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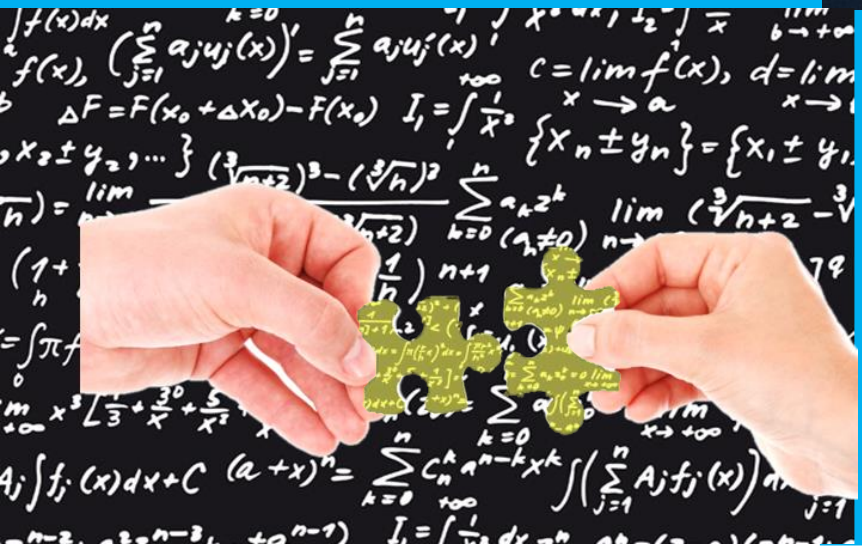
Partial and General Equilibrium Impacts of Trade Digitalization using Structural Gravity Model



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ASIA-PACIFIC RESEARCH AND TRAINING NETWORK ON TRADE

WORKING PAPER

Partial and General Equilibrium Impacts of Trade Digitalization using Structural Gravity Model

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Abstract

The study estimates partial and general equilibrium impacts of trade digitalization on trade flows using data from the UN Trade Digitalization Index (TDI) 2024 and a structural gravity model. This approach, unlike earlier gravity model studies on the topic, allows for the derivation of both trade and welfare effects associated with trade digitalization. Estimated partial equilibrium effects suggest that a 10 percent increase in trade digitalization may increase trade flows by approximately 8 percent globally. Based on the gravity model estimates, a general equilibrium model is constructed. Counterfactual simulations are conducted to further assess the potential effects of various trade digitalization reforms, where countries in different world regions and globally are brought from their current state of implementation to a common level. The general equilibrium results indicate that global trade increases by nearly 5 percent when partial implementation of the trade digitalization measures included in the UN TDI is achieved. When full trade digitalization is implemented, trade rises by almost 13 percent. Real wages also increase by over 3 percent when trade digitalization measures included in the UN TDI are fully implemented. Concurrently, producer prices fall by nearly 4 percent globally under the full implementation scenario. While the size of impacts varies across regions, the direction of impacts is consistent across all regions, confirming that trade digitalization offers great opportunities in inducing trade, as well as in increasing wages and reducing costs for consumers. The Pacific Islands and Sub-Saharan Africa emerge as the top beneficiaries in terms of potential trade growth, suggesting that trade digitalization be prioritized as part of their sustainable development plans.

Keywords: trade digitalization, trade digitalization index, TDI, structural gravity, general equilibrium

