The effect of trade and customs digitalization on agrifood trade: A gravity approach

André Bueno Rezende de Castro[1]

Lukas Kornher[2]

[1] PhD candidate at the Center for Development Research (ZEF), University of Bonn, Germany.

[2] Senior researcher at the Center for Development Research (ZEF), University of Bonn, Germany.

Abstract

In recent years, a growing number of non-tariff measures (NTMs) have been implemented to govern international agricultural trade. NTMs increase the bureaucratic burden on exporting firms and increase transaction costs, particularly in low- and middle-income countries (LMICs) that have limited institutional capacity. In these settings, paperless digital trade offers the potential to facilitate compliance with NTMs and other trade bureaucracies at lower costs. Recently, many countries have initiated the facilitation of international trade bureaucracy via digital processes and documentation. In this paper, we document trade and customs digitalization for a variety of indicators, focusing on two main variables of interest: paperless trade and digitalized NTMs. We argue that trade digitalization facilitates agrifood trade via cutting transaction costs, because it streamlines trade and customs operational procedures. We measure the impacts of trade digitalization on bilateral agrifood trade using a representative cross-country dataset. Our methodology employs a gravity model estimated by the Poisson pseudo-maximum-likelihood estimator, and we extend it with country- and time-fixed effects as well as socioeconomic controls. We find evidence that a one-unit increase in e-trade facilitation at the destination and at the origin increases agrifood exports by 0.13% and 0.58%, respectively, whereas a one-unit increase in digitalized NTMs at the destination and the origin increase the same by 0.24% and 0.27%, respectively - considering averages. Specifically, we find that these effects are larger for processed products and for Sub-Saharan African countries. Furthermore, we ascertain a strong relationship between agrifood exports and e-trade facilitation also at the origin. Therefore, it is inevitable for LMICs to facilitate digital trade to avoid trade diversion. Despite technical challenges, there are ample opportunities for LMICs to benefit from trade digitalization, especially by adapting policy implementation to their local realities in order to take advantage of agrifood export markets.

Key words: Trade digitalization; Trade barriers; Agrifood trade; Gravity model; Sub-Saharan Africa.

JEL classification: F13, F14, Q17

1. Introduction

Agrifood trade offers great potential for low and middle-income countries (LMICs) to create additional income and to diversify their export structures into non-traditional export sectors, particularly processed agricultural products. Largely based on consumption of locally grown crops, with the exception of some grains, the food systems of LMICs undergo a structural transformation towards: (1) higher capital intensity, (2) larger scale of production, (3) deeper integration to global value chains (GVCs), and (4) lower dependence on subsistence agriculture in benefit of crop commercialization (Barrett et al., 2020). Despite the potential from natural endowments and comparative advantages in agrifood products, agrifood trade in Sub-Saharan Africa (SSA) is still comparatively low. The launch of the African Continental Free Trade Area (AfCFTA) at the beginning of 2021 increased the political momentum for deepening regional trade integration – in particular harmonization of customs procedures and reduction of tariffs and non-tariff measures (NTMs) among regional trade partners – and also bears great potential to redefine and improve SSA's role in global agricultural trade. Notwithstanding recent integration efforts, intra-African agrifood trade still represents a small share of continental exports (~20%) and imports (~15%), with strong regional differences and, in particular, with a higher share of processed products vis-à-vis unprocessed (Bouët et al., 2021). Therefore, markets in high-income countries (HICs) are still the destination of the bulk of SSA agrifood exports, frequently in raw unprocessed form (Kornher & von Braun, 2020).

Higher value domestic markets are increasingly playing an important role and intra-African trade is gradually deepening, however, in the medium-term, there is more value to be accrued by tapping into international food markets, especially from HICs. The two reasons for this are that HICs have a higher demand for processed products and these products have higher income elasticity compared to unprocessed ones (Fukase & Martin, 2020). Moreover, international trade has the potential to alleviate hunger situations via matching food surplus regions with food-deficit regions as well as contributing to climate change adaptation (Janssens et al., 2020). Hence, international trade is an important pathway for small-scale farmers (SSFs) in LMICs to increase food commercialization, constituting an important developmental step for these countries to integrate their agricultural production to trade flows as a pre-condition to increase value addition.

The question is how can agrifood exports from SSA be expanded? Logistic and bureaucratic costs related to transportation and customs procedures of goods and services exports and imports, are the major impediment to increasing international trade (Feenstra, 2015). In addition to a large number of actors and technical complexities, one of the most stringent barriers to international trade are customs bureaucracies, which, in general, are country- or region-specific, thus susceptible to a plethora of standards – in particular when trading with HICs, many LMICs face difficulties in meeting demanding standards (Sun et al., 2021). These formalities occur in four stages of procedures: commercial, transportation, regulatory, and financial (Civelek et al., 2017). In this sense, they represent a key factor in the positioning and competitiveness of countries in regional value chains (RVCs) and GVCs (Ma & Van Assche, 2011). Tariff reduction was central to all World Trade Organization (WTO) negotiation rounds and many least developed countries (LDCs) in SSA are granted free access to HICs through preferential trade agreements or initiatives with unilateral trade preferences, such as the European Union's "Everything but Arms" or the North American African Growth and Opportunity Act. The challenge is then how to take advantage of recent waves of trade liberalization to not only expand trade volumes but mainly increase value addition in the commerce of traditional unprocessed agrifood exports.

One pathway to deliver this goal is digitalization, that can increase economy-wide productivity, which is the major source of long-term growth. This paper investigates in depth how trade digitalization measures can increase bilateral agrifood trade. The digitalization processes we look at facilitate trade via a reduction in transaction costs (TCs) related to logistics and bureaucracy, that can be implemented more widely, in terms of general procedures and processes, or more specifically, in terms of facilitating compliance with NTMs. There is evidence that businesses find it important that governments adopt and improve their usage of technology as a means of reducing bureaucracy in the relationship between public authorities and citizens and companies – accelerating and reducing the cost of processes (Reil et al., 2022). Therefore, digitalization of trade procedures has a promising role to play and is quickly unrolling throughout the developing world, however, SSA is threatened to be left overtaken by trade competitors due to a slower pace of adoption (Ibrahim et al., 2019). Currently, the implementation of the WTO Trade Facilitation Agreement (TFA) stands at only 41.3% for LDCs, while for developing countries in general it is almost double[1].

As per the WTO TFA, trade and customs digitization is defined as the substitution of physical documentation of regular trade procedures (e.g., payments, auditing, the release of cargoes, certificate compliance, etc.) by the application of modern information and communication technologies (ICTs), e.g., paperless digitized tracking of the trade process (Duval et al., 2019), henceforth referred to as paperless trade (PT) – we also analyze cross-border (CB) NTMs. Although it is not a silver bullet to shift comparative advantages and boost economic growth via exports, paperless mechanisms and procedures can facilitate and expand international trade flows. In particular, trade with HICs often has a higher level of detail in bureaucratic formalities and, thus, higher requirements, but it also has more value addition potential due to the higher purchasing power of the buyer markets, especially considering that agrifood products tend to face low income elasticities (Fukase & Martin, 2020).

[1] https://tfadatabase.org/

In this paper, we adopt two main variables of interest (PT and CB) that cover the digitalization of transportation, regulatory, and customs procedures. The secondary policy variables deal with commercial and financial aspects. Regarding the introduction of PT measures, SSA lags behind other competing markets and target destinations, such as Asia and less so the European Union (EU) (Laryea, 2005), thus there is ample potential for improvement.

