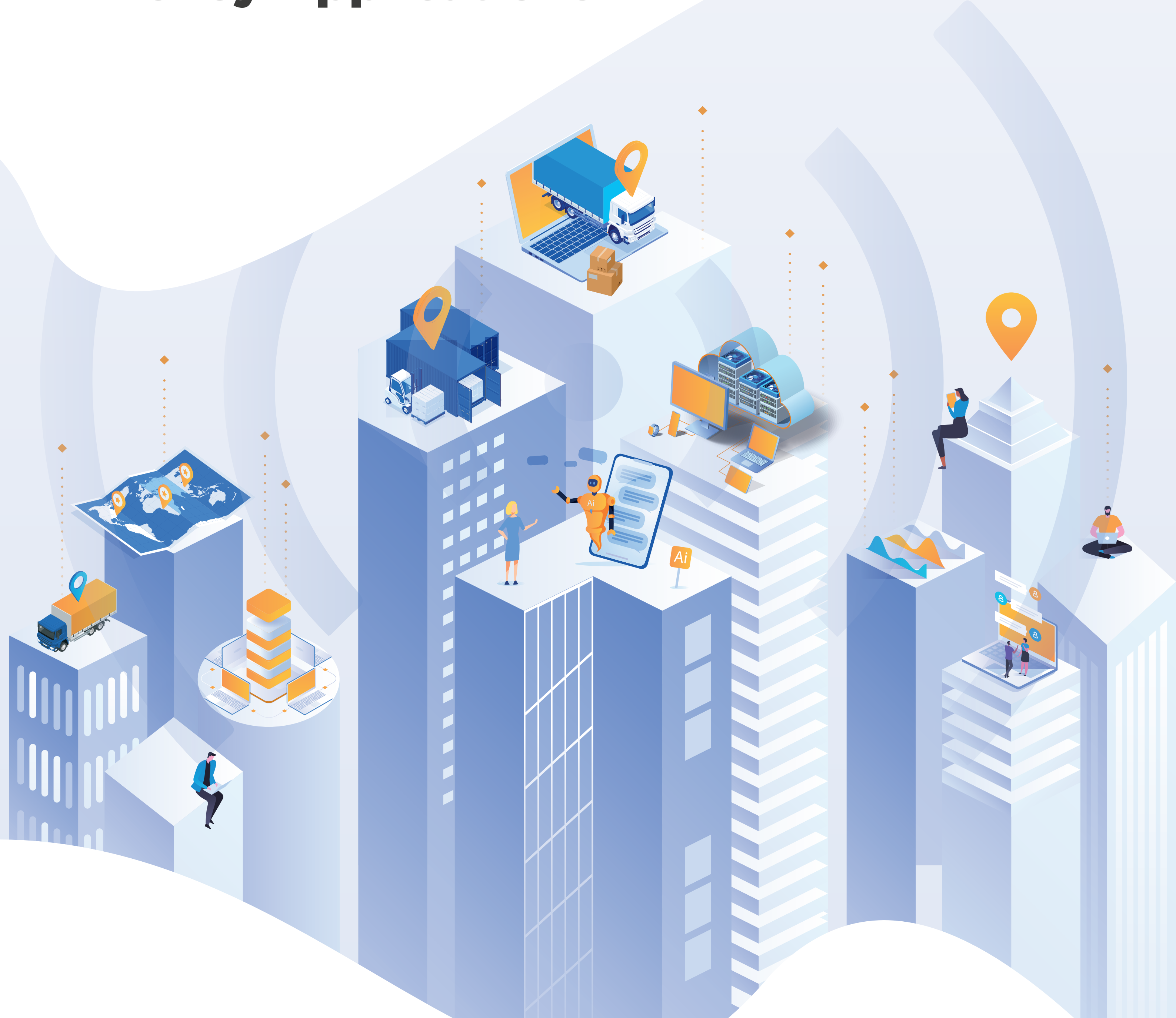

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Abstract

In recent years, the world has witnessed the rise of multiple specific digital technologies, including online trade platforms, robotics, artificial intelligence (AI), 3D printing, cloud computing, blockchain, and financial technology (fintech). These digital technologies are fundamentally transforming the ways that firms and individuals—as both workers and consumers—communicate, search, trade, and invest. They are also substantially changing how governments design and implement trade and investment policies and programs and, in so doing, how they interact with firms, individuals, and each other. This paper reviews the growing empirical literature on the trade, investment, and broader development effects of the adoption of specific digital technologies. It also describes the policy applications of these technologies and discusses the incipient empirical literature on the impacts thereof. Based on this review, it identifies several open questions and avenues of future research that may be useful for deepening our understanding of digital technologies and their policy implications.

Keywords: Digital technologies, international trade, FDI, trade and investment facilitation and promotion
JEL-codes: F10, F13, F14, F21, F23, O33

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1 Introduction

The rise of digital technology—ranging from online trade platforms, artificial intelligence (AI), and 3D printing to cloud computing, blockchain, and financial technology (fintech)—is rapidly transforming the ways that firms, workers, and consumers communicate, search, trade, and interact with governments. The latest generation of digital technology is affecting the production, organization, and exchange of economic activities in more varied and complex ways than previous revolutions in information and communication technologies (ICTs).

New digital technologies and applications of these can be broadly grouped into three main categories based on the mechanisms through which they generate productivity gains.[1] The first category—which includes online trade platforms (involving a package of technologies such as digital payments, database systems, ranking algorithms, and chatbots) and some applications of AI and blockchain—lowers search, communication, and transaction costs and expands market access. For example, the establishment of online trade platforms enables firms and retailers of all sizes to make their products available to new consumers, including those in foreign markets, by reducing market entry costs and search costs. As a result, merchants and consumers, who traditionally face high costs when searching for suppliers, can now access a large number of suppliers around the world more easily. The introduction of AI applications such as machine translation and learning is cutting search, communication, and transaction costs, thus allowing businesses to gain a real-time understanding of consumer demand and consumers to access customized products and services. Blockchain and the Internet of Things (IoT) can support traceability by increasing visibility and transparency and enhancing trade integrity by aligning the physical, financial, and regulatory aspects of trade.

The second group of technologies contains innovations that affect primarily production costs. For example, the introduction of robots and automation lowers production costs and replaces routine tasks that were previously performed by humans. By enabling firms and even consumers to create goods and components from a digital file, 3D printing can also lower production costs and affect the need to import. By making services available on-demand via pay-as-you-go subscriptions and access from locations around the world, cloud computing transforms IT input costs from large, centralized sunk costs into variable costs.

The third group of innovations centers on financial innovations that allow businesses and individuals to manage their financial operations and lives more efficiently. For instance, some blockchain applications increase the efficiency of trade finance by reducing the expense and time required to facilitate trade that depends on third-party lending or insurance. Fintech innovations such as mobile banking and mobile

[1] It is worth noting that the mapping of technologies is not always one-on-one and that categories are not necessarily mutually exclusive, as certain technologies can operate through different mechanisms (for example, AI and blockchain can help reduce both search and production costs). Furthermore, technologies can interact with each other and reinforce each other's effects (e.g., machine translation affects online platforms, fintech, and mobile phones), as discussed in detail below.

money significantly reduce transaction costs, improve transparency, and lower the risks of saving, lending, and insurance. Table 1 provides a summary of these digital technologies and their distinct productivity-enhancing mechanisms. While the productivity gains from these innovations are evident, there are widespread concerns around how new digital technologies might reshape the patterns of global economic activity and ultimately influence the sources of economic growth, jobs, and income inequality in both technologically advanced and lagging countries. Because of the different mechanisms through which they operate, different technologies can have varying effects on trade, investment, jobs, and growth. Market-expanding innovations such as online trade platforms, which help small businesses enter export markets, can increase international trade and create new entrepreneurial opportunities in developing countries (Caballo et al., 2020a, 2020b; Chen and Wu, 2021), reduce costs of living (Couture et al., 2020), and alleviate consumption inequality (Fan et al., 2018). Labor-cost-saving technologies such as robots may replace low-skilled tasks and exert ambiguous effects on trade and offshoring (e.g., Acemoglu and Restrepo, 2018; Artuc et al., 2018; Faia et al., 2020; Prettner and Bloom, 2020). 3D printing could have ambiguous effects on trade depending on product characteristics such as bulkiness (Freund et al., 2020).

Digital technologies are also reshaping decisions regarding international trade and investment policy and the way these are implemented. Countries around the world have been incorporating new technologies to reduce cross-border transaction times and costs, increase the transparency of information, enhance trade integrity, and facilitate trade and investment flows. These applications range from the digitization of customs procedures and investment platforms to uses of IoT, blockchain, and machine learning to facilitate value chains and improve policy efficiency. In both developed and developing countries, new technologies are presenting new opportunities and challenges to international economic policymakers.

In this paper, we provide a systematic review of research and policy trends on how digital technologies are reshaping the incentives for and patterns of international trade, investment, and policymaking (see Table A1 in the Appendix for a list of specific studies thereon, including relevant information on the main variables, sample periods, and sources).[2] The current discussion covers analysis and debate on a range of technologies starting with the role of ICTs in general and moving on to the effects of recent technologies, including online trade platforms, AI and machine learning, robots, 3D printing, cloud computing, blockchain, and fintech. In contrast to the rapid adoption of these technologies in the private sector, data is generally still lacking on the technologies and their uses and limited economic research available on most of the innovations. While some areas such as online trade platforms, AI, and robots have attracted growing attention from researchers, there has been relatively little work and evidence on the role of the technology in international trade and investment in other areas, including cloud computing, blockchain, and fintech. In the policy arena, trade and investment policies that incorporate new technologies are also evolving and

[2] See Estevadeordal et al. (2020) for a related comprehensive review on the roles of new technologies in the motives for and patterns of trade.

spreading across countries rapidly. The existing analysis and policy applications provide a useful roadmap for future research and policymaking by highlighting areas that may prove particularly useful for deepening our understanding of digital technologies and their potential implications for international economic growth.

Table 1
A Summary of Digital Technology and Productivity Mechanisms

Technology	Examples	Productivity mechanism
ICT	Internet, mobile phone	Communication costs, information, trade costs
Technologies reducing search costs and expanding market access		
Online trade platform	*eBay, Amazon, Alibaba, AliExpress, MercadoLibre, ConnectAmericas*	Entry costs, search costs, information
AI	Machine learning, machine translation, facial recognition	Information, search costs, communication costs
Technologies affecting production costs		
Robotics	Industrial robots, logistics robots, healthcare robots	Production costs, logistic costs
3D printing	Bioprinting, drug printing, hearing aids	Local production costs
Cloud computing	On-demand network access to a shared pool of computing resources, including networks, servers, data storage, applications, and services	Change IT input costs from large, centralized sunk costs to largely variable costs; allow for flexibility in data access and teamwork
Technologies addressing supply chain and financial transaction costs		
Blockchain	Cross-border payments, real-time IoT operating systems, supply chain and logistics monitoring	Reduced expense and time required for third-party lending and insurance, expediting customs procedures, real-time information on the origin and movement of goods
Fintech	Mobile banking, mobile money	Reduced transaction costs, improved transparency, reduced risks

Source: Compiled by the authors.

2 The Impacts of Digital Technologies on Trade, Investment, and Development

2.1 The Role of ICTs in Trade and FDI

The first generation of studies focused on the role of earlier ICTs—specifically the internet, computers, and mobile phones—in trade, investment, and firm performance. Through reductions in communication costs and information asymmetry, these technologies have been found to raise aggregate trade and FDI volumes, reduce price dispersions, and expand business participation in trade and firm performance.

2.1.1 ICTs, Trade, and Firm Performance

A significant volume of literature, starting with Freund and Weinhold (2002, 2004), has offered evidence on the effects of internet access on international trade and firm performance. Freund and Weinhold (2002) show that internet access is significantly related to growth in services trade: a 10-percent increase in internet penetration is associated with a 1.7-percentage-point increase in export growth and a 1.1-percentage-point increase in import growth. Exploring the effect of the internet on total trade, Freund and Weinhold (2004) show that the internet contributed to about a 1-percentage-point increase in annual export growth from 1997 to 1999.