JEL Codes: D50, F13, O14

Table of Contents

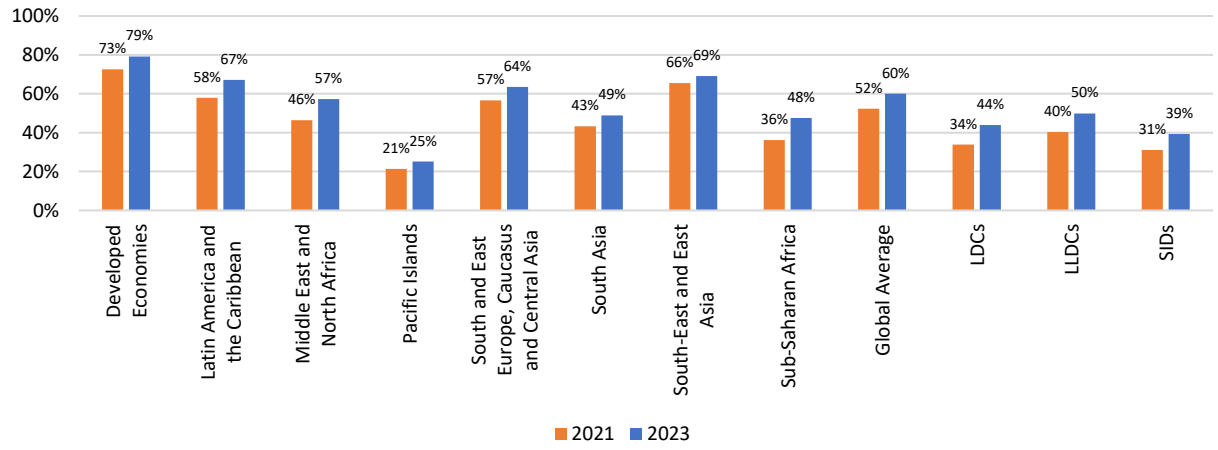
List of Tables

List of Figures

1. Introduction

As the growth of the digital economy continues, digital transformation has become a key concern of policymakers in developed and developing countries alike. Indeed, effectively engaging in a global economy where interactions and transactions are increasingly taking place online requires both development of new ICT infrastructure as well a new laws, regulations and processes. In this context, trade digitalization, or the improvement of trade processes using digital technologies and digitized data,[3] has become an important priority, as evidenced by the growing number of related provisions included in multilateral and other trade agreements (ESCAP, UNCTAD and UNIDO, 2023).[4] It is also a natural extension of on-going trade facilitation efforts undertaken in many countries, including as part of the implementation of the WTO Trade Facilitation Agreement (TFA).[5]

Figure 1: Trade digitalization implementation around the world (2021 and 2023)



Source: Author's calculation based on data from tdi.digitalizetrade.org – accessed on 15 July 2024.

Note: This shows the average implementation rate of measures included in the UN TDI by world regions. World regions are grouped as in United Nations (2023).

The recently launched United Nations Trade Digitalization Index (TDI) leverages digital trade facilitation data from the UN Digital and Sustainable Global Survey to measure the progress made by over 160 countries in implementing a range of paperless trade measures, aggregating implementation rates of 15 paperless trade and cross-border paperless trade measures. The global average level of implementation of these measures stands at approximately 60% as of 2023 (Duval et al., 2024). Figure 1

[3] Nguyen (2022) gives a brief definition of digitization and digitalization as follows: Digitization: creating a digital representation of physical objects or attributes; Digitalization: enabling or improving processes by leveraging digital technologies and digitized data.
[4] See chapter 5 of the Asia-Pacific Trade and Investment Report at: https://www.unescap.org/kp/APTIR2023
[5] Trade facilitation in the context of the World Trade Organization (WTO) and the United Nations generally refers to the simplification, modernization and harmonization of export and import processes.

illustrates trade digitalization performance across world regions, with implementation ranging from 25% in small developing Pacific Islands economies, to 78 percent in developed economies. The top performing developing region is South-East and East Asia (69%), with Sub-Saharan Africa and Middle East and North Africa making the most progress between 2021 and 2023.

While much progress has been made, much remains to be done to achieve seamless electronic exchange and legal recognition of trade-related data and documents across borders. Accordingly, this study aims to investigate the potential impact of trade digitalization using a structural gravity model. We review the literature in section 2 and then discuss the data and methodology in section 3. Empirical results are presented and discussed in section 4, followed by conclusions in section 5.

2. Literature review[6]

Studies on the impact of trade facilitation on trade began to emerge about 20 years ago, along with new datasets providing information on trade costs and time, e.g., Wilson et al. (2003) or Djankov et al. (2006) - Djankov et al. found that one day of delay in delivery was associated with a 1 percent loss in trade, using data from the World Bank Doing Business initiative. These foundational studies were followed by more detailed studies with more specialized dataset and indices and increasingly elaborate model specifications (e.g. Arvis et al., 2016; Kim and Mariano, 2020; Sharafeyeva, 2023) providing further insights on the importance of various aspects of trade facilitation and its impact on trade flows and costs. However, these studies generally focused on general trade facilitation measures or aggregate proxies, rather than on trade digitalization measures – also referred to as "digital trade facilitation" measures.

To monitor the implementation of trade facilitation, including trade digitalization measures, various indicators have been developed. Moïsé and Sorescu (2013) utilize OECD Trade Facilitation Indicators (OECD-TFIs) to evaluate the potential impacts of the WTO Trade Facilitation Agreement (TFA), where digitalization components are reflected partially in the "Formalities" indicator. The study applies both gravity and trade cost models, using ordinary least squares (OLS) and pseudo-Poisson maximum likelihood (PPML) with fixed effects, to measure the overall impact of OECD-TFIs on trade flows and the negative impact on trade costs across different income groups, regions, and types of goods. Their findings suggest that a 10% increase in "automation" of formalities can boost trade by up to 6%, depending on the income group. Additionally, variance decomposition of trade costs reveals that automation can account for up to a 2.6% decrease in trade costs on average. Hillberry and Zhang (2015) later use a log-linear model with multiple imputation to examine the effects of automation on trade costs, finding that a one-point increase in the automation index (on a scale from 0 to 2) leads to a reduction of over 30% in import costs.[7] However, the coverage of trade digitalization in the OECD-TFIs has remained limited since it mirrors that of the TFA.[8]

The United Nations (UN) has also developed indicators of trade facilitation implementation (UN-TFIs), going beyond the measures listed in the WTO TFA to include more advanced and targeted trade facilitation and digitalization measures. The indicators are constructed based on data from the UN Global Survey on Digital and Sustainable

[6] Additional literature on the impact of broader digital connectivity and the use of computable equilibrium models can be found in Annex 1.