In this paper, we contribute to the literature in three ways: (1) based on Transaction Costs Economics, we elaborate how TCs related to trade digitalization are a key impediment to the diversification of SSA agrifood trade; (2) by combining two rich datasets[2], to the best of our knowledge, we are the first to employ a gravity model approach to estimate the effects of e-facilitation of trade procedures and bureaucracies on agrifood trade; (3) we provide granular results with respect to different agrifood products and different regions, thus filling the literature gap on how trade and customs digitalization can benefit the agrifood sector, especially in SSA. Following this Introduction, Section 2 gives the background of the problem by framing a literature review into our conceptual framework. Then Section 3 lays out the data and explains how the empirical methodology addresses endogeneities. Section 4 presents and discusses the results and Section 5 concludes the paper with several relevant policy implications.

2. Background and Conceptual Framework

This section has three objectives: (1) introduce the conceptual framework this paper employs, which explains the causal pathways of trade digitalization measures on bilateral agri-food trade flows (see Figure 1); (2) place the literature review in the context of our conceptual framework; (3) discuss the microeconomic foundations of the gravity model.

[2] See Section 3.1 for more details.

We embed this study in the field of transaction cost economics, which assumes that the exchange of goods and services involves TCs. Given the gradual convergence of production technologies, the competitiveness of a firm or a country in international trade is largely due to the TCs and costs of cooperation. We start with two definitions that we will use throughout the paper. First, we understand trade facilitation as the simplification and harmonization of trade processes related to sending, receiving, and processing data, documents, and other information required for international trade (Engman, 2009; Grainger, 2011). Second, directly related to the previous concept, e-trade facilitation simply makes all of these processes and information related to international trade electronically, and often remotely, available for customs, other official authorities, and the trading parties, thus reducing TCs (Duval & Mengjing, 2017; Lewis, 2009). When trade facilitation is hampered by bureaucratic hurdles or inappropriate digitalization, firms face longer waiting times to clear goods and process all paperwork (either at the origin and/or at the destination), which reduces firms' and countries' competitiveness in the GVCs via the channel of increased TCs. Figure 1 summarizes the relationships between the trade digitalization measures captured in this study and trade competitiveness.

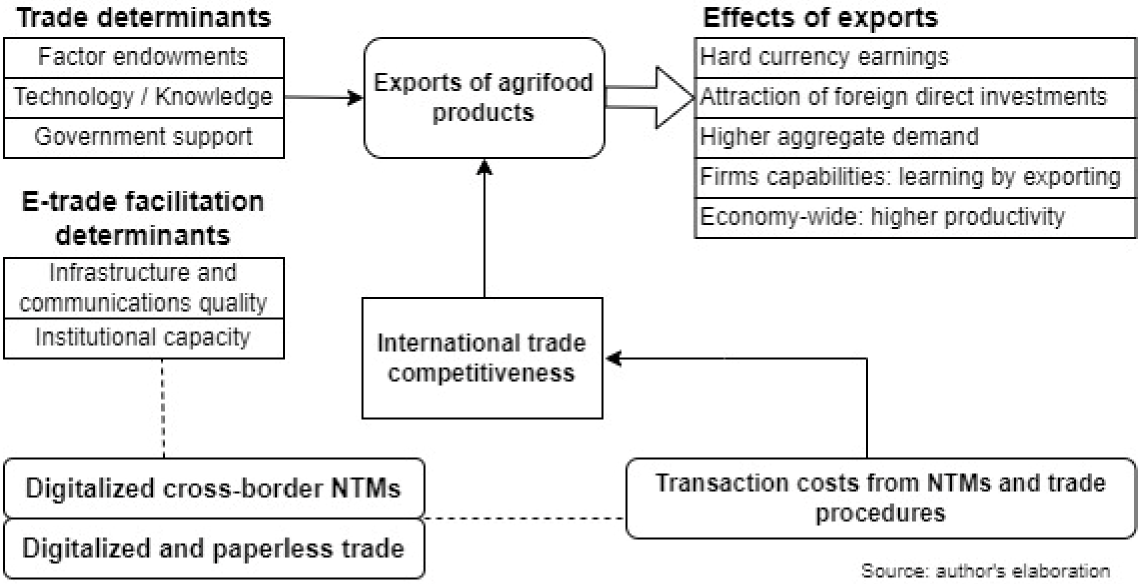


FIGURE 1 Theoretical framework: cutting transaction costs related to trade and customs digitalization increase agrifood

A group of factors related to the diamond model (Porter, 1985) determines the performance of countries in international export markets, mostly related to the production process (i.e., technology and factor endowments) and the enabling environment (i.e., ICTs, infrastructure, institutions, and government support). More trade, particularly exports, are positively related to overall economic growth (Frankel & Romer, 1999), albeit weaker for SSA countries (Were, 2015), therefore we expect that e-trade facilitation roles of our policy variables lead to better developmental outcomes. In this paper we focus on the channel of transaction costs, specifically those related to trade and customs digitalization measures, represented by the two key policy variables, PT and CB.

Usually, NTMs are classified into technical and non-technical barriers to trade. In the agrifood sector, NTMs, e.g., sanitary and phytosanitary (SPS) standards, are often justified by consumer protection reasons and the standardization of product quality, but also used to protect domestic producers without legal recourse to imposing tariffs. Despite the merit of such concerns, which is not the subject of this paper, NTMs invariably increase the import parity price of agrifood products not only because of their direct effect but also indirectly by imposing TCs related to the compliance with and monitoring of these measures (Melo & Shepherd, 2018). Given the lower institutional capacity and lower quality of ICTs that LMICs generally have vis-à-vis HICs, TCs arising from NTMs, coupled with laggard e-trade facilitation, tend to be higher in LMICs. The consequence is that exporting LMICs face decreasing competitiveness in products in which most of them have revealed comparative advantages, such as agrifood products, therefore reducing their exports. Below we state the three hypotheses that this paper tests:

1. PT: Facilitation of e-trade bureaucracy via standardized electronic documentation and processes[3] cuts TCs and, thus, has a positive effect on bilateral flows of agrifood trade.

[3] Interchangeably referred as "paperless trade" throughout this paper.

2. CB: Facilitation of electronic processes and paperwork related to cross-border NTMs also cuts TCs and, thus, has a positive effect on agrifood trade.

3. Facilitation of e-trade bureaucracy and NTMs has a greater impact when done in LMICs as compared to HICs, because the former are lagging the latter in this aspect, due to their lower income level.

The main impact pathway is directly related to the increase/reduction of TCs stemming from trade digitalization measures, which then decreases/increases total flows of exports of agricultural products (Goedhuys & Sleuwaegen, 2016; Milner et al., 2000). For instance, when an LMIC exports a certain agricultural product to a HIC, it often faces high TCs related to different and complex procedures to comply with NTMs; standardizing and streamlining these steps can increase efficiency by reducing the time taken to trade and financial costs (Czubala et al., 2009). Furthermore, the rapid worldwide spread of the internet in the early 2000s greatly increased the growth of goods' exports (Freund & Weinhold, 2004), which served as the springboard for the recent wave of e-trade facilitation. The data set employed captures these trade facilitation variables[4] from both the importer and exporter sides, thus we can more precisely analyze the specific impacts of PT and CB on agrifood trade compared to when measures are taken by only one side of the bilateral trade relationship.

