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BETTER TOGETHER: HOW DIGITAL CONNECTIVITY AND REGULATION REDUCE TRADE COSTS*

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Better Together: How Digital Connectivity and Regulation Reduce Trade Costs*

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Abstract

In this paper we study the impact of digitalization on trade costs in 58 economies over the period 2014 - 2018. Improvements in digital connectivity can reduce trade costs through multiple channels, including better access to information, lower transaction costs, the reduced need for business travel, more efficient customs and logistics, and easier communication. However, these positive effects depend on effective regulation that ensures trust in digital markets and open access to digital infrastructure, services and data. We assess the impact of digital connectivity, proxied by the number of active mobile broadband subscriptions per capita, on a broad measure of trade costs that captures all impediments that make international trade more difficult or costly than domestic trade. We estimate that a 10 percentage point higher digital connectivity is associated with around 2 per cent lower trade costs both in goods and services. Digital trade regulation that ensures cross-border connectivity and information flows amplifies the trade-cost-reducing effect of improved digital connectivity. This result is particularly strong in digitally deliverable services where the marginal effect of connectivity at the best regulation is 80 per cent larger than at the median regulation.

JEL codes: F10, F14, F15
Keywords: digital trade; trade costs; gravity model; digital regulation

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1 Introduction

Throughout recent decades, the fast improvement of information and communication technology (ICT) and advancements in digitalization have considerably affected international trade, enabling direct connections between producers and consumers from around the world, helping in spreading ideas and technologies, and easing the management of global value chains (GVCs). These technological advances thus reduced international trade costs and enhanced trade flows.

Access to modern ICT can reduce trade costs through multiple channels. First, digital transformation reduces the importance of physical proximity and face-to-face interaction for business relationships. ICT tools such as internet search, e-commerce platforms and services that allow real-time production monitoring lower the costs associated with searching for foreign products, information frictions, as well as GVC management costs. Moreover, the possibility of delivering some services digitally increases their cross-border tradability. As the costs of delivering a service over the internet are much lower than delivering it in person or through a foreign affiliate, digitalization can significantly reduce trade costs for these digitally deliverable services. This also applies to physical goods that can be digitized, allowing them to be traded at a reduced cost by eliminating transportation expenses.

Second, digital tools contribute to reductions in communication costs. Communication services via the Voice over Internet Protocol equalized the costs of international and domestic calls. Furthermore, the availability of automatic translations helps overcome language barriers and further lowers communication and search costs. Third, digital technologies facilitate trade in goods through enhanced logistics and customs efficiency. Tracking systems and automation of port and airport activities reduce the time spent in transit while digitalization of customs results in goods spending less time at borders and lower administrative costs.

Moreover, digitalization has ushered in the use of electronic payments and e-commerce platforms, thereby reducing transaction costs, particularly when purchasing products from foreign suppliers. The recent surge in the utilization of blockchain technologies enables the creation of a more secure contract environment by ensuring safe contracts and decreasing transaction costs. Finally, an easier access to foreign financial services through digital banking and e-commerce platforms' own credit services can alleviate the effects of a poor credit environment.

Policies at both national and international levels are key in providing the right environment for digital technologies to facilitate trade. Newly emerged digital markets need adequate regulation that preserves competitive environment and strengthens trust by ensuring that consumers' rights are protected and personal information is safe

and private. Discussions at various international fora aim to reduce the heterogeneity in domestic regulations, including by establishment of new regulations where none previously existed, to facilitate cross-border digital trade and to ensure that access to digital infrastructure is open for all suppliers. At the WTO, the work programme on e-commerce aims to examine all trade-related aspects of e-commerce. Moreover, negotiations are under way among a group of 90 members to advance discussions on several topics related to e-commerce such as facilitating electronic transactions, access to internet and to government data, consumer protection and privacy, cross-border data flows, transparency and capacity building as well as additional regulatory disciplines relating to telecommunication services.

This paper contributes to the existing literature by providing robust and theory consistent estimates of the impact of digital connectivity on trade costs by sector, level of development and region. Most importantly, we are the first to provide evidence of the magnifying effect of an open regulatory regime. Our results suggest that domestic policies that ensure smooth cross-border access to communications infrastructure and facilitate data flows amplify the impact of digital connectivity, especially in low- and middle-income economies. This finding has important policy implications. While there have been significant improvements in digital infrastructure, the regulatory framework has been lagging behind in many cases and some governments have introduced polices that tighten the regulatory environment (OECD, 2023).

Several recent studies have evaluated the impact of digitalization on trade costs, trade flows and economic development using various measures of digital connectivity and digital infrastructure. Using data for 37 economies in 2016, Rubínová and Sebti (2021) estimate that ICT connectivity, measured by the share of population using the internet and the share of population with mobile phone subscriptions, can explain on average 4 to 6 per cent of the variation in trade costs across trade partners. The seminal works of Freund and Weinhold (2002) and Freund and Weinhold (2004) show that the internet has had positive effects on export growth. Subsequent studies from Choi (2010), Liu and Nath (2013), Lin (2015), Anderson et al. (2018), López González et al. (2023) and Herman and Oliver (2023) provide consistent evidence that digital infrastructure and the growing share of population using the internet boost trade in both goods and services. Using firm-level data, Akerman et al. (2022) exploit the exogenous variation in broadband adoption resulting from the roll-out of a public program in Norway to establish broadband infrastructure between 2000 and 2008. Contrary to studies focusing on trade through e-commerce platforms (Hortaçsu et al., 2009; Lendle et al., 2016), they find that increased broadband adoption increases the sensitivity of exports to geographical distance and to the size of the destination market. The authors propose that these findings are consistent with a model where

ICT adoption lowers information frictions and thus expands the choice set of exporters and importers, making demand more elastic with respect to trade costs and thus distance. Hjort and Poulsen (2019) show that better digital infrastructure increases employment and incomes in developing countries, including through boosting exports. The authors exploit the gradual arrival of submarine internet cables in Africa and show large positive effects on employment rates, primarily driven by higher-skill occupations. They find evidence that these employment effects are partly driven by an increase in direct exports, suggesting that internet availability makes it easier for firms to sell to customers abroad.

There is an emerging literature that studies the impact of regulation in the digital economy on trade. Van der Marel and Ferracane (2021) develop an index to assess the restrictiveness of countries' data policy concerning cross-border movements of data and domestic use of data, finding that more rigid policies negatively affect imports of data-intensive services. Focusing on preferential trade agreements, López González et al. (2023) find that agreements with e-commerce provisions have a stronger positive impact on trade of high-income economies than other agreements while Herman and Oliver (2023) find that data flows provisions increase trade in services for high-income economies.

We build on previous work to estimate how digital connectivity, digital regulation and their interaction impact trade costs. Our empirical methodology follows two steps. We first estimate bilateral sector-level trade costs using a fixed effects gravity model following the methodology introduced in Egger et al. (2021). In a second step, we exploit the variation in trade costs within country-sector-year across partners and within sector-country-pair over time to estimate the impact of digital connectivity. Our preferred measure of digital connectivity is the number of active mobile broadband subscription per capita, which is a reliable proxy for internet use, particularly in developing countries where mobile internet is a more widespread technology compared to fixed broadband internet access. Considering that enabling legal and regulatory environment is an essential component of the ecosystem for digital trade, we then estimate how improvements in digital trade regulation can amplify the impact of digital connectivity on trade costs. To capture the impact of regulation, we employ a component of the OECD's Digital Services Trade Restrictiveness Index (DSTRI) that measures the extent to which regulation enables smooth cross-border access to communications infrastructure and facilitates data flows.

Our findings indicate that the expansion of digital connectivity has had a significant effect on reducing trade costs across all economic sectors. We estimate that a 10 percentage point higher connectivity is associated with around 2 per cent lower trade costs both in goods and services. Additionally, we find suggestive evidence that this

effect is channeled through reductions in language barriers and costs associated with customs procedures and regulatory differences.

