Trade, Policy, and Economic Development in the Digital Economy

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Abstract

We assess the impact of internet connectivity and digital trade policies on trade and welfare. Using a bilateral measure of internet connectivity, we find a significant positive relationship between the internet and both domestic and international trade for goods and services—at the both the intensive and extensive margin. We also find that digital trade facilitation provisions in trade agreements have significantly increased trade in services but not goods. These findings highlight that digital trade determinants play different roles for goods and services: the internet is beneficial for goods trade but critical for services. Finally, using a general equilibrium model of trade, we assess the trade and welfare impacts of increased internet connectivity in developing countries and find that increases in internet use can have large positive impacts on poorly connected countries. However, it also highlights the danger of developing countries falling behind as the digital economy continues to grow.

Keywords: Digital trade, gravity, internet, development, data policies, international trade, domestic trade, services, extensive margin.

JEL: D600, F140, F680, C540, O300

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1 Introduction

In recent years, trade policy has increasingly looked beyond tariffs and towards non-tariff determinants of trade. As part of that trend, digital trade considerations, such as the use of the internet and transmission of data across borders, 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—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). These chapters cover a wide variety of policies, including the promotion of e-commerce, facilitation of electronic authentication, prohibitions of customs duties on electronic transmissions, provisions related to electronic transfer of data, and protections for consumer data, for example. 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). 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 digital trade determinants play in the global economy.

In this paper, we seek to provide a thorough and contemporary picture of the influences of digital trade determinants. We estimate the impacts of two prominent components of digital trade: internet connectivity and digital trade policies. Our analysis finds that there is a robust role for the internet in trade and that recent digital trade policies have increased trade for at least some sectors of the economy. Given the often large effects of these digital trade determinants on trade, we also examine the potential welfare impacts of increased internet connectivity. We find that even modest increases in internet usage within poorly connected countries could have large, positive, and far reaching impacts on their economy.

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 as well as a direct trade channel for services trade (video streaming vs DVDs, for example) and creation of new types of services (cloud computing, 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 role of the internet on reducing the trade-dampening effects of geographic distance, several studies have found that the internet decreases the effect of distance for goods (Hortasçsu et al., 2009; Lendle et al., 2009) and services (Blum and Goldfarb, 2006; Alaveras and Martens, 2015), but does not eliminate home bias.

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 economic development level of trade partners. Anderson et al. (2018) find that digital infrastructure development 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 across developing countries. Similarly, growth in internet use can drive increased trade. Riker (2014) simulates the effect of developing countries "catching up" to developed country broadband use, and finds a 29 percentage point increase in trade to GDP ratios on average for developing countries.

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 generally, 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 types of services trade flows.

We build on this prior work by examining two aspects of digital trade: internet connectivity and digital facilitation policies in preferential trade agreements (PTA). First, we empirically estimate the impacts of these two trade determinants using a modern, theoretically motivated gravity model of trade. In addition to the digital trade determinants, we include a comprehensive collection of controls to mitigate endogeneity concerns, capture global integration trends, and better identify the true effects of our digital trade factors. Because of these controls, we consider this work an important methodological update of much of the existing empirical literature. The results provide strong evidence that internet connectivity is a powerful means of facilitating trade, especially internationally. A one standard deviation increase in joint internet connectivity between trading partners would increase bilateral trade by more than 38 percent. Second, we find some evidence of positive impacts from recent digital trade facilitation policies for trade in services. Finally, by examining the extensive margin directly, we find that growth in internet connectivity increases the number of products exported for both goods and services exports, though the effect is considerably stronger for services exports. This provides further support for the notion that the internet is a cost reducing factor for goods trade and a significant vehicle for services trade.

To better understand the global impacts of digital trade facilitation, we examine the general equilibrium effects of changes in internet connectivity on trade and welfare.[1] Our analysis considers a hypothetical scenario in which internet connectivity 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 nearly 16 percent increase in real GDP. In the rest of the world, countries with high internet use would mostly benefit from Nigeria's increased internet use due to lower trade costs with Nigeria. Meanwhile, countries with low internet use would largely experience losses due to global trade diversion towards Nigeria. These losses signal risk for developing countries that fall behind in the expanding digital economy.

The remainder of the paper details these findings, the data used, and the methods employed. Section 2 describes our measures of internet connectivity and free data flow provisions. Section 3 describes the empirical approaches and presents their findings. Section 4 describes the general equilibrium model and presents results of the hypothetical scenario involving internet connectivity in Nigeria. Finally, section 5

[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., 2018), Brexit (Brakman et al., 2018), and common language (Gurevich et al., 2021).

concludes.

2 Internet Connectivity and Data Flow Provisions

To study the effects of digital trade determinants, we compile data reflecting two important components of digital trade. The first component is digital connectivity, which we examine using information on internet usage around the world. The second component is digital policies, which we examine by looking at provisions in PTAs that promote the free flow of data across borders via the internet. In this section, we detail these components and the data used to measure them.

2.1 Internet Connectivity

A key component to the digital economy, domestically and internationally, is the use of the internet. In order to communicate or complete transactions over the internet, both partners need access. Thus, general internet connectivity between markets is a necessary starting point for digital trade. To measure internet connectivity, we construct a bilateral measure of internet use that varies across trade partners and time.