The importance of e-trade facilitation lies in the simplification of the manifold processes in international trade, the main ones related to shipment and payment, in addition to a variety of procedures pertaining to customs inspections and clearances on both origin and destination, taxes and tariffs invoicing, technical and sanitary inspections, etc. This bureaucracy related to international trade is of the last-mile type since it is not related to the production process per se, but rather to the last economic activity: selling and transporting the goods between countries.

[4] The definitions of the policy variables are in the Annex Table A1.

This process can often be troublesome due to language and cultural barriers, the different standards, and requirements, and the additional costs it contains, especially to first-time exporters and small and medium firms. Particularly in LMICs, few firms export large quantities (World Bank, 2020); in addition to poor business planning and limited competitiveness, the lack of PT measures can impose an extra burden. Some firms even resort to hiring intermediate agents who assist them with the paperwork and bureaucratic processes (viz. logistic, legal, administrative, exchange rates, etc.), which naturally increases costs. Therefore, arguably, one of the easiest ways of promoting trade flows is to introduce standardized electronic documents and information exchange.

There are plentiful studies analyzing the Asia-Pacific region in terms of the impact of trade facilitation measures, which is mainly due to its export-led growth model and trade opening in the 1970s and 1980s, resulting in a proliferation of regional trade agreements (RTAs) (Duval & Mengjing, 2017; Shepherd & Duval, 2016). Kumar Roy & Xiaoling (2020) found evidence that trade facilitation policies introducing PT measures in South and Central Asia increased export performance. Using the same dataset that this paper employs (see the next section for more details), Duval et al. (2018) and Duval et al. (2019) also found evidence in the same direction for these regions, but focusing on the potential for trade cost reduction of PT measures. South Korea, in particular, was already pioneering the introduction of ICTs into trade formalities in the early 2000s (Yang, 2009).

In the case of SSA, Adaba & Rusu (2014) used the capabilities approach to demonstrate how a policy directed at improving e-government services can improve ICTs and foster trade, thus improving developmental outcomes in Ghana.

[More examples of literature review here]

Apart from trade flows, e-trade facilitation was found to also stimulate foreign direct investments (FDI) (Yasui & Engman, 2009). The main pathway for this effect is similar to the one we describe in our conceptual framework: more efficient procedures for risk management, pre-arrival processing, and post-clearance audits reduce TCs. Engman (2009) also found that tax revenues are more effectively collected in the presence of e-trade facilitation measures.

The literature is clear that imposing NTMs, especially SPSs, has negative impacts on trade (Melo & Shepherd, 2018; Otsuki et al., 2001). However, many of these SPSs are justified on basis of animal and human health, thus harmonizing and sharing common SPSs can stimulate trade because the barriers to trade that NTMs impose are outweighed by a reduction in the burden of information asymmetry and TCs that such harmonization brings (Moenius, 2004). This reinforces the role of CB measures to ease the flow of trade. Avery et al. (2021) document an increasing usage of digital technologies to facilitate SPS in agrifood trade, for instance, traceability and supply chain integrity checks, screening for pesticides, advancement consignment declaration, and e-certificates for plants and animal products.

With the increasing emergence of GVCs, some theories of trade portray that the exchange of goods and services is majorly driven by countries' need to have access to different technologies, however, the bulk of global trade is concentrated in countries with similar factor endowments and productivity levels (Feenstra, 2015). Moreover, a significant share of trade is done in intermediate products, including agricultural raw materials that are lightly processed in the origin for further processing in the destination (World Bank, 2020). Although trade in goods has become less sensitive to the distance between countries, given the technological advances that slashed transportation costs, geographical distance is still a strong predictor of bilateral trade flows – as our results demonstrate – and, thus, can increase transport costs and thwart trade (Brun et al., 2005). The negative correlation between distance and trade is particularly strong when at least one of the two trading countries is a LMIC, with the bulk of the positive effects of technological progress and lower transaction/transportation costs being accrued by HICs (Arvis et al., 2016).

In this regard, we turn to the gravity model and place it in the context of the trade literature, where it first appeared relatively disconnected from theoretical groundings (Tinbergen, 1962), however, it has seen significant improvements (Anderson, 1979; Bergstrand, 1985; Philippidis et al., 2013). The main contribution to enhance the gravity model theoretical micro-foundations came from Anderson & van Wincoop (2003) who explicitly accounted for the role of trade costs by incorporating the multilateral resistance term, which are price indices dependent on trade barriers. These can be either natural (transportation costs and time, comparative advantages, etc.) or artificial (usually tariffs and NTMs), and are important determinants of bilateral trade, together with external trade barriers with third parties, which are captured in the model by fixed effect dummies for each country (Anderson & van Wincoop, 2004).

The recent literature has been producing a growing body of evidence on a wide array of TCs and other impediments to trade in food and agricultural products; recent developments have also applied the gravity model to this topic (Grant & Lambert, 2008; Lambert & McKoy, 2009; Mujahid & Kalkuhl, 2016; Philippidis et al., 2013; Sarker & Jayasinghe, 2007; L. Sun & Reed, 2010). Nevertheless, there are still limited studies on the effects of digitizing paperwork and customs formalities on trade flows of agrifood products between LMICs and HICs – apart from one study of digitalization of SPSs but considering total trade flows (Avery et al., 2021). This paper fills this specific literature gap by providing evidence of the heterogenous effects of the digitalization of bureaucratic procedures related to bilateral agrifood trade, with focus on SSA.