When we look at the interplay between digital connectivity and digital regulation, we find that the trade-cost-reducing effect of improved connectivity is magnified by an open regulatory environment, especially for digitally deliverable services. To illustrate the magnitude of the estimated effects, we consider a scenario in which all economies improved their connectivity to at least the 75th percentile of the global distribution. We then show that the predicted decline in trade costs at the actual average level of digital trade regulation is much smaller than if all economies were at most at the 25th percentile of the global distribution or at the global best level. This impact is particularly pronounced for trade costs in digitally deliverable services which would register almost four times larger reduction in the most open regulatory environment.

The rest of the paper is organized as follows: Section 2 provides descriptive statistics of trade costs, digital connectivity and digital trade regulation, Section 3 describes our empirical strategy, Section 4 discusses the estimated impact of digital connectivity and Section 5 focuses on the estimated interaction between connectivity and regulation. Section 4 concludes.

2 Data and descriptive statistics

In our analysis, we are mainly interested in understanding how improvements in digital infrastructure and digital regulation help in lowering trade costs. We document below the evolution over time of our variables of interests, as well as the differences that exist across country income groups and regions.

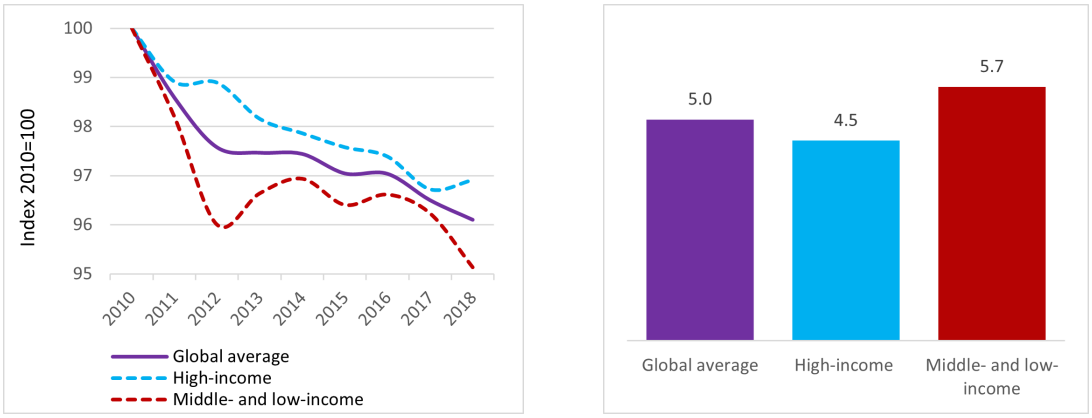
2.1 Trade costs

We estimate bilateral sector-specific trade costs following the methodology proposed by Egger et al. (2021) using data from the OECD Inter-Country Input-Output (ICIO) tables 2021 edition. The data cover 61 individual economies disaggregated into 34 sector groups including agriculture, industry and service sectors. The estimated Trade Cost Index captures all impediments that make international trade more difficult or costly than domestic trade.

Panel (a) of Figure 1 shows that global trade costs decreased by 4 per cent between 2010 and 2018. This was a combination of a 3 per cent decline in high-income economies and a faster, 5 per cent, decline in emerging and developing economies. Despite the narrowing gap, trade costs in emerging and developing economies were almost 30 per cent higher than in high-income economies in 2018, as shown in Panel

(b) of Figure 1.

Figure 1: Global Trade Cost Index by income groups



(a) time series 2010-2018 (b) levels 2018

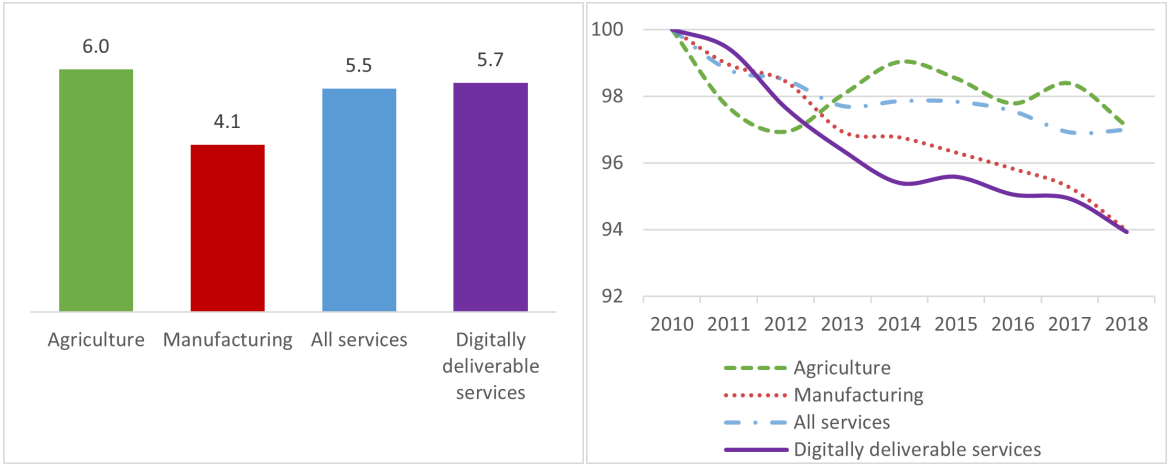
Note: The Trade Cost Index captures the magnitude of global trade costs relative to domestic trade costs. It can also be interpreted as ad valorem equivalent: global trade costs in 2018 (5.0) correspond to an ad valorem equivalent of 400 per cent. Bilateral sector-specific trade costs are aggregated to the economy level using theory-consistent weights. Simple averages are used to aggregate trade costs to the global level. Income groups are based on the World Bank classification in 2018.

There is a considerable level of heterogeneity in trade costs across broad economic sectors. While trade costs are the lowest in the manufacturing sector, cross-border trade in services faces more than 30 per cent higher trade costs and trade costs in agriculture are almost 50 per cent higher (see Panel (a) of Figure 2). Cross-border trade in digitally deliverable services such as administrative, computer, professional and other business activities also faces higher costs than trade in manufacturing products.[1] While digital delivery avoids transportation costs associated with delivering goods, many other costs remain, including the costs of finding foreign business partners, establishing trust across different institutional systems, the need for face-to-face communication, as well as trade barriers and heterogeneity in regulation.

The cost of trading manufactured products dropped by 6 per cent between 2010 and 2018, as shown in Panel (b) of Figure 2, while trade costs in agriculture and services saw a more modest drop of 3 per cent. Notably, the subset of services that can be delivered digitally registered a similarly sharp decline as manufactured goods between 2010 and 2018 (6 per cent).

[1]Digitally deliverable services also include financial intermediation and other services such as audio-visual services. There are two main reasons why we focus on a narrower category of business and professional activities. First, the sector aggregation of trade costs is such that audio-visual and other cultural services are bundled together with other personal, social and community services that typically cannot be delivered digitally. Second, financial services are a highly regulated sector were cross-border trade likely interacts with commercial presence and as such might require a tailored empirical model (Oldenski, 2012).