[7] Several other gravity modeling studies using TFI data were also subsequently released, e.g. ADB (2017) uses PPML and found that a 10 percent improvement in overall OECD-TFIs could contribute to 0.5 to 1 percent improvement in trade. Results of studies consistently pointed to the significant impact of trade facilitation on trade, but with large variation in the size of the impact – For example, Nguyen and Tran (2021) investigates the case of ASEAN and find that a 1 percent improvement in OECD-TFIs among ASEAN members with 88 trading partners increase trade by 1 percent.

[8] The WTO TFA has very ambition in terms of trade digitalization, with specific trade digitalization measures limited non-binding provisions on single window and electronic payments of duties and fees – see Annex 1.

Trade Facilitation conducted biennially since 2015, now covering 163 countries and over 50 trade facilitation measures, including 16 digital trade facilitation – or trade digitalization - measures. Duval et al. (2018, 2019) investigated the effects digital trade facilitation measures on trade costs using UN-TFIs. Their analysis found that a 10% improvement in digital trade facilitation in both reporting countries and their trading partners results in a 1.4% decrease in trade costs.[9] Simulation results by United Nations (2023) suggests that the effects of full implementation of trade digitalization above and beyond the coverage of the WTO TFA amount to a 7 percent reduction in trade cost on average.

Some studies have focused on evaluating the impact of specific trade digitalization measures. For example, De Sa Porto et al. (2015) finds positive impact on trade from the existence of (electronic trade) single-window programs. Nguyen (2022) and Casanova et al. (2022) have focused on e-Bill of Ladings (eBL). The latter find that full adoption of eBL could lead to global savings of USD 6.5 billion in direct costs and generate USD 30 to USD 40 billion in new trade volume.

The gravity model of trade has long been utilized to analyze the effects of policy changes on international trade. To achieve theoretically consistent estimates, several foundational approaches have been established: Anderson and Van Wincoop (2003) emphasize the importance of multilateral resistance, Fally (2015) focuses on fixed effect controls, and Santos Silva and Tenreyro (2006) advocates for the inclusion zero trade flows. Recent advancements by Yotov et al. (2016), Baier et al. (2019), and Heid et al. (2021) propose a new methodology that integrates both international and intra-national trade flows into the gravity model, incorporating a comprehensive range of fixed effect controls specific to international trade. These “new generation” gravity models are generally called structural gravity models. Their application in the context of trade facilitation or trade digitalization remains relatively limited.

Most recently, Masood and Martinez-Zarzoso (2024) applies structural gravity - including both intra-national trade as well as international trade flows into the model - using UN-TFIs data up to 2019. Their findings indicate that the impact of trade facilitation is influenced by both the level of economic development and the type of goods. They find that the positive effects of digital trade facilitation in non-OECD countries are generally more pronounced than those in OECD countries. However, even for non-OECD countries, their results suggest that a 10% improvement in digital trade facilitation leads to only a 0.3% increase in trade for overall goods.[10]

[9] United Nations (2023) finds a slightly smaller effects on trade costs (1.3%) when the 10 percent improvement in digital trade facilitation only occurs in the reporting countries.

[10] This relatively marginal increase in trade might be attributed to Masood and Martinez-Zarzoso (2024) adding an additional international border-time fixed effect to their model in an effort to capture globalization effects. This diverges from the structural gravity methodologies used by Baier and Bergstrand (2007), Yotov et al. (2016), and Heid et al. (2021), which only include country pair fixed effects to allow for the time dimension to detect the average causal effect of policy variables on trade in the panel dataset.

3. Methodology and data

In order to examine the partial and general equilibrium effects of trade digitalization on trade, we follow Yotov et al. (2016) and Baier et al. (2019) to develop and estimate a structural gravity model and evaluate the impact of general equilibrium.[11] The model is extended to include relevant trade facilitation and digitalization variables using data from the recently released UN Trade Digitalization Index (Duval et al., 2024).

Following best practices in the literature we use panel data and year intervals to improve estimation efficiency and allow adjustment of trade flows/trade costs as a result of trade policy implementation (Olivero and Yotov (2012). Intra-national trade is included in the data to ensure consistency with gravity theory, also enabling the inclusion of non-discriminatory trade policies in the model as well as a more complete specification of fixed effects. Country-pair fixed effects are included in the model, as in Baier and Bergstrand (2007), Anderson and Yotov (2016) and Heid et al. (2021), which helps resolve endogeneity problems associated with bilateral implementation of trade policies.[12] Directional time varying fixed effects i.e., exporter-time and importer-time fixed effects are also used to control for country-time varying observables and unobservables, including theory-consistent exporter and importer multilateral resistances, as in Olivero and Yotov (2012) and Fally (2015). The model is estimated using pseudo poisson maximum likelihood (PPML) to handle heteroskedasticity issues and zero trade flows, as in Santos Silva and Tenreyro (2006).

