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Trade, policy, and economic development in the digital economy☆

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ABSTRACT

This paper assesses the impact of internet connectivity and digital trade policies on trade and welfare. Using new measures of internet connectivity, we find a significant positive relationship between internet use, bandwidth capacity, and trade. The positive relationship between internet use and trade is present for international and domestic trade, goods and services, high- and low-income exporters, and at the intensive and extensive margin. We also find that digital trade facilitation provisions in trade agreements have significantly increased trade for high-income exporters, especially for services trade. Informed by these findings, we use a general equilibrium model of trade to assess the trade and welfare impacts of increased internet connectivity and digital trade policies for developing countries. Increasing internet connectivity can have large positive welfare impacts on poorly connected countries, but these results also highlight the dangers of developing countries falling behind if they are not able to improve internet infrastructure. Introducing digital trade provisions into an existing trade agreement between high- and low-income countries can facilitate growth in trade in services for both members.

1. Introduction

For many years, international trade and internet connectivity have been considered integral building blocks for connecting developing countries to the global economy and improving their economic outcomes. The positive impact of trade on growth and development has been well documented. In their survey of this literature, Harrison and Rodríguez-Clare (2010) note that trade helps to improve product variety, spread new technologies, increase competition, and improve productivity, among other potential benefits. As Engel et al. (2021) note, by connecting small firms and low-skilled or informal workers to global markets via e-commerce marketplaces and international supply chains, the internet can be an influential means of promoting growth through trade. In particular, these connections can help citizens in developing countries overcome poor transportation infrastructure and economic remoteness. There is also extensive evidence that internet connectivity has promoted economic development overall. Recent studies have found that economic growth is positively correlated with broadband internet (Bertschek et al., 2015) as well as information and communication technology more broadly (Niebel, 2018). Looking beyond economic growth, the internet has been shown to significantly improve many other important aspects of development such as education (Derksen et al., 2022), employment (Hjort and Poulsen, 2019), innovation and productivity (Paunov and Rollo, 2016), as well as decrease government corruption (Elbahnasawy, 2014). Little work, however, has explored the joint relationship of all three components: trade, digital technology, and economic development.

At the same time, trade policy has increasingly looked beyond tariffs and towards non-tariff determinants of trade. As part of that trend, digital trade provisions in trade agreements have rapidly risen to the forefront of modern trade policy. By 2017, 75 trade agreements — representing almost 30 percent of all trade agreements in force —

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contained provisions related to trade in digital goods and services. Of those agreements, 61 contained a specific chapter dedicated to digital trade (Monteiro and Teh, 2017). Such chapters have been considered highly influential components in major agreements including the U.S.-Mexico-Canada Agreement (USMCA) and the Comprehensive and Progressive Agreement for Trans-Pacific Partnership (CPTPP). For example, in their analysis of the probable effects of USMCA, the U.S. International Trade Commission found that commitments to maintaining the open transfer of data via the internet would be one of the most significant drivers of the agreement's effects on trade and the U.S. economy (USITC, 2019). The formation of policies that protect and promote digital trade are also expected to significantly benefit developing countries. The World Bank (2021) notes that policies limiting the free flow of data across borders could prove damaging for low- and middle-income countries, especially in countries where the domestic market is insufficiently large to support the development of modern internet and communications infrastructure on its own. Given the significant role of digital trade provisions in ongoing and future trade negotiations, it is more important than ever to understand the role that the internet plays in the global economy.

In this paper, we seek to provide a thorough and contemporary assessment of the role of internet connectivity and digital policies in international trade and the ways in which they shape economic development. We estimate the impacts of two prominent components of digital trade: internet connectivity and digital trade provisions in trade agreements. Our analysis finds that there is a robust role for internet connectivity in promoting trade for both high-income exporters (HIEs) and low-income exporters (LIEs). Meanwhile, digital provisions also have a positive impact on trade but in more limited cases, primarily increasing trade for HIEs and services industries. Given the often large estimated effects of internet connectivity on trade, we also examine the potential welfare impacts of increased internet connectivity in developing markets using a general equilibrium extension of the empirical model. We find that even modest increases in internet use within poorly connected countries could have large, positive impacts on their trade and GDP — as well as far reaching effects on other countries. In a second welfare analysis, we consider the addition of new digital provisions in a free trade agreement and find increases in trade and real output of services for both high-income and low-income member countries.

This work builds upon several earlier studies examining the role of the internet in trade. For goods trade, the internet primarily acts as a trade facilitation tool. For services trade, it can act as both a facilitation tool and a direct means of delivering the service (video streaming vs DVDs, for example). In a recent review of the literature on the digital economy, Goldfarb and Tucker (2019) identify several channels through which digital technology can facilitate trade. First, the internet decreases numerous costs such as those related to search, replication, transportation, tracking, and verification. Second, the low-cost communication associated with internet access can benefit both urban businesses via agglomeration effects and geographically isolated businesses by providing access to larger markets. Fernandes et al. (2019) found that growth in internet usage in China led to significant export growth for goods at the firm level, highlighting the influential role that the internet has in facilitating business transactions. Gnangnon (2020) found similar results for services, noting that the internet has increased services export diversification globally. Focusing specifically on the relationship between geographic distance and the internet in trade, studies have found that online products (such as software, videos, music, and games) face smaller distance related costs (Blum and Goldfarb, 2006; Alaveras and Martens, 2015), that the internet increases import sourcing from closer markets due to better information (Akerman et al., 2022), and that it can decrease the trade-dampening effects of distance on goods trade (Hortaçsu et al., 2009; Lendle et al., 2009).

Several studies have attempted to estimate the effects of the internet using gravity models of trade. These models typically regress bilateral trade flows against measures of internet connectivity and other trade determinants to assess the impact that the internet has had on bilateral trade. Freund and Weinhold (2002) and Freund and Weinhold (2004) represent relatively early studies that find that increased internet use is associated with an increase in trade for both services and goods, respectively. Subsequent work, including that by Vemuri and Siddiqi (2009), Liu and Nath (2013), Choi (2010), and Lin (2015), has found similar empirical support for a positive relationship between the internet and trade in both goods and services.

Other studies have found that the role of the internet may depend on the level of economic development among trade partners. Anderson et al. (2018a) find that digital infrastructure improvement decreases border barriers for a variety of service sectors from 2000 to 2006 and that these effects may differ based on level of development of a particular market. Clarke and Wallsten (2006) find a positive correlation between internet penetration and trade from developing to developed countries, but not between developing countries. Riker (2014) simulates the effect of developing countries "catching up" to broadband use in developed countries and finds a 29 percentage point increase in trade to GDP ratios for developing countries on average.

In addition to internet use in general, there are a variety of different internet-related policy measures around the world that further affect digital trade. Although more limited than the literature examining the internet and trade, there is a small but growing literature studying digital trade policies. Spiezia and Tscheke (2020) suggest that provisions in trade agreements that address free data flows have two potential effects: a positive trade facilitating effect due to better international harmonization of regulatory frameworks and enhanced trust, and a trade restricting effect due to compliance costs and restrictions to the free flow of data. Consistent with these trade-offs, the authors find that some data agreements, such as the Council of Europe Convention 108, increased goods and services trade. Meanwhile, others, like the EU Data protection directive, decreased trade. Focusing on barriers to trade in digital services, van der Marel and Ferracane (2021) find that more restrictive policies on the cross-border flow of data decrease services trade, conditional on the digital intensity of these sectors. Finally, USITC (2021) looks at the impact of provisions in trade agreements that facilitate free flows of data via the internet on international trade flows and finds a positive and significant relationship between these provisions and trade in seven services sectors.

We build on this prior work by examining two aspects of digital trade: internet connectivity and digital trade policies in preferential trade agreements (PTA). First, we empirically estimate the impacts of these two aspects using a modern, theoretically motivated gravity model of trade. In addition to the digital trade-related variables, we include a comprehensive collection of controls to mitigate endogeneity concerns, capture global integration trends, and more accurately identify the effects of internet connectivity and digital provisions. Because of these controls, we consider this work an important methodological update of much of the existing empirical literature. Within this framework, we also consider several new dimensions of internet connectivity including measures of internet use and the quality of connections, thereby shedding new light on the different ways in which the internet affects trade. The results provide strong evidence that internet connectivity is a powerful means of facilitating trade, for both HIEs and LIEs as well as goods and services. A one standard deviation increase in joint internet use between trading partners would increase bilateral foreign trade by more than 30 percent in the preferred version of the model. Increases in bandwidth capacity result in gains as well but are generally of a smaller magnitude. Second, we find evidence of positive impacts from recent digital trade policies. These effects appear to be primarily driven by HIEs and trade in services, and are therefore more limited in their impacts than internet connectivity.

To better understand the global impacts of improved internet connectivity, we examine the general equilibrium effects of changes in internet use on trade and welfare.[1] Our analysis considers a hypothetical scenario in which internet use in Nigeria, a large developing economy with relatively limited internet penetration, were to rise to the level of Brazil, a similarly sized developing country with much higher internet use. We find that such an increase in internet use would have significant impacts on the Nigerian economy as well as the rest of the world. Nigeria would participate much more in international trade, raising its exports by more than 9 percent. The increase in economic activity and more favorable prices would result in a more than 17 percent increase in real GDP. In the rest of the world, countries with high incomes or high internet use would mostly benefit from Nigeria's increased internet use due to lower trade costs with Nigeria. Meanwhile, countries with low incomes or low internet use would largely experience losses due to global trade diversion towards Nigeria. These losses signal a risk for developing countries that fall behind in the expanding digital economy. In a second hypothetical scenario, we examine the welfare impacts of introducing digital trade provisions in a free trade agreement (FTA). In particular, we consider a hypothetical scenario in which the 2011 India–Japan FTA, which contains no digital provisions, were to adopt seven new types of digital provisions. The policy change would directly increase services exports from Japan (a high-income country) to India (a lower-income country). Meanwhile, India would benefit from lower cost services imported from Japan and — to a lesser extent — increased exports to the rest of the world because of trade diversion. For both countries, the provisions increase real services output by more than $12 billion, suggesting that there are welfare gains to be had from digital policy provisions for both high- and low-income countries.

Taken together, these findings demonstrate that both internet connectivity and the inclusion of digital trade provisions in PTAs can enhance trade and improve economic welfare for high- and low-income countries, and can play a role in trade-related development strategies. However, while internet connectivity and digital policies directly impact goods exports of low-income countries, they appear to have a much more limited direct impact on the services exports of low-income countries. This suggests that developing countries may be succeeding in realizing the benefits of the information channel of digital trade but are falling short of using the internet as a direct means of trading services. This finding casts some doubt on the effectiveness of services-led development strategies for these countries.

The remainder of the paper details these findings, the data used, and the methods employed. Section 2 describes our measures of internet connectivity and digital provisions. Section 3 describes the empirical approaches and presents their findings. Section 4 describes the general equilibrium model and presents the results of the hypothetical scenarios involving internet connectivity in Nigeria and the introduction of digital provisions in the India–Japan FTA. Finally, Section 5 concludes.

2. Measuring internet connectivity and digital trade provisions

In this paper, we consider both the role of internet technology and international policy on trade. The first component of our analysis is internet connectivity, which we examine using information on internet use and quality around the world. The second component is digital trade policies, which we examine by looking at provisions in preferential trade agreements (PTAs) that deal with the treatment of digital products, electronic authentication, data privacy and security, and the free movement of data. In this section, we detail these components and the data used to measure them.[2]

[1] This analysis follows a growing literature using new quantitative trade models to evaluate trade policies. For example, similar models have been used to assess the impacts of trade agreements (Anderson and Yotov, 2016), international borders (Anderson et al., 2018b), Brexit (Brakman et al., 2018), and common language (Gurevich et al., 2021).

[2] We use PTA here as a broader term that covers several different types of trade agreements: free trade agreements, partial scope agreements, customs unions, and economic integration agreements.

2.1. Internet connectivity

A key component to the digital economy is the use of the internet. There are several factors that determine how effectively the internet can be used to facilitate communication, transactions, or other activities. First, both parties need access to the internet, implying that basic internet connectivity between markets is a necessary starting point for digital trade. Second, the speed and quality of the internet connection between parties can impact the types of activities that can occur over it. For example, if internet users only have access to a 2G mobile connection, they may be unable to access many online services like video streaming. Meanwhile, users with access to high bandwidth, direct fiber optic cable connections are able to engage in a greater number data-intensive activities with minimal delay. To examine the impacts of the internet on trade, we consider both of these dimensions of connectivity.

To measure access to the internet, we construct a bilateral measure of internet use that varies across trade partners and time, drawing on the literature examining the role of communication in international trade. This past work has found a consistently strong trade facilitating role for common languages and the ease of communication.[3] Recent work, such as that by Melitz and Toubal (2014), has examined language and communication by measuring the likelihood that two people, selected at random from different countries, can speak the same language. They find that the higher the likelihood of this match, the higher the volume of trade. We apply this same logic to internet use and build a measure that reflects the likelihood that two people are both users. The index is defined as $IU_{ijt} = \phi_{it} \times \phi_{jt}$ where ϕ_{it} and ϕ_{jt} are the proportion of the population using the internet in countries i and j during year t, respectively. The constructed index ranges from 1, in which all residents in both countries use the internet, to zero, in which no one in at least one of the countries uses the internet. Notably, the measure is constructed both internationally ($i \neq j$) and domestically ($i = j$). By treating internet use as a bilateral factor, we diverge from most of the existing literature, which has treated internet use as a country-level characteristic. In doing so, we are able to more effectively capture the important fact that digital trade inherently requires that both parties be connected, resulting in potentially important bilateral heterogeneity.

Given the recent expansion of internet access via mobile devices, particularly in developing countries, we employ a broad measure of internet use sourced from the International Telecommunication Union (ITU) World Telecommunication/ICT Indicators Database (2021), which provides an annual measure of "Individuals using the internet".[4] The data series defines internet users as individuals who have used the internet in the last 3 months via essentially any means (computer, mobile phone, video game system, etc.) and covers up to 217 countries from 1996 to the present.[5]

Our IU index takes this unilateral measure of internet use and makes it a time varying bilateral measure that captures the extent to which pairs of countries have become mutually better connected by the internet. In 2000, the beginning of our sample, the average index value was 0.01, suggesting two randomly selected people from a pair

[3] In their meta-analysis of the gravity literature, Head and Mayer (2014) find that language is one of the most frequently included factors in gravity specifications and is typically found to be trade facilitating. For a survey of language and international trade, see Egger and Toubal (2016).