How did the adoption of broadband internet affect firms and workers? Akerman et al. (2015) consider a Norwegian public program that rolled out broadband access points and find that broadband internet improves the labor market outcomes and productivity of skilled workers but has the opposite effect on unskilled workers. Their findings suggest that the adoption of broadband in firms complements skilled workers executing nonroutine abstract tasks and substitutes for unskilled workers in performing routine tasks. Broadband access also affects bilateral trade by making trade patterns more sensitive to distance and economic size, as shown in Akerman et al. (2021). The paper shows that the adoption of information technology enlarges the choice set of exporters and importers, leading to more elastic demand with respect to trade costs and distance.

Fernandes et al. (2019) examine the expansion of internet access in China and show that the internet rollout boosted firm manufacturing exports, even before the rise of major e-commerce platforms. The analysis finds that the results are consistent with improvements in communication with both buyers and input suppliers and that benefits arose not just from better communication but from establishing a visible virtual presence.

Information technologies, particularly mobile phone services, have also been documented to affect price dispersion and market performance. Jensen (2007), examining how mobile phone services had affected price variations and welfare in India, uses micro-level survey data to show that the adoption of mobile phones by fishermen and wholesalers was associated with a dramatic reduction in price dispersion and an increase in both producer and consumer welfare.

Aker (2010) shows a similar effect in Niger. Using market and trader-level data, the paper shows that the introduction of mobile phone services between 2001 and 2006 explains a 10- to 16-percent reduction in grain price dispersion, one that is particularly strong for market pairs with higher transportation costs.

More recently, Allen (2014) embeds information frictions in a trade model and explores agricultural trade data from the Philippines to show that information frictions account for roughly half the observed regional price dispersion. The empirical evidence suggests that access to mobile phones significantly increases price pass-throughs and the probability of small farmers participating in trade.

While the majority of the literature has focused on modern information technologies like the internet and mobile phones, Steinwender (2018) and Juhász and Steinwender (2019) show that historical technology adoption like the establishment of the transatlantic telegraph in 1866 exerted similar effects on trade and price dispersion. Steinwender (2018) finds that the average and the volatility of the transatlantic price difference for cotton fell after the introduction of the telegraph, while average trade flows increased and became more volatile. Juhász and Steinwender (2019) further investigate the mechanisms through which information frictions impact trade by estimating the effect of the transatlantic telegraph on imports of three product categories in the 19th-century cotton textile trade: yarn, plain cloth, and finished cloth. They find that reductions in communication times had the largest effect on imports of the most codifiable product, yarn, and the smallest effect on the most noncodifiable product, finished cotton cloth.

2.1.2 ICTs, Multinational Activity, and Firm Organization

In contrast to the body of work on ICTs and trade, there is relatively less direct analysis on the role of ICTs in multinational activity. Traditional models of FDI have tended to emphasize the role of physical transportation costs and infrastructure, but as noted by Oldenski (2012) and Keller and Yeaple (2013), communication both within firms and with customers plays a significant role in firms' organization and location decisions. Oldenski (2012) shows that goods and services requiring direct communication with consumers are more likely to be produced in the destination market while activities requiring complex within-firm communication are more likely to occur at the multinational's headquarters for export. Further, technology is subject to the laws of gravity, as found in Keller and Yeaple (2013): individual multinational affiliates sell less the further away they are from their home country, especially when it comes to knowledge-intensive goods.

The work by Alfaro and Chen (2018) directly examines the relationship between ICT adoption and multinational activity. Using a cross-country firm-level panel dataset, the study explores how the location patterns of multinational firms vary across countries depending on their levels of ICT adoption as measured by internet access, fixed broadband subscription, telephone subscription, and business uses of ICTs. The analysis finds a positive relationship between ICT adoption levels and multinational entry. When exploring how the effect of ICTs might vary across industries depending on industries' ICT requirements, the evidence suggests that the effect of business computer and internet uses is larger for less routine and more communication-intensive industries.

While multinationals tend to be attracted to countries with better ICT infrastructure, there is significant heterogeneity in multinational firms' productivity gains from IT capital. Bloom et al. (2012) examine the differences in IT-related productivity between establishments owned by US multinationals and establishments that are either owned by non-US multinationals or are purely (non-US) domestic. The research finds that not only are foreign affiliates of US multinationals more IT-intensive but they also obtain higher productivity from their IT capital than domestic firms and affiliates of non-US multinationals. This US IT-related productivity advantage is attributed in the paper to the US tougher "people management" practices.

Further, as shown in Bloom et al. (2014), ICTs may exert different effects on the organization of firms in which information technology constitutes a decentralizing force while communication technology acts as a centralizing force. Using a new data set of American and European manufacturing firms, the study finds that better information technologies (enterprise resource planning [ERP] for plant managers and computer-assisted design or manufacturing for production workers) are indeed associated with more autonomy and a wider control span, while technologies that improve communication decrease the autonomy of workers and plant managers.

2.1.3 ICTs and Labor Market Effect

In addition to the effects of ICTs on trade, FDI, and firm organization, how ICTs impact employment in developing countries has also been a topic of recent research. For example, Hjort and Poulsen (2019) examine the way that fast internet affects employment in Africa by exploiting the gradual arrival of submarine internet cables on the coast and the terrestrial cable network. They find large positive effects on employment rates—especially for higher-skill occupations and, to a lesser extent, for less-educated worker groups—with little or no job displacement across space. The paper also shows that increased firm entry, productivity, and exporting contribute to higher net job creation and offers evidence of a higher average income.

ICTs may also play a role in the polarization of jobs, a phenomenon characterized by relative growth of employment in high-skill and low-skill jobs amid the concurrent decline in middle-skill jobs. Goos et al. (2014) examine the roles of routine-biased technological change and offshoring in uneven patterns of job growth. The research shows that technological change and offshoring can explain much of total job polarization as well as the split into within-industry and between-industry components.

Similarly, Michaels et al. (2014) estimate the effects of ICTs on the polarization of labor markets. Using data from the United States, Japan, and nine European countries in 1980–2004, the paper shows that industries with faster ICT growth shifted demand from middle-educated workers to highly educated workers and technologies account for a quarter of high-skill job growth. In contrast, the paper does not find trade openness to be consistently related to job polarization.

2.2 Trade on International E-Commerce Platforms

In the last decade, the fast-rising importance of online platforms such as eBay and Alibaba has attracted an increasing volume of research assessing the effect of these platforms on trade patterns. Accounting for 14 percent of total global retail sales in 2018 (UNCTAD, 2020), global e-commerce platforms have presented new export opportunities for small and medium-sized enterprises (SMEs), especially in developing countries. Research in this area has explored the patterns of online trade and how access to e-commerce is affecting both the volume and distribution of trade and rural areas' economic development.

2.2.1 Cross-Border E-Commerce Trade

Several important patterns of international e-commerce trade have emerged from the empirical and theoretical analysis. First, several studies, including Lendle et al. (2013) and Chen and Wu (2018, 2021), find that compared to offline export firms, online export firms sell, on average, more products and export to more destinations. For example, Lendle et al. (2013) show that on eBay a much larger share of exporters (50 percent) sell to more than five countries, compared to less than 15 percent offline. The average number of destinations per exporter is 9.4. Further, Chen and Wu (2018) show that across different margins of exports, the numbers of new buyers and new markets contribute the most to online export growth. These findings are summarized in the following stylized fact.

Stylized Fact 1: *Firms export more products to more destinations online than offline, and the numbers of buyers and markets contribute the most to the growth of online exporters.*

Second, evidence suggests that there is substantial heterogeneity in export volume online, even among sellers offering similar products. As in offline trade, online markets are shown to be highly concentrated in "superstar" (e.g., top 5-percent) exporters, who account for the majority of online export revenue. For example, the largest 10 percent of sellers account for 70–85 percent of the market on eBay and AliExpress according to Lendle et al. (2013) and Chen and Wu (2018, 2021). In the meantime, due to the low entry barriers and low fixed costs of operation, there is a long tail of tiny sellers that live in the shadow of superstars and are indefinitely idle in the marketplace despite selling products whose quality and price are similar to those of the superstars. This result is summarized below:

Stylized Fact 2: *Online exports are highly concentrated among superstar exporters while exhibiting a long tail of small and idle sellers.*

Third, a recent study by Bai et al. (2020) investigates how search and information frictions shape firm dynamics and market evolution in global e-commerce. Using detailed data from AliEpxress as well as a set of self-collected objective quality measures, the paper documents empirical regularities consistent with the presence of search and information frictions. In particular, the paper finds that quality only weakly predicts export sales and that "superstars" do not necessarily have the highest quality (nor the lowest price). The paper also conducts a randomized experiment that offers exogenous demand and information shocks to small prospective exporters. It establishes that firms with larger past sales have an advantage in overcoming the search friction and generating future orders, suggesting the importance of initial demand shocks as opposed to firm fundamentals such as product quality. The above empirical regularity is summarized in the next stylized fact:

Stylized Fact 3: *Online superstars do not necessarily exhibit quality advantages.*

Another focus of existing research on online trade is assessing the effect of distance and gravity on online trade. Hortaçsu et al. (2009) use domestic transactions data from eBay and MercadoLibre to examine geographic patterns of online trade between individuals and find that distance continues to be an important deterrent to trade, albeit to a lesser extent than for offline trade between businesses. Lendle et al. (2016) further show that the effect of geographic distance on eBay is 65 percent smaller than on offline trade and attribute the result to the lower search costs in online trade. This finding leads to the next empirical regularity:

Stylized Fact 4: *Distance continues to deter online trade, but to a lesser extent than for offline trade.*

Not only can online trade platforms weaken the effect of traditional trade barriers such as distance, they can also offer a mechanism for consumers to access larger numbers of sellers and share information with other consumers. Caballo et al. (2020, 2022) estimate the impact of using online trade platforms (specifically, ConnectAmericas) on Peruvian firm exports. The study finds that ConnectAmericas results in increased firm exports, particularly for those that had no digital presence, produce different products, and export to less-familiar destinations. Access to ConnectAmericas allowed firms to expand their exports primarily by increasing the number of products they sell abroad and enlarging the buyer base. These results are attributed to the role of the platform as a search-cost-reducing mechanism.

The feedback system in online trade platforms also enables buyers to communicate information on product quality and in turn allows sellers to establish a reputation and reveal quality. Chen and Wu (2021) examine the role of online trade platforms as a reputation regime of this sort. The paper shows that exporters displaying a superior reputation perform significantly better than peers with nearly identical true ratings and observables. Further, the value of reputation rises with the level of information friction and the specificity of information. The paper also uses a dynamic reputation model with heterogeneous cross-country information friction to quantify the effect of the reputation mechanism and finds a 20-percent increase in aggregate exports, fueled by a market reallocation toward superstars.

The effect of online trade platforms on small sellers can be further strengthened when the platforms integrate intermediation services such as customs clearance and international shipping and handling. Hui (2020) shows that the introduction of the Global Shipping Program on eBay, which integrated an existing export intermediary service into its platform and offers customs clearance and international logistics services to its sellers, increased exports from small sellers to new destinations. The increase in exports was found to be driven by a reduction in export entry costs.

The next stylized fact summarizes the findings:

Stylized Fact 5: *Online trade platforms raise total exports for small and medium-sized businesses, especially at the product and buyer margins.*

While online trade platforms can effectively lower entry costs compared to offline trade, Bai et al. (2020) note that the low entry costs and lack of market selection mechanism on online platforms can lead to congestion in consumer searches and make it difficult for high-quality sellers to stand out. In fact, in such online environments, initial demand shocks—as opposed to firm fundamentals such as quality and productivity—may play a significant role in firm performance and growth, hindering market allocation toward better firms. The research shows that altering the search mechanism such that initial demand shocks are proportional to true quality and reducing the number of sellers can help mitigate congestion in consumer searches, thereby improving allocative efficiency and consumer welfare. This finding is summarized below:

Stylized Fact 6: *Alleviating search frictions on online trade platforms can help improve allocative efficiency and raise consumer welfare.*

2.2.2 E-Commerce and Economic Development

The rise of e-commerce platforms can shape economic development. The growth of domestic e-commerce in rural markets has particularly motivated policies in countries such as China, Egypt, India, and Vietnam to expand e-commerce to the countryside to foster rural economic development and reduce rural-urban economic inequality. These programs include China's Taobao villages and nationwide e-commerce program, Egypt's National E-Commerce Strategy, the Digital India program, Vietnam's E-Commerce Development Masterplan, and UNCTAD's new technical assistance platform, eTrade For All: Unlocking the Potential of E-Commerce in Developing Countries (UNCTAD, 2016). But important questions remain about whether market integration through online trading platforms might have a significant impact on rural economic development.