Unlike in the standard gravity model, time invariant traditional bilateral trade costs, such as those associated with geographical distance (e.g., distance, contiguity, etc.) and cultural distance (e.g., common official/unofficial language, colonial ties, or formerly being the same country, etc.), are captured by bilateral fixed effects, while exporter-time fixed effects and importer-time fixed effects capture outward and inward multilateral resistance terms. As such, the structural gravity model's partial equilibrium specification is as follows:

$$m_{ji,t} = \exp\left[\alpha_{i,t} + \gamma_{j,t} + \delta_{ij} + \beta_1\left(\ln\left(\boldsymbol{GTF_{i,t}}\right) \times INTER_{ij}\right) + \beta_2\left(\ln\left(\boldsymbol{TDI_{i,t}}\right) \times INTER_{ij}\right) + \beta_3\left(\ln\left(gtariff_{ij,t}\right) + \beta_4(RTA_{ij,t})\right] \times \varepsilon_{ij,t} \quad (1)$$

where $GTF_{i,t}$ is country i's general trade facilitation as a proxy representing commitments in the WTO TFA not specifically related to trade digitalization; $TDI_{i,t}$ is country i's trade digitalization index representing trade digitalization measures; $gtariff_{ij,t}$ is geometric average of bilateral tariff and; $RTA_{ij,t}$ is indicator variable taking value of 1 if country i and

[11] Yotov et al. (2016) narrates the computational method from Piermartini and Yotov (2016) and, Larch and Yotov (2016). Baier et al. (2019) explains their general equilibrium method, based on Armington-CES trade model.

[12] Although this study is dealing with non-discriminatory policies i.e., country-specific policy variable, another benefit of using country-pair fixed effect is that such fixed effects will completely absorb time-invariant bilateral trade costs factors, making the use of geographical/cultural distance of bilateral pairs unnecessary.

j are members of the same RTA, and 0 otherwise. Table 1 summarizes variable descriptions, treatment of data, data sources, and expected effect of variable on trade. The GTF and TDI variables are constructed following United Nations (2023) and Duval et al. (2024), respectively.[13]

The model is estimated using a dataset covering exports of goods of 85 economies[14] and their intra-national trade in 2015, 2017, 2019, and 2021 using PPML. The model includes exporter-year fixed effects ($\alpha_{i,t}$), importer-year fixed effects ($\gamma_{j,t}$), country-pair fixed effect (δ_{ij}) as well as robust and clustered standard errors by country pair to take care of endogeneity of trade policies and cross-country data heterogeneity. Following Yotov et al. (2016) and Heid et al. (2021), the country-specific variables are interacted with dummy variable "$INTER_{ij}$", which equals to 1 if it is international trade and zero otherwise. This method allows the complete set of fixed effects to be included in the estimation.

To investigate the impact of the trade facilitation and digitalization in partner countries, a modified model is also estimated that uses the geometric average of country i and j's general trade facilitation and trade digitalization implementation indices, as follows:

$$m_{ji,t} = \exp\left[\alpha_{i,t} + \gamma_{j,t} + \delta_{ij} + \beta_1\left(\ln\left(\boldsymbol{GTF_{ij,t}}\right) \times INTER_{ij}\right) + \beta_2\left(\ln\left(\boldsymbol{TDI_{ij,t}}\right) \times INTER_{ij}\right) + \beta_3\left(\ln\left(gtariff_{ij,t}\right) + \beta_4(RTA_{ij,t})\right] \times \varepsilon_{ij,t} \quad (2)$$

Based on model (2), we then use a general equilibrium in one-sector Armington-CES trade model as in Baier, Yotov and Zylkin (2019) to further investigates trade and real income (welfare) effect when a country pair improves. Data from 2021 provides the baseline to conduct counterfactual simulations of the potential effects of trade digitalization reforms, as follows:[15]

- Case 1: partial Implementation of trade digitalization measures included in the UN TDI. All countries whose trade digitalization measures are either not implemented or are implemented on a pilot basis take action to achieve at least partial implementation.

- Case 2: full implementation of digitalization measures included in the UN TDI. All countries whose measures have not achieved full implementation of a measure take action to achieve full implementation.

[13] See Annex 2 for details on the measures included in General trade facilitation and Trade digitalization index.
[14] See Annex 3 for detailed list of countries covered. The study uses mirror images of imports for data completeness.
[15] See Annex 4 for additional simulation results on WTO TFA and WTO TFA+ trade digitalization reforms.