[4] The data is accessible from World Bank's World Development Indicators database.

[5] In the previous literature, a variety of other measures have been used to determine the level of internet connectivity in a country, including number of web hosts (Freund and Weinhold, 2002, 2004), cross-country hyperlinks between websites (Hellmanzik and Schmitz, 2015, 2017), internet subscriptions (Liu and Nath, 2013), page views (Alaveras and Martens, 2015), and broadband use (Riker, 2014).

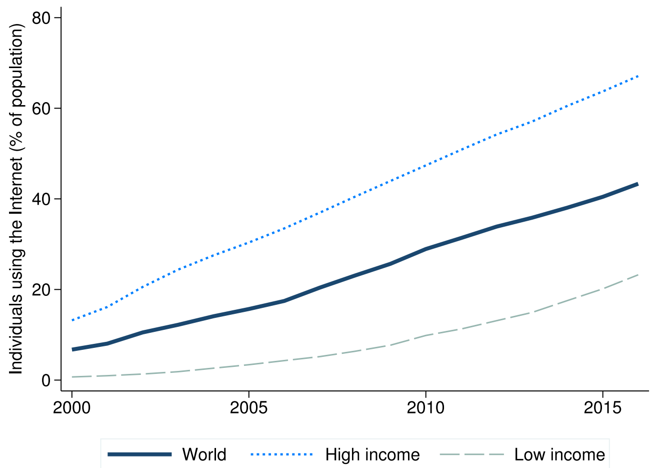

Fig. 1. Growth of Internet connectivity by income group, 2000–2016.
Note: High-income countries are those with a gross national income (GNI) of at least $4256 in 2021, based on the World Bank designations for high-income and upper middle-income countries. Low-income countries are those with a GNI of less than $4,256 and composed of lower middle-income and low-income countries.

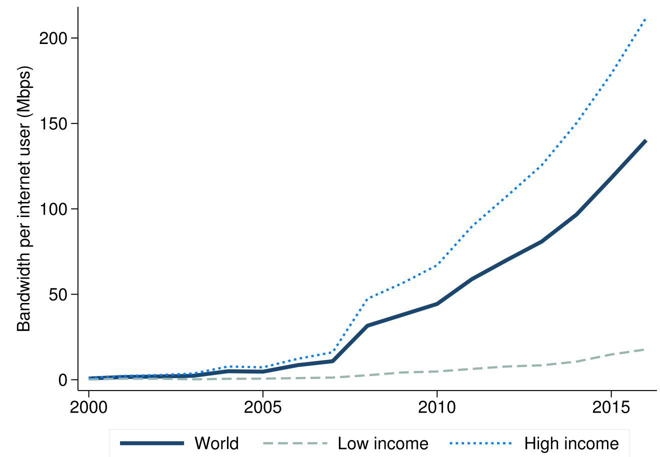

Fig. 2. Average growth of international bandwidth by income group, 2000–2016.
Note: High-income countries are those with a gross national income (GNI) of at least $4256 in 2021, based on the World Bank designations for high-income and upper middle-income countries. Low-income countries are those with a GNI of less than $4,256 and composed of lower middle-income and low-income countries.

of countries had only a 1 percent chance of both being internet users. By 2016, the average index value had increased to 0.27.

While internet use has increased globally throughout our data sample, levels of internet connectivity vary considerably across countries, as illustrated in Fig. 1. Here and elsewhere, we divide countries into two groups: high-income and lower-income. High-income countries (HICs) are those with a gross national income (GNI) of at least $4,256 in 2021, based on the World Bank designations for high-income and upper middle-income countries. Low-income countries (LICs) are those with a GNI of less than $4,256 and are composed of lower middle-income and low-income countries. Unsurprisingly, HICs have had substantially higher rates of internet connectivity throughout all of our sample period and experienced a higher rate of growth for many of the earlier years. However, connectivity in LICs has also grown steadily over our sample period, accelerating in more recent years. Nonetheless, there remain large portions of the population without access to the internet, even among HICs.

To measure the quality of internet connections, we consider two different factors: the bandwidth capacity between parties and the presence of direct fiber optic connections between countries. First, we focus on bandwidth between trade partners. Bandwidth, which is a measure of speed or volume, refers to the maximum amount of data that can be transmitted over an internet connection during a certain period of time, typically measured in megabits per second (Mbps). Bandwidth can be measured as uplink capacity (user to website uploads) or downlink capacity (website to user downloads). Different internet applications have different minimum bandwidth requirements; while basic email and web browsing require as little as 1 Mbps for downloads, more data intensive applications such as video streaming and gaming requires 3–8 Mbps or more.[6]

To measure bilateral internet bandwidth capacity, we use data from the ITU on "International internet bandwidth per internet user", which measures the total used capacity of all internet exchanges where international bandwidth is available.[7] To transform this measure into a bilateral index of internet quality (BW_{ijt}), we take the minimum bandwidth capacity across country pairs in each year.[8] This reflects the idea that the degree of internet-trade depends on the quality of internet in both markets and is only as good as the lowest quality connection. For example, a video conference is not feasible if one party lacks sufficient bandwidth to conduct a video call.

Internet bandwidth has grown considerably in recent years, as shown in Fig. 2. For HICs, the adoption of high bandwidth connections took off after 2007 and has continued to rise rapidly. Meanwhile, LICs have experienced relatively little growth, resulting in a large divergence in internet quality between LICs and the rest of the world.

Using the bilateral minimum bandwidth described above, we construct two different version of the measure. For the first, we normalize the bilateral value into an $[0, 1]$ index, where 0 represents no bandwidth capacity for at least one of the two countries and 1 reflects the highest bilateral bandwidth capacity in our sample (intra-national bandwidth in Luxembourg). The second version of the index divides bilateral broadband capacity into high, medium, and low levels reflecting the types of activities that are possible with the capacity available. Low bandwidth (0–1 Mbps) allows for limited access and modest activities, medium (1–3 Mbps) allows for basic internet browsing and email, and high (3+ Mbps) allows for video streaming or conferencing, for example. Dividing bandwidth into these different categories allows for the identification of nonlinear impacts of broadband and the possibility that achieving certain threshold levels of quality may have a larger impact on digital trade than others.

Our second measure of internet quality considers the role of direct internet connections between markets via bilateral fiber optic cables, including both undersea and overland connections. As shown in Cariolle (2021), direct connections to international fiber optic networks can improve internet penetration rates considerably. In Sub-Saharan Africa, deployment of undersea cables led to a 3–5 percentage point increase in internet penetration rates compared to countries without cable connections.

Data on undersea cables were derived from TeleGeography's Submarine Cable Map.[9] From this map, we recorded the number of direct fiber optic cable connections between each country along with their

[6] See https://www.fcc.gov/consumers/guides/broadband-speed-guide.

[7] If uplink and downlink capacity are asymmetrical, as is typical with downlink exceeding uplink capacity in most cases, the higher value of the two is reported.

[8] The intra-national bandwidth measure is also based on international bandwidth as the source data do not separately report domestic-specific measures.

[9] The data used represent the November 21, 2021 version of the Map, which are available at https://www.submarinecablemap.com/.

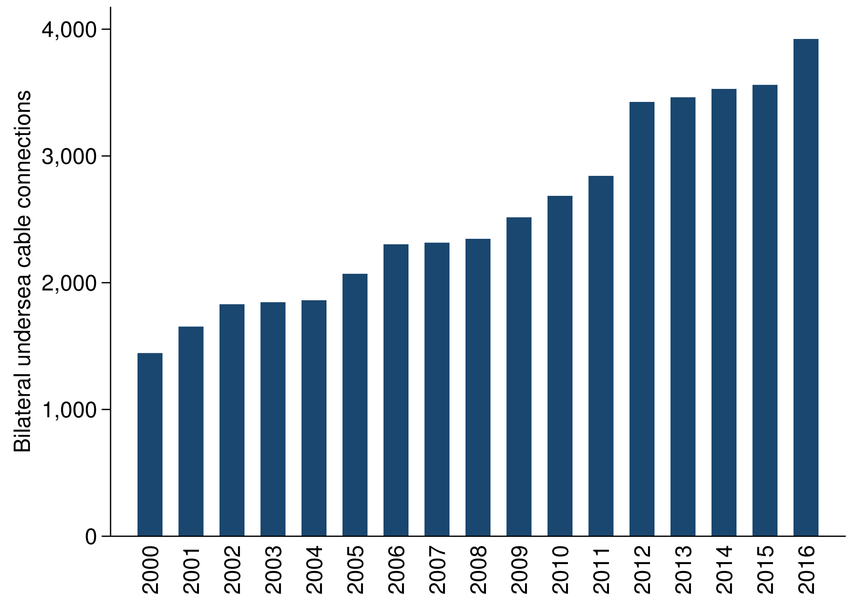

Fig. 3. Bilateral cable connections, 2000–2016.

"ready for service" date, resulting in a time-varying measure covering our sample period (FOS_{ijt}). Undersea cable connections include both international and domestic connections (such as connections between islands in Indonesia). Between 2000 and 2016, the number of bilateral undersea cable connections more than doubled from 1445 to 3923, as shown in Fig. 3. However, the distribution of these cables is highly unequal with the vast majority of country-pairs having no undersea cable connections. Only 5 percent of pairs were connected during this period, although the share of connected pairs did increase from 4.5 percent in 2000 to 6 percent in 2016. Much of the growth in undersea cables has occurred between pairs that increased their number of fiber optic connections rather than between previously unconnected countries. For example, the number of cables between Ireland and the UK doubled from 5 to 10 between 2000 and 2016.

Data on overland cable connections were sourced from the International Telecommunications Union (ITU) Interactive Transmission Map.[10] This map provides a snapshot of overland fiber optic cables that were operational as of April 2022. Using this map, we count the number of cable connections that cross each border to construct a measure of overland cable connectivity (FOL_{ij}). While this measure is moderately correlated with contiguity (coefficient of 0.53), it does capture variation in geography and unobserved political considerations. For example, China has fewer overland connections with countries that share a border in the Himalayan mountains than other borders. Armenia is not connected at all to Turkey or Azerbaijan despite sharing borders, reflecting contentious political relationships between these countries. While this data provides insight into recent fiber optic connections, it is limited by its lack of variation over time. As with undersea cables, cross-border overland connections are relatively rare in the sample, with less than one percent of country pairs connected bilaterally. Domestic overland connections are coded as zero, due to the difficulty assessing the number of connections within a country.

A challenge with the data on fiber optic connections is that neither series provides complete coverage of fiber optic internet infrastructure. Undersea cables provide a good indication of where parties have been willing to invest in costly undersea connections to transfer greater amounts of data quickly. They also provide a measure of connections that sometimes extend beyond standard geopolitical or geographical proximity, with some cables extending past more immediate neighbors and onto distant countries, like the 2011 "Europe India Gateway" cable which runs from the UK to India. However, undersea cables may not capture the full magnitude of connectivity, which often features extensive land connections as well. Notably, this data limitation is especially prominent for landlocked countries that cannot construct undersea cables. In principle, these limitations could be adequately addressed using data on land connections. However, these data are significantly more limited. To our knowledge, there is no source of data on global fiber optic land connections over time. The data we have collected represents a single year snapshot and is unable to fully supplement the undersea cable data. In the analysis that follows, we consider a few approaches to make the most of these data despite the limitations, including dropping landlocked countries from the sample and replacing country-pair fixed effects with other controls in order to allow for the measure of overland cable connections.

2.2. Digital provisions in trade agreements

In recent years, many countries have adopted digital provisions in their trade agreements that seek to govern and — in many cases — promote digital trade. These policies can target many different aspects of digital trade such as duty free treatment of electronic transmissions, electronic authentication, cybersecurity, data privacy, and free movement of data. When assessing the impact of digital provisions on trade, one important consideration is whether the policies liberalize trade or increase costs. For example, provisions that promote digital authentication, signatures, and certificates are often designed to lower transaction costs and expedite trade. Alternatively, provisions outlining cybersecurity requirements may facilitate digital trade by improving the security of digital transactions — but may also increase trade costs for PTA members if they have to improve cybersecurity practices to come into compliance with the new requirements. Another consideration is whether a provision is likely to have a differential impact on certain types of industries, such as goods vs services. While we generally focus on broad-cutting measures rather than sector-specific requirements (such as regulations governing internet services providers), some provisions may be more relevant to services than goods, or vice versa. For example, provisions related to free data flows may be more beneficial for services providers whose products are traded directly online. Meanwhile, electronic signatures may be more beneficial for goods trade because they can improve customs procedures.

[10] Available at https://www.itu.int/itu-d/tnd-map-public/.

Table 1
Digital provisions in trade agreements by type of provision and members, 2000–2016.

	High-income members	High- and low-income members	Total
Data flow measures	39	12	51
Technological neutrality	17	1	18
Customs duties prohibition	44	11	55
Data protection	48	17	65
Electronic authentication	35	12	47
Cybersecurity	19	8	27
Big data	34	13	47

Note: Data include agreements that entered into force between 2000 and 2016. Agreements that were signed but not in force by 2016 were excluded.

Data on digital provisions were compiled from the Trade Agreements Provisions on Electronic-Commerce and Data (TAPED) database (Burri and Polanco, 2020).[11] Focusing on broad measures, we consider seven types of provisions, described below.

- **Data flow measures:** Provisions that contain language allowing cross-border electronic data transfer (personal and business), recognizing importance of information flows for trade, asking parties to refrain from imposing barriers, prohibiting data localization policies that require companies store data in a particular country, and specifying that cross-border data flows will be free between members in general and not only for specific service sectors or commercial transactions (Questions 1.28.1, 2.1, 1.28.4, and 2.4 in the TAPED database).
- **Technological Neutrality:** Provisions with the principle of same treatment of digital and physical supply of a product, such as physical vs online software (Question 1.5).
- **Customs Duties Prohibition for Electronic Transmission:** Provisions for non-imposition of customs duties for electronic transmission, affirming the existing WTO moratorium (Question 1.11. 1).
- **Data Protection:** Provisions on data protection requirements for members (Questions 1.24.1–1.24.5).
- **Electronic authentication:** Provisions allowing for electronic authentication, signatures and digital certificates (Question 1.2).
- **Cybersecurity:** Provisions on cybersecurity requirements for members (Question 1.32).
- **Big Data:** Provisions on trade in goods related to big data, such as provisions governing internet of things or robotics (Question 6).