Two recent studies have examined the role of online platforms in addressing inequality. Fan et al. (2018) show that access to e-commerce can increase intercity trade and alleviate spatial consumption inequality by removing the fixed cost of market entry and reducing the effects of distance on trade costs. The analysis uses data from China's leading e-commerce platform (Taobao) to show that online trade is less hindered by distance relative to offline trade and residents from smaller and more remote cities spend a larger fraction of their income online. The research further estimates that the emergence of e-commerce increases aggregate domestic trade and total welfare, especially for cities in the smallest population and market potential quintiles.

Also looking at China's leading e-commerce platform, Couture et al. (2020) reach more mixed results when estimating the impact of the first nationwide e-commerce expansion program on rural households. The research finds little evidence for income gains to rural producers and workers; instead, the gains are found to be driven by a reduction in the cost of living for a minority of rural households, which tend to be younger, richer, and in more remote markets. These effects, as summarized below, are mainly due to the overcoming of logistical barriers to e-commerce, rather than to additional investments to adapt e-commerce to the rural population.

Stylized Fact 7: *Access to e-commerce benefits rural areas via reduced trade costs and lower costs of living.*

Altogether, studies suggest that online trade platforms could shape the growth, distribution, and welfare effect of trade through various mechanisms. On the one hand, the platforms significantly lower export entry costs and search costs and reduce information frictions between sellers and buyers as well as between buyers. By doing so, the platforms enable small businesses to enter and expand in export markets and weaken the effect of traditional trade barriers. The platforms can also lower costs of living and lead to consumer gains, especially for less populated and rural areas.

On the other hand, increased entry on the platforms could lead to congestion in consumer searches and slow down the revelation of information. This could confound the role of firms' true quality in determining firm growth and the long-run market structure and hinder market allocation toward better firms. These findings suggest that establishing online trade platforms and giving firms easy access to foreign markets alone may not be sufficient for generating sustained growth. Policies should be designed to help firms, especially new businesses, overcome the additional demand-side frictions and ensure the allocative efficiency of the online markets.

Examining the effects of restrictive data policies, Ferracane et al. (2018) distinguish between policies regulating the cross-border movement of data and policies regulating the domestic use of data. They show that in countries applying restrictive data policies, particularly with respect to cross-border data flows, the level of services traded online is lower. This negative impact is stronger for countries with better-developed digital networks.

The impacts of data policies also go beyond trade. Ferracane et al. (2020) investigate how policies regulating the cross-border movement and domestic use of electronic data affect the productivity performance of downstream firms and industries, respectively. The paper shows that stricter data policies have a negative and significant impact on the performance of downstream firms in sectors reliant on electronic data. This adverse effect is stronger for countries with strong technology networks and for servicified firms.

2.3 AI, Trade, and Firm Growth

In recent years, AI has made significant progress in domains such as machine learning, which provides useful inputs for decision-making. Economic research has sought to understand the implications of machine learning for the labor market. Agrawal et al. (2019) provide a systematic discussion of how AI will affect labor, emphasizing, in particular, the differences between the case in which the automation of prediction leads to the automation of decisions versus the case of enhancing decision-making by humans. Brynjolfsson and Mitchell (2017) outline a list of factors including substitutability, complementarity, price elasticity, income elasticity, the elasticity of labor supply, and process redesign costs, all of which can affect the implications of machine learning for the workforce.

There is, however, relatively little existing research investigating the effect of AI on globalization. Using data from a digital platform, a recent study by Brynjolfsson et al. (2019) studies the trade effect of machine translation and finds that the introduction of a new machine translation system increased international trade on this platform by 10.9 percent. Exploring the broader dimensions of AI, Goldfarb and Trefler (2018) examine key features of AI and prescribe a model of international trade in the context of AI. The authors note that such models should account for scale, knowledge creation, and the geography of knowledge diffusion and suggest that whether AI-focused trade policies or investments in clusters are optimal will depend on the presence of scale and international knowledge diffusion. For example, in the presence of a scale economy in data, the government can beneficially subsidize the education of AI scientists and/or subsidize the entry of firms by offering tax breaks, subsidies, expertise, and incubators. The paper also discusses how regulations including data localization rules, limited access to government data, industry regulations on the use of drones, and forced access to source code might be used to favor domestic industry.

The overall effects of AI on economic growth are considered in Aghion et al. (2019), who model AI as a process where capital replaces labor for an increasing range of tasks. Among many insights, the authors show that AI may in part discourage future innovation by speeding up imitation and rapid creative destruction may impose its own limit on the growth process. Further, they find that, while AI may be skill-biased, more AI-intensive firms tend to outsource a higher fraction of low-skill tasks as well as pay a higher premium to the low-skill workers inside the firm.

The question of how the state and access to government data might shape the growth of data-intensive industries is also examined empirically in a recent study by Beraja et al. (2020). Specifically, the study examines facial recognition AI in China, where the state is a key collector of such data, using comprehensive data on firms and government procurement contracts. The analysis finds evidence of economies of scope arising from government data: firms awarded contracts with access to more government data produce both more government and commercial software. The findings suggest that access to government data could lead to more software innovation and growth and that data-intensive innovation may be shaped by the state.[3]

2.4 The Effects of Robots on Trade, Offshoring, and the Labor Market

Across different forms of new technology, the rise of robots and automation has sparked the most intense debate on the effects that the adoption of these innovations is having on globalization and labor markets (Baldwin, 2019). One of the main reasons that robots and automation have attracted such widespread attention is the unique and complex mechanisms through which they are shaping economic activity and labor markets. Unlike the technologies discussed above (internet, e-commerce platforms, and AI), which lower costs of communication, searches, and entry, robots and automation reduce production costs and replace some tasks previously performed by humans. An increase in robot adoption and

[3] While data access may have important implications for growth and innovation, policymakers are confronted with the need to balance the benefits of free information flow with the protection of consumer privacy and cybersecurity. Fostering the growth of digital sectors while ensuring data rights and privacy constitutes a key challenge for policymakers.

automation may thus lower demand for unskilled labor and alter incentives to trade and offshore production to developing countries. In the meantime, by raising firm productivity and enhancing scale economy, the adoption of robots and automation can lead to greater specialization, stronger demand for skilled labor, and expansion across markets. Altogether, the implications for trade and offshoring are ambiguous, whereas the effects on workers are expected to vary with skill and between short and long terms.

2.4.1 *Robots, Trade, and Offshoring*

These hypotheses are examined in a growing strand of literature. Examining the effects of robotization on trade and welfare, Artuc et al. (2018) show that greater robot intensity in firms' own production leads to a rise in both imports from and exports to less developed countries. The analysis further shows that robotization in developed economies raises domestic welfare despite an initial decrease in wages.

Another related study, Stapleton and Webb (2020), assesses how automation in a high-income country like Spain affects trade and multinational activity involving lower-income countries. The analysis shows that, contrary to the widespread belief that automation in high-income countries will trigger a reshoring of production, the use of robots in Spanish firms had a positive impact on their imports from lower-income countries and the number of affiliates in these. Robot adoption caused firms to expand production and increase labor productivity and total factor productivity (TFP). For firms that had not previously offshored production to lower-income countries, the productivity and revenue-enhancing effects of robot adoption made them more likely to do so.

In contrast to the above findings, Rodríguez Chatruc and Nievas Offidani (2019) explore the impact of changes in robot density on the degree of offshoring and find that increases in the former are associated with declines in the latter. The study estimates a 16-percent reduction in offshoring in 1993–2015 when an industry moves from the bottom to the top of the ranking of changes in robotization. The result is attributed to the role of automation in reducing domestic production costs in developed countries and thus their incentives to offshore production to lower-income countries.

These findings are summarized in the stylized fact below:

Stylized Fact 8: *The adoption of robots and automation in developed countries can have mixed effects on trade and offshoring to less developed countries.*

2.4.2 *Robots, Employment, and Wages*

Aside from their effect on globalization, the implications of robot adoption and automation on labor markets and income inequality have also emerged as a topic of fundamental importance.

Graetz and Michaels (2018) use robot adoption data in 17 countries from 1993 to 2007 to show that increased robot use contributed approximately 0.36 percentage points to annual labor productivity growth, while at the same time raising TFP and lowering output prices. Their analysis also suggests that robots did not significantly reduce total employment, except for the share of low-skilled workers' employment.

Using micro data in the French manufacturing sector between 1994 and 2015, Aghion et al. (2020) find that automation exerted a positive impact on employment at all levels of analysis—plant, firm, and industry—suggesting that the productivity effects of automation outweigh its potential displacement effects. The study also finds that automation leads to higher profits, lower consumer prices, and higher sales.

Another influential study by Acemoglu and Restrepo (2018) examines the effects of industrial robots on US labor markets and reaches a different conclusion. In contrast to the previous examples, they find robust negative effects on employment and wages across commuting zones. Their analysis indicates that the impact of robots is distinct from other capital and technologies and that each additional robot per thousand workers reduces the employment-to-population ratio by 0.2 percentage points and wages by 0.42 percent.

Autor (2015) provides an overview of the history and future of workplace automation and notes that automation both substitutes and complements labor, altering both the types of jobs available and the pay for these. Interactions between machine and human comparative advantage allow computers to substitute for routine-task workers while enhancing the comparative advantage of problem-solving workers.

The question then naturally arises as to whether developing countries should expect a job displacement effect. The analysis by Artuc et al. (2018) shows that robotization in developed countries may depress wage rates in these countries, at least in the short run, but may lead to higher wages and welfare in developing countries. A recent study by Das and Hilgenstock (2018) argues that although large-scale labor market dislocation is not imminent, emerging markets are becoming increasingly exposed to the routinization brought by the technologies and thus labor market polarization, from the long-term effects of structural transformation and the onshoring of routine-intensive jobs. This concern is also highlighted in Rodríguez Chatruc and Nievas Offidani (2019) and Estevadeordal et al. (2020), who note that an increase in robot intensity can reduce the offshoring of developed countries' production and subsequently labor demand in developing countries.

The effects of robot adoption and automation have also been compared to the impacts of offshoring. Faia et al. (2020) note that automation and offshoring fundamentally affect the matching between firms and workers in contrasting ways. Automation increases firms' and workers' job selectivity and decreases employment, while offshoring has the opposite effect. This finding is echoed in Prettner and Bloom (2020) which reviews the recent trends in automation and shows that the main effects are increased output per capita, which comes at the expense of rising inequality because the routine tasks of low-skilled workers are replaced while the income of capital owners increases. The research further argues that the current COVID-19 pandemic is likely to reinforce these trends. These results are summarized below:

Stylized Fact 9: *The adoption of robots and automation in developed countries has been shown to decrease employment and wages, especially those of low-skilled workers, in these developed countries.*

2.5 3D Printing and Trade

Another technological breakthrough that is expected to reduce the cost of production is 3D printing. One hypothesis is that by allowing firms and consumers to produce goods from a digital file, 3D printing can reduce the need to import these goods. At the same time, 3D printing can also help expand productivity and exports by reducing the cost and time required to source inputs and components and clear customs at the border.

New research by Freund et al. (2020) examines 3D printing for hearing aids and 35 other products and shows that adopting the new technology in production increased trade significantly. The finding is explained by the production cost-saving and quality improvement effects of 3D printing. However, the analysis notes that product characteristics such as bulkiness can affect the relationship between 3D printing and trade.

The trade effect of 3D printing can also be negative as shown in Abeliansky et al. (2020). Examining the relationship between 3D printing, trade, and FDI, the authors use a standard trade model with firm-specific heterogeneity to make three predictions: first, 3D printers tend to be adopted in areas where economic activities face high transport costs; second, 3D printing motivates the gradual replacement of traditional FDI dependent on traditional techniques with 3D-printing-dependent FDI; third, wider adoption of 3D printing leads to a gradual replacement of international trade. These hypotheses are supported by empirical evidence and case studies, suggesting that the export-led industrialization model used in low-income countries can be challenged by the widespread adoption of 3D printing.

These findings are summarized in the stylized fact below:

Stylized Fact 10: *3D printing has been shown to grow in areas facing high transportation costs and has mixed effects on trade.*

2.6 Cloud Computing and the Growth of Young Firms

Another technology that has significantly boosted firm productivity over the last decade is cloud computing, which lowers the need for businesses to make upfront investments in hardware and software and maintain IT infrastructure. As noted above, by making services available on-demand and accessible from different locations around the world, cloud computing transforms IT input costs from large, centralized sunk costs to largely variable costs and enhances both internal and external scale economies. This change in the nature of IT costs can be beneficial for young firms by lowering the entry barriers to upfront IT investments and enabling them to scale up production.