3. Materials and Methods

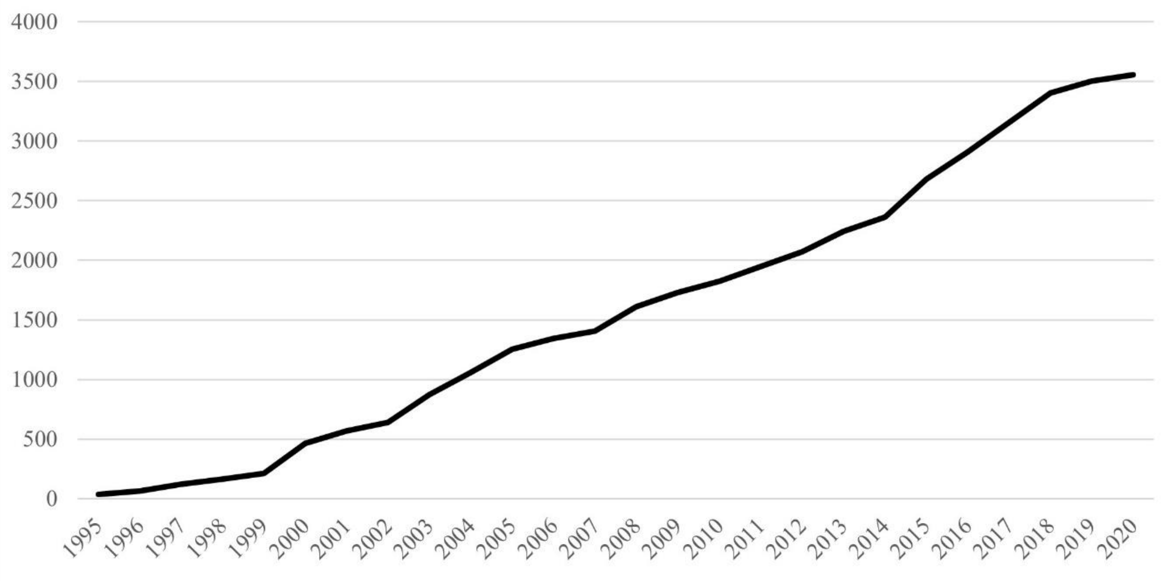
3.1. Data

The main dataset we use in this paper is the International Trade Database at the Product-Level (BACI) from the Center for Prospective Studies and International Information (CEPII) (Gaulier & Zignago, 2010). It provides importer and exporter data with the breadth of 200 countries, the level of product disaggregation at the 6-digit level of the Harmonized System (HS) nomenclature based on UN Comtrade data but reviewed for its accuracy and consistency. In addition to that, we use the CEPII's gravity modeling data set that encompasses the most relevant gravity modelling control variables. Our main trade policy variables (PT and CB) are extracted from the United Nations Global Survey on Digital and Sustainable Trade Facilitation (UNTFS) (United Nations, 2019), which is then merged with the BACI dataset, thus yielding a time span of five years, and three points in time: 2015, 2017, 2019. The UNTFS data set includes 128 countries.

We provide two types of analysis based on a different set of countries. First, an analysis of digital trade facilitation available in the exporting country (country of origin), and second, an analysis of the same digital trade facilitation available in the importing country (country of destination). Naturally, the selection of countries in the first analysis is more restrictive and will not be based on a representative data set for LMICs. In the second analysis, we make use of the fact that agrifood imports are concentrated among fewer (mostly industrialized) countries and, therefore, we consider this country sample representative. We motivate the selection of this set of 128 countries by computing the share of world imports they collectively are responsible for 87%[5].

[5] Data from UN Comtrade.

The full set of policy variables that we investigate in this paper is detailed in Table A1 and they are retrieved and constructed from the UNTFS. They are all involved with the introduction and adoption of ICT-related mechanisms and procedures to simplify trade: PT, CB, transparency, formalities, and institutional arrangement and cooperation. Individual measures have values equal to 0: not implemented, 1: partially implemented, and 2: fully implemented. Then, the indices are compiled by averaging those individual measures. From this list, we analyze two main outcome variables from the digital trade facilitation sub-group: PT and CB. From the definition of CB (United Nations, 2019), these measures are related to the digital exchange and facilitation of specific NTMs-relate data. Figure 2 captures for the past few decades the growing number of NTMs in agriculture, the sector most affected by NTMs (Melo & Shepherd, 2018). From this sector's perspective, digitizing documents related to SPS and the rules of origin certification are prominent and provide the potential to facilitate exports of LMICs. The difference of CB and PT is that the latter refers to general e-facilitation of trade procedures not related to NTMs, in other words, it encompasses the "application of modern information and communication technologies (ICTs) to trade-related services (United Nations, 2019).



Source: Author's elaboration based on data from UNCTAD Trains

Figure 2 Number of total NTMs valid in each year in the agricultural sector – period 1995-2020

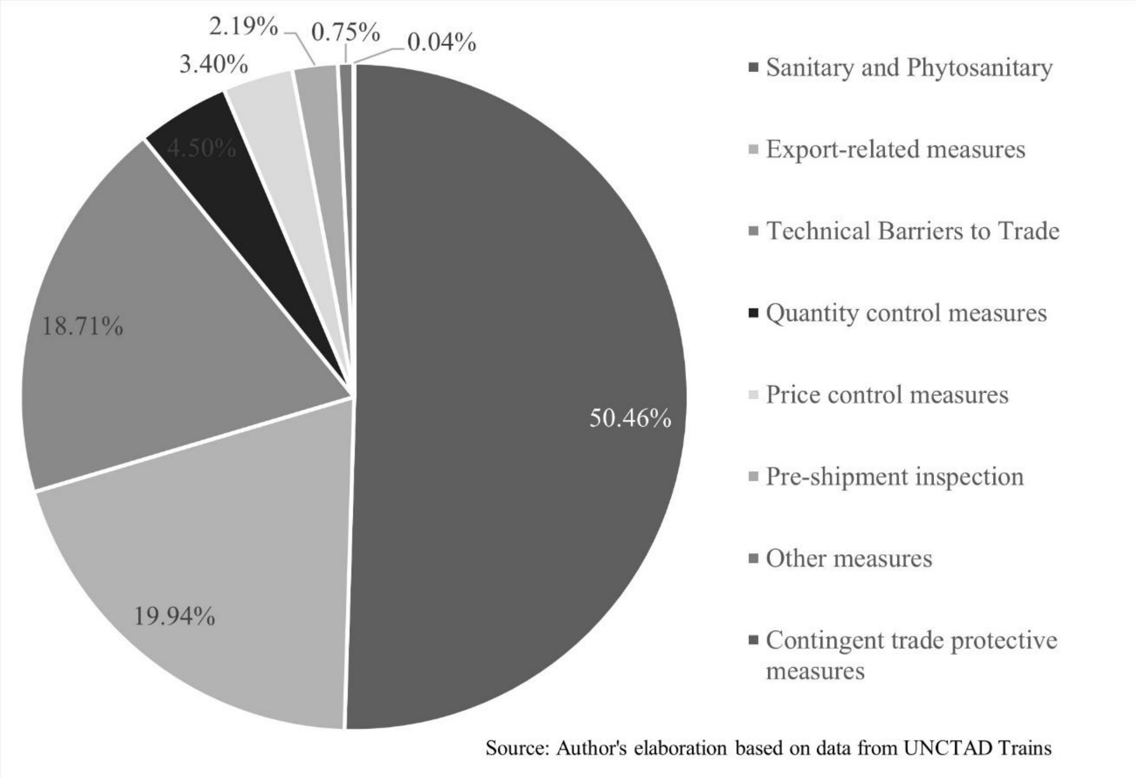


Figure 3 Percentage of non-tariff measures in the agricultural sector by type (10/2021)

Food standards of major agrifood importers have been identified as a major impediment to agricultural trade (World Bank, 2008). In fact, the definition of standards beyond the international regulation level could be considered a quasi-protection of the domestic agricultural sector in the European Union (Shepherd & Wilson, 2013). Figure 3 reports that over half of the NTMs in the agrifood sector are related to SPS measures, and another fifth of NTMs are other export-related measures, both types of NTMs that are captured by the CB policy variable.