Table 1: Data definition, treatment, source, and expected sign in partial equilibrium analysis

Variable	Definition	Data Treatment	Source	Expected Sign
$m_{ji,t}$	Import flows of j from i (equivalent to export of i to j). If i and j are different countries, the variable denotes international trade i.e. imports of country j to destination i to represent exportation of i to j (as imports data are more completed). If i and j are the same country, the value denotes intra-national trade i.e. domestic production of country i less total exports	None	**International trade:** World Integrated Trade Solution (WITS) **Intra-national trade:** Retrieve production data from UN DataBank with application from Arvis et al. (2016) to obtain intra-national trade.	N/A
$INTER_{ij}$	Indicator variable value of 1 if i and j are different countries and zero otherwise	None	Author's calculation	N/A
GTF_i/GTF_{ij}	Rate of general trade facilitation implementation of country i (generaltf_i) / geometric average of trade facilitation implementation rate of country i and j (generaltf_ij: (square root of generaltf_i times generaltf_j), which covers measures included in the WTO TFA	0.0001 replacement if implementation equals zero	Global Survey on Trade Facilitation and Paperless Trade Implementation 2023, United Nations	+
TDI_i/TDI_{ij}	Rate of trade digitalization implementation of country i (tdi_i) / geometric average of trade digitalization implementation rate of country i and j (tdi_ij: (square root of tdi_i times tdi_j)	0.0001 replacement if implementation equals zero	Trade digitalization Index 2024, United Nations	+
$gtariff_{ij}$	Geometric average tariff of country i and j.	Tariff is structured as 1+tariff rate. The study sets rate to zero if it is intra-national trade observation	World Integrated Trade Solution (WITS)	-
RTA_{ij}	Dummy variable equal to 1 if country i and j are members of the same regional trade agreement and zero otherwise.	The study sets value to zero if it is intra-national trade observation	Egger, P. H. and Larch, M. (2008)[16]	+

Abbreviation: TF = trade facilitation; TFI = trade facilitation implementation; N/A = not applicable.

Note: This shows the average implementation rate of measures included in the UN TDI by world regions. World regions are grouped as in United Nations (2023).

[16] This dataset includes all RTA as notified to the World Trade Organization in 1950-2022. Details are available at: https://www.ewf.uni-bayreuth.de/en/research/RTA-data/index.html

4. Empirical results

Table 2 summarizes the partial equilibrium results from the models. All explanatory variables are statically significant with correct signs. Model 1 suggests a 7.6 percent increase in exports may be expected from a 10 percent improvement in trade digitalization, while model 2 suggests a 7.9 percent increase. A 10 percent increase in the exporter's general TF implementation rate results in about half the increase expected from digitalization measures (3.7% in model 2 to 3.9 % in model 1). [17] The higher impact of trade digitalization improvements found using model 2, where trade digitalization is featured as the geometric average of exporter's and importer's trade digitalization performance, supports the view that cooperation between countries in this area may be particularly important and fruitful, including in ensuring interoperability among paperless systems.

Table 2: Partial equilibrium results

Dependent variable: mji	(1) PPML | exporter	(2) PPML | exporter-importer
ln_generaltf_i_inter	0.390**	
	[2.346]	
ln_TDI_i_inter	0.764***	
	[5.719]	
ln_generaltf_ij_inter		0.371**
		[2.141]
ln_TDI_ij_inter		0.785***
		[5.657]
ln_gtariff	-1.238**	-1.114*
	[-2.108]	[-1.774]
rta	0.241***	0.235***
	[5.885]	[5.693]
Constant	26.49***	26.58***
	[296.3]	[303.6]
Observations	21,144	18,094
Reporter-year FE	Yes	Yes
Partner-year FE	Yes	Yes
Pair FE	Yes	Yes

*** p<0.01, ** p<0.05, * p<0.1
Z-stat. in square brackets

[17] When compared to the ADB-ESCAP (2024) using exporter-side model (similar to our Model 1), the impact of general TF is slightly lower in this study (3.9 percent increase versus 5.2 percent in ADB-ESCAP), whereas the effect of trade digitalization on trade is slightly higher (7.6 percent increase versus 7.1 percent in ADB-ESCAP) at a 10 percent improvement rate in trade digitalization.

Table 3 summarizes general equilibrium impacts from trade digitalization reforms by regions as well as global results. Full implementation of trade digitalization measures in the UN TDI is expected to result in a 12.6 percent increase in exports at the global level, ranging from 9 percent in South-East and East Asia to 102 percent in Pacific Islands. This is essentially because many countries in these two regions had achieved very limited trade digitalization as of 2021. Adopting a more comprehensive and ambitious trade digitalization strategy in these two regions remain worthy of consideration as it is found to more than triple these expected export gains, even when partially implemented. Full implementation of trade digitalization is estimated to enable the doubling of current exports in Pacific Islands, as efficiency gains and reductions in trade costs open up new opportunities.

Table 3: General equilibrium results on export growth, real wage growth and growth in producer price (in %) as a result of further progress in trade digitalization

Region	Export growth		Change in real wage		Change in producer's prices	
	Partially implemented	Fully implemented	Partially implemented	Fully implemented	Partially implemented	Fully implemented
Developed Economies	5.2%	12.4%	1.5%	3.4%	-1.2%	-2.8%
Latin America and the Caribbean	4.9%	15.8%	1.2%	2.4%	-1.9%	-3.7%
Middle East and North Africa	19.4%	34.7%	1.3%	2.7%	-2.0%	-3.8%
Pacific Islands	68.0%	102.0%	3.1%	4.8%	-8.0%	-10.9%
South and East Europe, Caucasus and Central Asia	9.7%	20.8%	2.2%	4.4%	-2.0%	-4.2%
South Asia	7.8%	19.0%	1.4%	2.5%	-2.7%	-4.9%
South-East and East Asia	2.2%	9.0%	1.6%	4.1%	-1.2%	-2.7%
Sub-Saharan Africa	50.6%	80.0%	1.4%	2.4%	-3.0%	-4.8%
Global (85 countries)	**4.8%**	**12.6%**	**1.5%**	**3.1%**	**-2.1%**	**-3.9%**

Source: Author's calculation.