These hypotheses are examined in DeStefano et al. (2020), who find that cloud services and high-speed fiber broadband infrastructure enable young firms to scale up without increasing their geographic footprint, while incumbents use the technology to reorganize, reduce their costs, and increase their geographic dispersion. The authors' results also show that cloud services enhance worker mobility within the firm by enabling the movement of workers across plants.

A related study by Jin and McElheran (2018) examines how firms' ability to access information technology as a service affected the survival and performance of young establishments in the US manufacturing sector. The analysis shows that the ability to "rent" IT as needed—particularly via cloud computing—was associated with significantly higher survival and growth rates among young plants. This contrasts with investments in traditional IT capital, which increased their likelihood of failure.

Berry and Reisman (2012) present an overview of the global market for cloud services and explore the role of cloud computing in US exports. The paper also discusses the main policy challenges associated with cross-border cloud computing, including data privacy, security, and ensuring the free flow of information, and the ways that countries are addressing these challenges through domestic policymaking, international agreements, and other cooperative arrangements.

The provision of online computing services has great potential for expanding trade in services. Cloud technology can intensify global specialization and competition in high-technology services, as technology users easily access services from around the world, posing new issues and challenges for international trade and international economic policy.

2.7 Blockchain and Global Value Chains

One technology domain that is particularly relevant to globalization is blockchain. Based on Patel and Ganne (2020), blockchain is a "decentralized, distributed record or 'ledger' of transactions in which the transactions are stored in a permanent and near inalterable way using cryptographic techniques." Ganne (2018) discusses the mechanisms through which the technology can affect cross-border trade, including substantially reducing trade costs, helping build trust, enhancing the transparency of supply chains, and opening up new opportunities for micro, small, and medium-sized enterprises from developing countries.

A related study by McDaniel and Norberg (2019) examines the potential role of blockchain technologies in international trade and discusses how such technologies might affect trade finance, customs procedures, and the provenance (origin) of goods. First, the paper argues that blockchain could increase the efficiency of trade finance by reducing the expense and time required to facilitate trade that depends on third-party lending or insurance. Second, blockchain could reduce trade costs by expediting customs procedures, thereby boosting both global trade volumes and economic output more than the worldwide elimination of tariffs. Third, blockchain could improve the management of supply chains by providing real-time information on the origin and movement of goods. Blockchain may also be used to improve the integrity of trade; it can help in the detection of illicit trade flows and deter illegitimate efforts to circumvent trade rules, supporting efforts to fight trade-based money laundering (TBML). Such applications could aid customs and law enforcement in facilitating the flow of legitimate trade.[4]

Despite the significant roles of blockchain technology, the empirical research assessing its impact on the patterns and efficiency of trade and global value chains remains limited. Further, more attention is needed on the policy challenges of technology adoption.[5] As noted in Patel and Ganne (2020), the adoption and growth of blockchain pose several key challenges, ranging from technical issues related to the use of standards, scalability, interoperability, security, and complementarity to legal issues such as data privacy and cross-country cooperation in regulations.

2.8 Fintech: Mobile Money and Households

Finally, digital innovations in the finance sector are also rapidly transforming the delivery and use of financial services. By providing specialized software and algorithms via computers (and, increasingly, smartphones), financial technology (fintech) is helping businesses and consumers manage their financial operations and lives more efficiently. As shown in Cornelli et al. (2020), fintech is providing more lending

[4] Some studies have also examined the impact of blockchain technology on business models; see, for example, Weking et al. (2020).

[5] Additional research is also called for on the energy consumption associated with this technology and the implied environmental consequences.

to households and small businesses: fintech credit flows reached $223 billion in 2019, especially in markets where there is greater (unmet) demand for credit and where economic and institutional factors favor the supply of such lending.

There is, however, little empirical research on the role of fintech in international trade and investment. Existing economic research has focused on the adoption of fintech and how innovations such as mobile banking and mobile money have affected micro-economic outcomes such as improved risk-sharing, food security, consumption, business profitability, saving, and the effective use of cash transfers by reducing transaction costs, improving transparency, and helping with saving and insurance. For example, Jack and Suri (2014) show that in Kenya mobile money users' consumption levels are unaffected by negative income shocks, while the consumption of nonusers drops, especially among the poorest. Suri and Jack (2016) also examine the broader effect of mobile money and find that access to mobile money increases consumption for female-headed households, shifts jobs out of farming, and helps lift households out of poverty. Aron and Muellbauer (2019) provide a recent review of the economics and effects of mobile money.

Similarly exploring the role of fintech in financial inclusion, Sahay et al. (2020) use both available data and interviews to show that digital finance is associated with higher GDP growth and greater financial inclusion, even where traditional financial inclusion is declining. Further, the analysis shows that digital finance helps to close gender gaps in financial inclusion in most countries, but there is a concern that they may rise in the post-COVID era. In addition, digital finance can lead to other risks due to unequal access to digital infrastructure and constraints to financial and digital literacy. In Table 2, we summarize the findings discussed in this section for each type of digital technology. As shown in the table, digital technologies are exerting varied and complex effects on globalization and beyond. Existing evidence suggests that the growth of digital technologies such as ICTs, online trade platforms, AI, and robots could reshape cross-border trade and offshoring activity, but the effect varies across technology, industries, and firms and there are also other important effects on labor markets and economic development. In the next section, we turn to the impacts of these new technologies on trade and investment policies and how they pose both new opportunities and challenges to policymaking.

Table 2
A Summary of Existing Evidence on the Effects of Technologies

Technology	Trade	FDI	Other effects
ICT	Trade growth; services trade growth; reduced price dispersions; participation of small farmers in trade	Greater multinational entry, especially for communication-intensive industries; heterogeneous productivity gains	Employment growth
Online trade platform	Trade growth, especially at the extensive margins; weaker effect of distance; potential allocative inefficiency		Little income gains to rural producers and workers; reduced cost of living
AI	Increased trade; growth and innovation in data-intensive industries		
Robotics	Increased trade and offshoring	More multinational entry	Lower employment, especially for unskilled workers; rising income inequality
3D printing	Increased trade for lighter goods; effect depends on product bulkiness		
Cloud computing			Growth of young firms; reorganization, reduced costs, and increased geographic dispersion for incumbent firms
Blockchain	Increased trade volume; efficiency of global value chains		Traceability and reduced TBML (blockchain in trade finance)
Fintech			Improved risk-sharing, food security, consumption, business profitability, and saving; effective use of cash transfers; reduced gender gap in financial inclusion; risks due to unequal access to digital infrastructure and constraints to financial and digital literacy

Source: Compiled by the authors.

3 New Technologies and Trade and Investment Policies

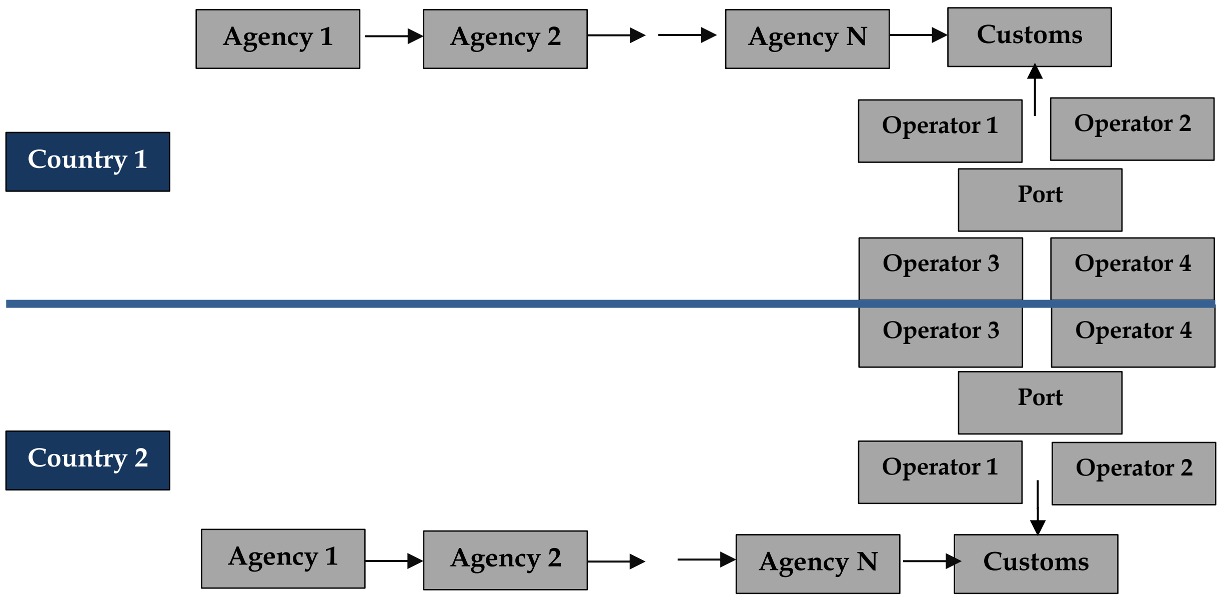
In the previous section, we discuss in detail how new technologies are affecting the level and patterns of trade and investment and, more broadly, economic development. These new technologies also allow for both new policy designs and new approaches to implement policies. In this section, we describe several of these innovations in trade and investment policymaking. In so doing, we explain how they can impact trade costs and, whenever available, we present evidence on their effects on trade and investment outcomes based on the very incipient—yet growing—empirical literature thereon.

3.1 Digitalization and Trade and Investment Facilitation and Promotion

Firms engaging in international trade and investment are usually confronted with cumbersome procedures and a lack of appropriate, state-of-the-art processing technologies. Firms engaging in international trade have to interact with a relatively large number of government entities, including customs and agencies responsible for health, food, quarantine, safety, and consumer protection on both sides of borders (Figure 1). Survey-based evidence reveals that the median number of government agencies that have direct regulatory involvement (or require information) in transactions is 15 and that their number can reach 30 or more in some cases (Choi, 2011).[6] Many of these agencies have their own procedures and specific data requests, which are frequently paper-based and overlap with those of their counterparts and even their own processing systems. As a consequence, trading firms must submit the same information to multiple agencies multiple times, through processes that have been largely paper-based and manual. This generates thick, labyrinthine borders that are time-consuming and costly to cross.

[6] For instance, in Indonesia and Nigeria there are 37 and around 50 agencies with trade regulatory compliance responsibilities, respectively (see, UNESCWA, 2011).

Figure 1
Schematic Representation of a Two-Sided Border



Source: Authors.

Countries around the world are responding to these complexities by streamlining border procedures through process reengineering and, importantly, the incorporation of new technologies that allow them to complete these procedures online and hence reduce processing times and the associated costs. Digitalization within and between agencies can particularly help facilitate trade and investment at the border and across borders. This section reviews selected initiatives in this area and discusses the available empirical evidence on their effects when available.

3.1.1 *Digitalization and Trade Facilitation*

3.1.1.1 *Digital Forms and Invoices*

To complete border procedures, firms must fill in forms, which typically include customs declarations. Such declarations are official documents that specify and provide details of goods that are being imported or exported that must be submitted by firms owning the goods or those with control over them. Most customs agencies around the world have digitized these declarations in recent decades, enabling firms to submit them online before their goods arrive at customs facilities and allowing the electronic administrative processing of trade transactions. The picture has been different, though, for other border agencies, which in many countries still rely significantly on paper forms (Volpe Martincus, 2016).

In addition to customs and --when applicable—other border agencies' forms, firms must present the invoice associated with the operation. These documents have been also increasingly digitized with the introduction of electronic invoices. These are machine-readable invoices with structured data issued in Electronic Data Interchange (EDI) or XML formats or using standard internet-based web forms and received and processed electronically between buyers' and suppliers' finance and tax systems. It is worth noting that these electronic invoices are not only important supporting documents for traditional trade but also crucially for services and digital trade (Cory, 2020).[7]

3.1.1.2 Digitalization of Procedures in a Country's Single Border Agency

The digitalization of customs procedures leads to reduced trade costs by shortening administrative processing times and hence lowering the immobilization costs of goods.[8] It also increases transparency in terms of both the actors involved and their specific actions and accordingly diminishes the potential for corruption derived from in-person interactions between officials and traders and unregistered arbitrary decisions by the former, such as what shipments to inspect, when to release a shipment, and so on (e.g., Sequeira and Djankov, 2014).