3.2. Empirical Methodology

Our identification strategy employs the gravity model to estimate the impact of our policy variables on bilateral agrifood trade. One of the most important problems with naïve gravity modeling is that it does not consider the heterogeneity of the socio-economic structures of trading countries, thus in order to avoid the omitted variable bias in the estimation we need to control for these characteristics; in our case, specific to country pairs since we are using bilateral trade data. The most common of those characteristics are cultural, political, and historical factors; even when controlling for the size of the economy and distance between trading countries, such factors are important co-determinants of bilateral trade flows (Yotov et al., 2016). Namely, we expand the baseline gravity model by including the following country-specific socio-economic and cultural factors: contiguity (Bergstrand, 1985); common official language and/or a former colonial relationship, including common colonizer (Frankel et al., 1995); common origin of the legal system; percentage of the population professing certain major religions; and coverage and type of regional and preferential trade areas/agreements (Grant & Lambert, 2008; Lambert & McKoy, 2009; Sarker & Jayasinghe, 2007; L. Sun & Reed, 2010). We capture these variables with the vector C in Equation 1 (original gravity model). The full list of the social-cultural aspects is in Table A2.

$$\ln X_{ijs} = \alpha_0 + \beta_1 \ln GDP_i + \beta_2 GDP_j + \beta_3 D_{ij} + \beta_4 PT_{ij} + \beta_5 CB_{ij} + \beta_6 Z_{ij} + \beta_7 C_{ijs} + \varepsilon_{ijs}.$$

(Equation 1)

Here, α is the positive gravitational constant, X is the trade flow between exporter i (origin country) and importer j (destination country), s is the product Standard International Trade Classification (SITC) code, gross domestic product (GDP) measures the size of the economies in each country, D is the geographical distance in Kms between the pair of trading partners (a proxy for transport costs), and ε is the idiosyncratic error term. In particular, we highlight PT and CB, which are the main policy variables: e-trade facilitation via paperless trade and cross-border NTMs in the pair of trading countries. The vector Z represents the other secondary policy variables.

Despite the validity of this methodological approach, there may still be potential threats to our identification strategy. First, there is omitted variable bias when the model does not account for relevant variables either because they are difficult to observe, and/or to quantify. We address this by adding various socioeconomic controls, but there might always be a few relevant missing variables, which means we can minimize this bias, but not completely rule it out. Second, there are problems with the lack of a time dimension to allow explanatory variables to adjust (Yotov et al., 2016). In this regard, we make use of the panel characteristic of our data set (term t in Equation 2) in order to consider the time dimension. Third, although we cannot fully rule out reverse causality between the dependent and the policy variables, we consider that this is a minor issue because bilateral trade flows are less likely to determine the decision to adopt trade digitalization measures, as opposed to unidirectional trade. Moreover, introducing a lagged dependent variable would make the error term correlated with the dependent variable, thus incurring the dynamic panel bias. Fourth, unobserved country-specific relevant variables might be correlated with the error term and, thus, impact agrifood trade. To tackle this issue, we further expand the baseline gravity model with the inclusion of the multilateral resistance term, accounting both for time- and country-fixed effects, captured by the terms t and γ, respectively, for the importing and exporting country. The mechanics are simple: we include a dummy variable for each pair of trading countries (Cheng & Wall, 2005). We incorporate fixed effects for the opposite country vis-à-vis the country of the policy variable. Effectively, we swap between destination and origin, so if the policy variable is measured at country i, the fixed effect incorporated into the regression is from country j, and vice versa. This strategy avoids incorporating all country- and time-pairs fixed effects – which only identify the effect based on variation over time –, which absorbs most of the variation of the policy variables, thus jeopardizing its identification (Cipollina et al., 2016).

$$\ln X_{ijst} = \alpha_0 + \beta_1 \ln GDP_{it} + \beta_2 GDP_{jt} + \beta_3 D_{ij} + \beta_4 PT_{ijt} + \beta_5 CB_{ijt} + \beta_6 Z_{ijt} + \beta_7 C_{ijts} + \gamma_i + t_t + \varepsilon_{ijts}. \quad \text{(Equation 2)}$$

Standard errors are clustered at the distance between trading country pairs to mitigate skewness stemming from missing unobserved variables that may differ systematically by country.

Despite this extended version, there is still an underlying problem with gravity models in the form of a large number of zero-valued bilateral trade flows that inevitably happen when dealing with one-sided large data sets. This is expected as neither all countries produce all goods, nor all countries trade with all other countries. For instance, Haveman & Hummels (2004) report that 10% of all countries concentrate 58% of trade flows, providing evidence for the hypothesis that zero-valued trade is a normal occurrence and needs to be controlled for, especially in the case of agrifood data (Haq et al., 2013). Common strategies are to (1) simply exclude the zero values, and (2) attribute an arbitrarily small value to the zeros. However, neither strategy is adequate because the presence of zero values, which are often non-randomly distributed, convey important information about the nature of the trade flows (Eichengreen & Irwin, 1998); additionally, the attribution of small numbers is too arbitrary and can bias the estimators, depending on the selected value (Burger et al., 2009). Moreover, excluding the zero values preclude analysis of bilateral trade creation as the sample would only have observations of actually traded goods, and no potential trade – the estimates would be conditioned on actual trade taking place.

The most robust solution to deal with the problem of zero-valued trade flows is to employ a model that originally uses count data, but adapted to non-negative continuous variables accounting for fixed-effects (FE) (see Equation 2) (Anderson & van Wincoop, 2003) – thus, our preferred specification is the Poisson pseudo-maximum-likelihood (PPML) expanded with country FE (Silva & Tenreyro, 2006), which solves the problem of the omission of the multilateral resistance terms (Fally, 2015). Since this estimator belongs to the class of pseudo maximum likelihood, the PPML does not make any assumptions about the distributional form of the variables; it simply requires that the conditional mean of the dependent variable is correctly specified (Santos Silva & Tenreyro, 2010; Yotov et al., 2016). This specification has six main advantages: (1) consistent, unbiased, and efficient in presence of heteroskedasticity – as it does not assume that the error variance is constant across observations; (2) consistent in the presence of over- or under-dispersion as it makes no assumptions on the data distribution; (3) appropriately deals with zero-valued trade flows due to its multiplicative form, resulting in a positive mean; (4) all observations are weighted equally; (5) better avoids sample selection bias; (6) produces estimates in which actual and estimated trade flows are equal across all bilateral trade partners (Arvis & Shepherd, 2013; Santos Silva & Tenreyro, 2010, 2011; Yotov et al., 2016).

Accordingly, we inflate the PPML model with the introduction of all zero-valued trade flows and then estimate it (Brakman et al., 2010; Burger et al., 2009). The main difference to the other methods of estimating the GM, such as the negative binomial, is that the zero-inflated PPML model accounts for two states with probability p_i: excess of zeros, indicating no trade of a particular product between a pair of countries, or the probability of trade, $1 – p_i$. This approach considers the true zero values processes that capture the non-existence of trade, but with a non-zero probability of trade, as opposed to the false zero processes that simply record all zero trade values. In short, this means that a pair of countries might not be trading a particular product due to demand and supply particularities as well as other precluding factors, but this does not mean that trade cannot happen in this context. Consequently, the class of PPML models performs well in presence of large numbers of zero (Santos Silva & Tenreyro, 2011). Given this rationale, we employ the PPML estimator to Equation 2 and we drop a baseline estimated with OLS because it is not a consistent estimator in our case.

4. Results

4.1. Descriptive statistics

We start by providing an overview of our policy variables. Figures 4-6 capture the adopting countries' relative frequency of the degree of implementation of three policy variables: total measures (measured from 0-1.0), PT (measured from 0-0.3), and CB (measured from 0-0.2), respectively. All charts are sub-divided by year of the panel and by origin/exporter vis-à-vis destination/importer. We highlight three patterns from these figures: (1) The distributions of CB are skewed to the left, which means many countries have not yet adopted such measures, and those that adopted have not fully implemented them, considering the low scores; (2) PT and the variable capturing all measures combined (total) have a higher degree of implementation compared to CB; (3) The graphs show some improvements as the curves become less skewed to the left – i.e., countries started to implement the measures –, which means that, despite some recent progress, there is ample scope for improvement in e-trade facilitation, especially regarding NTMs; (4) Another potential explanation for the lack of implementation of the e-trade facilitation measures is that the majority of our sample comprises developing countries, which are in early stages of e-digitalization, while developed countries face difficulties in adapting their old analogical systems (United Nations, 2019).