Figure 2: Global Trade Cost Index by economic sectors



(a) Levels in 2018 (b) Index 2010 = 100

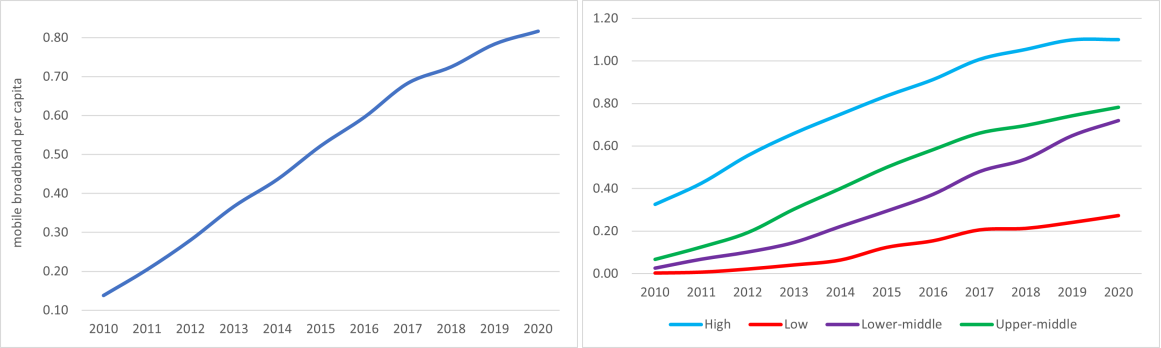
Note: The Trade Cost Index captures the magnitude of international trade costs relative to domestic trade costs. Services exclude construction and public services. Digitally deliverable services comprise of business activities such as information, administrative, and professional services (sectors 71-74 of the International Standard Industrial Classification (ISIC) revision 3.1). Bilateral sector-specific trade costs are aggregated to the economy-broad-sector level using theory-consistent weights. Simple averages are used to aggregate trade costs to the global level.

2.2 Digital connectivity

We measure digital connectivity with the number of active mobile broadband subscriptions, provided by the International Telecommunication Union (ITU), relative to total population. Between 2014 and 2020, the global average connectivity almost doubled, reaching just above 0.8 subscriptions per capita in 2020, meaning that on average eight out of ten people had an active mobile broadband subscription (see Figure 3a). Figure 3b shows that the average connectivity increases with the income level of the economy. While high-income economies had on average more than one subscription per capita[2], in low-income economies only one in four people had a subscription in 2020. The figure also shows that lower-middle-income economies saw a particularly rapid increase in digital connectivity between 2014 and 2020.

[2]One individual (or business) can have multiple subscriptions and therefore the number of subscriptions per capita can be higher than one.

Figure 3: Active mobile broadband subscriptions per capita



(a) world (b) income groups

Note: Data from ITU for 146 economies. One individual (or business) can have multiple subscriptions and therefore the number of subscriptions per capita can be higher than one. Income groups are based on World Bank classification in 2018.

2.3 Digital trade regulation

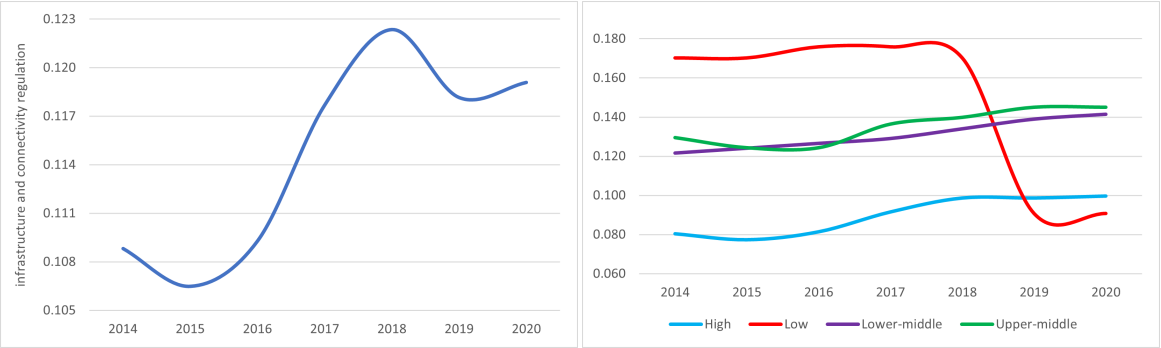
Regulations may act through several dimensions to restrict or foster trade. The Digital Services Trade Restrictiveness Index published by the OECD quantifies barriers to trade in digitally enabled services across 85 economies from 2014 onward. In our analysis we focus on the "infrastructure and connectivity" component of DSTRI that quantifies regulation related to the access to communications infrastructure, interconnectivity and cross-border data flows.[3] It captures best practice regulations on interconnections among network operators as well as measures limiting or blocking the use of communications services. It comprises also a coverage of policies that affect cross-border data flows and data localisation. The restrictiveness of regulatory measures increases when there is a "lack of efficient regulation on interconnection as well as burdensome conditions on cross-border data flows beyond those imposed to ensure the protection and security of personal data" (Ferencz, 2019).

The regulatory index ranges between zero and one where zero indicates complete openness of regulation while one indicates the highest level of restrictiveness. On average, restrictive measures have been increasingly put in place starting from 2015, reaching their maximum in 2018, as shown in Figure 4a. There was a substantial decline in 2019 that was driven by low-income economies who reduced in a remarkable

[3]The overall DSTRI is a composite index that captures impediments affecting services traded digitally across five dimensions: (1) access to communications infrastructure and interconnectivity, (2) measures related to electronic transactions like standards on electronic contracts and (3) electronic payments, (4) intellectual property rights, as well as (5) other types of barriers to digital trade. Our focus on the first component is mainly driven by empirical considerations - it has the largest variation across economies while the second and third component vary very little. Accordingly, when we use the full composite DSTRI in our estimations, the results are qualitatively similar but less statistically significant.

way the restrictiveness of their regulatory frameworks, down to a level comparable to high-income economies (Figure 4b).[4] Middle-income economies, on the other hand, still display high average regulatory restrictiveness.

Figure 4: Restrictiveness of digital regulation



(a) world (b) income groups

Note: The figure shows the evolution of the "infrastructure and connectivity" component of DSTRI. Data from OECD for 85 economies. Income groups are based on World Bank classification in 2018.

3 Empirical strategy

We run a regression analysis of bilateral trade costs disaggregated into 24 economic sectors (including agriculture, mining products, manufacturing and commercial services) in 58 economies over the period 2014-2018. Similar to the empirical strategy in Rubínová and Sebti (2021), we base our analysis on explaining the variation in trade costs in a given sector, country and year across partners.

Our baseline regression specification is as follows:

$$ln(TC_{ijts}) = \alpha + \beta_1 connectivity_{ijts} + \beta_2 X_{ijt} + \theta_{its} + \delta_{jts} + \epsilon_{ijts} \quad (1)$$

Where TC are trade costs, i is the exporter, j is the importer, t is year and s is the sector. X_{ijt} includes standard variables at bilateral level which capture several determinants of trade costs. For transport and travel costs we include log of population-weighted bilateral distance, a binary variable indicating if the trading partners share

[4]This drop was mainly driven by two African economies: Ethiopia and Uganda. In 2019, Ethiopia introduced a directive making it mandatory for the public disclosure of interconnection reference offers. This was a shift from the past, where there was no such obligation, despite the regulation of interconnection prices. Uganda implemented a regulation facilitating cross-border data transfer. This regulation ensures that recipient countries have robust data protection measures in place and that the transfer of personal data is only possible to countries with substantially similar privacy protection laws. Furthermore, in the same year, Uganda rolled out rules for both mobile and fixed connectivity sectors. These rules mandated public disclosure of interconnection reference offers, regulated interconnection prices and conditions, and enforced vertical accounting separation among operators.

a border, a binary variable indicating if either of the trading partners is landlocked, and we control for time zone differences. We account for information and transaction costs by including binary variables for colonial dependency, colonial sibling relationship and include binary variables indicating if the partners share a common official language and if they have common legal origins. We include also the log of the 1970 stock of migrants from the importing in the exporting country, and vice versa. As for trade costs deriving from trade policy and regulatory differences, we include being in a regional trade agreement and being in a customs union. We control for governance quality by including differences in corruption between the importer and the exporter. We also control for differences in GDP per capita and differences in human capital. Finally, we include exporter-year-sector θ_{its} and importer-year-sector δ_{jts} fixed effects.