Specifically, the digitalization of customs procedures creates the conditions needed to introduce more systematic risk management approaches for assigning shipments to different processing channels: no inspection (green channel), documentary inspection (yellow/orange channel), and documentary and physical inspection (red channel)—whereby the latter implies significantly longer times in customs (Volpe Martincus, 2016).[9] These risk management systems are enabling customs authorities to shift from inspecting 100 percent of shipments, as was common in several developing countries a few years ago (at least on the import side), to focusing their attention and limited customs inspection resources on a substantially smaller subset of those shipments, namely those that are considered riskier (i.e., less likely to comply with regulations), thereby facilitating the border crossing of lower-risk shipments.[10] Risk management systems have been consistently shown to be associated with lower physical inspection rates, shorter processing times, and larger exports and imports from firms in Uruguay and Albania (see, e.g., Volpe Martincus et el., 2015; Fernandes et al., 2021). Furthermore, evidence from Colombia reveals that the sequential computerization of customs import procedures across ports in the early years of the 2000s

[7] The IDB is supporting countries in the design and implementation of electronic invoicing systems, both in general and for international trade in particular.

[8] Digitalization helps expedite the administrative processing of trade transactions both directly and indirectly by reducing the scope for human reporting errors that prevail in paper-based processes.

[9] Customs agency controls aim to ensure that shipments are in accordance with the relevant trade regulations and meet security standards.

[10] Admittedly, several importing countries are currently requiring 100 percent shipment inspection at exporting countries' ports as a consequence of an increase in irregular exports.

resulted in benefits for firms that included increased value-added, employment, productivity, and propensity to export—especially for SMEs—and larger revenues, and that the main channels were a reduction in customs processing times and the variability of these and a decrease in corruption and smuggling (Laajaj et al., 2021).

Digitalization also made it possible to operationalize firm-level trade facilitation initiatives. This is particularly the case with authorized economic operator (AEO) programs, which have been introduced in more than 90 countries worldwide (WCO, 2020). These programs offer trustworthy trading firms several advantages in the administrative processing of their shipments, including less frequent physical and documentary customs inspections as they are assigned a lower risk score in the customs risk management system; expedited processing and release of shipments, which specifically involves priority treatment when goods are selected for inspection and during periods of elevated threat conditions or in post-incident resumptions; and streamlined administrative compliance procedures, which encompass the use of simplified customs declaration forms. All these advantages translate into shorter clearance times at the border, lower per-shipment costs, and lower trade costs in general, and thereby increased shipping flexibility. This is likely to provide certified exporters with a competitive edge.[11]

Evidence on Mexico's AEO program suggests that this is indeed the case: the program has resulted in increased exports for firms. This positive effect can be traced back to lower rates of physical inspections (which implies shorter times in customs for shipments) and, to a certain extent, reduced information barriers due to the quality signaling associated with certification. Importantly, this effect does not come at the expense of noncertified exporters, so the program appears to have positively affected country-level exports. The evidence further indicates that the program has favored an expansion in foreign sales along both the destination-intensive margin—certified firms registered an increased number of shipments to importing countries already being served—and the destination-extensive margin. Finally, the effects seem to have been stronger on time-sensitive products such as textiles, consumer goods, and industrial inputs (Carballo et al., 2016a; Volpe Martincus, 2016).

[11] In general, in order to be certified as authorized economic operators, firms must meet a number of eligibility criteria which include record of compliance with customs requirements; satisfactory system of managing commercial records and, whenever applicable, transport records which allow for appropriate customs control; proven financial solvency; and adequate security and safety standards.

3.1.1.3 Digitalization of Procedures in a Country's Set of Border Agencies: Electronic Trade Single Windows and Port Community Systems

Coordinated Border Management

As shown in Figure 1 and mentioned above, there is a multiplicity of border agencies. These agencies collaborate in different forms and to different extents. Interagency interactions can be informal, unstructured, and aperiodic or formal and organic, based on regulations, procedures, and explicit agreements and mechanisms. The latter imply a coordinated intervention approach by border agencies within a given country or both within and across countries, which is commonly known as *coordinated border management*.

Coordinated border management allows agencies to tap shared resources, leverage the pool of joint capabilities, and generally exploit positive synergies, which reduces the cost of the regulatory process. By favoring the elimination of duplications and redundancies, it also streamlines this process, thereby making border times shorter and more predictable, which benefits trading firms (WCO, 2021).

Electronic trade single windows can be thought of as one of the electronic expressions of coordinated border management.[12] These are discussed next.

Electronic Trade Single Windows: Administrative Procedures

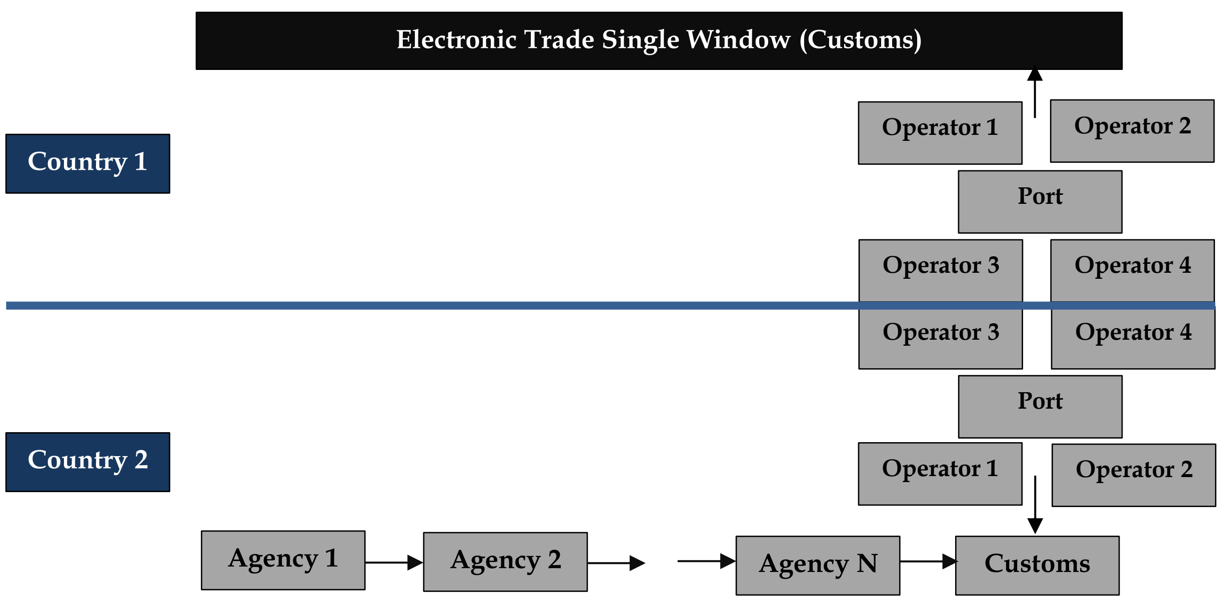
As mentioned above, firms trading across borders interact not only with customs authorities but also with several other bodies. To streamline the administrative process for international trade transactions and reduce the hurdles associated with these multiple interactions, governments in many countries have introduced trade single windows. These are a facility that allows parties involved in trade and transportation to fulfill all import, export, and transit-related regulatory requirements by lodging standardized information with a single-entry point (UNECE, 2005a, 2005b). Information technology and interoperability-enabling methods (e.g., service-oriented architectures through which disparate systems "talk" to each other) have made it possible to implement digital versions of these arrangements—in other words, electronic trade single windows (UNESCWA, 2011). Instead of paper-based documents needed to be filled in and moved consecutively through different agencies, these single windows allow digital

[12] Coordinated border management also involves operations at overland border crossings. The IDB has been supporting Central American countries in the adoption of this approach. Recent surveys conducted by the WCO reveal that border times are significantly shorter in those border crossings in which agencies' interventions are coordinated.

documents to be submitted and exchanged online among agencies dealing with trade regulations, and trade-related permits and certificates to be issued electronically (Figure 2)

Upgrading technology from a paper-based system to an electronic single window speeds up information submission and processing, improves the accuracy of this information, and reduces response times. Firms now interact with a single virtual agency instead of having to pay physical visits to obtain paper forms and file them with the various regulatory agencies. Their administrative processing costs decrease as they can manage trade-related documentation more efficiently, thus minimizing clerical work. Furthermore, the data submitted can be reused multiple times, errors from rekeying identical data are eliminated, and data consistency is enhanced. Moreover, these systems generally enable users to track their progress toward completing procedures more effectively, while also leading to more predictable decisions (UNECE, 2003; UNECE, 2005; UNESCWA, 2011; and van Stijn et al., 2011).

Figure 2
Electronic Trade Single Window



Source: Authors.

Empirical evidence from Costa Rica indicates that the gradual implementation of the electronic trade single window has been associated with an increase in exports from firms whose products require permits that need to be processed by border agencies other than customs. This increase in exports can be traced back to higher shipping frequency, buyer diversification, and greater sales per buyer and has been stronger for firms that have to interact with several public agencies without offices in the regions where these firms are located. This points to the benefits of relaxing the geographical constraints that come with the creation of a virtual exporter–agency interface. The number of exporters (especially SMEs) has also responded positively to the implementation of the electronic single window. This implies that the streamlined trade processing enabled by information technologies reduces entry costs and significantly affects the extensive margin of trade (Carballo et al., 2016b; and Volpe Martincus, 2016).[13]

Port Community Systems: Logistics Activities

At countries' points of entry and exit (i.e., ports, airports, and land border crossings), several transportation and logistics activities (e.g., loading/unloading, cargo movement, and deposit, transport) are carried out by multiple actors such as shipping lines, agents, freight forwarders, stevedores, terminal and depot operators, and hinterland transportation companies (e.g., truck, rail, and inland waterways), involving exporting and importing firms, port authorities, and customs. These private and public actors, which together form a port community, must communicate and exchange significant quantities of information on the specific tasks that they are responsible for in handling shipments of goods.

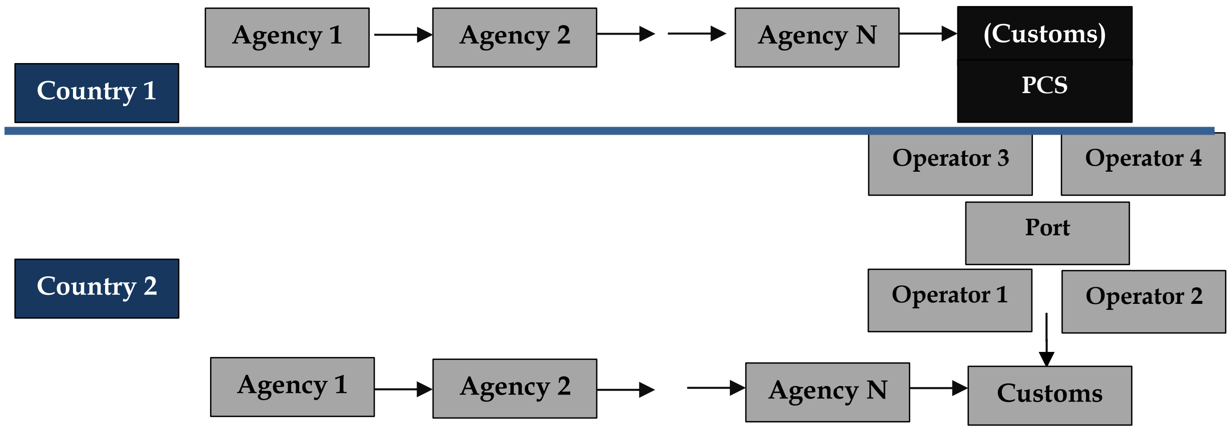
To increase the efficiency in the completion of these activities, countries have introduced port community systems (PCS). These systems are open, neutral electronic platforms that interconnect public and private entities and operators. They allow information to be submitted on a single occasion and exchanged intelligently and securely between the entities in question (Figure 3).