To study the effects of internet connectivity on trade, we draw 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.[2] 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 connectivity and build a measure that reflects the likelihood that two people are both connected to the internet. The index (IC_{ijt}) is defined as $IC_{ijt} = \phi_{it} \times \phi_{jt}$ where ϕ_{it} and ϕ_{jt} are the proportion of the population connected to the internet in countries i and j respectively. The constructed index ranges between 1, in which all residents in both countries use the internet, and zero, in which no one in at least one of the countries is a user. Notably, the measure is constructed both internationally ($i \neq j$) and domestically ($i = j$). By treating internet connectivity 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 believe we are able to more effectively capture the important fact that internet connectivity 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,

[2] 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).

we choose to focus on a broad measure of internet use sourced from the International Telecommunication Union (ITU) World Telecommunication/ICT Indicators Database, which provides an annual measure of "Individuals using the internet".[3] 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.). It covers up to 217 countries from 1996 to the present.[4]

Our IC index takes this unilateral measure of internet connectivity 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 of countries only had a 1 percent chance of both being internet users. By 2016, the average index value 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 figure 1. Unsurprisingly, high-income countries 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 middle- and low-income countries has also grown steadily over our sample period, accelerating in more recent years. Nonetheless, there were still large portions of the population without access to the internet at the end of our sample, even among high-income countries.

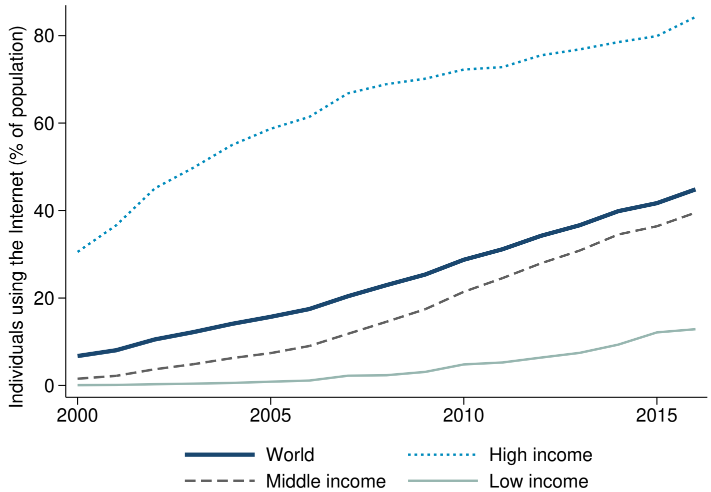
2.2 Free Data Flow Policies in Trade Agreements

In recent years, many countries have adopted digital policies in their trade agreements that seek to promote digital trade. These policies frequently target many different aspects of digital trade such as duty free treatment of electronic transmissions, electronic authentication, cybersecurity, data privacy, free movement of data, and intellectual property rights protection. Given the variety of provisions that can appear under the broad category of "digital trade", we further restrict the policies considered to provisions in trade agreements that promote the free flow of data over the internet between countries. Data flow provisions were selected because they represent some of the most broad-cutting digital trade provisions and they potentially impact all sectors of the economy. This narrowing of focus allows us to eliminate policies that may be sector-specific (such as regulations governing internet services providers), or may not aim to lower trade barriers (such as a requirement that one PTA signatory increase their data protection standards to international standards). Additionally, free data flow provisions are a clear policy analog to internet connectivity and thus pair nicely

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

[4] In the previous literature, a variety of other measures have been used 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).

Figure 1: Growth of Internet connectivity by income group, 2000–2016



Note: High-, middle-, and low-income classifications come from World Bank aggregation of country data. High-income countries had a GNI per capita above $12,695 in 2020, middle-income countries fell between $1,046 and $12,695 per capita in 2020, and low-income countries had a GNI per capita below $1,046.

with the other components of our analysis.

Data flow provisions in trade agreements represent just some of the many policies that countries have introduced to govern the internet. Many of the most familiar are domestic policies seeking to establish rules for things like data privacy, copyright protections, and net neutrality. While these types of policies may have an indirect impact on international trade, they are often motivated by non-commercial objectives and therefore are not strictly digital trade policies. Our choice to examine only digital trade policies in PTAs intentionally focuses our analysis on policies that are unambiguously targeted at trade.

Data on free data flow measures is compiled from the Trade Agreements Provisions on Electronic-Commerce and Data (TAPED) database (Burri and Polanco, 2020).[5] We derive a bilateral indicator (DFP_{ijt}) for the presence of data flow policies in a PTA based on the combination of several categories of provisions. The indicator is coded as having a data flow provision if any of the following provisions appear in an agreement between countries i and j in year t.[6]

- The agreement's e-commerce chapter includes provisions on data flows. Specifically, the chapter contains language (i) allowing cross-border electronic data transfer (personal and business) or (ii) recognizing the importance of information flows for trade and asking parties to refrain from imposing barriers.

[5]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/`.

[6]These categories correspond to questions 1.28.1, 2.1, 1.28.4, and 2.4 in the TAPED database.

- The agreement specifies that cross-border data flows will be free between members in general and not only for specific service sectors or commercial transactions.
- The agreement prohibits data localisation policies that would require that companies store data in a particular country.

From 2000 to 2016, 50 international agreements containing data flow provisions went into force, beginning with a 2001 agreement between New Zealand and Singapore.[7] The number of agreements with free data flow provisions increased over our sample from 5 agreements in the first five years of our data (2000-2004) to 23 agreements in the last five years (2012-2016). It is important to note that two major agreements with free data flow provisions—CPTPP and USMCA—are not included in our data because they entered into force after 2016, the last year for which we had the necessary trade data. Of the agreements covered, 18 are between high-income country pairs (36 percent), 29 are between high-income and low- or middle-income countries (58 percent), and 3 are between low- or middle-income countries (6 percent).