Our variable of interest refers to digital connectivity, which we proxy with the number of active mobile broadband subscriptions per capita.[5] Our empirical model assumes that bilateral trade costs depend on the minimum of digital connectivity between the importer and the exporter. This means that good connectivity in one of the trade partners does not help reduce trade costs with a partner that is poorly connected. For instance, calls over the internet dramatically reduce communication costs but both partners need to be well connected and the quality of the call will be determined by the worse connection. Or, even if all producers in the exporting economy are connected and thus able to deliver a service digitally, they can do so only to the number of consumers in the importing economy that are connected as well. We also control for the the minimum of the number of mobile telephone subscriptions per capita between the importer and the exporter.

For a smaller sample of economies, we augment the model by allowing the impact of digital connectivity to depend on the level of digital trade restrictiveness. We measure the latter considering the maximum between the importer and the exporter. The effectiveness of digital connectivity in reducing trade costs thus depends on the trade partner with more restrictive digital regulation.

For robust inference, we cluster standard errors at the importer and at the exporter level (two-way clustering) as suggested in Egger and Tarlea (2015). Our empirical strategy also mitigates concerns related to endogeneity issues. First, our two-step procedure is a theory-consistent approach that permits identifying partial effects of observable variables on total trade costs which do not suffer from the unobserved-trade-cost bias (Egger and Nigai, 2015). Second, we include fixed effects that capture the unobservable characteristics at the country-year-sector level, as well as a rich set

[5] As a robustness, we run an estimation using the *log* of the number of active mobile broadband subscriptions per capita and an estimation where we include the share of individuals using the internet as a proxy for digital connectivity.

of controls at the bilateral level. Both potential reverse causality and omitted variable bias are further attenuated by the fact that we bilateralize digital connectivity and regulation variables by considering the country-pair minimum.

4 The impact of digital connectivity on trade costs

Table 1 shows results of our baseline regression analysis. We find consistent evidence that better ICT connectivity decreases trade costs for both goods and services. On average, a 10 percentage point increase in the number of active mobile broadband subscriptions per capita reduces trade costs by around 2 per cent.[6] These reductions in trade costs translate into increases in trade flows of 6-7 per cent on average.[7]

We extend the baseline empirical model to investigate whether better access to digital infrastructure has reduced trade costs through specific channels. First, we test whether better digital connectivity decreased trade costs by lowering language barriers and thus reducing communication and information costs. We therefore augment our baseline specification by including an interaction between connectivity and the binary variable of common language. Columns (1) to (3) of Table 2 Panel A report the results. We find heterogeneous results across broad sectors. Reduction in language barriers appears to drive our results in goods sectors where we find a large and statistically significant cost-reducing effect of connectivity only for countries that do not share a common spoken language. Therefore, for trade in goods, reductions in communication and information costs seem to be a major channel through which connectivity reduces overall trade costs. For trade in digitally deliverable services, on the other hand, we find similar effects of connectivity irrespective of whether the trade partners share a common language.

[6]Results using alternative measures/functional forms of connectivity are reported in Table A3 of the Appendix. The table shows that a 10 percentage point increase in the share of individuals using the internet reduces trade costs by around 3.5 per cent and a 10 per cent increase in the number of active mobile broadband subscriptions per capita reduces trade costs by around 1 per cent.

[7]The results are reported in Table A4 in Appendix. They reflect the average sectoral elasticities of trade flows to trade costs which we estimate to be 3.90 for goods, 3.95 for services and 3.71 for digitally deliverable services.

Table 1: The impact of digital connectivity on trade costs

VARIABLES	(1) Goods	(2) Services	(3) Digitally Deliverable Services
Connectivity	-0.171***	-0.157***	-0.194***
	(0.0448)	(0.0391)	(0.0456)
Distance	0.289***	0.226***	0.233***
	(0.0204)	(0.0170)	(0.0180)
Contiguity	-0.069**	-0.077***	-0.027
	(0.0294)	(0.0203)	(0.0222)
Landlocked	0.096**	0.156***	0.087
	(0.0369)	(0.0432)	(0.0563)
Colonial dependency	-0.089***	-0.127***	-0.140***
	(0.0232)	(0.0224)	(0.0223)
Colonial siblings	-0.169***	-0.142***	-0.130***
	(0.0313)	(0.0326)	(0.0379)
Common language	-0.046**	-0.018	-0.043*
	(0.0226)	(0.0214)	(0.0257)
Common legal origin	-0.005	-0.011	-0.019
	(0.0124)	(0.0115)	(0.0151)
Time zone difference	-0.018***	-0.015***	-0.016***
	(0.0057)	(0.0039)	(0.0046)
Migrants_{od}	-0.012***	-0.014***	-0.013***
	(0.0029)	(0.0023)	(0.0029)
Migrants_{do}	-0.011***	-0.010***	-0.012***
	(0.0032)	(0.0028)	(0.0032)
RTA	-0.070***	-0.048***	-0.030
	(0.0201)	(0.0147)	(0.0184)
Customs union	-0.058	-0.055	-0.070*
	(0.0477)	(0.0376)	(0.0409)
Differences in corruption	0.032	-0.031	-0.122
	(0.2952)	(0.2267)	(0.3062)
Differences in GDPpc	-0.155***	-0.148***	-0.184***
	(0.0518)	(0.0415)	(0.0538)
Differences in human capital	0.010	0.045	0.055
	(0.0684)	(0.0576)	(0.0597)
Mobile telephone	0.016	-0.036	-0.009
	(0.0313)	(0.0335)	(0.0553)
Constant	-0.194	0.397***	0.538***
	(0.1752)	(0.1433)	(0.1450)
Observations	221,328	143,260	15,924
R-squared	0.800	0.841	0.813
Within R-squared	0.420	0.496	0.471

Note: We include exporter-year-sector and importer-year-sector fixed effects. Cluster-robust standard errors in parentheses, two-way clustering at importer and exporter level. *** p<0.01, ** p<0.05, * p<0.1.

Second, we analyse whether digitalization helps overcome costs related to compliance with customs procedures and regulatory differences. For this purpose, we interact connectivity with a common membership in a customs union or an even deeper economic integration agreement, assuming that trade costs related to customs and regulatory differences are much lower or null between members of such agreements. We find strong evidence across all sectors that improvements in digital connectivity help overcome costs of customs procedures and regulatory differences as the average impact in our baseline specification is entirely driven by economies that are not part of a customs union or a deeper economic integration agreement, as shown in Panel B. This is further corroborated by results in Panel C, which show that the impact of connectivity on trade costs does not depend on whether the trade partners are part of a regional trade agreement (RTA), including shallow agreements, or not.

Table 2: The channels through which digital connectivity reduces trade costs

VARIABLES	(1) Goods	(2) Services	(3) Digitally Deliverable Services
Panel A: common language			
Different language	-0.175***	-0.159***	-0.194***
	(0.0446)	(0.0386)	(0.0452)
Same language	-0.105	-0.128*	-0.188**
	(0.0916)	(0.0728)	(0.0835)
Panel B: customs union			
Not in customs union	-0.194***	-0.171***	-0.220***
	(0.0482)	(0.0419)	(0.0494)
Within customs union	-0.078	-0.098	-0.081
	(0.0849)	(0.0649)	(0.0738)
Panel C: RTA			
Not in RTA	-0.153**	-0.153***	-0.186***
	(0.0585)	(0.0486)	(0.0554)
Within RTA	-0.183***	-0.160***	-0.199***
	(0.0446)	(0.0397)	(0.0495)
Observations	221,328	143,260	15,924

Note: We include exporter-year-sector and importer-year-sector fixed effects. Cluster-robust standard errors in parentheses, two-way clustering at importer and exporter level. *** p<0.01, ** p<0.05, * p<0.1. The model also includes the set variables reported in Table 1, coefficients not reported.