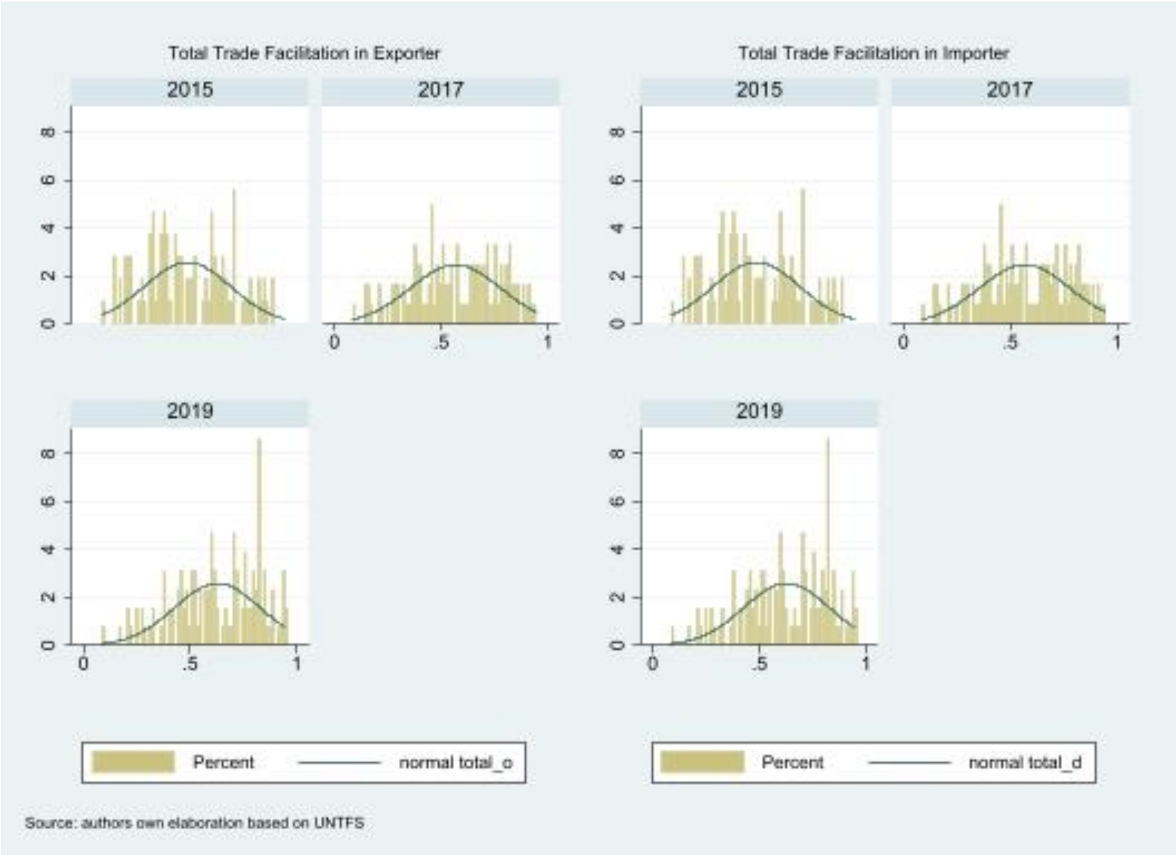


Figure 4 Country implementation of total trade facilitation

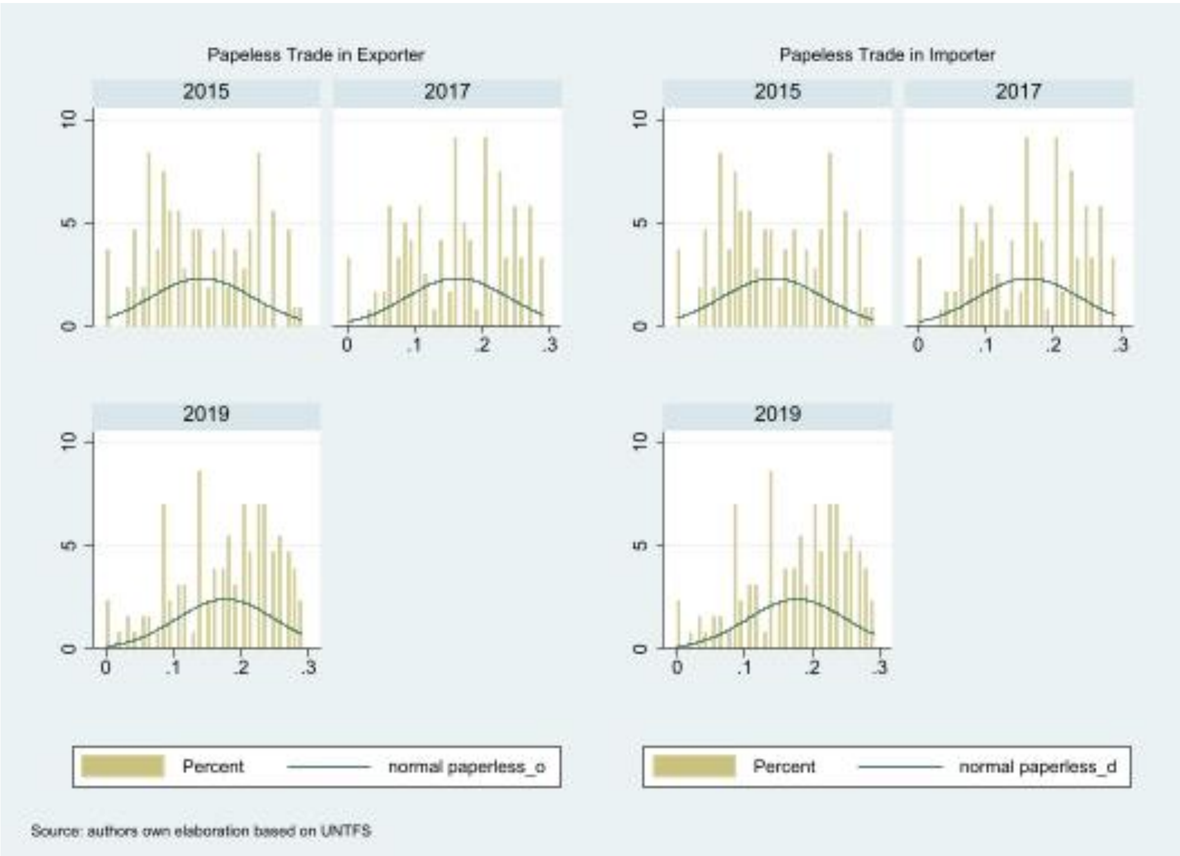


Figure 5 Country implementation of paperless trade measures

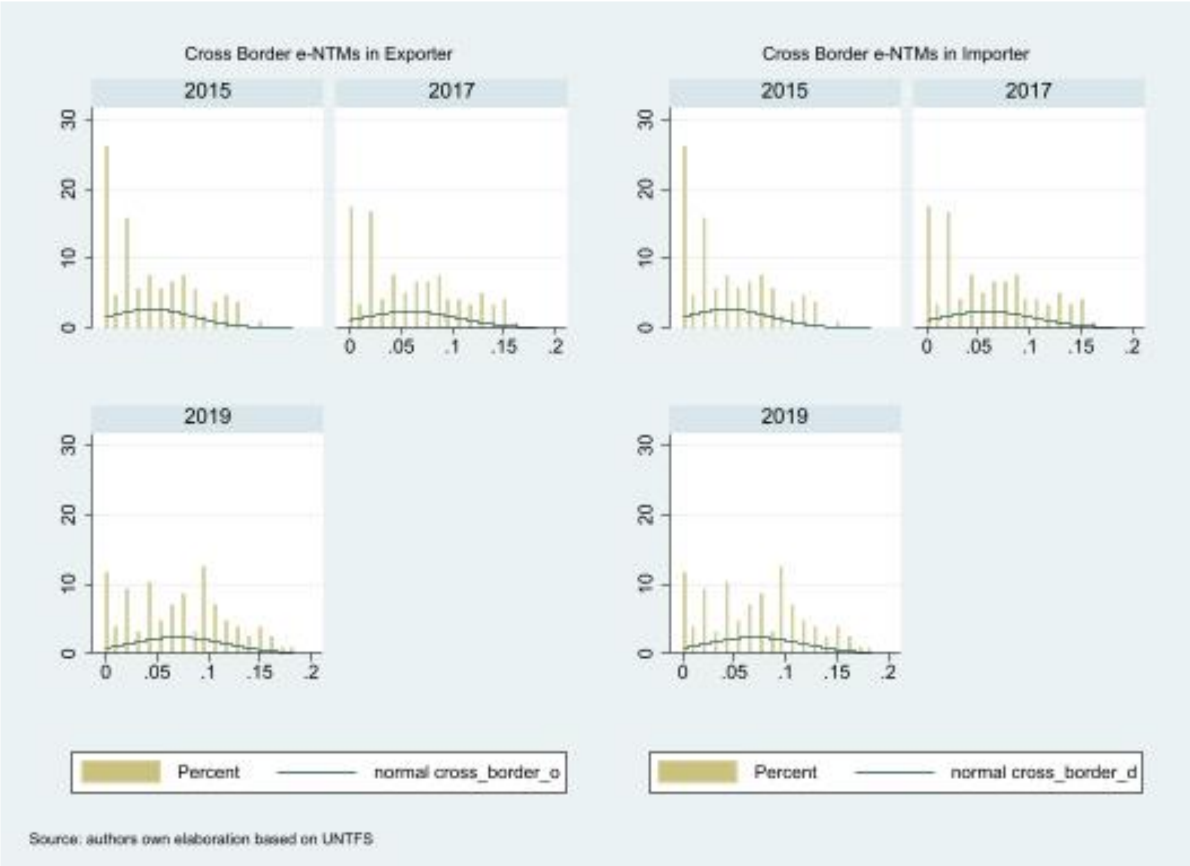


Figure 6 Country implementation of cross-border NTMs

4.2. Regression estimations

In this sub-section we report our results, which follows an estimation strategy that consists of a comparison of different specifications of the extended gravity model from Equation 2. We analyze the point estimates and the goodness of fit of the different variations, thus comparing the advantages and drawbacks of each model. Overall, we observe that: (1) the R-squared varies from 23% to 41%, however, we caveat that simply adding more variables to increase the goodness of fit might have the drawback of lowering internal validity; (2) the gravity variables have the signal and the significance expected, thus our sample yields results that match findings of previous studies employing the gravity model. In sum, the results corroborate our hypotheses that both standardized electronic documentation and processes (what we refer to as paperless trade) and digitization of NTM documentation (CB) are important channels to cut TCs via facilitation of trade bureaucracy, resulting in higher bilateral trade flows; but this happens in heterogeneous ways. We also find evidence for the role of the policy variables formalities and transparency in facilitating trade, though this evidence is less robust compared to PT and CB, which fits into our conceptual framework.

In Tables 1 and 2 we present a summary of the results of the estimations in a three-step order:

a. Sub-divide the policy variables by destination/importer (odd columns) and origin/exporter (even columns).

b. Break the tables down into two policy variables, one for PT and the other for CB.

c. Estimate five different model specifications captured by the numbered columns in Tables 1 and 2: (1-2) baseline PPML with gravity variables and the main policy variable; (3-4) PPML with socioeconomic controls from Table A2 and the main policy variable; (5-6) PPML with all controls and all policy variables together; (7-8) PPML for the main policy variable only with all controls and country-fixed effects employing the PPML with multiple high-dimensional fixed effects (PPML-HDFE) (Correia et al., 2020); (9-10) PPML-HDFE with all controls and all policy variables. We do not include CB and PT in the same model to avoid multicollinearity, as the correlation between these two policy variables is 78.5%.

First, we find that PT has a positive and significant impact on bilateral agrifood trade across all specifications, corroborating our hypothesis #1. Moreover, we find that both PT and CB have their magnitudes reduced when we move from the naïve to the more complete models. This suggests that the inclusion of gravity and socioeconomic controls absorbs part of the omitted variable bias from the naïve model, which was introduced by unobserved confounders. Variables such as the structure of import tariffs and some