3 Estimating Digital Trade Determinants

To estimate the impacts of internet connectivity and internet-related trade policies, 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).[8] 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 digital trade determinants 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:

$$X_{ijt} = \exp\{\beta_1 IC_{ijt} + \beta_2 EU_{ijt} + PTA_{ijt} * (\beta_3 + \beta_4 DFP_{ijt}) + \sum_t b_t + \mu_{it} + \nu_{jt} + \rho_{ij}\} + \epsilon_{ijt}. \tag{1}$$

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 our measure of internet connectivity (IC_{ijt}), EU membership (EU_{ijt}), preferential trade agreements (PTA_{ijt}), and free data flow provisions (DFP_{ijt}). Because free data flow 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_3 and the marginal impact of data flow restrictions

[7] This date range corresponds with available trade data in our sample.
[8] We provide a more thorough discussion of the theoretical model in section 4.

when they appear in PTAs via β_4. 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 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 for several reasons. First, they capture non time-varying bilateral factors that determine trade between pairs of countries, such as distance, shared borders, and cultural ties. Second, as noted by Baier and Bergstrand (2007), bilateral fixed effects can help mitigate endogeneity concerns with the time-varying factors of interest. 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 data flow provisions.

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.[9]

We combine the internet connectivity and data flow provisions information with data from several other sources. Bilateral trade data, including both international and domestic (intra-national) flows, was taken from the International Trade and Production Database for Estimation (ITPD-E) of Borchert et al. (2021).[10]

3.1 The Effects of Digital Determinants

Table 1 presents the results from a series of estimations based on equation 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 a collection of fixed effects. In both cases, the estimates are positive, significant, and consistent with prior estimates in the literature.

Column (2) introduces the the internet connectivity measure, which is also positive and significant. The magnitude of the estimate implies that a one standard deviation increase in internet connectivity between two countries, which represents a 16 percentage point increase in the likelihood that two randomly selected

[9] To perform the regressions, we use the estimation routines of Correia et al. (2019) and Larch et al. (2019).
[10] The ITPD-E database can be downloaded from `https://www.usitc.gov/data/gravity/itpde.htm`.

Table 1: Gravity model estimates of the effects of digital trade determinants

	(1)	(2)	(3)	(4)	(5)
PTA	0.156***	0.153***	0.153***	0.165***	0.160***
	(0.0435)	(0.0408)	(0.0405)	(0.0426)	(0.0415)
EU membership	0.127***	0.102**	0.0812*	0.107**	0.0598
	(0.0420)	(0.0427)	(0.0438)	(0.0425)	(0.0432)
Internet		1.988***			
		(0.431)			
Internet × International			1.724***	1.704***	1.666***
			(0.464)	(0.455)	(0.445)
Internet × Domestic			1.114**	1.065**	0.958**
			(0.518)	(0.502)	(0.483)
PTA × Data flow provision				-0.0394	0.276***
				(0.0284)	(0.0600)
PTA × Data flow × Internet × International					-0.557***
					(0.128)
Dependent variable	Trade value	Trade value	Trade value	Trade value	Trade value
N	613,333	613,333	613,333	613,333	613,333
AIC	36721824	36139699	35838432	35824262	35662422

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

people both use the internet, would increase their bilateral trade by more than 38 percent.[11] Given the positive effect of the internet on trade, a natural question is whether internet connectivity matters more for international or domestic trade. To explore this question, column (3) separates the internet connectivity measure into two measures. The first interacts the internet measure with an indicator for international trade while the second interacts it with an indicator for domestic trade. The results indicate that internet connectivity increases trade for both but, it has a larger impact on international trade. A one standard deviation increase in internet connectivity increases international trade by about 33 percent compared to 20 percent for domestic trade.

We next add data flow provisions to the model, which is done in column (4). The estimate suggests that data flow provisions in trade agreements have not had a significant impact on total trade. Members of agreements with these provisions appear to trade less than members of agreements that do not feature data flow provisions. This result is somewhat unexpected given that these provisions are typically meant to facilitate trade. However, it may be the case that the estimate is more reflective of the agreements that tend to have these provisions than the effectiveness of the provisions themselves. Data flow provisions are relatively new features in trade agreements and are present in relatively few of the PTAs in our sample period (50 out of more than 400 PTAs). Additionally, two of the major recent trade agreements with these provisions—CPTPP and USMCA—were enacted after the latest year in our sample.

The agreements in the sample that do feature these provisions are typically not between the digitally

[11] Calculated as $100 * (\exp(0.164 * 1.988) - 1) = 38.546$.

intensive countries that would benefit most from them. Instead, they predominantly appear in agreements between developed and developing countries that may not yet be able to take full advantage of digital trade facilitation.[12] It is also the case that many of the data flow provisions in our sample represent commitments to maintain the free flow of data for markets and sectors in which data could already flow freely across borders. While research has shown that commitments like these can have an impact on trade by reducing trade policy uncertainty, we would expect the impact to be smaller than if the provisions overturned existing data flow restrictions (Handley and Limão, 2017; Lamprecht and Miroudot, 2020). For these reasons, we suspect the insignificant effect of data flow provisions found here is more reflective of the limited number of cases in which they exist than the general usefulness of the provisions. Were they more common in agreements between developed, highly internet connected countries, we would expect these provisions to be more significantly trade facilitating.