From 2000 to 2016, 65 trade agreements containing at least one of these provisions entered into force. The most common provision in these agreements were those related to data protection, followed by measures prohibiting customs duties on electronic transmissions, and free data flow measures (Table 1). Of the agreements considered, only 9 contain all 7 types of provisions.[12] Across all categories of measures, these digital trade provisions are most often found in agreements between HICs, though there are some agreements between HICs and LICs that feature digital provisions too (e.g. the Japan–Mongolia FTA).[13]

We condense this information into two bilateral measures of digital provisions in trade agreements. The first is an indicator (DPA_{ijt}) that takes the value of 1 if the two countries have an active agreement with *any* of the seven provisions described above and 0 otherwise. Second, we construct a continuous digital provision index (DPI_{ijt}) that reflects the number of different types of provisions that are present, which ranges from 0 (no digital trade provisions in any active PTA) to 1 (all seven types of provisions are included at least one active PTA). In robustness tests, we also consider each provision separately but find that due to correlation between the variables, it is difficult to make a conclusive statement about the impact of individual types of provisions on trade.

3. Trade impacts of internet connectivity and digital trade policies

To estimate the impacts of internet connectivity and digital trade policies in PTAs, we use a gravity model of trade. The gravity model is a framework that is well grounded in economic theory and has been shown for decades to perform well in empirical applications (Head and Mayer, 2014; Yotov et al., 2016).[14] In particular, empirical gravity models have often been used to estimate a wide range of bilateral trade determinants, ranging from tariff costs and other policy measures to geographic factors and cultural affinities. Estimating the impacts of internet connectivity and digital trade policies is a natural extension. Much of the past work empirically studying the effects of digital trade have utilized gravity specifications.

Our empirical gravity framework is given by the following model:

$$X_{ijt} = \exp\{\beta_1 IU_{ijt} + \beta_2 BW_{ijt} + \beta_3 FO_{ijt} + PTA_{ijt} * \left(\beta_4 + \beta_5 DP_{ijt}\right) + \beta_6 EU_{ijt} + \sum_t b_t + \mu_{it} + \nu_{jt} + \rho_{ij}\} + \epsilon_{ijt}. \quad (1)$$

Bilateral trade between an exporter (i) and an importer (j) in year (t) is denoted by X_{ijt}. Trade is modeled as a function of internet connectivity (IU_{ijt}, BW_{ijt}, and FO_{ijt}), preferential trade agreements (PTA_{ijt}), digital provisions (DP_{ijt}), and joint EU membership (EU_{ijt}). Because digital provisions are components of trade agreements, we include that term as an interaction with the PTA variable. As a result, the model estimates the general impact of PTAs via β_4 and the marginal impact of digital trade policies when they appear in PTAs via β_5. The separate inclusion of an EU control reflects that EU members are more economically integrated with each other than with PTA partners. Additionally, it controls for the fact that the TAPED database includes agreements between the EU and non-EU members but not the digital provisions in the EU's own laws.[15] We also include several other sets of controls that are standard in the literature. Exporter-year (μ_{it}) and importer-year (ν_{jt}) fixed effects are included in order to control for

[11] The data is available from the University of Lucerne at https://www.unilu.ch/en/faculties/faculty-of-law/professorships/managing-director-internationalisation/research/taped/.

[12] Agreements with all 7 types of provisions include: Canada–Peru FTA, Canada–Columbia FTA, Korea–Peru FTA, Columbia–Costa Rica FTA, Pacific Alliance Additional Protocol (PAAP), Mexico–Panama FTA, Australia–Japan FTA, Canada–Korea FTA, and Japan–Mongolia FTA.

[13] Given that our definition of high-income countries includes upper middle-income countries, there are no FTAs with digital provisions between only LICs. However, there are several trade agreements between upper middle-income countries, such the Columbia–Costa Rica FTA.

[14] We provide a more thorough discussion of the theoretical gravity model in Section 4.

[15] There is considerable variation in the digital provisions in EU agreements with outside trade partners, with more digital trade provisions appearing over time. For example, while the EC Lebanon Euro-Med Association Agreement (in force starting in 2006) contains none of digital trade provisions considered in this paper, the 2014 EC Moldova Association Agreement includes six of the seven provisions (all except technological neutrality).

the multilateral resistances described by Anderson and van Wincoop (2003). These terms capture the many country-specific factors that determine price levels and trade cost incidences in each exporting and importing country. Exporter-importer fixed effects (ρ_{ij}) are included to control for a wide range of unobserved, time-invariant trade determinants such as geographic distance, historical ties, and shared borders. Finally, following the recommendations of Bergstrand et al. (2015), we include a series of international border-year fixed effects (b_t), which take a value of 1 in year t if the trade flow is international ($i \neq j$). These terms are meant to control for heterogeneity in unobservable bilateral international trade costs. Including these controls should help better capture changes in the costs of international trade relative to domestic trade and therefore mitigate potential biases in the estimates for internet connectivity and digital provisions.

As with many determinants of trade, there are concerns that internet connectivity and digital provisions present endogeneity issues that could bias the estimates. To mitigate these concerns, we follow the advice of Baier and Bergstrand (2007) and include country-pair fixed effects (ρ_{ij}). As they argue, endogeneity issues like those posed by our measures are likely due to omitted variable biases in which internet adoption, digital provisions, and trade are all influenced by common factors that may not be readily observed. The inclusion of exporter-importer fixed effects mitigates these issues by controlling broadly for a wide range of additional factors. While these fixed effects are not time-varying, it is likely that the main sources of endogeneity are longer term, cross-sectional factors that influence the general levels of these components rather than their recent changes. For example, while level of development likely influences two countries' trade and internet connectivity overall, development is less likely to have a sizeable impact on year-to-year changes in trade flows or internet use. Similarly, digital provisions — which are not randomly introduced into trade agreements — are adopted because of long-term considerations such as mutual preferences for privacy rather than recent fluctuations in trade. For these reasons, we expect that these fixed effects are effective at reducing potential endogeneity biases. The few specifications in which we omit the exporter-importer fixed effects support this belief as doing so has a large impact on many of the estimates, suggesting that the fixed effects do substantially reduce biases. In the case of internet use, we also follow the work of Beverelli et al. (2023) and Nizalova and Murtazashvili (2016), who note that interactions with exogenous variables can allow us to obtain consistent estimates of the effects of a variable of interest, even if this variable of interest is correlated with omitted variables. In particular, we regularly utilize an interaction between our internet use measure and an indicator for foreign (or domestic) trade. Foreign trade is independent of any country selection and therefore represents an effective interaction variable for this purpose.

The model is estimated using a Poisson Pseudo Maximum Likelihood (PPML) procedure, as recommended by Santos Silva and Tenreyro (2006). PPML offers several advantages over alternative estimators; it allows for the inclusion of zero trade flows and provides superior treatment of heteroskedasticity that is often present in trade data.[16]

We combine the internet connectivity and digital provision data with information from several other sources. Bilateral trade data, including both international and domestic (intra-national) flows, were taken from the International Trade and Production Database for Estimation (ITPD-E) of Borchert et al. (2021).[17] The ITPD-E combines "raw", unmodified goods and services trade data as reported at the industry level from multiple sources into a single database for use in statistical analysis. The data ultimately cover 170 industries and 243 countries between the years 2000–2016. Data for the 26 agriculture industries were derived from FAOSTAT. Data for the 7 mining and energy industries were derived from COMTRADE and MINSTAT. Data for the 120 manufacturing industries were derived from COMTRADE and INDSTAT. Finally, data on the 17 services industries were derived from the WTO-UNCTAD-ITC Annual Trade in Services Database and UN National Accounts database. Importantly, the data include information on domestic trade flows, which — as discussed in the next section — are useful for identifying and estimating international trade costs.[18] The data also include zeros for non-trading counties, which represent about 26 percent of the observations in the sample. In addition to the trade data, information on PTAs, EU membership, and other typical gravity variables was taken from the Dynamic Gravity Dataset of Gurevich and Herman (2018). After combining the ITPD-E data with our data on internet connectivity and digital trade policies, our final sample includes 614,552 observations and 210 countries.

3.1. Internet connectivity and trade

Table 2 presents the results from a series of estimations examining the relationship between internet connectivity and trade based on Eq. (1). The specifications in each column sequentially add terms to the model in an effort to understand the marginal impact of their respective inclusion. In all cases, the dependent variable is aggregate trade, reflecting flows of both goods and services. Column (1) reflects a baseline model that includes only the conventional gravity covariates for PTAs and EU membership as well as the collection of fixed effects. The estimates for these terms are positive, significant, and consistent with prior estimates in the literature.

Column (2) introduces two measures of internet connectivity: internet use and bandwidth capacity. Both estimates are positive and significant. To better understand the magnitude of these estimates, partial impacts can be computed that identify the direct effect of the determinant on bilateral trade (this effect may not fully account for indirect effects, which we explore more fully in Section 4). The magnitude of the internet use estimate implies that a one standard deviation increase in bilateral internet use, which represents a 16 percentage point increase in the likelihood that two randomly selected people both use the internet, is associated with a 38 percent increase in bilateral trade (standard error 9.76).[19] Bandwidth capacity, which measures quality of internet connections, is also positively related to trade. Based on the estimate in column (2), a one standard deviation increase in bandwidth capacity (a 0.4 percentage point increase in bandwidth per user) would increase trade by 0.2 percent (std. error 0.076). The small effect of bandwidth capacity on trade likely reflects the skewed nature of the distribution of bandwidth capacity across years. The bandwidth measure is concentrated at the low end of the distribution but exhibits a small number of especially high values.[20]

Columns (3), (4), and (5) examine alternative specifications of the internet use variable. Column (3) interacts internet use with indicators for international and domestic trade in order to identify whether internet connectivity matters more internationally or intra-nationally. This interaction provides several advantages. First, it provides an estimate of the relative importance of the internet on foreign compared to domestic trade. Second, it helps further separate the impacts of the internet from

[16] To perform the regressions, we use the estimation routines of Correia et al. (2020) and Larch et al. (2019).

[17] The ITPD-E database can be downloaded from https://www.usitc.gov/data/gravity/itpde.htm. This paper uses v1 of the database.

[18] As domestic trade flows are not generally reported, these records were calculated as the difference between production and total foreign exports for each country in each industry.

[19] Calculated as $100 * (\exp(0.164 * 1.987) - 1)$. The standard error was calculated using the delta method.

[20] In particular, geographically small HICs like Luxembourg, Hong Kong, and Singapore are better able to bring fast internet to their entire populations and exhibit significantly higher bandwidth capacity than other countries. By comparison, even many of the highest-income countries exhibit relatively low rates due to the challenges of connecting rural and remote areas across large geographic regions.

Table 2
Gravity model estimates of the effects of internet use and bandwidth.

	(1)	(2)	(3)	(4)	(5)	(6)
PTA	0.0966**	0.103**	0.101**	0.107**	0.104**	0.100**
	(0.0470)	(0.0447)	(0.0437)	(0.0427)	(0.0446)	(0.0468)
EU membership	0.128***	0.100**	0.0785*	0.0513	0.100**	0.104**
	(0.0422)	(0.0431)	(0.0444)	(0.0488)	(0.0431)	(0.0443)
Internet use		1.987***				
		(0.431)				
Bandwidth		0.473***	0.588***		0.475***	0.432**
		(0.180)	(0.181)		(0.180)	(0.185)
Internet use × foreign			1.713***			
			(0.464)			
Internet use × domestic			1.088**			
			(0.519)			
Internet use (medium-low)				0.169***		
				(0.0359)		
Internet use (medium-high)				0.0623		
				(0.0689)		
Internet use (high)				−0.0259		
				(0.0741)		
Bandwidth (basic internet)				0.0459*		
				(0.0271)		
Bandwidth (video streaming)				0.454***		
				(0.0632)		
Internet use × HIE					1.978***	2.016***
					(0.431)	(0.428)
Internet use × LIE					1.714**	1.697**
					(0.764)	(0.683)
Observations	613179	613179	613179	613179	613179	613775
Pseudo R^2	0.998	0.998	0.998	0.998	0.998	0.996
AIC	36780873.7	36165666.5	35852618.3	35532795.0	36164637.3	56714425.7
RMSE	0.186	0.185	0.184	0.183	0.185	0.237

Note: This table presents estimates derived from the gravity model of trade. The dependent variable was bilateral trade value in all columns. All specifications included exporter-year, importer-year, and border-year fixed effects, which are omitted for brevity. Columns (1)–(5) included exporter-importer fixed effects and column (6) included symmetric country-pair trends. HIE and LIE denote high-income exporter and low-income exporter, respectively. Standard errors were clustered at the country-pair level and are reported in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

other country-level effects captured in the country-year fixed effects and mitigates endogeneity concerns, as discussed above (Nizalova and Murtazashvili, 2016; Beverelli et al., 2023). The estimates in column (3) indicate that internet use increases both international and domestic trade but has a much larger impact on international trade.[21] A one standard deviation increase in internet connectivity increases foreign trade by 32.6 percent (std. error 10.1) and domestic trade by 19.5 percent (std. error 10.1).

Column (4) examines whether there are non-linearieties in the effects of internet use and bandwidth capacity. The continuous internet use variable is divided into quartiles and replaced with three dummy variables indicating whether each county-pair's value falls in that quartile (the lowest use quartile is the excluded group in the regression). We refer to these variables as "medium-low" (25–50th percentile), "medium-high" (50–75th percentile), and "high" (75–100th percentile) internet use, respectively.[22] Column (4) also uses the alternative version of the bandwidth measure described in Section 2.1, which segments the variable into groups depending on the types of tasks that can be completed with the quality of connection. The internet use estimates indicate that there are diminishing returns to increased internet use and that the biggest gains are experienced when countries achieve moderate levels of internet access. Improving internet connectivity from "low" to "medium-low" has a positive and significant impact on trade. However, additional improvement in internet connectivity to "medium-high" or "high" levels appears to have no significant effect. This finding in particular supports the idea that developing countries have much to gain from small improvements in their typically low levels of internet use. Meanwhile, the bandwidth capacity estimates show that high bandwidth sufficient for video streaming significantly increases trade by 57.5 percent (st.error 9.95).[23] The medium bandwidth category, which represents basic internet use, has a much smaller positive impact, reflecting a 4.7 percent increase in trade relative to the lowest levels of bandwidth. This suggests that there are threshold levels of bandwidth that must be attained in order to realize the biggest trade benefits of faster internet connections.