5 The interaction between technology and regulation

Policy design and regulatory frameworks may play an important role in determining the impact of digital connectivity on trade costs and trade flows. We therefore investigate whether the trade-cost-reducing effect of improved connectivity is magnified by an open regulatory environment. We include a measure of digital trade regulation restrictiveness (DSTRI) and its interaction with mobile broadband subscriptions in our empirical model. Furthermore, we control for the overall market access in services by including the OECD Services Trade Restrictiveness Index (STRI). Note that in this case we are using a sub-sample comprising 46 economies for which we have information about the (digital) services trade regulation.

We provide results in Table 3. Columns (1) to (3) report results for goods, services and digitally deliverable services. We find that having an open regulatory environment (low DSTRI) amplifies the effect of connectivity in reducing trade costs for services. For economies with the best digital trade regulation, the reduction in trade costs from improved digital connectivity is more than 60 per cent larger than for economies with the median regulation. The effect is even more pronounced for trade in digitally deliverable services where the marginal effect of connectivity at the best regulation is 80 pre cent larger than at the median regulation. Moreover, for the quarter of economies with the most restrictive digital trade regulation, digital connectivity does not have a statistically significant effect on trade costs.[8]

[8]The coefficient on regulation alone does not have a sensible interpretation because it represents the estimated marginal effect of digital trade regulation at zero digital connectivity. The last row of Table 3 therefore reports the marginal effect of regulation at the best level of connectivity in the sample.

Table 3: The impact of digital connectivity depends on digital trade regulation

VARIABLES	(1) Goods	(2) Services	(3) Digitally Deliverable Services
Connectivity	-0.236***	-0.227***	-0.269***
	(0.0489)	(0.0452)	(0.0638)
Connectivity x DSTRI	0.598	0.725***	1.002***
	(0.3882)	(0.2634)	(0.3432)
DSTRI	-0.472	-0.708***	-1.142***
	(0.3309)	(0.2617)	(0.2853)
Importer STRI		0.619***	0.545***
		(0.1334)	(0.1283)
Observations	142,857	90,798	10,229
R-squared	0.813	0.857	0.824
Within R-squared	0.473	0.535	0.504
DSTRI at best connectivity	0.555	0.536*	0.576
	(0.4179)	(0.2877)	(0.4007)

Note: We include exporter-year-sector and importer-year-sector fixed effects. Cluster-robust standard errors in parentheses, two-way clustering at importer and exporter level. *** p<0.01, ** p<0.05, * p<0.1. The model includes also the set of variables reported in Table 1, coefficients not reported. The last row presents the marginal effect of DSTRI at the best level of connectivity.

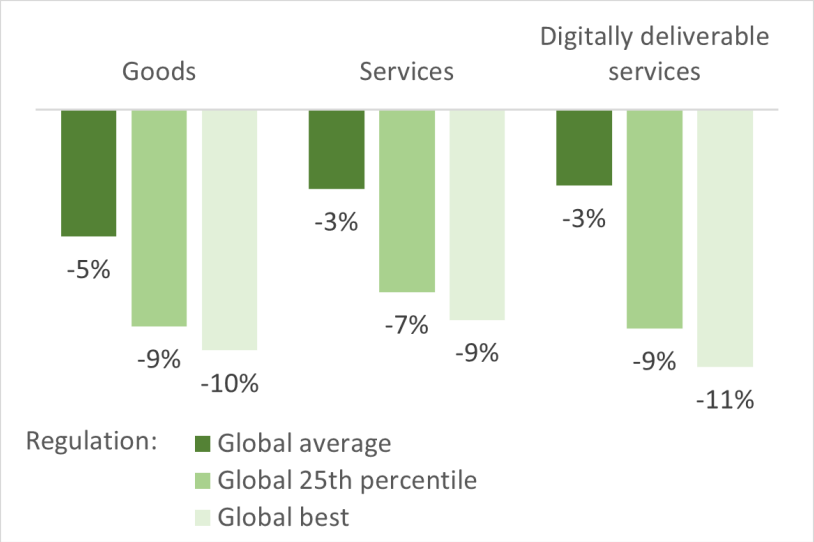
Based on these results, we gauge the potential for digital connectivity and regulation to reduce global trade costs. Using data on 79 economies, we perform out-of-sample predictions considering a scenario in which all economies improve their mobile broadband access at least to the 75th percentile of the global distribution.[9] We predict the change in trade costs at three different levels of digital trade regulation: at the current average regulation, at a less restrictive level where all economies are at most at the 25th percentile of the global distribution, and at the least restrictive level.

The results suggest that the counterfactual improvement in digital connectivity would reduce average trade costs by 3 per cent to 5 per cent across different sectors (Figure 5). The Figure also reveals the extent to which restrictive digital trade regulation impedes the impact of technology adoption on trade costs. For this purpose, we compare the reductions at current levels of regulation with reductions in the scenario with less restrictive regulation. If all economies were at most at the 25th percentile of

[9]We use data for 2020, which is the most recent year that maximizes the sample size for which information is available both on mobile broadband subscriptions and digital trade regulation. The 75th percentile is representative of countries such as Austria, Indonesia, Uruguay or South Africa.

the global distribution [global best], the reduction in trade costs resulting from better connectivity would be more than twice [three times] more pronounced in the service sector and three [almost four] times more pronounced in digitally deliverable services.[10]

Figure 5: Counterfactual reductions in trade costs by sector group and restrictiveness of regulation



Note: The figure shows the estimated average reduction in trade costs in a scenario where all economies improve their mobile broadband access at least to the level of the economy at the 75th percentile of the global distribution in 2020. The estimates for goods are not statistically significantly different from each other.

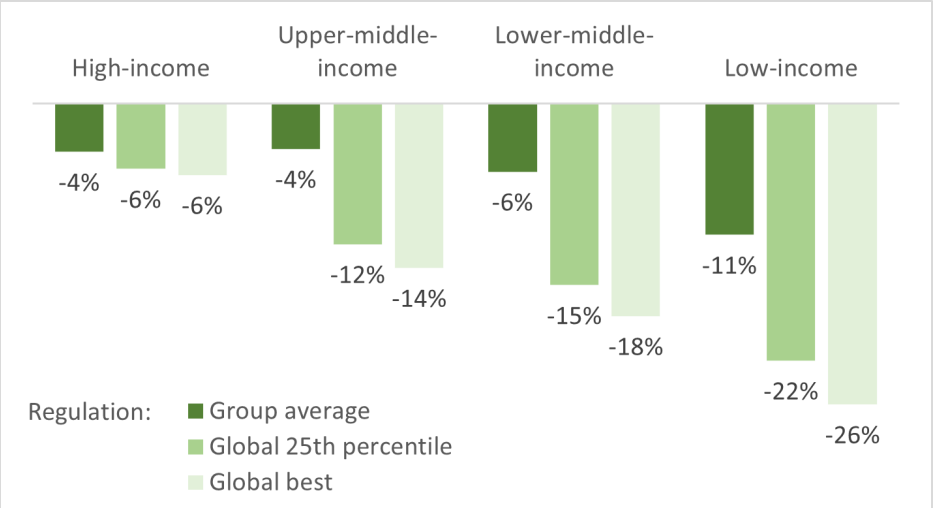
Figure 6 shows results of the same counterfactual scenarios for average trade costs across all economic sectors but differentiated by income groups.[11] While low-income economies would register the steepest decline in trade costs, a comparison between the different columns within each income group suggests that digital trade regulation constrains the effect of digital connectivity the most in the group of upper-middle-income economies. In the scenario with the least restrictive regulation, reductions in average trade costs would be 2.4 times larger in low-income economies, three times larger in lower-middle-income economies and 3.5 times larger in upper-middle-income economies.[12]

[10]Note that for goods the difference between the estimated trade costs reductions at the two levels of regulation is not statistically significant.

[11]For this set of predictions we use estimations where we allow the impact of connectivity and regulation to vary between high-income and lower-income economies (regression results are reported in Table A5 of the Appendix).

[12]Figure A1 of the Appendix presents additional charts by income group for each economic sector. Figure A2, A3 and A4 present additional charts by regions, showing that Africa has the largest potential to benefit from improved digital infrastructure and regulation.