Note: World regions are grouped as in the United Nations (2023).

The general equilibrium model simulations also reveal significant gains from trade digitalization in terms of real wages. Full implementation of TDI measures leads to a 3.1 percent higher real wages at the global level. Wages increase by over 4% in three of the regions considered: Pacific Islands and South and East Europe, Caucasus and Central Asia and South-East and East Asia. Such gains may be attributed to efficiency gains, which also leads to a fall in producers' prices. Prices fall up to 4 percent globally when trade digitalization is fully implemented. Producer's prices fall by over 10 % in Pacific Island countries, and by nearly 5% in South Asia and Sub-Saharan Africa.

5. Conclusion

This paper applies structural gravity model in examining the effect of trade digitalization on trade using the recently released UN Trade Digitalization Index. The empirical results show that a 10 percent improvement in implementation of trade digitalization increases trade by approximately 8%. Full implementation of the set of 15 measures included in the TDI is expected to boost trade by up to 12.6 percent globally. While all world regions benefit, Pacific Islands and Sub-Saharan Africa are top gainers in terms of trade growth from trade digitalization implementation. Real wages increase up to 3 percent globally and producer's prices fall by up to 4 percent globally, benefiting workers and consumers.

The results provide support for a comprehensive and ambitious approach to trade digitalization, including both paperless and cross-border paperless trade measures. While some of the measures included in the TDI can be implemented unilaterally, the full benefits of trade digitalization may only be achieved through international cooperation between all countries and actors along international supply chains. As such, participation in enabling multilateral trade digitalization platforms such as the one provided by the UN Framework Agreement on the Facilitation of Cross-Border Paperless Trade in Asia and the Pacific, should be actively considered. More research on the impact of individual trade digitalization measures would also be useful in developing more effective trade digitalization strategies.

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Annex 1: Additional literature review

Literature on the impact of broader digital connectivity on trade has emerged. López González et al. (2023) summarizes that digital connectivity (through the coverage of internet access of population) and digital trade policies (through digital services trade restrictiveness index) have become pivotal factors in reducing trade costs and inducing trade flows using PPML estimation.[18] Bellucci et al. (2023) uses active mobile broadband subscriptions per capita as a proxy of digital connectivity to estimate the trade cost reduction effect of 2 percent when there is an improvement of 10 percentage point in digital connectivity. The study further investigates how the overall digitalization of economies can reduce the costs associated with customs procedures and regulatory differences by examining the interaction between digital connectivity, customs unions, and the Digital Service Trade Restrictiveness Index. The results offer evidence that improvements in digital connectivity significantly mitigate these costs.

Computable general equilibrium (CGE) analysis has been employed to evaluate various "what if" policy scenarios that may affect not only on trade flows/trade costs but also on other macro aspects e.g., production and real income. While these studies provide valuable insights, only few studies have focused specifically on trade digitalization. For example, WTO (2020) uses CGE analysis to project that technological adoption could lead to an annual trade growth of approximately 2 percentage points between now and 2030. The effect is stronger (2.5 percentage point per annum) in the case of adoption of new digital technology in developing economies.

Herman and Oliver (2023) find a positive impact between internet use, bandwidth capacity, and trade. The study further explores general equilibrium impact of Nigeria increasing its internet usage to match Brazil's level. They project that such an increase could lead to trade and GDP growth of over 9% and 17%, respectively. This improvement would not only benefit Nigeria but also positively impact many other countries, especially developed ones with high levels of internet use. However, the study also underscores a potential downside: if less developed countries do not make similar advancements in internet access, they could face relative disadvantages. Thus, while the scenario illustrates the significant gains from enhanced internet connectivity, it also warns of the risk that developing countries might lag behind as the digital economy expands.

[18] The authors find that 1 percent improvement in digital connectivity has indeed played a key role in reducing domestic trade costs by 0.3 percent and international trade costs by 0.1 percent. Moreover, study explores the effects of inducing trade flows using TiVA database. The results finds that 1 percent improvement in digital connectivity leads to 2.1 and 1.5 percent in domestic and international trade, respectively. Regulatory environment and legal issues in digital trade are also crucial in reducing trade costs. An increase of 0.1 point of restrictiveness level leads to a 15.4 percent increase in international trade costs. In terms of trade facilitation, effects of digital access and regulatory environment is stronger in developing economies.