Column (5) of Table 2 considers the differential effect of internet use across different income levels. It may be the case that the internet has a different impact on trade with low-income, developing countries than high-income countries. For example, developing countries may tend to trade products for which there is more or less benefit from internet connectivity relative to the rest of the world. As evidence of such a difference, Clarke and Wallsten (2006) find that internet penetration increased trade between developing and developed countries but not between two developed countries. Similarly, Cariolle et al. (2020) find

[21] Using a Wald test, the difference between the foreign and domestic estimates is statistically significant (p-value < 0.01).

[22] The "medium-low" quartile contains index values 0.003–0.027, the "medium-high" quartile contains values 0.027–0.139, and the "high" quartile contains values 0.139–1.000.

[23] Calculated as $100 * (\exp(0.454) - 1)$.

that increased submarine cable connectivity increases export participation in developed countries but decreases participation in developing countries. To test for these effects, we divide the sample into two groups of exporters: high-income exporters (HIEs), which includes all high- and upper-middle income countries; and low-income exporters (LIEs), which includes low- and lower middle-income countries. We focus on the income level of the exporter because the related literature has often pointed to the benefit that internet connectivity offers in connecting exporters in developing countries to global markets. The results in column (4) indicate that internet use has a positive and statistically significant effect on exports from both HIEs and LIEs. Further, while the point estimate is slightly larger for HIEs, the difference is not statistically significant (p-value 0.67), underscoring the important impact that the internet has on trade among all countries.

Finally, column (6) considers an alternative fixed effects specification. Following the work of Bergstrand et al. (2015), we replace the exporter-importer fixed effects with symmetric country-pair trends. This change allows for linear trends over time in the unobserved bilateral costs captured by country-pair fixed effects. The estimates derived with these trends are largely consistent with those presented in column (5), which otherwise uses the same specification. The effects of internet use on HIEs is slightly larger while the effects of internet use on LIEs and bandwidth capacity are slightly lower. However, the differences between coefficients across the two specifications are modest for all of the reported variables and are not statistically significant at conventional levels.[24]

Next, we consider our third dimension of internet connectivity—direct fiber optic cable connections. Table 3 presents a series of specifications exploring direct connections via fiber optic cables. Column (1) introduces undersea fiber optic connections. Because these data are only available for countries that have access to waterways, landlocked countries were omitted from this sample, consistent with Hjort and Poulsen (2019). Restricting the sample leads to slight changes in the magnitudes of the other internet connectivity variables but the results are largely consistent with column (2) of Table 2. The estimate for undersea cables is positive and statistically significant, suggesting that an undersea fiber optic connection increases trade by about 2.1 percent (std. error 1.02). Columns (2) and (3) of Table 3 introduce the measure of overland connections. Recall that the overland measure is not time varying and is therefore collinear with the exporter-importer fixed effects. For this reason, these fixed effects were omitted in columns (2) and (3) and replaced with typical bilateral gravity controls for distance, contiguity, common language, and colonial relationships. In order to first determine the effects of omitting country-pair fixed effects, column (2) reproduces column (2) of Table 2 with the alternative bilateral controls. All of the main variables in column (2) are strikingly different; the coefficients on PTA membership and the bandwidth index switch signs and are both negative and significant, while the EU membership and internet connectivity measures are both considerably larger. We interpret these findings as evidence that the country-pair fixed effects are addressing biases.

Column (3) of Table 3 includes both undersea and overland fiber optic connections. The undersea cable coefficient is positive and significant, suggesting the installation of one additional undersea cable increases trade by 9.3 percent (std. error 1.57). While Hjort and Poulsen (2019) are able to control for non-random assignment of new undersea cables by looking at the variation in the quality of domestic internet infrastructure by country, our limited information on domestic networks does not allow for a similar approach. However, given we do observe a decline in both the magnitude and significance of the undersea cable variable when including pair fixed-effects, some of the bias associated with non-random assignment is likely eliminated by controlling for existing relationship between country-pairs. For this reason, we suspect the larger impact in column (3) may be biased upwards. Finally, there is no significant relationship between the presence of overland cables and trade. We consider these findings informative of the potential effects of direct fiber optic connections but underscore the limitations of the data as an important caveat.

Much of the past literature has emphasized that goods and services trade may rely on the internet in different ways. In Table 4, we explore these differences by subdividing trade into goods and services flows and estimating the gravity models at those levels. The sectoral estimates highlight that digital trade impacts do differ between goods and services. We begin by considering the effects of internet use on these sectors. Columns (1) and (4) consider the specification including the single measures of internet use and bandwidth. Internet use remains a large, positive, and significant driver of foreign trade for both goods and services. Interestingly, the magnitude of the impact is larger for trade in goods than trade in services, although the difference is not statistically significant (p-value 0.75).[25] Based on the estimates, a one standard deviation increase in connectivity would increase foreign goods trade by 39.8 percent (std. error 19.8) and foreign services trade by 32.8 percent (std. error 10.4). For domestic trade, internet use increases services trade by similar levels but has no significant impact on goods trade.

Table 3
Gravity model estimates of the effects of fiber optic cable connections.

	(1)	(2)	(3)
PTA	0.0984**	−0.702***	−0.713***
	(0.0453)	(0.0785)	(0.0817)
EU membership	0.0521	0.957***	0.910***
	(0.0524)	(0.144)	(0.142)
Internet × foreign	1.805***	4.403***	4.230***
	(0.472)	(0.530)	(0.503)
Internet × domestic	1.130**	5.424***	4.681***
	(0.524)	(0.530)	(0.485)
Bandwidth	0.560**	−7.907**	−7.171*
	(0.242)	(3.901)	(3.784)
Undersea cables	0.0207**		0.0889***
	(0.0100)		(0.0144)
Overland cables			−0.00654
			(0.0109)
Distance (log)		−1.170***	−1.079***
		(0.0534)	(0.0564)
Contiguity		−0.359***	−0.285**
		(0.0952)	(0.121)
Colonial relationship		−0.0806	−0.0342
		(0.164)	(0.131)
Common language		0.734***	0.818***
		(0.0835)	(0.0846)
Observations	498532	614546	614546
Pseudo R^2	0.998	0.975	0.976
AIC	33024665.9	367554432.9	349632004.0
RMSE	0.180	2.026	1.288

Note: This table presents estimates derived from the gravity model of trade. The dependent variable was bilateral trade value in all columns. All specifications included exporter-year, importer-year, and border-year fixed effects, which are omitted for brevity. Exporter-importer fixed effects were included in column (1) but not in (2) or (3). Column (1) omitted landlocked countries. HIE and LIE denote high-income exporter and low-income exporter, respectively. Standard errors were clustered at the country-pair level and are reported in parentheses.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

[24] For the main internet connectivity variables, p-values for statistical differences range between 0.69 (Bandwidth) to 0.97 (Internet connectivity × LIE). P-values were calculated using the t statistic $t = (\beta^* - \beta)/(s^2(\beta) - s^2(\beta^*)\sigma^2/\sigma_*^2)^{1/2}$ where β is the coefficient estimate, $s(\beta)$ is the standard error, and σ^2 is the mean squared error from the model with exporter-importer fixed effects. $*$ denotes the estimates from the model with pair-trends (Clogg et al., 1995).

[25] P-value computed using the Z statistic $Z = (\beta_g - \beta_s)/\sqrt{SE(\beta_g)^2 + SE(\beta_s)^2}$, where β denotes the coefficient estimates for (g)oods and (s)ervices and SE denotes their standard errors (Clogg et al., 1995).

Table 4
Gravity model estimates of internet connectivity by sector.

	Goods			Services		
	(1)	(2)	(3)	(4)	(5)	(6)
PTA	0.101*	0.115*	0.105	0.257***	0.260***	0.260***
	(0.0601)	(0.0682)	(0.0661)	(0.0767)	(0.0757)	(0.0781)
EU membership	−0.0534	0.0193	0.0373	0.306***	0.317***	0.295***
	(0.0619)	(0.0703)	(0.0696)	(0.108)	(0.108)	(0.108)
Internet × foreign	2.046**			1.736***		
	(0.867)			(0.480)		
Internet × domestic	−0.206			1.622***		
	(0.781)			(0.524)		
Internet use × HIE		2.889***	2.924***		1.797***	1.906***
		(0.952)	(0.946)		(0.480)	(0.485)
Internet use × LIE		3.807**	3.264**		−0.480	−1.137
		(1.549)	(1.293)		(1.665)	(1.013)
Bandwidth	1.384	−0.803	−1.020	−1.134***	−1.147***	−1.132***
	(1.004)	(2.270)	(2.444)	(0.206)	(0.204)	(0.208)
Observations	611787	611787	612383	72837	72837	72838
Pseudo R^2	0.992	0.991	0.987	0.999	0.999	0.999
AIC	39,813,088.1	42,228,569.2	62,173,637.3	9,352,981.2	9,352,753.1	11,114,069.1
RMSE	0.305	0.315	0.394	0.125	0.125	0.137

Note: This table presents the gravity model estimates for trade separated into goods and services. The dependent variable was bilateral goods trade value for columns (1)–(3) and bilateral services trade value for columns (4)–(6). All specifications included exporter-year, importer-year, and border-year fixed effects, which are omitted for brevity. Columns (1), (2), (4), and (5) included exporter-importer fixed effects. Columns (3) and (6) included symmetric country-pair trends. HIE and LIE denote high-income exporter and low-income exporter, respectively. Standard errors clustered by country-pair are reported in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Columns (2) and (5) reintroduce the version of the internet use measure interacted with the indicators for HIEs and LIEs. For goods trade in column (2), the estimate of internet use is larger for LIEs but not significantly so (p-value 0.28), which weakly supports the idea that the internet is especially valuable for connecting exporters in developing countries to global markets. As an extension, which is discussed later in Section 3.3.3, we consider further disaggregation into specific industries and find that this low-income effect appears to be especially large for agriculture and electronics manufacturing.

For services trade depicted in column (5), increased internet use significantly increases trade for HIEs but has no significant impact on LIEs. This may reflect the heterogeneity of the types of services provided by HIEs and LIEs. Recent work looking at the relationship between services and development more generally have distinguished between services that employ large shares of high-skilled labor — such as professional, information technology, financial, insurance, healthcare, and education — and services that employ large shares of low-skilled labor — such as transportation, warehousing, wholesale, retail, accommodation, and food services. Using data for 13 Sub-Saharan African countries, Baccini et al. (2023) find that increased employment in services is only positively related to development indicators in the high-skilled labor services. Meanwhile, Nayyar et al. (2021) find that labor productivity growth in developing markets has increased at a similar rate as employment in high-skilled services but has been slower than employment growth in low-skilled services. In addition to these general trends, Nayyar et al. (2021) also note that developments in global digital technology create exporting opportunities among high-skilled tradable services by improving opportunities for remote work. However, low-skilled tradable services tend not to be able to shift operations online and thus may not see a similar export boost from improved technology. This dichotomy is consistent with our sector-specific results discussed later in Section 3.3.3. In particular, internet connectivity has a positive and significant effect on business service exports (which include professional and information technology services) for LIEs that is larger than for HIEs. By comparison, the travel and transportation category exhibits no relationship between internet connectivity and trade.

Finally, columns (3) and (6) replace the exporter-importer fixed effects with symmetric pair trends, as was done in column (6) of Table 2. The effects of internet use on HIEs increase slightly with the pair-trends while the effect on LIEs for goods is a little smaller. However, the differences in these estimates are not statistically significant at conventional levels.[26]

In contrast to the aggregate results and the estimates for internet use, bandwidth quality has no significant relationship with trade in goods and a negative and significant relationship with trade in services. That bandwidth has no systematic impact on goods trade may be due to most goods trade needing only basic connectivity to perform typical tasks like completing orders, communicating information, and facilitating administrative tasks. For services, however, the large negative effect is surprising. One reason for this counterintuitive result may be the influence of geographically small HIEs like Luxembourg, Hong Kong, and Singapore that exhibit bandwidth capacities that are considerably higher than anywhere else. In 2016, average bandwidth per user in our sample was 143.1 Mbps/user; meanwhile, in Luxembourg, bandwidth was 7920.0 Mbps/user. In the services sample of countries, these high bandwidth countries — which are relatively minor services traders (together representing only 1.6 percent of total services exports in our sample in 2016) — appear to be driving the negative sign on the bandwidth index. Robustness checks excluding pairs of countries where the minimum bandwidth per user exceeded 400 Mbps/user (such as trade within and between Luxembourg, Hong Kong, and Singapore) from the services specification produce a positive but insignificant relationship between bandwidth capacity and trade.

[26] The p-values for the internet use × HIE coefficients for goods and services are 0.95 and 0.56, respectively. The p-value for Internet use × LIE for goods is 0.64.

3.2. Digital trade provisions and trade

Having found a strong impact of internet connectivity on trade, we turn next to digital trade provisions. Table 5 presents a series of specifications based on total trade that introduce the measures of digital provisions. Column (1) introduces the indicator for any of the seven categories of digital provisions in a PTA alongside the internet use and bandwidth measures. The provision indicator estimate is positive and significant, implying higher trade under PTAs with at least one digital provision. The magnitude of the estimate indicates that an agreement with digital provisions is associated with 9.1 percent (std. error 3.2) more trade than an agreement without any provisions. Column (2) replaces the indicator with the continuous index counting the number of types of provisions in a PTA and finds no significant relationship between the index and trade. These two estimates suggest some interesting characteristics of digital provisions. In particular, they suggest that while there is some evidence that digital provisions are trade facilitating overall, there may be little marginal impact from additional individual provisions. This notion is consistent with the observation that many of the provisions are often highly correlated, appearing either together or not at all. Given this, it may be that the indicator variable does a better job of reflecting the underlying variation of the provision data. It is also notable that the estimate on PTAs is rendered insignificant in column (1) but not (2), suggesting that the blunter indicator measure may inadvertently be capturing other dimensions of PTAs, such as deep coverage of other non-tariff issues. Finally, the inclusion of the provision variables has only small impacts on the other internet connectivity estimates, implying that the provision measures are capturing new aspects of digital trade.

Columns (3) and (4) of Table 5 consider the role of income level by interacting the digital provision and internet use variables with indicators for HIEs and LIEs. Of the four new provision terms in both columns, only the HIE version of the any provision indicator produces a significant positive effect. These results indicate that the main impact of digital provisions appears to be for high-income exporters, which is sensible as digital provisions often provide specialized benefits to the most digitally intensive firms that are prominent in high-income countries. Finally, column (5) replicates column (3) but includes country-pair trends instead of exporter-importer fixed effects. The estimates of all variables of interest are largely the same and exhibit only minor, insignificant differences in magnitude.