PCS can thus help streamline communication among relevant parties in the port community, improve workflow within and across them, and automate and optimize transportation and logistics processes. More specifically, the gains associated with PCS include: (i) reductions in communication costs and access to reliable, accurate information as a result of fewer communication channels and processes and documents being exchanged, faster handling of vast amounts of data, and the elimination of redundant rekeying and hence lower error rates and data inconsistencies; (ii) real-time track and trace capabilities for the entire door-to-door shipment process, which allows haulers and truckers to better plan movements and improve overall turnaround times; (iii) shorter handling and process times associated with the elimination of unnecessary and wasted (truck) movements and automated gate clearance at seaports, among others; and (iv) a lower incidence of illegal transactions (Mendes Constante, 2019; and Lucenti and Mendes Constante, 2019).

Despite the facts that these logistics single windows have been already adopted by several countries (many years ago, in the case of Europe) and that their rollout is typically gradual—thus lending themselves to a difference-in-differences estimation of their effects—no single rigorous microeconometric impact evaluation of these initiatives has been conducted. Lack of access to the required data seems to be a major impediment.

[13] These digital systems can also help deter and reduce irregular trade as they are associated with increased traceability, improved auditing, and less human intervention.

Figure 3
Port Community Systems (PCS)



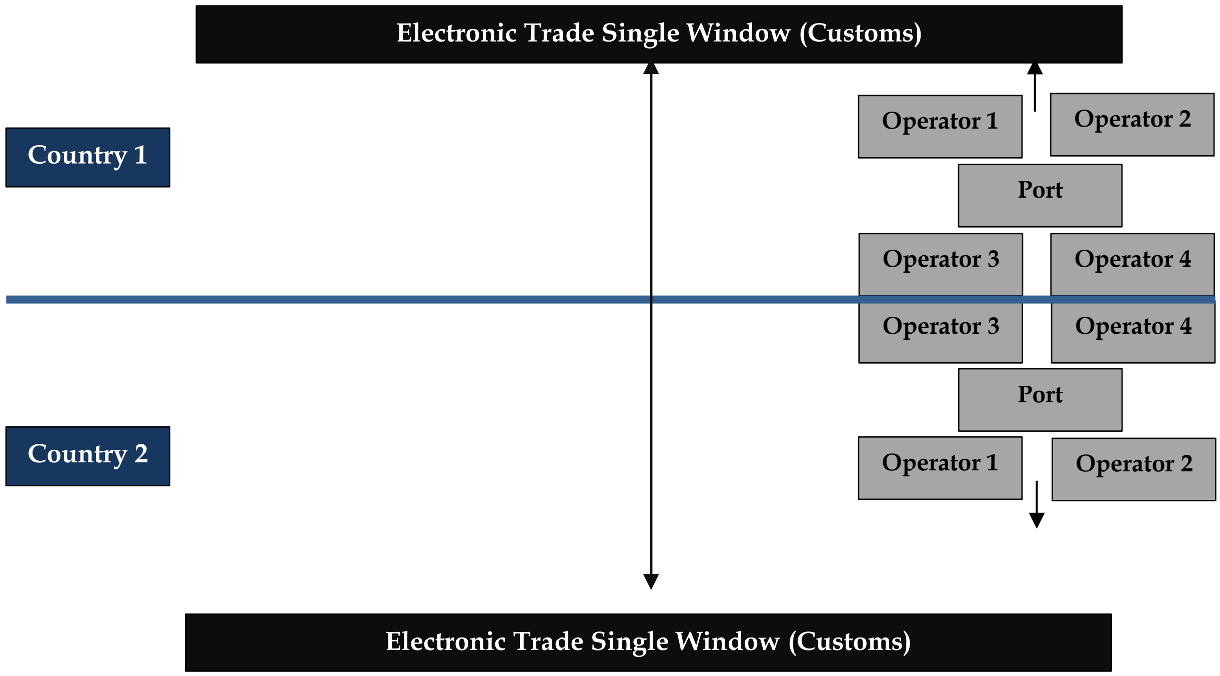
Source: Authors.

3.1.1.4 Digitalization of Procedures in Multiple Border Agencies Across Multiple Countries: Interoperability of Electronic Single Windows, Regional Transit Systems, and Regional Trade Platforms

As shown in the figures above, firms incur trade costs related to the handling and administrative processing of their shipments on both sides of the borders. Technology-enabled trade facilitation initiatives such as the digitalization of procedures and the introduction of electronic trade single windows in a given country help reduce these trade costs but only do so on one side of the border. This reduction in trade costs may be made more pronounced when initiatives facilitating trade are combined and coordinated across countries and thus operate on both sides of the borders.

This can be achieved by making the respective national information systems interoperable, that is, "able to exchange and use information across borders without additional effort on the part of the user" (UNECE, 2017). A prominent case in this regard is the interoperability of national electronic single windows among regional partners, which allows the economies involved to exchange data from the main documents supporting international trade transactions (Figure 4). These cross-border arrangements are associated with several specific advantages, including shorter total processing times, enhanced data security, improved risk management, more effective detection of illicit trade, reduced corruption, and more efficient allocation and use of infrastructure (UNECE, 2017; Mejia Rivas and Maday, 2019).

Figure 4
Interoperable Electronic Trade Single Windows



Source: Authors.

One such initiative has been recently implemented by the Pacific Alliance (PA) countries (i.e., Chile, Colombia, Mexico, and Peru). These countries established their national electronic trade single windows between 2006 and 2013, launched their interoperability project in 2016, and began actual operations in 2018 (APEC, 2018; Mejia Rivas and Maday, 2019).[14] In 2018, countries started to exchange data from phytosanitary certificates bilaterally, then in 2019, this automatic point-to-point exchange expanded to cover data from origin certificates.[15] Since 2018, data from more than 65,000 phytosanitary certificates and data from more than 33,000 origin certificates were exchanged between PA member countries.

As with PCS, solid microeconometric evidence on the size and nature of the impacts of these important cross-border mechanisms is not yet available. Sequentially phased-in initiatives in Latin America and Asia in this area create unique opportunities to fill in this knowledge gap.

[14] Member countries of the Association of Southeast Asian Nations (ASEAN) also moved to make their national electronic trade single windows interoperable and started to exchange data in 2018 (APEC, 2018).
[15] Data is exchanged without going through a central body, so the scheme does not have a central coordinator, which facilitates the inclusion of other countries in the region (Mejia Rivas and Maday, 2020).

Regional Transit Systems

In many cases, goods must be transported through intermediate countries when shipped overland.[16] The technical term for this is *international transit.* Figure 5 shows an example of this: road-based exports from El Salvador to a nonborder partner, Panama).[17]

Figure 5
Typical Export Route from El Salvador to Panama

Source: Carballo et al. (2016).

Without explicit special provisions for transit, deliveries undergo a succession of import and export border clearance procedures, including the filling of paper-based documents and the loading and unloading of trucks. These repetitive procedures create substantial congestion at borders and escalate transaction costs substantially (Arvis et al., 2008).

In contrast, in well-functioning transit regimes, the administrative burden is decentralized away from entry points to lower the costs of border crossing. Shipments flow through third countries under customs control but without being cleared by customs (Arvis et al., 2007). More precisely, customs clearance is delayed, so there is no need to import and re-export the products at intermediate points, pay import duties, domestic consumption taxes, or other charges, or go through processes associated with import regulations. In the most advanced versions, transit regimes involve unified border transit controls, along with the use of a common electronic document to simultaneously comply with all relevant transit border formalities.

[16] Overland trade is overwhelmingly prevalent among neighboring countries. For instance, the median share of road and rail in total intra-EU trade is 95.7 percent (Cristea et al., 2013).
[17] Transit accounts for a substantial portion of foreign trade. For example, in El Salvador, road accounts for 96 percent of the exports to neighboring Central American countries Costa Rica, Guatemala, Honduras, Nicaragua, and Panama. Roughly one-third of these exports are carried through a country which is not the final destination of the shipment.

This streamlining of border procedures results in a substantial reduction in delays and trade costs and can therefore facilitate international transit operations and cross-border trade.

One such system was adopted in Central America some years ago, the Central American International Transit of Goods (*Tránsito Internacional de Mercancías* or TIM), which covered border crossings between Costa Rica, El Salvador, Honduras, Nicaragua, Panama, and Mexico. The TIM introduced: (1) stronger within- and across-country interagency cooperation; (2) process reengineering, whereby previous multiple paper-based declarations were harmonized into a comprehensive single document that gathers all data required by customs, migration, and phytosanitary agencies, and the creation of a single unified border transit control; and (3) the use of information technologies to interconnect the intranet system of all agencies participating in the project to manage and track the international transit process, and to carry out risk analysis and cargo controls (Sarmiento et al., 2010; Figure 6).[18]

The TIM led to the simplification of clearance procedures, the gradual adoption of a single electronic form, and the interconnection of all participating border agencies to enable one-step clearance control at each bilateral border. More specifically, shipments in transit are now processed under the logic of an electronic single window, whereby transporters interact simultaneously and in the same place with all border agencies (customs, migration, and quarantine) without using printed copies of documents. This substantially lowered document preparation costs and sped up document review and processing at these borders. Moreover, the TIM facilitated information flows on each order and improved the real-time control of shipments. This is likely to have resulted in significant reductions in order servicing costs and trade costs generally (Sarmiento et al., 2010).

[18] The TIM was recently absorbed by the Central American Single Declaration system (*Declaración Única Centroamericana* or DUCA).

Figure 6
Regional Transit Systems

Source: Authors.

Evidence from an impact evaluation suggests that the adoption of the TIM resulted in an increase in the growth rate of Salvadoran firms' exports (Carballo et al., 2022). In particular, estimates indicate that TIM's positive effect on firms' exports can mainly be traced back to an increased number of shipments and have been heterogeneous across products—they are larger for time-sensitive and differentiated goods (Carballo et al., 2016c).

Integrated Regional Digital Trade Platforms

Available ICTs now make it possible to integrate all the processes and procedures described above across multiple countries through regional digital trade platforms that include all the relevant functionalities (Figure 7). This is precisely what the Central American Digital Trade Platform will do. This platform, which is currently at the implementation phase, will interconnect the information systems of customs, migration, internal revenues, health, and sanitary and phytosanitary agencies of Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama, thus allowing for real-time data exchange, shorter and less variable processing (and transportation) times, and increased transparency and enhanced traceability across these countries and with the rest of the world (SIECA, 2021). This important initiative will provide a natural experiment through which the effects of simultaneously reducing several costs incurred in trade (and transportation) operations across multiple borders can be estimated.

Figure 7
Integrated Regional Digital Trade Platforms

Source: Authors.

Box 1[19]

Digitalization and Trade Facilitation and Promotion: The Experience of Singapore

Singapore has always been one of the countries leading the way in trade facilitation initiatives. In 1989, it pioneered the introduction of an electronic national trade single window, TradeNet, which provided exporting, importing, and logistic firms with a single digital B2G platform to submit a single digitized declaration to fulfill all trade-related regulatory requirements from all relevant border agencies. In recent years, nine million declarations worth U$S 900 billion of trade were channeled annually through this platform. A noteworthy 99 percent of the associated permits were processed within 10 minutes and 100 percent of the taxes and duties were collected electronically (Leong, 2018).

In 2007 and as a result of a multiagency initiative involving the Singapore Customs and the Economic Development Board, among others, the national single window was expanded to support B2B services through TradeXchange, a national platform integrating government, firms, and logistic providers' trade and logistic IT systems for sea, air, and land, which made its interface specifications available to allow other parties to join it (e.g., banking firms). This platform allowed relevant players to pass on documents and information on industry-accepted standardized formats covering areas such as trade permit preparation and applications for trade finance and maritime cargo insurance, thereby contributing to greater efficiency and clearer visibility to businesses across the supply chain (WCO, 2014).

In 2018 Singapore formally launched the Networked Trade Platform (NTP), which combines and builds upon TradeNet and TradeXchange. The NTP is a one-stop-interface that further streamlines and digitizes end-to-end processes and enables firms to connect and interact with all business partners, stakeholders, and regulators in Singapore on trade-related transactions and with their counterparts abroad (Singapore Customs, 2018a). In addition to government services, the NTP: (i) offers so-called value added services pertaining to the preparation of customs declarations and permits, digitization, arranging and tracking shipments, trade financing, and, distinctively, market insights; (ii) includes a novel set of functions that allow firms to communicate through fora, communities, and blogs, search for commercial opportunities, and specifically source business partners and customers; and (iii) has a built-in innovation space, a developer portal in which it is possible to design and introduce new services that facilitate a dynamic adjustment to the businesses' evolving needs. By innovatively combining the functionalities of an electronic single window and a digital marketplace, the NTP has the potential to facilitate and promote trade. As of 2018, approximately 800 firms from several industries had already registered with the platform (Singapore Customs, 2018b).