To explore this theory, we examine whether data flow provisions are more impactful if internet connectivity is higher. We do so by interacting the data flow provision with foreign internet connectivity (the interaction between internet connectivity and foreign trade introduced in column (3)). The estimates, which are presented in column (5), indicate that when international internet connectivity is interacted with data flow provisions, the base effect of the provisions are positive and significant but decreasing in the level of internet connectivity. Again, this result is seemingly counter-intuitive and is likely also a reflection of the particular agreements in our sample that happen to have these provisions, which are typically between developed and developing countries rather than between countries with similar levels of internet connectivity.

3.2 Digital Determinants of Goods and Services Trade

Much of the past literature has emphasized that goods and services trade may rely on the internet in different ways. In this section, we explore these differences by subdividing trade into goods and services flows and estimating the gravity models at those levels. We focus on the model specification in column (4) that included internet connectivity—domestically and internationally—and data flow provisions, which we consider our preferred specification. The estimates from these models are presented in table 2.

The sectoral estimates highlight that digital trade impacts that differ between goods and services. First, the estimates indicate that internet connectivity increases international trade for both goods and services. Interestingly, the magnitude of the impact is larger for trade in goods than trade in services; a one standard deviation increase in connectivity would increase cross-border bilateral goods trade by about 38 percent, compared to 26 percent for services. Domestic internet connectivity is only positively and significantly

[12] Some examples of these agreements include the U.S. FTAs with Peru, Panama, and Columbia; the Australia, New Zealand, ASEAN free trade area; and the EU-Algeria Euro-Mediterranean Agreement

Table 2: Gravity model estimates by sector

	Goods (1)	Services (2)
PTA	0.144**	0.161**
	(0.0630)	(0.0737)
EU membership	0.0849	0.209*
	(0.0520)	(0.111)
Internet connectivity × International	1.965**	1.428***
	(0.850)	(0.474)
Internet connectivity × Domestic	-0.430	1.330***
	(0.748)	(0.515)
PTA × Data flow provision	-0.220***	0.118***
	(0.0556)	(0.0435)
Dependent variable	Trade value	Trade value
N	611,787	72,837
AIC	39556715.4	9397343.3

Note: This table presents the gravity model estimates for trade separated by goods and services. All models included exporter-importer, exporter-year, importer-year, and border-year fixed effects, which are omitted for brevity. Standard errors clustered by country-pair are reported in parentheses. * $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$.

related to trade in services. This finding is consistent with the idea that the internet plays a special role as a vehicle for services trade, making it a key component in remote services delivery both within and between countries. In contrast, if the internet is primarily used to reduce information costs for goods trade, it may not offer large additional benefits domestically where information costs are relatively low and producers are more familiar with market conditions. The estimates for data flow measures highlight additional nuances in their effects. For goods trade, the estimates remain negative, as before. For services trade, however, they are positive and significant. The estimate suggests that the inclusion of data flow provisions in trade agreements has increased services trade by more than 12 percent among members.

These estimates provide further evidence that digital connectivity and data flow policies play a special role in services trade relative to goods. For goods trade, the data flow provisions in our sample may not be particularly impactful among member countries with insufficient digital infrastructure to fully take advantage of the marginal cost savings that they promote. Instead, the trade promoting aspects of the digital economy are recognized through increased internet connectivity. For services, the digital connectivity represents an important channel of trade such that any limitations to data flows could severely limit services trade, domestically and internationally. Thus, the protection of free data flows through trade policy represents a much more impactful commitment than for goods because the inability to trade digitally could restrict some types of services trade entirely. We explore this notion further in section 3.3, which considers the extensive margin of trade.

Before turning to the extensive margin, we consider an additional robustness exercise that addresses

Table 3: Gravity model estimates with asymptotic bias correction

	All Sectors (1)	Goods (2)	Services (3)
PTA	0.103*	0.166**	0.162**
	(0.0550)	(0.0772)	(0.0750)
EU membership	0.00476	0.0763	0.203*
	(0.0231)	(0.0579)	(0.113)
Internet connectivity × International	2.031**	2.567**	1.558***
	(0.986)	(1.282)	(0.373)
Internet connectivity × Domestic	0.192***	0.0879	1.412***
	(0.0328)	(1.0966)	(0.281)
PTA × Data flow provision	-0.050***	-0.277***	0.111*
	[0.0284]	(0.0612)	(0.0618)
Dependent variable	Trade value	Trade value	Trade value
N	613,333	611,787	72,837
AIC	35824262	39556715.4	9397343.3

Note: This table reports the gravity model estimates derived using the bias corrections proposed by Weidner and Zylkin (2021) to adjust for potential bias in our main three-way gravity specification. All models included exporter-importer, exporter-year, importer-year, and border-year fixed effects, which are omitted for brevity. Standard errors, which are reported in parentheses, were clustered by pair and derived using a local de-biasing adjustment to account for estimation noise in the exporter-year and importer-year fixed effects. A bias corrected standard error could not be produced for one estimate; in its place, a non-corrected standard error is reported in brackets. * $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$.

potential concerns regarding asymptotic bias stemming from the use of exporter-importer fixed effects in many of the gravity specifications. 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. Weidner and Zylkin 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.[13] To mitigate these issues, they recommend using a bias correction as part of the estimation procedure. We conduct such a correction for each of our specifications and report the estimates in table 3. Overall, the results of this bias correction are consistent with our main findings. The primary differences are that the magnitudes of the coefficients for internet connectivity interacted with international trade are higher, and the negative relationship between total trade and PTAs with free data flow provisions is statistically significant.[14]

3.3 Internet and Data Flow Impacts on the Extensive Margin

Given the belief that many services could not be traded at all without the internet, we would expect that digital trade determinants have an especially large impact on services trade at the extensive margin. We

[13]In particular, this bias can lead to a distribution estimates that is not centered around the "true" β value as N approaches infinity.