Next, we consider the effects of digital provisions on goods and services trade separately. Table 6 divides the sample into goods and services flows and reproduces columns (3), (4), and (5) of Table 5. For goods, the provision index once again has no significant impact on trade. The provision indicator, however, exhibits some negative and significant impacts when pair-trends are included in column (3). This could be an indication that for goods trade, digital provisions (and their potential associated compliance costs) may tend to be more restrictive than trade facilitating for low income exporters. For services, the impacts of digital provisions are more positive. The provision index in column (4) has a significant positive impact on services exports from HIEs, suggesting that each additional provision increases trade by 6.2 percent (std. error 1.5). Meanwhile, the provision indicator in column (5) is similarly positive for exports from HIEs. The estimate implies that presence of at least one digital provision increases high-income services exports by 43.1 percent (std. error 13.4). As with total trade, digital provisions appear to have no significant impact on services trade for LIEs. The results in column (6), which included country-pair trends, are largely consistent with those in column (4).

These estimates suggest that while goods and services trade both benefit from increased internet connectivity, digital trade policies appear to be mostly beneficial for services trade. That the significant effect is found for the count of provisions in addition to the indicator suggests that for services, the marginal impact of individual provisions is more meaningful. This is not surprising given that many of these individual types of provisions exclusively or disproportionately target services trade, such as those covering customs duties on electronic transmissions.

Notably, neither internet connectivity nor digital trade provisions appear to have a significant impact on low-income services exports. This suggests that neither internet infrastructure development nor the adoption of digital trade policies are likely to offer a direct way for low-income developing countries to grow the services portion of their export portfolio on their own. As noted above, certain types of services exports (e.g. business and IT services) may be better engines of development than others (e.g. transportation and travel). This suggests that in order to reap many of the benefits of internet connectivity in trade, LIEs may need to pursue additional strategies to shift the economy towards the service sectors that most benefit from improved connectivity. Such strategies might include increased investment in education, skill development, and innovation. However, the success of such a shift — particularly if targeting export growth — also depends on whether internet infrastructure is sufficient to support online trade in these services.

Taken together, all of these estimates demonstrate the importance of digital trade. However, our results suggest that at least during the time period from 2000 to 2016, the most broadly important component of digital trade is internet connectivity. While we find some evidence of digital trade provisions having a positive impact, these benefits appear to be limited to high-income exporters of services. This suggests that for the time being at least, the main focus of growing the digital economy should be the expansion of high-quality internet to more people around the world. Doing so would have a large impact on all parties and would provide valuable low-cost access to global markets for people in developing countries. As this trend continues and trade becomes increasingly digital, it is likely that digital policy provisions will have a growing impact that will be more apparent in coming years.

3.3. Robustness checks and extensions

We conclude this section by presenting several robustness checks and extensions of our main findings. First, we consider the impact of internet connectivity and digital provisions on the extensive margin of trade, as measured by the number of products traded between each pair of countries. Second, we further disaggregate the data and examine differences in the estimates across a collection of individual industries. Third, we look at the impacts of individual digital trade provisions rather than combining them into a single measure. Fourth, we estimate the model using a new approach to mitigate biases arising from the incidental parameter problem. Fifth, we consider alternative groupings of countries and sectors: by level of trade restrictions and by use of intermediate inputs of information technology services. Finally, we estimate the model using interval-data instead of continuous years, as has often been suggested in the literature. In most cases and unless otherwise noted, we focus on a common preferred specification from column (3) of Table 5, which includes PTA and EU membership, internet use interacted with the HIE and LIE indicators, bandwidth, and the digital provision indicator interacted with the HIE and LIE indicators. For the sake of parsimony, we discuss the main findings from each test here and present the full set of results in the appendix. Overall, the additional results largely support the main findings discussed above.

3.3.1. Extensive margin

It may be the case that many services could not be traded without the internet. For example, data-intensive services like accounting likely would not be traded if physical copies of balance sheets had to be shipped across borders. To the extent that this dynamic is present across all types of services, internet connectivity and digital trade policies are likely to have an especially large impact on services trade at the extensive margin. We examine this possibility by estimating an extensive margin version of the model and examining the relationship

Table 5
Gravity model estimates of the effects of digital trade provisions.

	(1)	(2)	(3)	(4)	(5)
PTA	0.0588	0.109**	0.0460	0.0973**	0.0389
	(0.0453)	(0.0446)	(0.0462)	(0.0455)	(0.0478)
EU membership	0.0167	0.0972**	0.0165	0.0828*	0.0207
	(0.0481)	(0.0467)	(0.0468)	(0.0465)	(0.0481)
Internet × foreign	1.689***	1.710***			
	(0.463)	(0.462)			
Internet × domestic	1.092**	1.071**			
	(0.518)	(0.510)			
Internet use × HIE			1.930***	1.976***	1.964***
			(0.431)	(0.433)	(0.428)
Internet use × LIE			1.780**	1.738**	1.754**
			(0.761)	(0.755)	(0.682)
Bandwidth	0.574***	0.595***	0.463**	0.470***	0.419**
	(0.181)	(0.182)	(0.181)	(0.182)	(0.185)
Any provision	0.0872***				
	(0.0294)				
Provision index		−0.0347			
		(0.0545)			
Any provision × HIE			0.120***		0.128***
			(0.0285)		(0.0283)
Any provision × LIE			0.0620		−0.0683
			(0.0857)		(0.0864)
Provision index × HIE				0.0281	
				(0.0538)	
Provision index × LIE				0.107	
				(0.151)	
Observations	613179	613179	613179	613179	613775
Pseudo R^2	0.998	0.998	0.998	0.998	0.996
AIC	35815324.3	35849039.2	36095026.3	36161137.1	56623826.6
RMSE	0.184	0.184	0.185	0.185	0.237

Note: This table presents estimates derived from the gravity model of trade. The dependent variable was bilateral trade value in all columns. All specifications included exporter-year, importer-year, and border-year fixed effects, which are omitted for brevity. Columns (1)–(4) included exporter-importer fixed effects. Column (5) included symmetric country-pair trends. HIE and LIE denote high-income exporter and low-income exporter, respectively. Standard errors were clustered at the country-pair level and are reported in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

between internet connectivity, digital provisions, and the number of different goods or services that countries trade. Using the same ITPD-E data at the industry level, we construct a new dependant variable that counts the number of industries for which a non-zero value is traded between each pair of countries in each year. Within the data, there are 153 different goods industries and 17 services industries. Thus, the maximum number of products that can be traded between country-pairs is 170 for total trade, 153 for goods, and 17 for services. On average, country-pairs in the sample tended to trade 29 different products. HIEs tended to export a wider variety of products on average (37 products) than LIEs (16), suggesting that there is the potential for large increases in the extensive margin for developing markets.

Following Santos Silva et al. (2014), we use a flexible Bernoulli pseudo maximum likelihood (Flex) estimator to analyze the extensive margin. Unlike much of the literature that examines the extensive margin as a binary phenomenon, the Flex model views the extensive margin as a count of the number of goods or services traded. For computational reasons, we replace the exporter-importer fixed effects with a collection of typical trade cost measures from the gravity literature, including geographic distance, contiguity, common language, and colonial ties.[27]

We also restrict the sample period for the services-only specification to 2005–2016 in order to avoid convergence issues. Services trade data feature a significant number of zero trade flows prior to 2005, which presented a computational challenge for the Flex model.[28] The results of these estimations are presented in Table A.1.

The estimates based on total trade show that for both HIEs and LIEs, higher internet use has also increased the number of products exported. On the other hand, digital trade provisions have significantly decreased the number of products exported by both HIEs and LIEs relative to PTAs with no digital provisions. As with other specifications without country-pair fixed effects, the impact of bandwidth quality on the extensive margin is large, negative and significant, again likely reflecting the impact of geographically small, well-connected countries that export relatively few products.

For goods trade, the impact of internet use differs by type of exporter. For HIEs, internet use significantly increases the number of goods products exported; for LIEs, it decreases the number. This negative effect could reflect specialization among low-income goods producers over time. It may be the case that internet connectivity has inspired increased specialization in certain goods because importers have better information about potential international sources of products that their home market does not produce efficiently, resulting in

[27] To estimate the models, we use the Flex package for Stata made available by Santos Silva et al. (2014), which proved to be non-convergent when exporter-importer fixed effects were included with our sample and preferred specification. Notably, the Flex routine does not feature many of the high-performance techniques present in modern PPML routines that make estimation with pair fixed effects feasible.

[28] The ITPD-E database draws on an additional source for services trade data beginning in 2005 (the WTO-UNCTAD-ITC Annual Trade in Services Database), resulting in a noticeable decrease in the number of reported zeros after 2004.

Table 6
Gravity model estimates of the effects of digital trade provisions by sector.

	Goods			Services		
	(1)	(2)	(3)	(4)	(5)	(6)
PTA	0.149*	0.141**	0.126*	0.119	0.0268	0.0281
	(0.0765)	(0.0679)	(0.0660)	(0.0788)	(0.0872)	(0.0875)
EU membership	0.0896	0.0580	0.0713	0.117	0.0825	0.0629
	(0.0667)	(0.0675)	(0.0667)	(0.124)	(0.132)	(0.135)
Internet × HIE	2.899***	2.908***	2.937***	1.668***	1.832***	1.945***
	(0.952)	(0.955)	(0.951)	(0.479)	(0.478)	(0.485)
Internet × LIE	3.674**	3.813**	3.311**	0.0465	0.0694	−0.681
	(1.521)	(1.543)	(1.290)	(1.618)	(1.596)	(1.000)
Bandwidth	−0.964	−0.893	−1.110	−1.184***	−1.175***	−1.159***
	(2.446)	(2.359)	(2.537)	(0.199)	(0.202)	(0.205)
Provision index × HIE	−0.137			0.419***		
	(0.0973)			(0.101)		
Provision index × LIE	−0.262			0.188		
	(0.197)			(0.180)		
Any provision × HIE		−0.0542	−0.0429		0.359***	0.358***
		(0.0440)	(0.0431)		(0.0933)	(0.0913)
Any provision × LIE		−0.166	−0.274***		0.0463	0.0441
		(0.110)	(0.102)		(0.125)	(0.121)
Observations	611787	611787	612383	72837	72837	72838
Pseudo R^2	0.991	0.991	0.987	0.999	0.999	0.999
AIC	42185431.8	42211022.6	62133006.1	9265288.6	9270251.3	11028483.2
RMSE	0.315	0.315	0.394	0.125	0.125	0.137

Note: This table presents the gravity model estimates for trade separated into goods and services. The dependent variable was bilateral goods trade values for columns (1)–(3) and bilateral services trade values for columns (4)–(6). All specifications included exporter-year, importer-year, and border-year fixed effects, which are omitted for brevity. Columns (1), (2), (4), and (5) included exporter-importer fixed effects. Columns (3) and (6) included symmetric country-pair trends. HIE and LIE denote high-income exporter and low-income exporter, respectively. Standard errors clustered by country-pair are reported in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

diversion from domestic goods towards international goods at the extensive margin. The inclusion of digital provisions in PTAs significantly increases the number of goods exported by HIEs but not LIEs, though the magnitude of the effect is small.

In contrast, internet use significantly increases the number of services products exported by both HIEs and LIEs. The magnitude of the effect is also considerably larger than the impact of internet use for goods and services combined, for both types of exporters. These findings support the idea that the internet is necessary for trade in many services, and improvements in internet connectivity is helping to facilitate entry of LIEs into online-tradable service sectors like business and IT services. In contrast to the main findings, the inclusion of digital provisions in PTAs increases the number of services products exported by both HIEs and LIEs, and the magnitude of the effect is larger for LIEs. This provides more evidence that policies promoting digital trade in PTAs are uniquely important for services sectors.

3.3.2. Individual digital trade provisions

A challenge that arises when analyzing the digital provisions is that many of them tend to appear together when included in a PTA and are therefore highly correlated. A simple correlation matrix between the seven types of digital trade policies (Table A.2) shows that cybersecurity and technological neutrality provisions exhibit fairly low correlation with the other provisions. However, the remaining five provisions are highly correlated (coefficients > 0.75). This makes it difficult to assess the effects of many of the specific provisions considered as this potential multicollinearity could contribute to inconsistent parameter estimates across specifications, unexpected signs, or low significance levels of individual parameters despite high joint significance. At the same time, omitting relevant trade policy variables due to collinearity could lead to biased coefficients on the other variables.

In our main specifications, we avoid the potential issues of collinearity between digital trade provisions by grouping the provisions together. Here, however, we explore the impacts of separating them out in order to see what insights can be gained from looking at each type of provision independently. First, we consider a series of regressions that include each type of provision one at a time (columns 1–7 of Table A.3). Second, we estimate a specification that includes all seven types side-by-side (column 8).

When included alone, free data flows, technological neutrality, regulations governing data protection, and use of big data in manufacturing significantly increase trade. On the other hand, cybersecurity provisions significantly decrease trade. This latter estimate may be an indication that not all provisions are meant to be trade facilitating; cybersecurity provisions may very well increase export costs, particularly in the short run, as firms must invest to comply with enhanced cybersecurity procedures. When all provision types are included side-by-side, two types of provisions — free data flows and technological neutrality — significantly increase trade, holding all other types of digital provisions constant. Meanwhile, cybersecurity policies are again found to significantly decrease trade. These diverging signs in the individual provision results may also help explain the lack of relationship between trade and the combined provision indices considered in the specifications presented in the previous section. However, given the high correlation between different types of provisions, these results should be treated with caution.

3.3.3. Industry-specific estimates

It is likely that there is significant heterogeneity in the effects of internet connectivity and digital provisions across industries, as each industry uses digital trade in different ways and at different levels of intensity. To explore some of this heterogeneity, we consider 11 narrowly defined goods and services industries (Table A.4): agriculture, mining, food and beverage manufacturing, textiles, chemicals, basic metals, fabricated metals, electronics, transport equipment, travel and transportation services, financial services (including insurance), and other business services (including computer and telecommunications services).[29]

As expected, the industry-specific results (presented in Table A.5) exhibit considerable heterogeneity among both the internet connectivity and digital trade provision variables as well as the controls for PTA and EU membership. For HIEs, internet use is associated with significantly higher trade in other business services and significantly lower trade in textiles, basic metals, fabricated metals, and electronics manufacturing. These results could indicate the shifting composition of HIE exports in our sample from manufacturing to services. For LIEs, increased internet use is associated with greatly increased trade in other business services (82 percent higher for a one standard deviation increase in internet use, std. error 64.2) and more moderately increased trade in agriculture and electronics manufacturing. These positive impacts in goods sectors for LIEs point to the role of the internet in increasing access to other markets. Meanwhile, there appears to be a significant negative relationship between internet use and LIE exports of mining and textile products, which are unsurprisingly two of the least technology-intensive industries. Finally, bandwidth is associated with significantly higher trade in textiles, fabricated metals, and electronics — and significantly lower trade in chemicals, basic metals, business services, and travel and transportation services.