Figure 6: Counterfactual reductions in trade costs by income group and restrictiveness of regulation



Note: The figure shows the estimated average reduction in trade costs across all economic sectors in a scenario where all economies improve their mobile broadband access at least to the level of the economy at the 75th percentile of the global distribution in 2020. The estimates for high-income economies are not statistically significantly different from each other.

6 Conclusions

Digital connectivity is fundamental for trade. Advancements in ICT and the roll out of fast internet reduced communication, information and transaction costs associated with international business. Moreover, digitalization has dramatically reduced trade costs for services that can be delivered over the internet: the costs of delivering a service digitally are much lower than delivering it in person or through a foreign affiliate.

We estimate that a 10 percentage point increase in digital connectivity is associated with around 2 per cent lower trade costs in goods and services. We also find empirical support for two channels through which digital connectivity reduces trade cost. Our results suggest that reductions in communication and information costs are an important channel for trade in goods while reductions in the costs associated with customs procedures and regulatory differences are important for all types of trade.

The main contribution of our paper is to show that the impact of digital connectivity depends on digital trade regulation. Regulation that does not guarantee interconnection and restricts cross-border data flows reduces the potential for cross-border services trade created by digitalization. Our findings show that this is especially true for trade in digitally deliverable services such as business and professional services. For economies with the best digital trade regulation, the reduction in trade costs resulting from improved digital connectivity is around 80 per cent larger than for economies with

the median regulation. For the quarter of economies with the worst regulation, digital connectivity has no significant effect on trade costs in digitally deliverable services.

Our findings bear important policy implications. Investing in digital infrastructure and digital technology adoption is a necessary step towards reaping the benefits of the digital economy for international trade. However, these investments need to be supported by a robust regulatory framework that facilitates cross-border digital trade and avoids fragmentation of the digital economy due to regulatory heterogeneity.

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Appendix: Additional tables and figures

Table A1: Economies included in the econometric analysis

Economy	Income Group	Economy	Income Group
Argentina	Upper-middle	Lao People's Democratic Republic	Lower-middle
Australia	High	Latvia	High
Austria	High	Lithuania	High
Belgium	High	Malaysia	Upper-middle
Brazil	Upper-middle	Mexico	Upper-middle
Bulgaria	Upper-middle	Morocco	Lower-middle
Cambodia	Lower-middle	Netherlands	High
Canada	High	New Zealand	High
Chile	High	Norway	High
China	Upper-middle	Peru	Upper-middle
Colombia	Upper-middle	Philippines	Lower-middle
Costa Rica	Upper-middle	Poland	High
Croatia	High	Portugal	High
Czech Republic	High	Romania	Upper-middle
Denmark	High	Russian Federation	Upper-middle
Estonia	High	Saudi Arabia, Kingdom of	High
Finland	High	Slovak Republic	High
France	High	Slovenia	High
Germany	High	South Africa	Upper-middle
Greece	High	Spain	High
Hungary	High	Sweden	High
Iceland	High	Switzerland	High
India	Lower-middle	Chinese Taipei	High
Indonesia	Lower-middle	Thailand	Upper-middle
Israel	High	Tunisia	Lower-middle
Italy	High	Türkiye	Upper-middle
Japan	High	United Kingdom	High
Kazakhstan	Upper-middle	United States of America	High
Korea, Republic of	High	Viet Nam	Lower-middle

Note: Income groups based on World Bank classification in 2018.

Table A2: List of sectors included in the econometric analysis

Sector	ISIC code
Primary	01T05
Mining	10T14
Food	15T16
Textiles & Leather	17T19
Wood	20
Paper	21T22
Chemicals	24
Plastics	25
Mineral	26
Metal	27T28
Other machinery	29
Electronics	30T33
Transport	34T35
Other manuf	36T37
Wholesale & Retail	50T52
Inland transport	60
Maritime transport	61
Air transport	62
Logistics	63
Post & Telecom	64
Financial intermediation	65T67
Business & Professional	71T74
Other Services	90T93

Note: Based on ISIC Revision 3.1 classification.

Table A3: The impact of digital connectivity on trade costs: alternative measures of connectivity

	Individuals using the internet			Log(mobile broadband subscriptions)		
	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Goods	Services	Digitally deliverable services	Goods	Services	Digitally deliverable services
Connectivity	-0.352**	-0.348***	-0.367***	-0.109***	-0.102***	-0.140***
	(0.1566)	(0.1008)	(0.1228)	(0.0357)	(0.0305)	(0.0364)
Distance	0.287***	0.224***	0.232***	0.289***	0.227***	0.234***
	(0.0199)	(0.0167)	(0.0178)	(0.0205)	(0.0171)	(0.0180)
Contiguity	-0.071**	-0.079***	-0.027	-0.069**	-0.077***	-0.027
	(0.0297)	(0.0207)	(0.0220)	(0.0296)	(0.0204)	(0.0224)
Landlocked	0.094**	0.156***	0.088	0.097**	0.157***	0.089
	(0.0368)	(0.0443)	(0.0558)	(0.0370)	(0.0433)	(0.0563)
Colonial dependency	-0.090***	-0.127***	-0.140***	-0.089***	-0.128***	-0.140***
	(0.0238)	(0.0234)	(0.0236)	(0.0235)	(0.0225)	(0.0225)
Colonial siblings	-0.172***	-0.145***	-0.132***	-0.169***	-0.142***	-0.130***
	(0.0318)	(0.0327)	(0.0380)	(0.0313)	(0.0326)	(0.0378)
Common language	-0.043*	-0.016	-0.042	-0.045*	-0.018	-0.044*
	(0.0228)	(0.0212)	(0.0257)	(0.0227)	(0.0215)	(0.0258)
Common legal origin	-0.006	-0.012	-0.020	-0.006	-0.012	-0.020
	(0.0125)	(0.0113)	(0.0151)	(0.0124)	(0.0114)	(0.0151)
Time zone difference	-0.018***	-0.015***	-0.016***	-0.018***	-0.015***	-0.016***
	(0.0056)	(0.0039)	(0.0046)	(0.0057)	(0.0039)	(0.0046)
Migrants_{od}	-0.012***	-0.014***	-0.014***	-0.012***	-0.014***	-0.013***
	(0.0029)	(0.0023)	(0.0029)	(0.0029)	(0.0023)	(0.0029)
Migrants_{do}	-0.012***	-0.010***	-0.011***	-0.011***	-0.010***	-0.012***
	(0.0032)	(0.0027)	(0.0031)	(0.0032)	(0.0028)	(0.0032)
RTA	-0.069***	-0.047***	-0.028	-0.069***	-0.047***	-0.029
	(0.0199)	(0.0146)	(0.0182)	(0.0202)	(0.0148)	(0.0185)
Customs	-0.060	-0.057	-0.071*	-0.057	-0.055	-0.070*
	(0.0473)	(0.0369)	(0.0403)	(0.0478)	(0.0376)	(0.0409)
Differences in corruption	0.028	-0.055	-0.154	0.063	-0.004	-0.094
	(0.2892)	(0.2156)	(0.3051)	(0.2937)	(0.2246)	(0.3030)
Differences in GDPpc	-0.206***	-0.199***	-0.235***	-0.158***	-0.151***	-0.190***
	(0.0581)	(0.0458)	(0.0604)	(0.0518)	(0.0419)	(0.0542)
Differences in human capital	0.003	0.037	0.050	0.015	0.050	0.058
	(0.0673)	(0.0554)	(0.0576)	(0.0681)	(0.0571)	(0.0593)
Mobile telephone	0.009	-0.042	-0.017	0.017	-0.034	-0.004
	(0.0324)	(0.0346)	(0.0570)	(0.0315)	(0.0338)	(0.0556)
Constant	-0.056	0.539***	0.667***	0.209	0.779***	1.074***
	(0.1830)	(0.1453)	(0.1697)	(0.2340)	(0.2026)	(0.1948)
Observations	219,855	142,254	15,810	221,328	143,260	15,924
R-squared	0.800	0.842	0.813	0.800	0.841	0.813
Within R-squared	0.423	0.498	0.472	0.420	0.496	0.470

Note: We include exporter-year-sector and importer-year-sector fixed effects. Columns (1) to (3) show the impact of digital connectivity using as a proxy the share of population using the internet, columns (4) to (6) use as a proxy the log of active mobile broadband subscriptions per capita. Cluster-robust standard errors in parentheses, two-way clustering at importer and exporter level. *** p<0.01, ** p<0.05, * p<0.1.