[14]However, it should be noted that the bias correction, which was conducted using the STATA module provided by Weidner and Zylkin (2021), reports statistical significance but does not produce a bias corrected standard error estimate for that particular term.

examine this question by analyzing whether increased internet connectivity and data flow provisions have increased the number of goods or services that countries trade with one another.

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 it as a count of the number of goods or services traded. Using the same trade flow data described above, we construct a new dependant variable that reflects number of products for which a non-zero value is traded between each pair of countries in each year. We conduct the analysis for all traded products and for goods and services individually. Within the data, there are 153 different goods categories and 17 services categories. Thus, the bilateral count variable ranges from 0–170 for total trade, 0–153 for goods, and 0–17 for services.

The Flex model specifications follow the preferred gravity model specification from section 3.1, which included PTA and EU membership, international and domestic internet connectivity, and data flow provisions. 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.[15] 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 model.[16] The results of these estimations are presented in table 4.

The extensive margin models provide further evidence that digital determinants are influential factors in trade. Additionally, they support the notion that these factors have different impacts on goods and services. For total trade, international internet connectivity has a positive and significant effect on the number of products traded across countries, a result that holds for goods and services independently as well. The magnitude of the effect of international internet connectivity is considerably larger for services. This is consistent with the idea that the internet represents a channel for trade in services; as internet connectivity increases, more services become tradable. For example, while cross-border trade in education services was limited by the movement of either students or teachers before the internet, classes conducted online have opened a new, less costly channel for providing education.

As was the case with the estimates based on trade values, domestic internet connectivity only increases the number of products traded for services products. It is not necessarily surprising that internet connectivity does not increase the extensive margin of goods, given that it largely represents a marginal reduction in trade

[15]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.

[16]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 4: Extensive Margin

	All sectors (1)	Goods (2)	Services (3)
PTA	0.400***	0.404***	0.103***
	(0.00578)	(0.00580)	(0.0313)
EU membership	0.490***	0.215***	-0.066
	(0.0177)	(0.0168)	(0.0464)
Internet connectivity × International	0.841***	0.606***	2.541***
	(0.0291)	(0.0292)	(0.199)
Internet connectivity × Domestic	-10.39***	-11.32***	3.413***
	(0.265)	(0.297)	(0.589)
PTA × Data flow provision	-0.133***	-0.125***	0.690***
	(0.0107)	(0.0106)	(0.0497)
Distance (log)	-1.123***	-1.119***	-1.017***
	(0.00519)	(0.00521)	(0.0279)
Contiguity	1.099***	1.133***	0.129*
	(0.0199)	(0.0204)	(0.0675)
Common language	0.662***	0.662***	0.184***
	(0.00551)	(0.00555)	(0.0257)
Colonial relationship	1.125***	1.167***	0.644***
	(0.0246)	(0.0253)	(0.0862)
Dependent variable	Product count	Product count	Product count
N	614,552	613,154	54,648
AIC	361915.7	366921	57769.4

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. Robust standard errors reported in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

costs and not a critical component of goods trade. However, that it is significantly negative is unexpected. This finding could reflect a specialization among domestic goods trade that is less present in services trade. The number of goods categories traded domestically has fallen from about 44 of 151 possible goods to about 30 in recent years. By comparison, the number of services categories traded domestically has remained steady at around 10 products throughout the sample. This trend is sensible; while goods producers in a country may specialize in particular types of products and rely on imports for others, some services like commercial banking are necessary in all markets, regardless of their specialization. It may be the case that internet connectivity has inspired increased specialization for goods because importers have better information about potential international sources of products that their home market does not produce efficiently, resulting in diversion from domestic goods towards international goods at the extensive margin. Total trade is also negative due to the fact that the number of potential goods sectors is significantly larger than the number of potential services sectors, resulting in total trade estimates that mostly reflect goods trade.

Finally, PTAs with data flow provisions have similar impacts at the extensive margin as they did for trade values. Data flow provisions are associated with fewer traded products for both total trade and goods trade, which is likely for the same reasons as with internet connectivity. For services, data flow provisions appear to have increased the number of services traded, providing more evidence that the free flow of digital information is uniquely important for services sectors.

4 The Global Impacts of Internet Connectivity on Welfare and Development

In the previous sections, we found robust evidence that internet connectivity has a significant positive impact on both international and domestic trade. In this section, we extend this analysis and demonstrate the positive trade and welfare impacts that could occur as a result of increased internet connectivity. In particular, we examine a hypothetical scenario in which Nigeria—a developing Sub-Saharan country with relatively low internet use—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.

The notion that internet connectivity can improve economic development is not new. For many years, it has been considered an integral building block in connecting developing countries to the global economy and improving their economic outcomes. For example, Engel et al. (2021) note the influential role that the internet plays in connecting small firms and low-skilled or informal workers to global markets via e-commerce marketplaces and international supply chains. These connections can help citizens in developing countries overcome poor transportation infrastructure and economic remoteness. 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. As such, the expansion of internet connectivity and the formation of policies that protect and promote it are expected to have significant benefits for developing countries.

4.1 Model Description

The analysis is conducted using 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. (2018) 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 a wide range of trade models (Arkolakis et al., 2012).

The model is given by the following system:

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

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

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

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

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

Equations (2), (3), and (4) reflect the structural gravity model of Anderson and van Wincoop (2003). In equation (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 equation (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 equation (4), is an aggregate trade cost index for the importer and reflects the constant elasticity of substitution (CES) demand price index.