The industry-specific results also show that although digital trade policies do not appear to have a systematic impact on LIEs overall, they do increase trade in specific industries. For LIEs, the inclusion of digital provisions significantly increases trade in travel and transport services and fabricated metals manufacturing. For HIEs, digital provisions significantly increase trade in agriculture, mining, and food manufacturing — as well as financial, business, and travel and transport services. The provisions are associated with significantly lower trade in chemicals for HIEs and transport equipment and other business services for LIEs.

3.3.4. Alternative groupings of countries and sectors

While the main specifications in our paper consider the differential effects of internet connectivity and digital trade provisions across HIEs and LIEs, and goods and services trade, we also consider two alternative groupings of the data. First, as an alternative to the differentiation between HIEs and LIEs, Table A.6 instead looks at the differential impact of internet connectivity across different levels of importer trade openness. For goods trade (column 1) we separate importing countries into groups with high and low trade barriers using the median value of the trade restriction index developed by Kee et al. (2009). In particular, we use the overall trade restrictiveness index (OTRI), which captures the impact of each country's trade policies on its aggregate goods imports taking into account both tariff and non-tariff measures. The OTRI was compiled using data from 1994–2004, and covers 98 countries. For services trade (column 2), we separate importing countries using the World Bank and WTO (2020) Services Trade Restrictions Index (STRI). For each importer, we first calculate the average STRI across individual service sectors. We then use the median value of these average STRIs to separate importers into high and low trade restrictions categories. The STRI represents conditions in 2016–2021, but has considerably higher country coverage (134) than other measures of trade barriers in services.

The results of this analysis (Table A.6) show that for goods, internet connectivity increases trade with both high and low restriction importers. This could reflect that the role of the internet as primarily an information-improving technology for goods trade rather than a direct trade channel. In contrast, while low-restriction importers still see an increase in services trade as internet connectivity improves, high-restriction importers see a significant decline in trade as internet connectivity increases. This may reflect some of the digital-trade limiting policies in high-restriction countries, such as requirements to establish local affiliates to trade cross-border or data localization measures. Finally, the presence of digital trade provisions in trade agreements significantly increases trade with both high- and low-restriction services importers, but significantly decreases goods trade with low-restriction importers.

Next, as an alternative to the separation of the data into goods and services sectors, columns (3) and (4) of Table A.6 instead separate the data based on the importance of information technology services as inputs to gross exports. In particular, using the OECD Trade in Value Added (TiVA) database (OECD, 2021), we calculate the share of total value-added in gross exports originating in either the computer services or telecommunications sectors. In each year of the data, sector-level observations above (below) the median share of value-added are coded as high-IT (low-IT) exports. The data is then aggregated across high-IT and low-IT export flows. The results show that the impact of internet connectivity is positive and significant for both high-IT and low-IT exports from HIEs. For LIEs, low-IT exports are significantly increased by internet use while high-IT exports are unaffected. Digital trade provisions only significantly increase trade for high-IT exports from HIEs; all other provision estimates are insignificant.

3.3.5. Technical robustness tests

Finally, we consider a collection of models that test the robustness of the technical approach. These tests include the use of a bias-correcting PPML estimator and a series of regressions that use interval data. Both tests are common in the gravity literature and demonstrate that our results are robust to these considerations.

In their recent work, Weidner and Zylkin (2021) find that "three-way" gravity models that include exporter-year, importer-year, and exporter-importer fixed effects may result in consequential biases due to the incidental parameter problem. The authors show that while inconsistency is not a source of bias in three-way-PPML gravity models, there may be a concern with asymptotic bias in the point estimates.[30] To mitigate these issues, they recommend using a bias correction as part of the estimation procedure. We conduct such a correction for our main specification. The bias correction, which is presented in Table A.7, yields results that are largely consistent with the original estimates. The main difference is that the bias correction produces larger standard errors for many of the estimates. While these larger standard errors lower the level of statistical significance for bandwidth and internet use for LIEs, both remain significant at conventional levels. Notably, the bias correction also produces larger estimates for both of the internet use terms and for the provision indicator for HIEs (the direct effect of internet use increases to a 46 and 51 percent increase in trade for HIEs and LIEs, respectively). Meanwhile, the estimate for bandwidth is slightly smaller. The remaining variables produced insignificant estimates, as before.

Many gravity studies in the past have argued the benefits of using interval data in which discontinuous years are included. Such approaches are sometimes said to allow for improved estimation of factors for which adjustments may not be immediate and impacts take several years to fully manifest. To explore this possibility, we consider two specifications based on three-year and five-year intervals.[31] Overall, the interval results (presented in Table A.7) are consistent with the main results in sign and significance but vary slightly is magnitude in some cases. When using the three-year interval results, the internet

[29] These industries are not inclusive of all trade.

[30] In particular, this bias can lead to a distribution of estimated β values that are not centered around the "true" β value as N approaches infinity.

[31] The three-year intervals include the years 2000, 2003, 2006, 2009, 2012 and 2015. The five-year intervals include 2000, 2005, 2010, and 2015.

use and bandwidth estimates are quite a bit larger than in the main specification. Meanwhile, the digital trade provision estimates are of a similar magnitude. When using the five-year interval results, internet use for LIEs, bandwidth, and digital provisions for HIEs are all larger than in the main specification while internet use for HIEs is a bit smaller.

Taken together, these robustness tests demonstrate the validity of our main findings and, in some cases, suggest that impacts of certain factors like internet use may be larger than previously indicated.

4. The global impacts of digital trade on welfare and development

In the previous sections, we found robust evidence that internet connectivity and digital provisions have had large positive impacts on bilateral trade. In this section, we extend this analysis and demonstrate the potential trade and welfare gains that could occur if connectivity and digital provisions were further expanded. We examine two scenarios that explore both of these channels. First, we consider a hypothetical scenario in which Nigeria — a developing Sub-Saharan country with relatively low internet use in 2016 — were to increase their internet connectivity. We find that doing so would substantially increase their international trade and significantly grow their GDP, suggesting that the expansion of internet connectivity could be a powerful means of economic development in areas where internet use remains low. Second, we examine the impacts on services trade of introducing digital provisions to the India–Japan free trade agreement. We find that this would result in sizeable gains for both India and Japan, highlighting the benefits of these provisions as facilitators of trade and economic growth.

4.1. Model description

The analysis is conducted using a general equilibrium version of a gravity model, one of the most widely used quantitative trade models in recent years. The model is an adaptation of the framework described by Anderson et al. (2018b) and Yotov et al. (2016), which is based on the structural gravity models of Anderson (1979) and Anderson and van Wincoop (2003). Notably, this model framework is representative of a wide range of trade models (Arkolakis et al., 2012).

The model is given by the following system:

$$X_{ijt} = \frac{Y_{it} E_{jt}}{Y_t} \left(\frac{\tau_{ijt}}{\Pi_{it} P_{jt}} \right)^{1-\sigma}, \tag{2}$$

$$\Pi_{it}^{1-\sigma} = \sum_j \left(\frac{\tau_{ijt}}{P_{jt}} \right)^{1-\sigma} \frac{E_{jt}}{Y_t}, \tag{3}$$

$$P_{jt}^{1-\sigma} = \sum_i \left(\frac{\tau_{ijt}}{\Pi_{it}} \right)^{1-\sigma} \frac{Y_{it}}{Y_t}, \tag{4}$$

$$p_{it} = \left(\frac{Y_{it}}{Y_t} \right)^{\frac{1}{1-\sigma}} \frac{1}{\gamma_{it} \Pi_{it}}, \tag{5}$$

$$E_{it} = \phi_{it} Y_{it} = \phi_{it} p_{it} Q_{it}. \tag{6}$$

Eqs. (2), (3), and (4) reflect the structural gravity model of Anderson and van Wincoop (2003). In Eq. (2), exports from country i to country j in period t (X_{ijt}) are determined by two components. The first reflects each country's market size, determined by the exporter's output (Y_{it}), the importer's expenditures (E_{jt}), and global output (Y_t). The second component reflects trade costs and is composed of bilateral trade costs (τ_{ijt}) and the "multilateral resistance" terms Π_{it} and P_{jt}, which aggregate the trade costs exporter i and importer j face in the world market. The parameter σ is the elasticity of substitution between different varieties. The outward multilateral resistance term, denoted by Π_{it} and defined by Eq. (3), is an aggregate trade cost index for products sourced from exporter i. Similarly, the inward multilateral resistance term, denoted by P_{jt} and defined by Eq. (4), is an aggregate trade cost index for the importer and reflects the constant elasticity of substitution (CES) demand price index.

Eqs. (5) and (6) introduce some additional features to the standard gravity model. Eq. (5) determines the price level for producers in country i. Producer prices (p_{it}) are a function of output, the country's aggregate trade costs, and the CES share parameter (γ_{jt}). Finally, Eq. (6) is a market clearing condition in which expenditures are equal to a fixed ratio (ϕ_{it}) of the country's output, which is the product of price and output quantity (Q_{it}).

The system given by Eqs. (2)–(6) is often referred to as a general equilibrium version of the gravity model. It is able to quantify the direct and indirect effects of a change in trade costs, thereby providing a measure of the total impact of the change. The total impact can be thought of as the culmination of three levels of effects. The first-order effects are those on trade flows stemming directly from changes to bilateral trade frictions via τ_{ijt} in Eq. (2). Higher bilateral trade costs result in lower bilateral trade, *ceterus paribus*, and vice versa. These are the effects captured by the partial effects calculations presented throughout the previous section. The second-order effects are those arising from the multilateral resistance terms. Since multilateral resistance terms capture all trade costs an importer or exporter face in the global market, a change in bilateral trade costs can affect aggregate costs and potentially create or divert trade with other third-party partners throughout the world. For example, decreases in trade costs between the United States and Nigeria could reduce trade between Nigeria and other partners like India because of trade diversion, even if Nigeria and India's respective bilateral trade costs are unchanged. The specific changes in multilateral resistances among all other countries are based on their characteristics and global trade patterns, and therefore reflect important considerations like remoteness, trade openness, and comparative advantage. Finally, the third-order effects are those resulting from changes to income. Changes in trade costs and the prices of imports and exports can result in income growth, which may cause countries to import more from all sources. Alternatively, price changes could result in lower income and reduced imports. The combined effects of these three channels provides a general equilibrium estimate of the likely impacts of a change in trade frictions on the global economy.

4.2. Improved internet use in Nigeria

We first use the general equilibrium model to assess the impacts of a change in internet connectivity. To do so, we consider a hypothetical scenario as a case in point in which Nigeria was to increase the share of its population using the internet. In 2016, the base year for our analysis, only about 26 percent of Nigerians were using the internet. By comparison, Brazil, another developing economy with a similar population, had a much higher rate of internet use — about 61 percent of the population. In our counterfactual experiment, we consider the impacts of increasing internet use in Nigeria to the level of Brazil, reflecting an increase of internet connectivity of about 35 percentage points for Nigeria's population.[32] This hypothetical simulation is informative of not only the specific case of Nigeria, but also the potential impacts of internet development around the world. While the model results are specific to Nigeria, the general findings are indicative of the type of economic gains that could be attained in other developing countries.

Increased internet use in Nigeria would be expected to have several effects. In general, it would increase connectivity among the Nigerian

[32] It should be noted that internet use has grown in Nigeria since 2016. By 2019, about 42 percent of the population used the internet. As a result, our estimates based on 2016 may overstate the impact of the counterfactual experiment were it conducted using more recent years as a baseline. Nonetheless, the analysis remains illustrative of the large potential gains to increasing internet use among less-connected populations, particularly since 42 percent internet connectivity is still well below the rates in most high-income countries.

population and with the rest of the world. Given the empirical estimates described in the preceding section, this would lower trade costs within the Nigerian domestic market as well as with each of its foreign trading partners. The first order direct effects would be an increase in both domestic and international trade for Nigeria. This growth in trade would then prompt trade adjustments globally. For example, increased trade between Nigeria and more internet-connected markets could divert trade away from some of Nigeria's less internet-connected partners. Meanwhile, those markets may adjust trade with their other partners in response, resulting in trade creation and diversion among countries other than Nigeria. Finally, the change in internet use would likely leave Nigeria wealthier due to lower trade costs and more favorable prices. This growth in wealth would lead to increased domestic sales and international imports, particularly from the markets experiencing the largest relative reductions in costs. The combined impacts from all three of these effects would likely benefit Nigeria's economy and result in heterogeneous outcomes for other countries.

To conduct the general equilibrium analysis, we use most of the same data that were used to estimate the econometric models in Section 3. The only change is that we replace the trade flows data with values from an alternative source. Because the ITPD-E data used for estimation is composed of "raw" administrative data, there are some trade flows that are missing due to unreported trade. As a result, the panel of trade flows is not perfectly balanced, which is important for conducting general equilibrium counterfactual simulations with the model. For this reason, we turn to the Eora input–output database, which does provide balanced trade flows (Lenzen et al., 2012, 2013). While there are several other prominent input–output databases with appropriately balanced trade data, Eora provides the greatest country coverage and is one of the only databases with extensive coverage of developing countries for the time period we consider.[33]

Using the Eora trade data and the internet connectivity, digital provision, and other gravity data described in the previous sections, we construct a baseline for the general equilibrium model. The model baseline includes a smaller sample of 60 of the highest trading countries, representing more than 95 percent of global trade and a mix of high- and low-income countries. Output and expenditure values were constructed by summing all exports and imports, respectively, including domestic trade values in both cases. The model assumes an elasticity of substitution of 7, following the related literature (Head and Mayer, 2014).

The analysis was conducted in several steps. First, the baseline model was solved by calculating aggregate trade costs using the trade cost estimates (internet connectivity, digital trade provisions, PTA and EU membership, international-border fixed effects, and exporter-importer fixed effects) from column (3) of Table 5.[34] Second, the derived trade costs were used to solve for baseline inward and outward multilateral resistances.[35] Third, counterfactual trade costs were constructed by raising Nigeria's internet use rate from 26 percent to 61 percent and recomputing our bilateral internet use index for Nigeria and all of its partners ($IU'_{ij,2016}$). Finally, the model was re-solved using the modified trade costs, producing counterfactual multilateral resistances, prices, trade flows, and other economic indicators such as changes to real GDP, which is the primary measure of welfare considered.[36]

Table 7
Global effects of increased internet use in Nigeria, percent changes.