Table A4: Impact of digital connectivity on trade flows

VARIABLES	(1) All	(2) Goods	(3) Services	(4) Digitally deliverable services
Mobile broadband subscriptions	0.647***	0.664***	0.618***	0.719***
	(0.1587)	(0.1744)	(0.1527)	(0.1693)
Observations	364,588	221,328	143,260	15,924
Individuals using the internet	1.367***	1.367**	1.369***	1.364***
	(0.5069)	(0.6091)	(0.3964)	(0.4559)
Observations	362,109	219,855	142,254	15,810
Log(mobile broadband subscriptions)	0.415***	0.422***	0.403***	0.520***
	(0.1254)	(0.1391)	(0.1194)	(0.1351)
Observations	364,588	221,328	143,260	15,924

Note: We include exporter-year-sector and importer-year-sector fixed effects. Results show the impact of digital connectivity on trade flows using as a proxy (i) active mobile broadband subscriptions per capita, (ii) the share of population using the internet and (iii) the log of active mobile broadband subscriptions per capita. Each model includes also the set of variables reported in Table 1, coefficients not reported. Cluster-robust standard errors in parentheses, two-way clustering at importer and exporter level. *** p<0.01, ** p<0.05, * p<0.1.

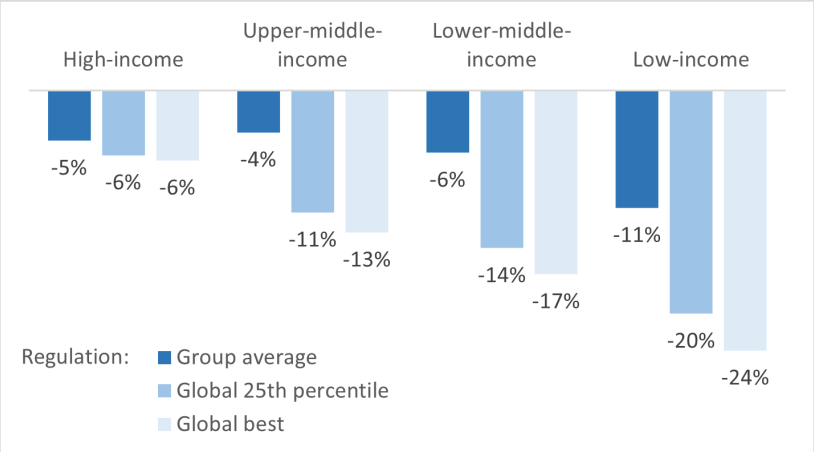
Table A5: Impact of digital connectivity depending on digital trade regulation across income groups

	Low/Middle income				High income			
VARIABLES	(1) All sectors	(2) Goods	(3) Services	(4) Digitally deliverable services	(5) All sectors	(6) Goods	(7) Services	(8) Digitally deliverable services
Connectivity	-0.337***	-0.310***	-0.365***	-0.386***	-0.207***	-0.216***	-0.194***	-0.230***
	(0.0582)	(0.0746)	(0.0521)	(0.0942)	(0.0458)	(0.0510)	(0.0460)	(0.0632)
Connectivity x DSTRI	1.237***	1.107**	1.351***	1.462***	0.447	0.406	0.485	0.740**
	(0.4225)	(0.5240)	(0.3214)	(0.4675)	(0.3961)	(0.4709)	(0.3073)	(0.3666)
DSTRI	-0.930***	-0.765**	-1.099***	-1.468***	-0.419	-0.333	-0.547*	-0.963***
	(0.2930)	(0.3325)	(0.2476)	(0.3059)	(0.3335)	(0.3795)	(0.2754)	(0.2836)
Importer STRI	0.064		0.611***	0.557***	0.066		0.616***	0.565***
	(0.1526)		(0.1286)	(0.1255)	(0.1519)		(0.1288)	(0.1245)
Observations	233,655	142,857	90,798	10,229	233,655	142,857	90,798	10,229
R-squared	0.826	0.813	0.857	0.825	0.827	0.813	0.857	0.825
Within R-squared	0.486	0.474	0.536	0.505	0.488	0.475	0.538	0.507
DSTRI at best connectivity	2.12***	1.898***	2.316***	2.507***	0.348	0.363	0.284	0.307
	(0.5066)	(0.6423)	(0.3941)	(0.5958)	(0.4100)	(0.493)	(0.3357)	(0.4404)

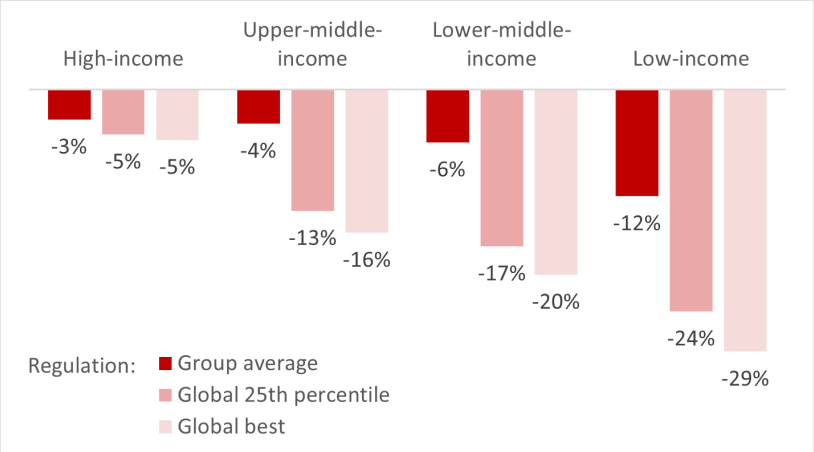
Note: We include exporter-year-sector and importer-year-sector fixed effects. Cluster-robust standard errors in parentheses, two-way clustering at importer and exporter level. *** p<0.01, ** p<0.05, * p<0.1. The model includes also the set of variables reported in Table 1, coefficients not reported. The last row presents the marginal effect of DSTRI at the best level connectivity in the sample.