Equations (5) and (6) introduce some additional features to the standard gravity model. Equation (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, equation 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 equations (2)–(6) is often referred to as a general equilibrium version of the gravity model. It is able to quantify the effects of changes in trade frictions through several different levels of effects. The first-order effects are those on trade flows stemming directly from changes to bilateral trade frictions via τ_{ijt} in equation (2). Higher bilateral trade costs result in lower bilateral trade, *ceterus paribus*, and vice versa. 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. 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.

We use the model to assess the general equilibrium impacts of a change in internet connectivity. To do so, we consider a hypothetical situation as a case in point in which Nigeria were to increase the share of its population using the internet. In 2016, the base year for our analysis, only about 25 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 60 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.[17] This hypothetical simulation

[17] 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 likely 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.

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 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 reduction 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 the same data that were used to estimate the econometric models in section 3. The model baseline includes the 60 countries with the greatest amount of trade in 2016, represent nearly 96 percent of global trade.[18] 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, free data flow provisions, PTA and EU membership, international-border fixed effects, and exporter-importer fixed effects) from column 4 of Table 1.[19] Second, the derived trade costs were used to solve for baseline inward and outward multilateral resistances.[20] Third, counterfactual trade costs were constructed by raising Nigeria's internet use rate from 25 percent to 60 percent and recomputing our bilateral internet connectivity index for Nigeria and all of its partners. 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 GDP.[21]

[18] Despite being a top 60 country in terms of total trade value, Armenia was not included in this analysis due to incomplete trade data with the other countries in this subsample.

[19] Specifically, we calculate $\hat{\tau}_{ij,2016}^{1-\sigma} = \exp\{\hat{\beta}_1 EU_{ij,2016} + IC_{ij,2016} \times (\hat{\beta}_2 1_{i \neq j} + \hat{\beta}_3 1_{i=j}) + PTA_{ij,2016} \times \left(\hat{\beta}_4 + \hat{\beta}_5 DFP_{ij,2016}\right) + \hat{b}_{2016} + \hat{\rho_{ij}}\}$, where 1 denotes an indicator for international or domestic trade.

[20] 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.

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

4.2 Impacts of Increased Internet Connectivity in Nigeria

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 5 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 $4 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, France and the Netherlands. However, there are also reductions in some of Nigeria's exports, mostly among less developed and less internet connected countries, including in South Africa, Egypt, and Algeria. The change internet connectivity has a relatively large impact on Nigeria's domestic trade. Despite the fact that internet connectivity lowers domestic trade costs, trade diversion towards foreign markets more than fully offsets the effects of lower domestic costs, resulting in 33 percent less domestic trade.

The increase in Nigerian internet connectivity results in more favorable prices for both producers and consumers. For producers, the reduction in trade costs reduces their share of the cost burden and raise the prices they receive for their output. Similarly, for consumers, the reduction in trade costs lowers the price of both foreign and domestic products. As a result, Nigerians generate higher incomes which—thanks to lower consumption prices—go further, 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 16 percent (more than $65 billion)!

Throughout the rest of the world, the effects differ across countries. Most countries tend to increase trade with Nigeria, which is especially true for developed countries with high internet use like the United States, Belgium, and Japan. About three fourths of the countries in the sample increase exports to Nigeria. This growth is 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.

However, despite the mostly positive outcomes for Nigeria and many other countries, there are countries that are generally made worse off by Nigeria becoming more internet connected. 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, including China and South Africa, experience

Table 5: Global effects of increased internet use in Nigeria

Country	Exports (%Δ)	GDP (%Δ)	Country	Exports (%Δ)	GDP (%Δ)
Algeria	-0.01	-0.07	Korea, South	0.03	0.03
Argentina	0.02	-0.00	Lithuania	0.01	0.00
Australia	0.02	0.02	Luxembourg	0.02	0.03
Austria	0.02	0.01	Malaysia	0.03	0.01
Bangladesh	-0.04	-0.14	Mexico	-0.00	-0.03
Belgium	0.02	0.02	Netherlands	0.02	0.02
Brazil	0.01	-0.03	**Nigeria**	**9.15**	**15.77**
Bulgaria	-0.00	-0.02	Norway	0.02	0.03
Canada	0.02	0.02	Pakistan	-0.07	-0.16
Chile	0.02	0.02	Peru	-0.01	-0.06
China	-0.01	-0.04	Philippines	0.01	-0.04
Costa Rica	0.00	-0.01	Poland	0.01	-0.00
Czechia	0.01	0.00	Portugal	0.01	-0.01
Denmark	0.02	0.03	Romania	0.01	-0.03
Ecuador	0.01	-0.04	Russia	0.01	-0.00
Egypt	-0.01	-0.07	Saudi Arabia	0.01	0.00
Finland	0.02	0.02	Singapore	0.03	0.02
France	0.02	0.01	Slovakia	0.01	0.01
Germany	0.03	0.01	Slovenia	0.01	0.00
Greece	0.00	-0.01	South Africa	-0.01	-0.04
Hong Kong	0.02	0.02	Spain	0.01	0.01
Hungary	0.01	0.01	Sri Lanka	-0.05	-0.15
India	-0.11	-0.12	Sweden	0.02	0.02
Indonesia	-0.04	-0.12	Switzerland	0.02	0.02
Iran	0.00	-0.04	Thailand	-0.01	-0.05
Ireland	0.01	0.01	Turkey	-0.00	-0.03
Israel	0.01	0.01	Ukraine	-0.01	-0.04
Italy	-0.00	-0.02	United Kingdom	0.02	0.03
Japan	0.05	0.03	United States	0.11	0.01
Kazakhstan	0.01	0.00	Vietnam	0.00	-0.04

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

lower trade with both Nigeria and many of the developed countries that trade more intensively with Nigeria. Others, such as India and Indonesia, benefit from greater wealth throughout much of the world and increase exports to many countries. 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 0.14–0.16 percent). Taken together, 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 policies/practices, as is the case with Nigeria independently increasing their internet connectivity 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 ever-growing digital economy if they are left behind in terms of digital access.