Annex 2: General Trade Facilitation (GTF) and Trade Digitalization Index (TDI)

Based on the fifth UN Global Survey on Digital and Sustainable Trade Facilitation, 16 core measures in “General Trade Facilitation” group in sub-groups of ‘transparency’, ‘formalities’, and ‘institutional arrangement and cooperation’ are used in constructing the GTF indicator (Table A1.1). Following Duval et al. (2024), the Trade Digitalization Index (TDI) focuses on the "Digital Trade Facilitation" group of measures in the UN Global Survey. This group is composed of two sub-groups, namely “paperless trade” and “cross-border paperless trade” measures, with a total of 15 measures included in the TDI indicator (Table A2.2).

Table A2.1: GTF measures and correspondence with TFA articles

Sub-groups	Measures	Related WTO TFA Article
GTF- Transparency	Publication of existing import-export regulations on the Internet	1.2
	Stakeholders' consultation on new draft regulations (prior to their finalization)	2.2
	Advance publication/notification of new trade-related regulations before their implementation	2.1
	Advance ruling on tariff classification and origin of imported goods	3
	Independent appeal mechanism	4
GTF- Formalities	Risk management	7.4
	Pre-arrival processing	7.1
	Post-clearance audits	7.5
	Separation of release from final determination of Customs duties, taxes, fees and charges	7.3
	Establishment and publication of average release times	7.6
	TF measures for authorized operators	7.7
	Expedited shipments	7.8
	Acceptance of copies of original supporting documents required for import, export or transit formalities	10.2.1
GTF- Institutional arrangement and cooperation	National Trade Facilitation Committee or similar body	23
	National legislative framework and/or institutional arrangements for border agencies cooperation	8
	Government agencies delegating border controls to Customs authorities	

Table A2.2: TDI measures and correspondence with TFA articles

Sub-groups	Measures	Relevant TFA Articles
TDI - Paperless trade	Automated Customs System	
	Internet connection available to Customs and other trade control agencies	
	Electronic Single Window System	10.4
	Electronic submission of Customs Declarations	
	Electronic application and issuance of import and export permit	
	Electronic submission of Air Cargo Manifests	
	Electronic application and issuance of Preferential Certificate of Origin	
	E-Payment of Customs Duties and Fees	7.2
	Electronic application for Customs refunds	
TDI - Cross-border paperless trade	Laws and regulations for electronic transactions	
	Recognised certification authority	
	Electronic exchange of Customs Declaration	
	Electronic exchange of Certificate of Origin	
	Electronic exchange of Sanitary and Phyto-Sanitary Certificate	
	Paperless collection of payment from a documentary letter of credit	

Annex 3: Country coverage of structural gravity model

Table A3.1: Country list

Country	Region	Country	Region
Argentina	Latin America and the Caribbean	Malaysia	South-East and East Asia
Armenia	South and East Europe, Caucasus and Central Asia	Maldives	South Asia
Australia	Developed Economies	Mauritania	Sub-Saharan Africa
Austria	Developed Economies	Mauritius	Sub-Saharan Africa
Azerbaijan	South and East Europe, Caucasus and Central Asia	Mexico	Latin America and the Caribbean
Belarus	South and East Europe, Caucasus and Central Asia	Moldova	South and East Europe, Caucasus and Central Asia
Belize	Latin America and the Caribbean	Mongolia	South-East and East Asia
Benin	Sub-Saharan Africa	Morocco	Middle East and North Africa
Bosnia and Herzegovina	South and East Europe, Caucasus and Central Asia	Mozambique	Sub-Saharan Africa
Botswana	Sub-Saharan Africa	Nepal	South Asia
Brazil	Latin America and the Caribbean	Nicaragua	Latin America and the Caribbean
Brunei	South-East and East Asia	Niger	Sub-Saharan Africa
Burkina Faso	Sub-Saharan Africa	Nigeria	Sub-Saharan Africa
Cambodia	South-East and East Asia	Norway	Developed Economies
Chile	Latin America and the Caribbean	Pakistan	South Asia
China	South-East and East Asia	Panama	Latin America and the Caribbean
Colombia	Latin America and the Caribbean	Paraguay	Latin America and the Caribbean
Costa Rica	Latin America and the Caribbean	Peru	Latin America and the Caribbean
Croatia	Developed Economies	Philippines	South-East and East Asia
Cyprus	Developed Economies	Poland	Developed Economies
Dominican Republic	Latin America and the Caribbean	Portugal	Developed Economies
Ecuador	Latin America and the Caribbean	Russian Federation	South and East Europe, Caucasus and Central Asia
Egypt, Arab Rep.	Middle East and North Africa	Samoa	Pacific Islands
El Salvador	Latin America and the Caribbean	Saudi Arabia	Middle East and North Africa
Ethiopia	Sub-Saharan Africa	Senegal	Sub-Saharan Africa
Fiji	Pacific Islands	Spain	Developed Economies
Finland	Developed Economies	Sri Lanka	South Asia
France	Developed Economies	St. Vincent and the Grenadines	Latin America and the Caribbean
Georgia	South and East Europe, Caucasus and Central Asia	Sweden	Developed Economies