Around the same time, Singapore's Monetary Authority signed a Memorandum of Understanding with its Hong Kong counterpart to jointly develop a cross-border distributed ledger technology-based utility infrastructure to initially connect trade finance applications between these countries and then eventually encompass other trade-related processes. The ultimate goal of this cross-border digital initiative, which is called the Global Trade Connectivity Network (GTCN), is to link up these and other countries' trade platforms as a building block for a regional digital trade and supply chain platform in Asia. The GTCN will allow different stakeholders to connect and automatically exchange information according to specific protocols, while maintaining data privacy and confidentiality, thus enhancing supply chain transparency, integrity, and security (Singapore Customs, 2018c).

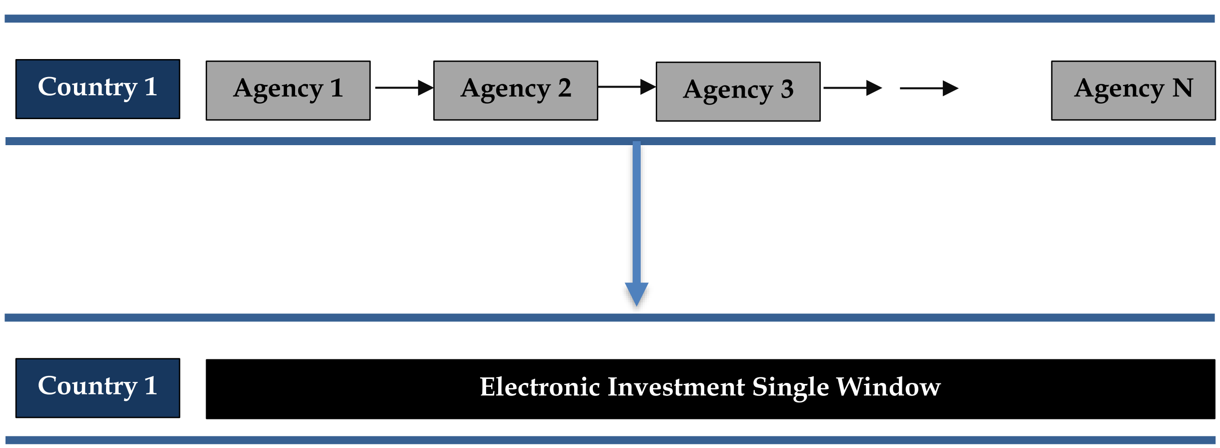
[19] This box draws from Estevadeordal et al. (2020).

3.1.2 *Digitalization and Investment Facilitation*

Like those trading across borders, firms establishing affiliates in foreign countries must typically complete a large number of general and sector-specific procedures at both the national and local levels that are designed and administered by various entities. In recent years, many economies have streamlined these administrative procedures and resorted to ICTs to digitize them and establish electronic investment single windows to enable their online completion, thereby shortening processing times and facilitating FDI (Figure 8).[20] As of 2019, around 70 countries have some form of such arrangements in place (e.g., online business registration with multiple agencies, either through integration or interconnection). In these countries, the average number of procedures was 5.6 and the average time to complete them was 13 days, whereas in counterparts without single windows, those figures were 7.6 and 20 days, respectively.

Furthermore, between 2010 and 2019, the average number of procedures and completion times decreased 8 percent and 33 percent, respectively, in economies that introduced these single windows (Solezzi, 2019). The introduction of these technology-enabled facilitation systems in several economies will make it possible to generate rigorous microeconometric evidence on their impact on multinational firms' investment decisions, which is still almost entirely missing.

Figure 8
Electronic Investment Single Windows



Source: Authors.

[20] See, for example, Novik and de Crombrugghe (2018), Berger et al. (2019, 2021), Adlung et al. (2020), Berger and Sauvant (2021), Hoekman (2021), and Sauvant et al. (2021) on investment facilitation.

3.2 Internet of Things, Blockchain, and Machine Learning to Facilitate and Promote Trade and Investment

3.2.1 Internet of Things and Logistics

As mentioned above, a large number of logistics activities are performed by multiple operators to move and handle shipments within ports (and airports) and to transition them to other means of transportation connecting with the surrounding cities and the regions beyond (e.g., railways and trucks). The overall efficiency of this process, the time it takes to complete it, and even its environmental implications depend on how well these various activities are scheduled, sequenced, and coordinated with each other and the relevant required infrastructure is allocated (e.g., waterways and road networks).

The aforementioned activities are carried out by physical objects such as mechanical machines (i.e., "things"). When embedded with hardware (e.g., sensors) and software that enable them to send and exchange data over the internet and assigned unique identifiers, these objects can connect with others, including computing devices, and collect and act based on the data they receive, without the need for almost any human intervention. IoT is precisely the system of these interrelated objects. As such, it allows each interaction between these objects to be recorded, monitored, and adjusted and can thereby help optimize movements, reduce wait times, enhance traceability, and increase the efficiency of processes at logistic hubs that can be transferred throughout the supply chains.[21] Several hubs around the world have introduced this new technology, with the port of Hamburg being a leading example (HPA, 2012, 2015; Ferretti and Schiavone, 2016). Provided the data on processes and times are made available, analyses of these experiences will help to establish trade (and investment) gains and the implications for transportation networks, including entrepôts (Ganapati et al., 2020).[22]

3.2.2 Blockchain and Trade Facilitation

International trade involves the exchange of significant amounts of data between multiple actors across borders (e.g., data from the various supporting documents such as customs declarations, bills of lading, letter of credit, and certifications of origin).

As secure digital transaction records (ledgers) that can be shared, replicated, and updated by various partners across different locations in near real-time, blockchains can help facilitate and expedite these trade-

[21] AI and machine learning can be used along with IoT to make processes more efficient.
[22] There are synergies between IoT and blockchain. Combining them can help improve the visibility and traceability of supply chains.

related data exchanges.[23] Governments around the world have accordingly started to consider using and have even actually introduced them as a means for conducting administrative trade processes.[24]

3.2.2.1 Mutual Recognition Agreements of AEO Programs

An interesting application of this technology has been as a mechanism to implement AEO programs' mutual recognition agreements (MRAs). These agreements allow the customs-treatment advantages enjoyed by AEO-certified firms in one country to be extended across all partners participating in the MRAs, thus reducing trade costs on each side of the respective bilateral borders. To date, 87 bilateral MRAs and four plurilateral/regional MRAs have been concluded, and 78 additional MRAs are currently under negotiation (WCO, 2020).

To operationalize the MRAs, customs agencies must exchange their lists of AEO firms. This is typically done through Excel files containing agreed data elements attached to emails sent by designated officers at a pre-arranged frequency, which is typically monthly. These data elements are then incorporated into the recipient customs agencies' risk management systems to weigh import shipments from AEO firms as less risky.

This operational approach has some drawbacks that limit the granting of advantages in a secure and timely manner, including the fact that emails communications are not entirely secure and there may be delays in the notification and proper customs treatment of firms that become or cease to be AEOs (Corcuera Santamaría and Moreno, 2019).

Since 2018, a set of Latin American countries that includes Bolivia, Ecuador, Guatemala, Chile, Colombia, Costa Rica, Mexico, and Peru have been validating the use of blockchain on a pilot basis to exchange data on their firms' AEO certificates—the CADENA project (Corcuera Santamaría, 2018; and Corcuera Santamaría and Moreno, 2020).[25] The more seamless, automated, secure, and real-time information-sharing enabled by this application helps increase the efficiency and effectiveness of the management and transparency of MRAs. It also allows certified firms to enjoy the advantages of MRAs (i.e., preferential treatment in the form of fewer inspections in the country whose goods are imported) from

[23] Blockchains have the following attributes: (i) no single party can fully control the entire network; (ii) data is dated and stored in a permanent and almost inalterable way using cryptographic techniques; (iii) transactions are authenticated through cryptographic means and a mathematical "consensus protocol" that determines the rules by which the ledger is updated; (iv) participants can access and check the ledgers at any time and transactions can be traced easily; and (v) smart contracts (i.e., computer programs that self-execute when certain conditions are met) can be used to automate processes, thus allowing for further cost reductions (Ganne, 2018). Given that it increases the visibility of actors involved in each transaction both in exporting and importing countries and the traceability of their actions along the supply chain, blockchain could also help deter and reduce international asset laundry.

[24] For instance, the Korean Customs Services has piloted the use of blockchain for cross-border information exchange, for export clearance when the consignor was a firm, and for e-commerce imports when the consignee was a natural person (Kang, 2019).

[25] The project was supported by the IDB. A pre-requisite was the use of a unique number for each AEO firm across the supply chain that is recognized by all the MRA's partners. This initiative used the WCO standards (SAFE Framework and Data Model) and the globally unique Trader Identification Number (TIN) format.

the very moment they acquire the AEO status through smart contracts (Corcuera Santamaría and Moreno, 2019).[26]

Existing empirical evidence seems to suggest that the combination of AEO programs across countries is associated with better export outcomes for firms (Carballo et al., 2016a). However, the trade gains derived from more efficient mechanisms to implement MRAs are still to be determined. CADENA provides a unique setting in which to estimate these gains.

3.2.2.2 Electronic Trade Single Windows (and PCS)

While the use of blockchain is still incipient and far from being a panacea, it could help improve the functioning of electronic single windows and potentially further reduce time and costs to trade, thereby strengthening the positive effect on trade by increasing: (i) interoperability, thus allowing multiple agencies that are part of the single window (and even PCS) to simultaneously access the same data to manage risks and hence recognize patterns and conduct pre-arrival processing; (ii) visibility and traceability of shipments (and firms) throughout the supply chains through consistent storage of more complete information thereon and audit trails based on data chains; (ii) the degree of process automation through built-in smart contracts, including automated payments and reconciliation to accelerate revenue collection; and (iii) the trustworthiness of data by uniquely identifying users and making the information virtually immutable and portable across service providers (Radl and Lin, 2019; IDB and WEF, 2019). These expected benefits, though, have yet to be shown and confirmed through solid microeconometric evaluations, which are virtually nonexistent.

3.2.2.3 Certificates of Origin

Firms intending to export under preferential tariffs to economies with which their home country has preferential trade agreements must obtain a certificate of origin—that is, a document that certifies that goods have been produced meeting the respective rules of origin in terms of either processing or use of inputs (see, e.g., Conconi et al., 2018; and Krishna et el., 2021). The certification process typically consists of three non-interconnected phases: (i) manufacturing the exported good; (ii) issuing the declaration and certification that the good qualifies as an originating good; and (iii) control and verification of origin.

Blockchain could be used to merge these three phases into an integrated process of origin (IPO), which will facilitate firms' access to tariff preferences. More precisely, the main advantages of this new process

[26] In the same way, data on suspensions and cancellations decided by customs agencies and firms' withdrawals is registered and shared in real time, which tends to strengthen the overall security of supply chains. Moreover, firms can access information related to their certificate as well as the list of other AEO-certified companies in the countries which are part of the MRA.

would be: (i) accessing more reliable and secure data on the origin of each product to determine compliance; (ii) streamlining the monitoring process, facilitating the application of risk analysis techniques, thus enabling customs to concentrate its efforts on the verification of origin of ex-ante riskier shipment, and improving security for operators; (iii) enhancing the implementation of cumulation of origin; and (iv) increasing the overall efficiency of transactions.[27] These advantages can help increase firms' and their countries' trade and expand regional value chains by leveraging the rich networks of trade agreements that are already in force (Cornejo, 2020; Radl and Sotelo, 2021). Studies to accurately estimate these effects are called for once these mechanisms are in place.

3.2.3 *Machine Learning and Trade and Investment Facilitation and Promotion*

3.2.3.1 *Machine Learning and Trade Facilitation*

The growth in foreign trade generally results in an increase in the number of shipments that must clear customs. This is particularly the case with cross-border e-commerce, which has implied an exponential expansion in the number of international lower-value parcels.[28] This creates pressure on customs agencies' limited resources and their ability to conduct proper risk management on these flows. More precisely, these continuously growing volumes of transactions can result in customs delays. There is suggestive evidence that this may be indeed the case. Specifically, larger numbers of shipments seem to have been associated with longer customs processing times in Uruguay in 2003–2016 (Volpe Martincus and Salas Santa, 2022).