One potential consideration for this analysis is that it assumes that internet connectivity has an equivalent effect on trade costs for all trading partners. Some past research has suggested that developing countries may face different marginal benefits from digital trade than developed countries. As a robustness exercise, we explore this possibility in a supplementary analysis, which is presented in full in the appendix. The analysis estimates a separate effect for internet connectivity on trade between developing countries and reassesses the hypothetical scenario using these estimates. We find that internet connectivity has a larger impact on international trade among developing countries than developed countries. However, unlike for trade overall, connectivity exhibits a negative impact on domestic trade within developing countries, which is likely driven by large trade diversion toward foreign partners. The results of the alternative hypothetical scenario indicate more muted effects from the growth in Nigeria's internet use—for both positive and negative outcomes—but that the outcomes rarely change signs. Thus, the general conclusions discussed above appear to be robust to this additional layer of nuance.

Finally, it should be noted that the estimated impacts of internet connectivity are derived from a model that primarily focuses on trade. The internet has many impacts on a country, its economy, and its citizens outside of domestic and international commerce. Our model does not necessarily capture all possible implications of increased internet connectivity, economic or otherwise. Thus our results should be properly understood to be only an evaluation of the economic impacts of the internet on trade and not a comprehensive evaluation of the impacts of the internet in general.

5 Conclusion

This work examines role of digital trade determinants in trade. Using a theoretically motivated gravity model, we find new evidence that internet connectivity and data flow policies can represent powerful means of facilitating trade. The internet has significantly increased international and domestic trade in both goods and services. Additionally, policies promoting the free flow of data in PTAs have had a positive and significant effect on trade in services sectors. These findings also highlight the different roles that digital trade determinants play for goods and services. While use of the internet in trade is beneficial for both goods and services, it is a necessity for many services—a result that bears out in the distinct impact that digital trade determinants have on the extensive margin of services trade.

In order to study the global impacts of internet connectivity, we estimate the general equilibrium impacts of a hypothetical increase in internet use in a developing country. We find that if Nigeria were to increase its internet use up to the levels of Brazil, a similarly sized developing nation, the global impacts could be considerable. Nigeria's total exports would increase by more than 9 percent and its GDP would grow by nearly 16 percent. This change would benefit many other countries, particularly developed countries with high internet usage, but would come at a cost to less developed countries were they to not make similar improvements in internet connectivity. 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.

As trade becomes increasingly reliant on digital connectivity, understanding the implications of digital technology and the policies that govern it domestically and internationally is crucial. A wide range of new policies and practices are being enacted around the world that have potentially large and wide reaching effects on trade. As this paper demonstrates, future research should pay special attention to digital trade determinants as they continue to grow in prominence and evolve in reaction to the ever-changing digital landscape.

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A Appendix

A.1 Differing Internet Effects in Developing Countries

The main analysis presented in section 4 assumes that internet connectivity has the same direct effect on trade for all countries, regardless of their level of development. It may, however, be the case that the internet has a different impact on lower-income, developing countries than developed countries. For example, developing countries may tend to trade products for which there is less (or more) benefit from internet connectivity relative to the rest of the world. As evidence of such a difference, Clarke and Wallsten (2006) found that internet penetration increased trade between developing and developed countries but not between two developed countries. As a robustness exercise, we explore the possibility that internet penetration has a different impact on trade among developing countries by adding two additional terms to our empirical model. The new terms add an interaction between the foreign/domestic internet connectivity terms and an indicator for trade flows between two developing countries (low- and middle-income countries, again following World Bank classifications). The estimates for these terms identify whether the effects of the internet on international and domestic trade are larger or smaller for trade between developing countries than for trade between other country pairs. While there are many possible combinations of developed and developing country groupings for which a heterogeneous impact could potentially be estimated, we focus on the combination of developing to developing, which was inspired by Clarke and Wallsten (2006).

The gravity model estimates for the developing country interactions, which are presented in table A1, indicate that there are differences in the effects of the internet on trade between developing countries compared to between other countries. For international flows, the effects of internet connectivity are larger for trade between developing countries, suggesting that digital connectivity represents a particularly important means of trade facilitation for lower-income countries. The estimates for domestic trade, however, indicate that internet use in a developing country tends to decrease domestic shipments. This is likely reflective of a relatively large diversion of trade away from the domestic market towards international partners.

That the internet has a different effect on trade between developing countries may impact the estimated effects of our hypothetical scenario looking at Nigeria. These new estimates imply larger effects between Nigeria and other developing countries, strong negative rather than positive effects for its domestic trade, and smaller effects on its trade with high-income countries. In order to quantify these differences, we replicate the general equilibrium analysis using the estimates from table A1. The results of this alternative simulation are presented in table A2

The main effects of controlling for different internet influences among developing countries is that the impacts of raising Nigeria's internet use are more muted on both Nigeria and most other countries. The growth in Nigeria's exports is 6.4 percent, compared to 9.2 percent using the original measure of internet connectivity. This reduction is largely due to the fact that the estimates in table A1 indicate a smaller effect for internet connectivity between Nigeria and high-income countries, resulting in lower trade growth between these pairs. There is also less trade diversion away from many of the other developing countries, resulting in smaller reductions in their exports. In fact, in some cases, there is trade growth between Nigeria and other developing countries where there was previously reductions. For example, these reversals include increased exports to Bulgaria and Brazil as well as increased imports from Mexico and Romania. These changes are due to the combination of lower trade diversion and a heightened impact of internet connectivity on trade between developing countries.