trade policies not related to participation in trade agreements – which are included in the controls – might drive part of this positive bias. Moreover, this interpretation is also corroborated by the fact that further including all policy variables in the model reduces the estimates for both CB and PT. We interpret this result in the sense that there are relevant interactions between some of the policy variables, so when they appear together in the model, they further absorb bias. Furthermore, controlling for country FEs mildly reduces the magnitudes of the point estimates, which means that FEs reduce the correlation between the independent variables and the error term, which stems from unobserved covariates that are fixed in time, probably related to commercial policies since the time span of the panel is not long enough to capture major policy shifts, such as effects of new trade agreements.

The same pattern is observed for all other policy variables in the models containing PT, except for institutions, which have a positive effect at the importer level, but a negative effect at the exporter level. We offer two possible interpretations for this: it indicates that the policies to align trade procedures between customs agencies at the origin have problems; and the policies that governments implement following the passing of legislation matters as well as their effectiveness, which is something this variable does not capture.

One important detail about the comparison of the results is that the point estimates for PT are greater in magnitude than for CB at the exporter level as well as the point estimates for PT at the exporter level are larger than at the importer level. We attribute two meanings for that: (1) the impact on agrifood trade of implementing measures related to PT is larger than those related to CB, so LICs should prioritize general e-facilitation measures; (2) changes in e-facilitation tend to have better results when they are implemented by exporters compared to importers, which is a result that bodes well for LICs, that notoriously lag behind in e-facilitation.

Next, we turn to CB. The direction and the statistical significance of the results are in line with those of PT, hence we corroborate our hypothesis #2. This is in line with our conceptual framework as it posits that while imposing NTMs negatively impacts trade, the e-facilitation of NTM documentation stimulates trade as it simplifies the steps and procedures that exporting firms need to follow, thus reducing TCs. In terms of the effects' magnitudes, the point estimates for CB at the importer level are greater than those for PT. According to our conceptual framework, this effect is higher at the destination, since, by definition, NTMs are imposed by the importing country; this is partially corroborated by the results in Table 2, as the magnitudes are similar when we introduce all policy variables in the model. When comparing the point estimates of CB between the importer and the exporter level, it is not clear which is larger since it depends on the model (with all policy variables or not).