Country	Exports	GDP	Country	Exports	GDP
Argentina	0.01	0.00	Lithuania	0.01	0.00
Australia	0.01	0.01	Luxembourg	0.01	0.02
Austria	0.01	0.01	Malaysia	0.01	0.01
Bangladesh	−0.02	−0.06	Mexico	0.00	−0.01
Belgium	0.01	0.01	Netherlands	0.02	0.01
Brazil	0.01	−0.01	Nigeria	**9.16**	**17.57**
Bulgaria	0.00	−0.01	Norway	0.02	0.02
Cambodia	−0.01	−0.04	Pakistan	−0.03	−0.06
Canada	0.02	0.01	Peru	−0.00	−0.02
Chile	0.01	0.01	Philippines	0.00	−0.01
China	−0.01	−0.01	Poland	0.01	0.00
Costa Rica	0.00	−0.00	Portugal	0.01	0.00
Czechia	0.01	0.00	Romania	0.00	−0.01
Denmark	0.02	0.02	Russia	0.01	0.00
Ecuador	0.00	−0.01	Saudi Arabia	0.01	0.00
Egypt	−0.01	−0.03	Singapore	0.01	0.01
Finland	0.01	0.01	Slovakia	0.01	0.01
France	0.01	0.01	Slovenia	0.01	0.00
Germany	0.02	0.01	South Africa	0.00	−0.01
Greece	0.01	−0.00	South Korea	0.02	0.02
Hong Kong	0.01	0.01	Spain	0.01	0.01
Hungary	0.01	0.01	Sri Lanka	−0.02	−0.06
India	−0.03	−0.05	Sweden	0.01	0.01
Indonesia	−0.02	−0.05	Switzerland	0.01	0.01
Iran	0.00	−0.02	Thailand	−0.00	−0.02
Ireland	0.01	0.01	Turkey	0.00	−0.01
Israel	0.01	0.01	Ukraine	−0.00	−0.02
Italy	0.00	−0.01	United Kingdom	0.02	0.02
Japan	0.03	0.02	United States	0.04	0.01
Kazakhstan	0.01	0.00	Vietnam	0.00	−0.02

Note: This table reports the estimated impacts of a hypothetical scenario in which 2016 internet usage in Nigeria was raised to the level of Brazil. Reported values reflect percent changes in the exports and real GDPs of each country as a result of the change.

The results indicate that increasing internet use in Nigeria would increase its connectivity to the world and likely have large positive effects on the Nigerian economy and small, mixed effects for most other countries. Table 7 presents the estimated impacts of the hypothetical scenario on total exports and GDP in each of the countries in the sample. The most important effects are on the Nigerian economy. As a result of this increase in internet connectivity, Nigeria can more easily trade with other countries, particularly large developed markets, and increases both its exports and GDP. Overall, Nigerian exports increase by more than 9 percent (about \$3.2 billion), demonstrating the significant role of internet use as a means of trade facilitation. The growth is fueled primarily by increased exports to large, developed, and highly internet-connected countries such as the United States, Spain, and Germany. However, there are also reductions in some of Nigeria's exports, mostly among less developed and less internet-connected countries, including India, Indonesia, and China. The change in internet use has a relatively large impact on Nigeria's domestic trade. Despite the fact that internet use lowers domestic trade costs, trade diversion towards foreign markets more than fully offsets the effects of lower domestic costs, resulting in almost 19 percent less domestic trade.

The increase in Nigerian internet use results in more favorable prices for both producers and consumers in Nigeria. For producers, the reduction in trade costs reduces their portion of the cost burden and raise the prices they receive for their output. Similarly, for consumers,

[33] A notable limitation of the Eora database is that it necessarily relies more heavily on data imputation methods than other prominent balanced databases, which allows for its greater country coverage. While this means that it may be poorly suited for use in estimations, data imputation is not as significant of a concern for these counterfactual simulations.

[34] Specifically, we calculate $\hat{\tau}_{ij,2016}^{1-\sigma} = \exp\{0.017EU_{ij,2016} + IU_{ij,2016} \times (1.930 \times 1_{HIE} + 1.780 \times 1_{LIE}) + 0.463BW_{ij,2016} + PTA_{ij,2016} \times \left(0.046 + DFP_{ij,2016} \times (0.120 \times 1_{HIE} + 0.062 \times 1_{LIE})\right) + \hat{b}_{2016} + \hat{\rho_{ij}}\}$, where 1 denotes an indicator for a high- or low-income exporter. Column (3) was chosen over column (5) based on the pseudo R^2 and AIC, which suggest the column (3) specification provides a better fit.

[35] The multilateral resistance terms are only determined up to a linear transformation so a single term is set as a numeraire. Following the past literature, we use the inward multilateral resistance of Germany as that numeraire.

[36] The analysis was completed using the *gegravity* Python package of Herman (2021).

Table 8
Global effects of increased internet use in Nigeria by country-type, percent and dollar changes.

Countries	Imports from Nigeria (%)	Imports from Nigeria ($M)	Exports to Nigeria (%)	Exports to Nigeria ($M)	GDP (%)	GDP ($M)
High income	12.6	3985	12.5	4683	0.0037	4889
Low income	−18.9	−584	−18.7	−967	−0.0421	−3452
High internet use	19.0	5652	18.5	5442	0.0080	8449
Low internet use	−8.2	−408	−7.7	−1006	−0.0199	−7012
European Union	18.3	2469	17.8	3,310	0.0083	2873
United States	21.9	2608	21.2	722	0.0071	2404
China	−3.3	−53	−2.7	−193	−0.0128	−3303

Note: This table reports the estimated impacts of a hypothetical scenario in which 2016 internet usage in Nigeria was raised to the level of Brazil. In several cases, outcomes for individual countries have been aggregated based on income level or rates of internet use. Nigeria is not included in any of the groups of countries. Reported values reflect changes in respective outcomes as a result of the scenario. ($M) denotes millions of U.S. dollars.

the reduction in trade costs lowers the price of both foreign and domestic products. As a result, Nigerians earn higher incomes that — in combination with lower consumption prices — can buy more, resulting in substantially improved purchasing power and welfare. The joint effect of these price changes is a large increase in Nigeria's real GDP of nearly 18 percent (more than $72 billion).

Throughout the rest of the world, the effects differ across countries. Most countries tend to increase exports to Nigeria, due both to the reduction in trade costs from the increase in internet use and Nigeria's GDP growth, which spurs increased demand for foreign imports generally. Overall, about two thirds of countries experience some growth in exports to Nigeria. As shown in Table 8, the largest gains are experienced by high income countries and those with high internet use like the United Kingdom, Germany, and the United States. Overall, the impacts on other countries are relatively small in magnitude as Nigeria is not an especially intensive trading partner for any of them — although they still amount to billions of dollars in trade in some cases.

However, despite the mostly positive outcomes for Nigeria and many other countries, there are countries that are made worse off by Nigeria increasing internet access. Low income developing countries with relatively limited internet use tend to trade less and have lower GDPs under the hypothetical scenario. A consequence of Nigeria growing as a trading partner throughout the world is that some of that growth manifests as trade diversion from other countries. Some countries, such as China, experience lower trade with both Nigeria and many of the developed countries that trade more intensively with Nigeria, suggesting broad trade diversion. Others, such as India and Indonesia, benefit from greater wealth throughout much of the world and experience increased exports to most countries rather than diversion. However, this third order trade growth is typically insufficient to offset the large reductions in trade with Nigeria itself, resulting in reductions in exports and GDP overall. Pakistan, Sri Lanka, and Bangladesh — which had the three lowest rates of internet use within the sample — experience the largest reductions in GDP (about 0.06–0.07 percent). Across all low income countries in the model, exports to Nigeria and GDP decline by a combined $1.0 and $3.5 billion, respectively (Table 8). Similarly, countries with low internet use see exports and GDP decline by a combined $1.0 and $7.0 billion, respectively.[37] These results suggest that there is a risk among less developed countries of being left behind if they are unable to match the development or trade promotion occurring in other developing countries, which is consistent with the earlier findings of Clarke and Wallsten (2006). Those that develop most rapidly or adopt the most significant trade facilitation practices, as is the case with Nigeria unilaterally increasing their internet use in the hypothetical scenario, can indirectly damage others by diverting economic activity. An important implication is that there is a risk that developing countries will fail to share in the global gains from the growing digital economy if they are left behind in terms of internet access.

[37] The estimated combined impacts for low-income and low internet use countries do not include the impacts for Nigeria.

4.3. Adoption of additional digital provisions in the India - Japan FTA

To examine the impacts of digital provisions, we conduct a second counterfactual exercise looking at the effects on services trade of increasing the digital provisions in a trade agreement. We consider the India–Japan trade agreement, which has been in effect since 2011 and features no digital trade chapter nor any of the provisions covered by the 7 categories described in Section 2.2. This agreement represents a useful example as it is comprised of a high- and low-income country that both trade extensively in services. The largest positive effects of digital provisions were found for services trade so we narrow the focus of the general equilibrium model to only services trade. Similarly, we narrow our main measure of welfare from total real GDP to just real services output. Because services trade data is sparser than goods trade, the number of countries included in the model is reduced to 41, covering about 92 percent of services trade.[38]

The experiment is conducted by adjusting the provision index to reflect increasing the number of digital provisions from 0 to 7 in the India–Japan FTA. Trade costs were constructed using the estimates from column (4) of Table 6, which included the continuous digital provision index and was estimated using services trade only. Within this specification, digital provisions had a statistically significant impact for only HIEs. To reflect this finding, the counterfactual simulation altered only the costs of exports from Japan to India and not the reciprocal flow.

Table 9 presents the estimated general equilibrium impacts for India, Japan, the European Union, the United States, and the rest of the world combined.[39] The adoption of digital provisions in the India–Japan FTA would have a positive impact on both member countries. Japan would increase exports to India by nearly 42 percent, due largely to the lower costs of exporting services under the agreement. Overall, Japan and India increase their total services trade globally by hundreds of millions of dollars and increase their real services output by more than $13 and $12 billion, respectively. The gains for Japan are largely driven by higher factory gate prices and incomes derived from services. Meanwhile, the gains for India are primarily driven by lower prices on purchased services. The impacts for the other 39 countries are all small, negative, and of comparable magnitude. These impacts largely reflect extensive trade diversion. As India and Japan trade more extensively together thanks to lower costs of doing so, all other countries must adjust their trade patterns. For example, services previously exported to India (or imported from Japan) must find new destinations (or sources), either domestically or internationally. Importantly, the new trading patterns exhibit higher trade costs, less favorable prices, and lower volumes. Together, these trade adjustments would result in decreases

[38] The limiting factor is the country-pair fixed effects, which cannot be estimated for countries that never trade services within the time period of the panel.

[39] A full presentation of results for each individual country is included in Table A.8 in the appendix.

Table 9
Global effects on services trade of adopting digital provisions in the India–Japan FTA, percent and dollar changes.

Countries	Imports (%)	Imports ($M)	Exports (%)	Exports ($M)	Output (%)	Output ($M)
Japan	0.623	691	0.630	354	0.228	13,403
India	0.773	174	0.780	312	0.758	12,372
European Union	−0.036	−272	−0.036	−317	−0.0229	−4,894
United States	−0.143	−596	−0.148	−123	−0.0170	−4,248
Rest of world	−0.028	−54	−0.028	−125	−0.0313	−1,657

Note: This table reports the estimated impacts of a hypothetical scenario in which 7 categories of digital provisions were added to the India–Japan FTA. In several cases, outcomes for individual countries have been aggregated together. Reported values reflect changes in respective outcomes as a result of the scenario. ($M) denotes millions of U.S. dollars. Full results are available in Table A.8 in the appendix.

in real services output of $4 to $5 billion for the United States and European Union, and a combined $1.7 billion for the rest of the countries in the model.

5. Conclusion

This work examines the impact of internet connectivity and digital trade provisions within trade agreements on trade. Using a theoretically motivated gravity model, we find new evidence that internet connectivity and digital provisions can represent powerful means of facilitating trade for both high- and low-income countries. Internet connectivity has significantly increased trade in both goods and services, for both LIEs and HIEs, and at both the intensive and the extensive margin. We also find that digital provisions can increase trade but that the effect is primarily on HIEs and trade in services. These findings highlight the different roles that digital policies play for goods and services. While increased connectivity benefits both goods and services, digital trade provisions appear to be primarily beneficial for services trade.

Informed by these findings, we estimate the general equilibrium impacts of two hypothetical scenarios. The first examines an increase in internet use in a developing country while the second examines the introduction of digital provisions to a trade agreement that does not feature any. In the first scenario, we find that if Nigeria were to increase its internet use up to the levels of Brazil, the global impacts could be considerable. Nigeria's total exports would increase by more than 9 percent and its GDP would grow by more than 17 percent. This change would benefit many other countries, particularly developed countries with high internet use, but would come at a cost to less developed countries were they to not make similar improvements in internet access. Thus, while the scenario makes clear the potential gains from internet connectivity, it also highlights the danger of developing countries falling behind as the digital economy continues to grow. In the second scenario, we find that if the 2011 India–Japan FTA was expanded to include digital provisions, both countries would experience large increases in their services trade and output.

As trade becomes increasingly reliant on digital connectivity, understanding the implications of internet technology and the policies that govern it for growth and welfare is crucial. Our results highlight that improvements to internet connectivity and the inclusion of digital trade provisions in trade agreements have different contributions to trade patterns. Internet connectivity increases trade for a wide range of countries and sectors, and can have considerable welfare benefits. On the other hand, the benefits of digital policies are less widespread but can have large positive impacts on certain industries and exporters. Thus, as policy makers move to incorporate digital trade in their development strategies, improved internet infrastructure may be a more effective immediate goal than deepening trade agreements to include digital trade provisions. As the digital landscape and related technology continues to evolve, future research should also pay special attention to the development implications of internet connectivity and digital policies.

CRediT authorship contribution statement

Peter R. Herman: Conceptualization, Methodology, Formal analysis, Data curation, Writing – original draft, Writing – review & editing. **Sarah Oliver:** Conceptualization, Methodology, Formal analysis, Data curation, Writing – original draft, Writing – review & editing, Visualization.

Data availability

The replication data and code files for this article are available in the Harvard Dataverse (https://doi.org/10.7910/DVN/X4AC4S).