Figure A1: Counterfactual reductions in trade costs by income group

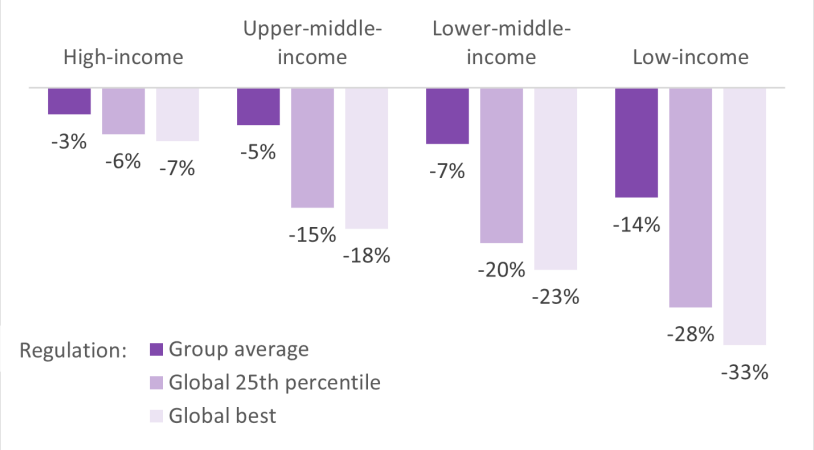
Goods



Services

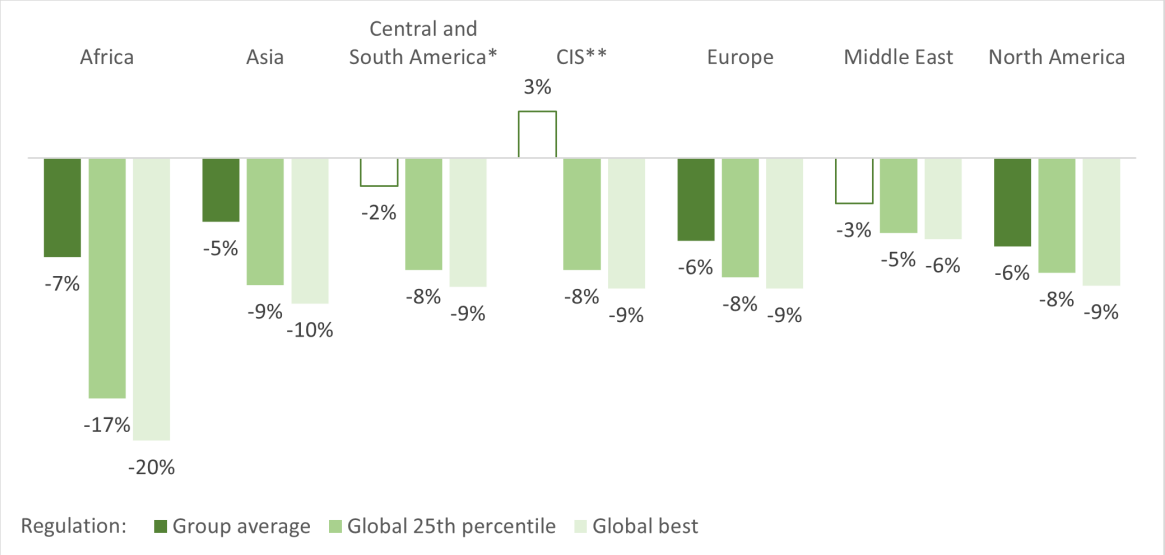


Digitally deliverable services



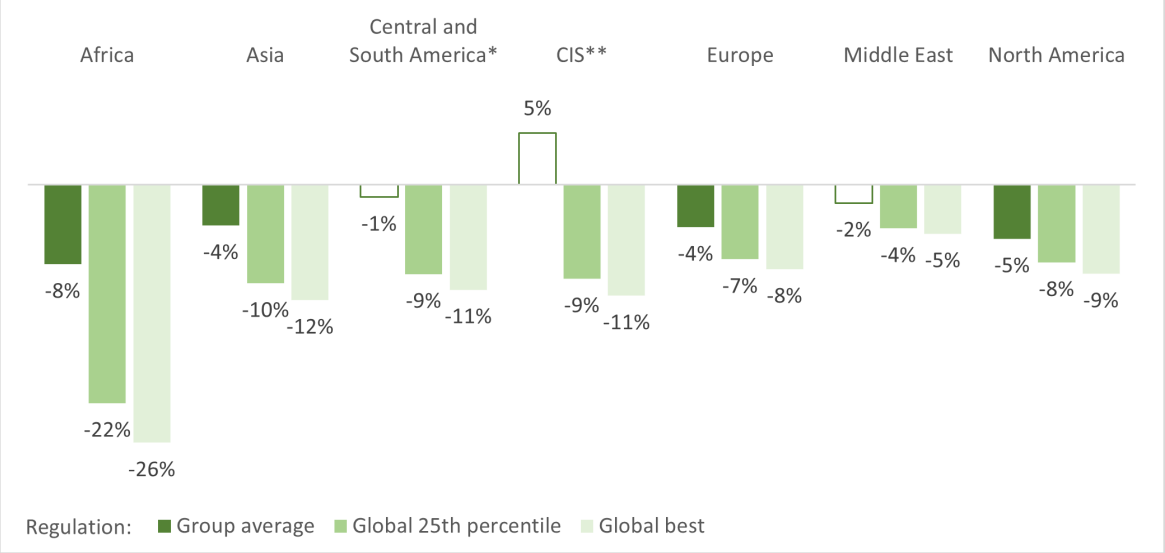
Note: The figures show the estimated average reductions in trade costs in a scenario where all economies improve their mobile broadband access at least to the level of the economy at the 75th percentile of the global distribution in 2020. In goods and in services, the estimates at different levels of regulation for high-income economies are not statistically significantly different from each other.

Figure A2: Counterfactual reductions in trade costs in goods by region



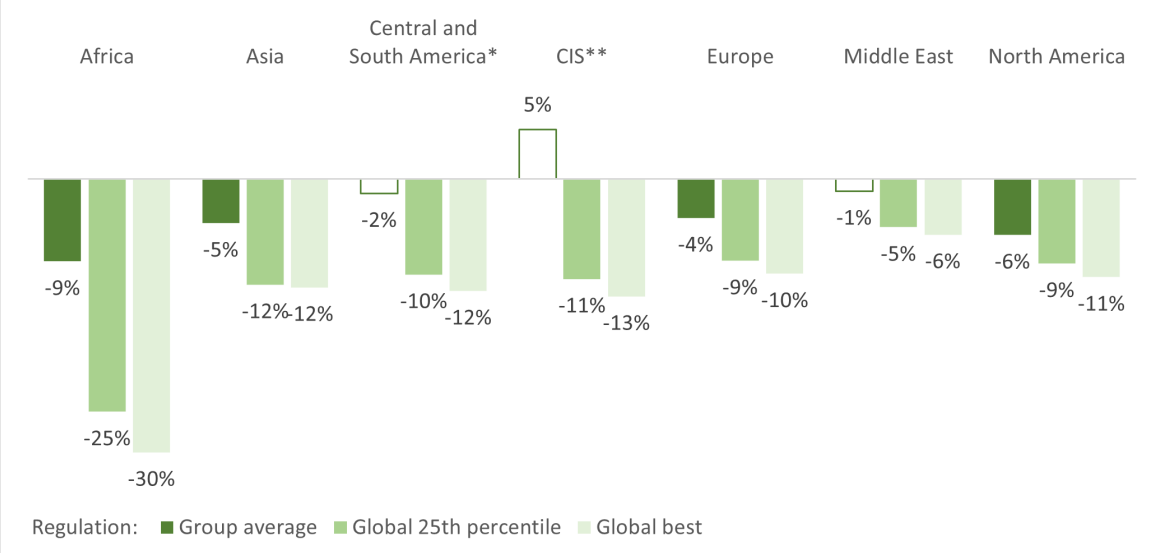
* Includes the Caribbean
** Commonwealth of Independent States, including certain associate and former member States
Note: The figures show the estimated average reductions in trade costs in a scenario where all economies improve their mobile broadband access at least to the level of the economy at the 75th percentile of the global distribution in 2020. White fill indicates that the estimate is not statistically significantly different from zero.

Figure A3: Counterfactual reductions in trade costs in services by region



* Includes the Caribbean
** Commonwealth of Independent States, including certain associate and former member States
Note: The figures show the estimated average reduction in trade costs in a scenario where all economies improve their mobile broadband access at least to the level of the economy at the 75th percentile of the global distribution in 2020. White fill indicates that the estimate is not statistically significantly different from zero.

Figure A4: Counterfactual reductions in trade costs in digitally deliverable services by region



* Includes the Caribbean

** Commonwealth of Independent States, including certain associate and former member States

Note: The figures show the estimated average reduction in trade costs in a scenario where all economies improve their mobile broadband access at least to the level of the economy at the 75th percentile of the global distribution in 2020. White fill indicates that the estimate is not statistically significantly different from zero.