Country	Region	Country	Region
Germany	Developed Economies	Switzerland	Developed Economies
Guatemala	Latin America and the Caribbean	Tanzania	Sub-Saharan Africa
Guyana	Latin America and the Caribbean	Thailand	South-East and East Asia
Honduras	Latin America and the Caribbean	Togo	Sub-Saharan Africa
India	South Asia	Trinidad and Tobago	Latin America and the Caribbean
Indonesia	South-East and East Asia	Tunisia	Middle East and North Africa
Ireland	Developed Economies	Turkey	South and East Europe, Caucasus and Central Asia
Italy	Developed Economies	Ukraine	South and East Europe, Caucasus and Central Asia
Jordan	Middle East and North Africa	United Kingdom	Developed Economies
Kenya	Sub-Saharan Africa	Uruguay	Latin America and the Caribbean
Korea, Rep.	South-East and East Asia	Uzbekistan	South and East Europe, Caucasus and Central Asia
Kyrgyz Republic	South and East Europe, Caucasus and Central Asia	Vietnam	South-East and East Asia
Lao PDR	South-East and East Asia	Zimbabwe	Sub-Saharan Africa
Lesotho	Sub-Saharan Africa		

Annex 4: Simulation results for WTO TFA and WTO TFA+ trade digitalization reforms

This appendix provides additional simulation results from those presented in the main text, specifically providing estimates of impact from implementation of (1) only trade digitalization specifically mentioned in the WTO TFA text and (2) trade digitalization measures specifically mentioned in the WTO text as well as other measures included in the UN TDI.

Table A4.1: Export growth (in %) as a result of further progress in trade digitalization

Trade digitalization: Export growth	**WTO TFA Trade Digitalization commitments**		**WTO TFA+ Trade Digitalization**	
Region	**Partially implemented**	**Fully implemented**	**Partially implemented**	**Fully implemented**
Developed Economies	0.62%	1.81%	5.25%	12.40%
Latin America and the Caribbean	0.16%	0.81%	4.91%	15.85%
Middle East and North Africa	1.65%	3.46%	19.41%	34.71%
Pacific Islands	5.45%	13.89%	68.01%	102.01%
South and East Europe, Caucasus and Central Asia	0.38%	2.31%	9.69%	20.75%
South Asia	0.81%	1.67%	7.81%	19.04%
South-East and East Asia	0.14%	0.50%	2.19%	8.96%
Sub-Saharan Africa	8.63%	13.58%	50.56%	80.01%
Global	**0.44%**	**1.33%**	**4.76%**	**12.56%**

Source: Author's calculation.

Note: World regions are grouped as in the United Nations (2023).

Table A4.2: Change in real wage (in %) as a result of further progress in trade digitalization

Trade digitalization impact on real wages	WTO TFA Trade Digitalization commitments		WTO TFA+ Trade Digitalization	
Region	**Partially implemented**	**Fully implemented**	**Partially implemented**	**Fully implemented**
Developed Economies	0.14%	0.44%	1.50%	3.38%
Latin America and the Caribbean	0.15%	0.29%	1.17%	2.41%
Middle East and North Africa	0.06%	0.19%	1.29%	2.70%
Pacific Islands	0.38%	0.74%	3.15%	4.80%
South and East Europe, Caucasus and Central Asia	0.25%	0.62%	2.24%	4.36%
South Asia	0.18%	0.37%	1.35%	2.50%
South-East and East Asia	0.10%	0.36%	1.64%	4.08%
Sub-Saharan Africa	0.17%	0.34%	1.39%	2.42%
Global	**0.16%**	**0.39%**	**1.53%**	**3.14%**

Source: Author's calculation.

Note: World regions are grouped as in the United Nations (2023).

Table A4.3: Change in producer's price (in %) as a result of further progress in types of trade facilitation

Trade digitalization impact on producers' prices	WTO TFA Trade Digitalization commitments		WTO TFA+ Trade Digitalization	
Region	**Partially implemented**	**Fully implemented**	**Partially implemented**	**Fully implemented**
Developed Economies	-0.10%	-0.34%	-1.16%	-2.77%
Latin America and the Caribbean	-0.32%	-0.57%	-1.90%	-3.71%
Middle East and North Africa	-0.15%	-0.38%	-1.99%	-3.80%
Pacific Islands	-1.41%	-2.52%	-7.96%	-10.85%
South and East Europe, Caucasus and Central Asia	-0.19%	-0.53%	-2.02%	-4.16%
South Asia	-0.41%	-0.82%	-2.68%	-4.89%
South-East and East Asia	-0.09%	-0.28%	-1.17%	-2.71%
Sub-Saharan Africa	-0.68%	-1.06%	-3.02%	-4.81%
Global	**-0.31%**	**-0.62%**	**-2.07%**	**-3.90%**

Source: Author's calculation.

Note: World regions are grouped as in the United Nations (2023). There are no digital trade facilitation measures that are classified as the WTO TFA binding measures.

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