Appendix A

A.1. Additional results

See Tables A.1–A.8.

Table A.1
Effects of internet connectivity and digital provisions on the extensive margin of trade.

	All sectors (1)	Goods (2)	Services (3)
PTA	0.439***	0.446***	0.238***
	(0.00532)	(0.00548)	(0.0125)
EU membership	0.723***	0.0246	0.293***
	(0.0264)	(0.0251)	(0.0256)
Internet use × HIE	0.552***	0.260***	1.248***
	(0.0265)	(0.0260)	(0.0651)
Internet use × LIE	0.156**	−0.211***	1.169***
	(0.0637)	(0.0640)	(0.189)
Bandwidth	−7.355***	−8.273***	−0.919***
	(2.315)	(1.970)	(0.281)
Any provision × HIE	−0.0277**	0.0266**	0.125***
	(0.0113)	(0.0115)	(0.0216)
Any provision × LIE	−0.0647**	0.0117	0.285***
	(0.0277)	(0.0295)	(0.0442)
Distance (log)	−0.837***	−0.836***	−0.250***
	(0.00463)	(0.00471)	(0.00867)
Contiguity	0.943***	1.058***	0.145***
	(0.0193)	(0.0214)	(0.0219)
Common language	0.501***	0.506***	−0.0149
	(0.00423)	(0.00433)	(0.0110)
Colonial relationship	0.652***	0.791***	0.0453**
	(0.0162)	(0.0181)	(0.0218)
Dependent variable	Product count	Product count	Product count
Observations	614,552	613,154	54,663
R^2	0.878	0.874	0.862
AIC	589097.6	582686	66129

Note: This table reports estimates derived using a flexible Bernoulli pseudo maximum likelihood estimator as proposed by Santos Silva et al. (2014). The services results are restricted to the period of 2005–2016 due to convergence issues seemingly related to sparsely recorded services flows in earlier years. All models include exporter-year, importer-year, and border-year fixed effects, which are omitted for brevity. HIE and LIE denote high-income exporter and low-income exporter, respectively. Robust standard errors reported in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A.2
Correlation between digital trade provisions.

	Free data flows	Technological neutrality	Customs duties prohibition	Data protection	Electronic authentication	Cybersecurity	Big Data
Data flow measures	1						
Technological Neutrality	0.06	1					
Customs Duties Prohibition	0.88	0.07	1				
Data Protection	0.97	0.07	0.90	1			
E-Signatures	0.88	0.13	0.87	0.90	1		
Cybersecurity	0.22	0.12	0.19	0.28	0.49	1	
Big Data	0.83	0.09	0.84	0.85	0.75	0.19	1

Table A.3
Estimated effects of individual digital trade provisions.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
PTA	0.0515	0.0736*	0.102**	0.101**	0.0603	0.0983**	0.0826*	0.00297
	(0.0447)	(0.0418)	(0.0457)	(0.0449)	(0.0462)	(0.0442)	(0.0445)	(0.0439)
EU membership	−0.00604	0.101**	0.0970**	0.0941**	0.000622	0.126***	0.0437	−0.00983
	(0.0466)	(0.0431)	(0.0429)	(0.0429)	(0.0473)	(0.0415)	(0.0466)	(0.0457)
Internet use	1.935***	1.985***	1.987***	1.987***	1.925***	1.918***	1.961***	1.831***
	(0.431)	(0.430)	(0.431)	(0.431)	(0.431)	(0.410)	(0.436)	(0.406)
Bandwidth	0.447**	0.461**	0.473***	0.472***	0.451**	0.505***	0.466***	0.466***
	(0.182)	(0.180)	(0.181)	(0.181)	(0.181)	(0.176)	(0.181)	(0.175)
Free data flow	0.150***							0.134***
	(0.0270)							(0.0450)
Technological neutrality		0.387*						0.370*
		(0.211)						(0.189)
Customs duties prohibition			0.00485					−0.0481
			(0.0283)					(0.0601)
Electronic authentication				0.00894				0.0835
				(0.0273)				(0.0574)
Data protection					0.140***			0.0539
					(0.0280)			(0.0455)
Cybersecurity						−0.178***		−0.241***
						(0.0509)		(0.0529)
Big data							0.0650**	−0.0132
							(0.0279)	(0.0326)
Dependent variable	Trade value	Trade value	Trade value	Trade value	Trade value	Trade value	Trade value	Trade value
Observations	613,179	613,179	613,179	613,179	613,179	613,179	613,179	613,179
Pseudo R^2 0.998	0.998	0.998	0.998	0.998	0.998	0.998	0.998	
AIC	36053061	36117032	36165455	36164900	36067789	35917557	36140303	35645862

Note: This table presents estimates derived from the gravity model of trade, estimated via PPML. Exporter-importer, exporter-year, importer-year, and border-year fixed effects were included all specifications in this table but not reported for brevity. HIE and LIE denote high-income exporter and low-income exporter, respectively. Standard errors were clustered at the country-pair level and are reported in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A.4
Composition of individual industries.

Sector	ITPD-E Codes	Average Trade (millions $) 2000–2016
Agriculture	1–26	94.0
Mining	27–33	169.1
Food	34–51	94.5
Textiles	52–62	35.6
Chemicals	81–88	83.4
Basic metals	93–103	92.5
Fabricated metals	105–120	61.8
Electronics	124–137	111.2
Transport equipment	138–147	100.5
Finance	159–160	1,361.2
Business services	162–163	2,751.1
Transport/travel	156–157	1,466.8

Table A.5
Estimated effects in individual industries.

	Agriculture	Mining	Food	Textiles	Chemicals	Basic metals	Fabricated metals	Electronics	Transport equipment	Finance	Business services	Travel & Transportation
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
PTA	−0.0409	−0.236***	−0.0289	−0.0678	0.0374	0.321**	0.0435	−0.149***	0.0301	−0.138	0.218*	−0.192**
	(0.0346)	(0.0768)	(0.0382)	(0.0673)	(0.0370)	(0.127)	(0.0281)	(0.0512)	(0.0592)	(0.223)	(0.129)	(0.0814)
EU membership	0.714***	0.852***	0.852***	−0.224***	0.379***	0.295***	0.0569	0.181**	−0.129	0.551**	0.457**	0.239***
	(0.0892)	(0.213)	(0.0796)	(0.0824)	(0.0736)	(0.0719)	(0.0663)	(0.0815)	(0.112)	(0.235)	(0.204)	(0.0873)
Internet use × HIE	0.369	−0.531	0.145	−1.472***	−0.360	−0.834**	−0.914***	−0.934***	−0.290	0.884	2.745***	0.166
	(0.237)	(0.419)	(0.189)	(0.348)	(0.222)	(0.378)	(0.201)	(0.231)	(0.290)	(1.283)	(0.622)	(0.434)
Internet use × LIE	1.561**	−1.855*	0.00607	−1.479*	−0.467	−0.838	0.221	1.664**	0.364	1.213	3.671*	−0.244
	(0.612)	(1.087)	(0.608)	(0.835)	(0.701)	(0.886)	(0.643)	(0.789)	(0.872)	(3.230)	(2.152)	(1.706)
Bandwidth	−1.097	0.410	−0.610	4.184*	−6.092*	−2.268*	2.165**	3.966**	−2.253	−0.504	−1.243***	−1.227***
	(0.765)	(2.644)	(0.407)	(2.276)	(3.411)	(1.171)	(0.953)	(1.585)	(1.867)	(0.322)	(0.330)	(0.318)
Any provision × HIE	0.0724**	0.262***	0.161***	−0.0624	−0.0620**	−0.0820	0.0192	−0.0481	−0.00114	0.705***	0.306**	0.320***
	(0.0347)	(0.0807)	(0.0310)	(0.0618)	(0.0293)	(0.0772)	(0.0311)	(0.0443)	(0.0457)	(0.184)	(0.140)	(0.0542)
Any provision × LIE	0.00300	−0.0294	−0.104	−0.0685	−0.0916	0.0108	0.202*	0.111	−0.220*	−0.150	−0.685***	0.222*
	(0.141)	(0.198)	(0.0931)	(0.111)	(0.101)	(0.103)	(0.103)	(0.130)	(0.132)	(0.289)	(0.191)	(0.120)
Observations	380,317	297,422	490,074	506,544	484,928	449,041	506,697	522,332	465,928	54,923	61,341	65,467
Pseudo R^2	0.996	0.989	0.996	0.992	0.994	0.992	0.995	0.994	0.993	0.999	0.998	0.997
AIC	1506728	5479429	1952392	1409326	2376618	3650615	1524339	3316222	3646144	981906	3024380	2735320

Note: This table presents estimates derived from the gravity model of trade, estimated via PPML. Exporter-importer, exporter-year, importer-year, and border-year fixed effects were included all specifications in this table but not reported for brevity. HIE and LIE denote high-income exporter and low-income exporter, respectively. Standard errors were clustered at the country-pair level and are reported in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A.6
Robustness checks: Differences in trade restrictions and information technology (IT) use.

	Trade restrictions		IT use	
	Goods	Services	High-IT exports	Low-IT exports
	(1)	(2)	(3)	(4)
PTA	0.129*	−0.00426	0.0557	0.054
	(0.0729)	(0.0963)	(0.0862)	(0.0447)
EU membership	0.0851	−0.0567	−0.0973	0.142**
	(0.0587)	(0.0800)	(0.0790)	(0.0577)
Internet use × High TRI	2.730***	−1.460*		
	(1.011)	(0.782)		
Internet use × Low TRI	3.495***	2.145***		
	(1.085)	(0.475)		
Internet use × HIE			4.388***	0.782*
			(1.644)	(0.958)
Internet use × LIE			4.393***	0.913
			(1.644)	(0.958)
Bandwidth	−0.311	−1.016***	−0.837*	−0.214
	(1.999)	(0.223)	(0.437)	(0.198)
Any provision × High TRI	0.0501	0.409*		
	(0.0956)	(0.211)		
Any provision × Low TRI	−0.129**	0.392***		
	(0.0619)	(0.109)		
Any provision × HIE			0.199***	0.0146
			(0.0660)	(0.0370)
Any provision × LIE			0.00812	−0.0473
			(0.148)	(0.0951)
Dependent variable	Trade value	Trade value	Trade value	Trade value
Observations	322,579	60,202	203,176	204,809
Pseudo R^2	0.991	0.999	0.995	0.999
AIC	35330717.5	8899373.8	20252598.8	12850360.9

Note: This table presents estimates derived from the gravity model of trade, estimated via PPML. Exporter-importer, exporter-year, importer-year, and border-year fixed effects were included in all specifications but are not reported for brevity. "High TRI" (trade restrictiveness index) and "Low TRI" denote importing countries with above-median and below-median levels of average trade restrictions, respectively. The TRI levels were derived using the Kee et al. (2009) Overall Trade Restrictiveness Index for goods trade and the World Bank/WTO Services Trade Restrictions Index for services trade (World Bank and WTO, 2020). Hi-IT and low-IT exports denote export flows from industries and countries using above-median levels of information technology service inputs, as measured by total value added. HIE and LIE denote high-income exporter and low-income exporter, respectively. Standard errors were clustered at the country-pair level and are reported in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A.7
Robustness checks using bias correction and intervals data.

	Bias Correction (1)	Three-year skip (2)	Five-year skip (3)
PTA	0.0433	0.0908*	0.0710
	(0.061)	(0.0529)	(0.0712)
EU membership	−0.0165	0.00302	−0.0602
	(0.065)	(0.0508)	(0.0686)
Internet use × HIE	2.316***	2.195***	1.546***
	(0.879)	(0.506)	(0.425)
Internet use × LIE	2.501**	2.062**	1.932**
	(1.054)	(0.869)	(0.947)
Bandwidth	0.434*	0.518***	0.549***
	(0.249)	(0.190)	(0.187)
Any provision × HIE	0.148***	0.131***	0.202***
	(0.0395)	(0.0371)	(0.0481)
Any provision × LIE	0.0932	0.0595	0.106
	(0.110)	(0.108)	(0.108)
Dependent variable	Trade value	Trade value	Trade value
Observations	613,179	202,914	129,767
Pseudo R^2	0.998	0.998	0.998
AIC	36163325	11777203	7414949

Note: This table presents estimates derived from the gravity model of trade. Column 1 estimated with Weidner and Zylkin (2021) bias correction. Columns 2-3 estimated via PPML, including every third year of data in column 2 and every fifth year of data in column 5. Exporter-importer, exporter-year, importer-year, and border-year fixed effects were included all specifications in this table but not reported for brevity. HIE and LIE denote high-income exporter and low-income exporter, respectively. Standard errors were clustered at the country-pair level and are reported in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A.8
Full results for the effects of additional provisions in the India–Japan FTA, percent changes.

Country	Exports	Terms of trade	Country	Exports	Output
Austria	−0.027	−0.023	Kyrgyzstan	−0.082	−0.076
Belgium	−0.027	−0.023	Latvia	−0.027	−0.024
Bulgaria	−0.075	−0.063	Lithuania	−0.029	−0.025
Canada	−0.036	−0.030	Luxembourg	−0.021	−0.021
Croatia	−0.030	−0.027	Malta	−0.028	−0.025
Cyprus	−0.028	−0.025	Netherlands	−0.028	−0.022
Czechia	−0.029	−0.025	New Zealand	−0.026	−0.036
Denmark	−0.022	−0.021	Norway	−0.023	−0.031
Estonia	−0.024	−0.023	Poland	−0.033	−0.025
Finland	−0.025	−0.023	Portugal	−0.032	−0.026
France	−0.040	−0.023	Romania	−0.037	−0.030
Germany	−0.042	−0.022	Serbia	−0.039	−0.043
Greece	−0.032	−0.026	Slovakia	−0.027	−0.024
Hong Kong	−0.024	−0.038	Slovenia	−0.029	−0.025
Hungary	−0.028	−0.024	South Korea	−0.029	−0.022
Iceland	−0.019	−0.032	Spain	−0.032	−0.023
India	0.773	0.758	Sweden	−0.026	−0.022
Ireland	−0.026	−0.022	Switzerland	−0.008	−0.045
Israel	−0.034	−0.036	United Kingdom	−0.034	−0.021
Italy	−0.045	−0.027	United States	−0.143	−0.017
Japan	0.623	0.228			

Note: The table reports the estimated impacts of increasing the number of digital provisions in the India–Japan FTA from 0 to 7. Reported values reflect percent changes in the exports and real outputs of services for each country as a result of the change.

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