To deal with this situation, customs agencies are adopting several measures, including the standardization of procedures and forms, the electronic interconnection between customs and postal (and logistic) operators to allow for advanced cargo information, and the automation of risk management for the shipments in questions, as currently being implemented in the European Union.[29] The latter specifically involves the use of machine learning to automatically cross-check e-commerce-related customs declarations against online information.[30] More precisely, the automated system gathers the description of

[27] Cumulation of origin is a mechanism that enables originating inputs that were produced in a member country of a given trade agreement to be recognized as originating goods in any other member country of the agreement. If cumulation is not allowed, producers in a given country can only source inputs produced within that country if they are to comply with the rules of origin for the final good (Cornejo, 2020). It will not be longer necessary to prove that a specific product qualifies as an originating good because the supply chain itself would show whether it qualifies for preferential market access.

[28] E-commerce is associated with a reduction in intermediation (i.e., disintermediation) and specifically with the deconsolidation of shipments, which now are delivered more directly to the end-user.

[29] The EU is working on implementing new digital technologies to improve their customs risk management systems, particularly to increase their effectiveness, such as by reducing errors, including both false positives (inspections that were carried out on shipments that turned out to be legal) and false negatives (illegal shipments that escaped inspection). In this context, five European countries (Belgium, Estonia, Netherlands, Norway, and Sweden) launched a project, PROFILE, which aims to improve data sources and analytics for risk assessment. Dutch Customs, in collaboration with IBM, is specifically leading a component that seeks to deploy artificial intelligence.

[30] Emerging technologies can be leveraged to address the challenges associated with e-commerce data sharing, thereby helping increase and enhance this exchange and improve risk assessment and targeting capabilities (BIT Institute, 2021).

the goods from declarations, searches for the product on the web, finds its selling price on e-commerce platforms, compares it with the value declared in the declaration, and returns a risk indicator of green/red flag to the targeting customs officer (Giordani, 2018).[31]

The application of machine learning to improve customs and other border agencies' predictive capabilities for risk management purposes, and hence the assertiveness of these agencies' interventions, does not need to be confined to cross-border e-commerce. In fact, several customs around the world are increasingly resorting to machine learning to decide on shipment inspections across all forms of trade.[32] This will create plenty of opportunities to evaluate the impact of trade facilitation policies through experimental designs.[33]

3.2.3.2 Machine Learning and Trade and Investment Promotion

Information can be highly incomplete and gathering it can be very costly. As a result, foreign firms looking for suppliers or locations may end up considering a small range of alternatives and disregard several potentially convenient ones (e.g., Loewendahl, 2018). This can be particularly detrimental for less popular markets, such as developing economies in LAC.

Countries have established export promotion agencies (EPAs) and investment promotion agencies (IPAs) to address these information barriers, place their territories on investors' maps, and make their firms visible to foreign firms sourcing goods and services from abroad (e.g., Volpe Martincus, 2010; Volpe Martincus and Sztajerowska, 2019).

This naturally prompts the question as to which firms EPAs and IPAs should proactively target and approach to match exporters and attract them to their countries, respectively. This is another highly dimensional problem, just like the one faced by firms pursuing sourcing or investment opportunities overseas. Consider, for instance, the case of investment promotion. According to Dun and Bradstreet's Worldbase, there are more than 200,000 multinational firms (i.e., firms with at least one affiliate in a foreign country) with differences in multiple attributes and performance measures that may influence their investment and location decisions (e.g., revenue, number of employees, number and geographical network of affiliates worldwide, assets, liabilities, etc.).

The dimensionality of this problem is typically reduced through the application of country and sector prioritization strategies, which are implemented by sector and country specialists (Volpe Martincus and Sztajerowska, 2019). While the existing macro evidence indicates that this approach is associated with

[31] Parcels are often exempted from tax and duties, which makes valuation a crucial issue in avoiding fiscal fraud. In this regard, the pricing databases typically available to customs to detect such frauds are virtually useless for cross-border e-commerce due to their vast product diversity, large number of online sellers, and fast-changing prices.
[32] The WCO's BACUDA initiative aims to support countries in adopting this new approach.
[33] The IDB is currently working with countries in LAC in this area.

positive average effects (e.g., Harding and Javorcik, 2011), it has clear shortcomings. In the case of investment promotion, neither sector nor country prioritization (which is mainly based on inputs from internal experts and consultations with international investors and experts) nor the selection of the specific firms to target (which relies on the expertise of the officials responsible for the respective sectors or countries) are sufficiently evidence-based. More specifically, IPAs make suboptimal use of the wealth of microdata on multinational firms available to them (e.g., Bureau van Dijk's Orbis, Dun Bradstreet's WorldBase, Standard and Poor's Capital IQ, or Financial Times' fDi Markets; Volpe Martincus, 2021). Only a fraction of this data is actually used, and this is done in a nonsystematic manner. The reason is that specialists can only look at a very limited number of firms along a very limited number of dimensions and they rarely do so in a way that is consistent with each other or over time. Furthermore, while specialist expertise is an invaluable asset for IPAs, one on which their targeting strategies rely, it usually gets lost when officials switch positions or leave the organization, thus restricting institutional memory and learning.

EPAs and IPAs are increasingly using the wealth of available micro trade and multinational production data more systematically through the consistent application of statistical methods to (i) predict the probability that a foreign firm will buy from a domestic exporter and hence identify the best firms' trade matches for export promotion purposes (i.e., which foreign firms should be introduced to a country's exporters to maximize the sales' probability); and (ii) predict the probability of a multinational firm establishing a first or subsequent affiliate in the country in question and hence identify the best firms to target as potential investors (i.e., which multinational firms are more likely to establish an affiliate in the country and should be accordingly approached). To generate the best possible predictions, supervised machine learning methods are starting to be applied. This new commercial intelligence tool, which could be called the *quantitative intelligence approach*, can help better inform and guide their promotional efforts and provide EPAs and IPAs with a unified framework to prioritize firms in general and within sectors and countries in particular.

Also importantly, export and investment promotion strategies based on the quantitative intelligence approach lend themselves to impact evaluations through experimental design. The lists of firms with the highest predicted probability of buying from an exporter or opening an affiliate in the country in question that are generated can be randomly split into two groups that will include firms that are similar in terms of such probabilities (and relevant control variables): a treatment group (i.e., firms that will be proactively approached by the EPA/IPA) and a control group (i.e., firms without contact with the EPA/IPA).[34]

[34] The IDB is currently working with countries in LAC in this area (e.g., Carballo and Volpe Martincus, 2022).

4 Future Research and Policy Considerations

Digital technologies have varied, complex impacts on globalization and beyond. Existing evidence suggests that the growth of digital technologies such as ICTs, online trade platforms, AI, and robots is not only reshaping cross-border trade and offshoring activity but also exerting significant effects on labor markets and economic development. For example, while online trade platforms offer new export opportunities to small businesses, not all are able to seize these opportunities: due to the congestion and search frictions on the platforms, initial demand shocks, rather than firm fundamentals, often determine long-run performance and distort market allocations. AI applications such as machine translation have been found to boost trade by reducing communication costs, but there is still little evidence on the many other applications of AI. Contrary to the widespread belief that robots and 3D printing lower trade incentives, their adoption has been shown to complement imports from less developed countries, though the effects are expected to vary across products. While more is being learned about the trade effects of e-commerce, AI, and robots, still little is known about how other digital technologies such as cloud computing, blockchain, and fintech are shaping the global value chain, as most existing research on these topics focuses on their implications for firm productivity and household outcomes.

Digital technologies are also fundamentally changing how trade and investment policies (as well as policies in other areas) are designed and implemented. As a consequence, technologies such as the internet (and IoT) have allowed border-related administrative and logistic procedures to be substantially streamlined, coordinated and integrated better, and completed online. This has led to significant reductions in processing times, thus allowing new firms to participate in international trade and firms that already trade to increase their exports along both the extensive and intensive margins (e.g., introducing new products, reaching new destinations, expanding their foreign sales of existing products or increasing sales in markets they already serve) and to source more and better inputs from abroad under better conditions.

Several avenues of future research may be particularly useful for deepening our understanding of digital technology. First, much more data is needed to help quantify the adoption and intensity of digital technologies, particularly the use of AI, 3D printing, blockchain, and fintech across firms, industries, and countries. More systematic data will greatly facilitate research on these technologies and help shed light on their aggregate as well as heterogeneous effects on firm trade and growth and labor market outcomes.

Second, while a body of research has examined the roles of online trade platforms, AI, and robots, many interesting questions remain. For example, still little is understood concerning the potential synergies between online and offline trade: how does the share of online trade in firms' total trade vary across firms and time; to what extent does growth in firms' online trade contribute to their overall growth; and how might firms differentiate their marketing choices depending on product types. Across technologies, are there synergies between different digital technologies such as online trade platforms, AI, and fintech?

Given the interdependence in the frictions addressed by the different technologies and their network structures, they may have mutually reinforcing effects in facilitating international economic activities.

Third, the majority of existing research has focused on the role of technologies in merchandise trade whereas little attention has been given to the impacts of these innovations on trade in services and multinational activity. Both service trade and multinational activity have been found to be essential to countries' productivity growth and economic development by producing knowledge spillovers and technology transfer. The gains depend, however, on technology composition and domestic firms' ability to absorb new technologies, both of which are likely affected by local countries' digital technology infrastructure and policies. Weaknesses in these areas may discourage the entry of technology-intensive firms and reduce the capacity of domestic industries to absorb foreign know-how and respond to the challenges and the opportunities presented by foreign entrants. The implications of new technologies may also vary across technology types, depending on their productivity mechanisms and complementarity with local markets.

Fourth, exploring the conditions for synergies between new digital technologies and existing local economies would be salient for reaping the benefits of digital innovation and globalization in both developed and developing countries. There are contextual conditions that need to be met for technologies and the interplay between them to produce the desired positive outcomes. As AI, robots, and automation replace certain tasks previously performed by humans and potentially reduce the need for corporations to offshore unskilled-labor-intensive tasks, the jobs, occupations, and economies with the greatest exposure to the substitution effect are particularly vulnerable to displacement by technologies. Understanding where substitutability and complementarity likely occur across countries, industries, and workers would be immensely valuable to policymakers.

Fifth, conventional trade models have defined comparative advantages based on countries' factor endowments and TFP. The prevalence of new digital technologies has the potential to redefine the source of comparative advantage. Big data, for example, may emerge as a new source of competitive advantage that underscores the importance of understanding the role of data access and regulation. Further, 3D printing, cloud computing, and fintech promise to alleviate the technology and financial constraints of small and new businesses, especially in countries with traditionally weak financial and technology endowments. Research is needed to help understand how these new technologies might reshape comparative advantage and enable countries to expand across product space in the long run. At the same time, with the rapid increase in cross-border data flows, international cooperation and agreements to ensure data security and protection and address intellectual property and cross-country differences in data legislation will be central for continued growth in cross-border digital trade.

Finally, as the Covid-19 pandemic accelerates the proliferation and effects of digital technology around the world, how should policymakers respond to both the challenges and opportunities presented by the unprecedented demand for digital technology? Despite lockdowns, international trade has rebounded quickly: is digital technology aiding globalization and helping the world stay connected amid the pandemic? How do such effects vary across tasks, occupations, and industries depending on their degree of remote work flexibility and reliance on communication technology? And how far are the country-level impacts conditional on the composition of their activities and digital technology infrastructure? These questions, which are crucial for our assessment of the interactions between digital technology and globalization during economic shocks, remain to be answered.

As discussed above, the range of policy applications for digital technologies is rapidly expanding. For instance, possible uses of blockchain include the implementation of mutual recognition of AEO programs, the processing of origin certificates, and even operations of single windows and PCS. Similarly, machine learning combined with big data analytics is currently transforming both prospection and business intelligence for trade and investment promotion and customs risk management by systematically exploiting the wealth of available microdata, hence making these processes more evidence-based. Whether, to what extent, and how the introduction of these new technologies will impact the effectiveness of the associated policies remains—to a large extent—an open question. The good news is that, given the comprehensive data gathering they allow and the way that they are implemented, the arrival of these technologies in the policy sphere creates an entirely new opportunity for experimental evaluations of policies in these areas. This will help decision-makers optimize policies dynamically, increase their effectiveness over time, and gain a better understanding of the mechanisms through which they affect both direct economic outcomes such as trade and investment and indirect economic outcomes such as productivity and employment in the firms that are the subject of these policies and firms that are related to them (e.g., through input and output linkages).

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