Perhaps the largest impact of using the developing-country-specific estimates is on Nigeria's domestic trade. In addition to the indirect trade diversion effect discussed above, the new estimates also indicate a strong direct reduction in trade stemming from increased internet connectivity. The result of these forces is that domestic trade in Nigeria decreases by 61 percent, compared to only 33 percent before.

The more muted effects found for trade extend to real GDP as well. Nigeria's GDP is estimated to increase by 9.4 percent, compared to 15.8 before. Similarly, the effects on the GDPs of other countries are mostly smaller too. The countries most negatively affected by the increase in Nigeria's internet use—Pakistan, Sri Lanka, and Bangladesh—fair slightly better, facing losses in GDP that are about 42 percent lower than before. Most countries that benefited from the change experience smaller gains, including South Korea and Norway, which experienced 20–30 percent reductions in GDP growth relative to the main analysis. Notably, some countries experience greater gains under the alternative specification. In particular, Kazakhstan and Saudi Arabia experience higher GDP growth under the alternative specification, due largely to the fact that both are categorized as developing but have Internet connectivity rates comparable to many high-income countries.

Ultimately, the welfare estimates under the alternative specification in which the internet has different effects for developing to developing trade are largely consistent with the main analysis. Nigeria and developed countries with high internet use benefit most from internet growth in Nigeria while other developing countries tend to face economic losses. In most cases, the gains and losses are smaller but rarely differ in sign. The higher estimated impact of internet use on developing country trade offsets some of the losses to developing countries but rarely eliminates them. Thus, the notion that there is a risk to developing countries being left behind in the digital economy remains.

Table A1: Gravity model estimates for internet effects on trade between developing countries

	(1)
PTA	0.124***
	(0.0418)
EU membership	0.124***
	(0.0429)
Internet connectivity × International	1.078***
	(0.343)
Internet connectivity × International × Developing	0.671**
	(0.339)
Internet connectivity × Domestic	0.890**
	(0.403)
Internet connectivity × Domestic × Developing	-2.504***
	(0.321)
PTA × Data flow provision	0.0333
	(0.0209)
Dependent variable	Trade value
N	
AIC	

Note: This table presents estimates derived from the gravity model of trade. Developing countries include those classified as low- or middle-income by the World Bank in 2020. Exporter-importer, exporter-year, importer-year, and border-year fixed effects were included in all specifications but not reported for brevity. Standard errors were clustered at the country-pair level and are reported in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A2: Global effects of increased internet use in Nigeria with separate internet effects for trade between developing countries

Country	Exports (%Δ)	GDP (%Δ)	Country	Exports (%Δ)	GDP (%Δ)
Algeria	-0.00	-0.04	Korea, South	0.02	0.02
Argentina	0.02	-0.00	Lithuania	0.01	0.00
Australia	0.01	0.01	Luxembourg	0.02	0.02
Austria	0.01	0.01	Malaysia	0.02	0.01
Bangladesh	-0.02	-0.08	Mexico	0.01	-0.02
Belgium	0.02	0.01	Netherlands	0.02	0.02
Brazil	0.01	-0.01	**Nigeria**	**6.40**	**9.43**
Bulgaria	0.00	-0.01	Norway	0.02	0.02
Canada	0.02	0.02	Pakistan	-0.03	-0.09
Chile	0.02	0.01	Peru	-0.00	-0.04
China	-0.00	-0.02	Philippines	0.01	-0.02
Costa Rica	0.01	-0.01	Poland	0.01	0.00
Czechia	0.01	0.00	Portugal	0.01	-0.00
Denmark	0.02	0.03	Romania	0.01	-0.02
Ecuador	0.01	-0.02	Russia	0.02	0.00
Egypt	-0.00	-0.04	Saudi Arabia	0.01	0.00
Finland	0.01	0.01	Singapore	0.02	0.01
France	0.02	0.01	Slovakia	0.01	0.01
Germany	0.02	0.01	Slovenia	0.01	0.00
Greece	0.00	-0.00	South Africa	0.00	-0.02
Hong Kong	0.02	0.02	Spain	0.01	0.01
Hungary	0.01	0.01	Sri Lanka	-0.03	-0.09
India	-0.05	-0.07	Sweden	0.01	0.02
Indonesia	-0.02	-0.07	Switzerland	0.02	0.02
Iran	0.01	-0.03	Thailand	0.00	-0.03
Ireland	0.02	0.01	Turkey	0.00	-0.02
Israel	0.01	0.01	Ukraine	0.00	-0.02
Italy	-0.00	-0.01	United Kingdom	0.02	0.02
Japan	0.04	0.02	United States	0.08	0.01
Kazakhstan	0.02	0.00	Vietnam	0.00	-0.03

Note: This table reports the estimated impacts of a hypothetical scenario in which internet usage in Nigeria was raised to the level of Brazil. Compared to the values in table 5, these estimates reflect the incorporation of a different level of effect with regards to internet connectivity for trade between two low-income countries. Reported values reflect percent changes (%Δ) in the exports and real GDPs of each country as a result of the change.