We stress that the effects' magnitudes should not be read directly, but rather calculated in the following way:

$$Impact\ magnitude\ (\%) = \frac{Maximum\ value\ of\ each\ policy\ variable}{Number\ of\ measures\ of\ each\ policy\ variable} .point\ estimate\ .100$$

(Equation 3)

Using this rule of thumb, for instance, allows us to interpret the regressions results in terms of percentual changes. Focusing on the last and most complete model – which includes all policy variables –, we report that each unit increase of the policy variables results in the following percentual increases in bilateral agri-food trade: 0.13% for PT_d, 0.58% for PT_o, 0.24% for CB_d, 0.27% for CB_o. Increases in the degree of trade digitalization usually happen gradually, so we can only observe small changes within a short period of time (see Figures 4-6). However, these percentage impacts on agrifood trade are non-trivial, considering that implementing trade digitalization is a low-hanging fruit compared to an overhaul in the barriers to trade or a shift in comparative advantages; therefore, we consider that our results have immediate importance to policymakers.

Table 1 Summary of effects of e-paperless trade digitalization on agrifood trade

Log of Agrifood Trade	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
PT, destination	1.753***		1.410***		0.405**		1.427***		0.420**	
	(0.160)		(0.157)		(0.206)		(0.133)		(0.170)	
PT, origin		2.972***		2.325***		1.740***		2.376***		1.936***
		(0.161)		(0.160)		(0.192)		(0.147)		(0.173)
Transparency, destination					2.066***				2.083***	
					(0.340)				(0.299)	
Transparency, origin						1.733***				2.172***
						(0.349)				(0.317)
Formalities, destination					1.154***				1.086***	
					(0.286)				(0.243)	
Formalities, origin						1.181***				0.803***
						(0.276)				(0.239)
Institutions, destination					0.687*				0.958***	
					(0.409)				(0.343)	
Institutions, origin						-3.489***				-3.796***
						(0.374)				(0.333)
Constant	-9.604***	-9.863***	-9.188***	-8.927***	-9.216***	-8.836***	-2.889***	-7.036**	-2.878***	-6.873***
	(0.825)	(0.848)	(0.188)	(0.179)	(0.188)	(0.179)	(0.670)	(0.521)	(0.665)	(0.523)
Time trend	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Country FE										
Gravity Variables	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Socioeconomic Controls	NO	NO	YES	YES	YES	YES	YES	YES	YES	YES
Fixed Effects	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES
Observations	2,978,868	2,978,868	2,739,806	2,739,806	2,739,806	2,739,806	2,618,182	2,618,182	2,618,182	2,618,182
No. of countries	128	128	128	128	128	128	128	128	128	128
R^2	0.242	0.238	0.284	0.280	0.286	0.281	0.415	0.382	0.416	0.384
AIC	1.64e+7	1.77e+7	1.48e+7	1.59e+7	1.48e+7	1.58e+7	1.35e+07	1.50e+07	1.34e+7	1.50e+7

Standard errors in parentheses and significance levels: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. For fixed-effects models, R^2 captures the Pseudo-R^2.

Table 2 Effect of cross-border NTMs digitalization on bilateral agrifood trade: All food groups

Log of Agrifood Trade	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
CB, destination	2.651***		1.826***		0.693**		1.863***		0.729***	
	(0.231)		(0.223)		(0.242)		(0.187)		(0.201)	
CB, origin		2.505***		1.385***		0.681***		1.442***		0.798***
		(0.216)		(0.211)		(0.224)		(0.186)		(0.196)
Transparency, destination					1.971***				1.982***	
					(0.337)				(0.300)	
Transparency, origin						1.941***				2.328***
						(0.345)				(0.316)
Formalities, destination					1.299***				1.232***	
					(0.260)				(0.219)	
Formalities, origin						2.379***				2.133***
						(0.259)				(0.228)
Institutions, destination					0.507				0.783**	
					(0.408)				(0.343)	
Institutions, origin						-3.314***				-3.511***
						(0.369)				(0.328)
Constant	-9.450***	-9.855***	-9.144***	-9.148***	-9.155***	-8.969***	-2.953***	-7.390***	-2.850***	-7.085***
	(0.805)	(0.835)	(0.189)	(0.183)	(0.189)	(0.182)	(0.676)	(0.530)	(0.667)	(0.527)
Time trend	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Gravity Variables	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Socioeconomic Controls	NO	NO	YES	YES	YES	YES	YES	YES	YES	YES
Fixed Effects	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES
Observations	2,978,868	2,978,868	2,739,806	2,739,806	2,739,806	2,739,806	2,618,182	2,618,182	2,618,182	2,618,182
No. of countries	128	128	128	128	128	128	128	128	128	128
R^2	0.240	0.232	0.281	0.277	0.285	0.281	0.415	0.380	0.416	0.383
AIC	1.64e+7	1.78e+7	1.48e+7	1.59e+7	1.48e+7	1.59e+7	1.35+07	1.50e+07	1.34e+7	1.50e+7

Standard errors in parentheses and significance levels: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. For fixed-effects models, R^2 captures the Pseudo-R^2.

4.3. Robustness Checks

Initially, the influence of zero-valued trade is indeed large as the mean of the bilateral trade flow (the dependent variable) is significantly affected when excluding the observations that equal zero, which gives support to the choice of employing the PPML estimator. We then conduct a number of tests to check for the robustness of our results (Yotov et al., 2016). First, the Akaike information criteria (AIC) compares the trade-off of overfitting vs. underfitting in different models, and it confirms that our preferred specification (PPML-HDFE) has a lower prediction error, thus being the best performing model. Second, we conduct both a Wald test and a likelihood-ratio (LR) test for the joint significance of the regressors in all our model specifications, and the tests statistics returned values compatible with a rejection of the null hypothesis that the regressors are jointly equal to zero both at the destination and at the origin.

The other robustness checks that we conducted are related to sub-sampling the main sample: (1) regional comparison for SSA[6]; (2) based on the economic sectors classified at the three-digit code by the SITC, we breakdown the main sample by the degree of processing of agrifood products into three categories: unprocessed, processed, and highly processed[7]. The summary results are in Appendix Tables A5 and A6.

First, when we limit the sample to SSA countries, we initially document a significant positive impact of PT on trade, but then the magnitude reduces moving to the HDFE models; a pattern similar to the one observed in the main sample. In the specific case of PT at the importer level (with all policy variables in the model), we do not observe statistical significance in the SSA sub-sample, contrasting with the strong effect of PT at the exporter level. This contrasting evidence suggests that e-trade facilitation is more relevant when it is implemented by SSA

[6] The list of sub-regions is in Appendix Table A3.
[7] The list of all products in each product category is in Appendix Table A4.

countries as opposed to the destination countries of their exports. Moreover, the impact of PT on agrifood trade at the exporter level is significantly larger for SSA countries than for the total sample, which indicates that changes in bureaucratic processes and formalities from a group of LMICs have a larger effect probably because they lag behind in terms of e-bureaucracy implementation. Second, once again considering the FE model, we observe a stronger effect of CB on agrifood trade in SSA countries. Furthermore, we observe a consistent pattern in the products sub-sample: the difference in the effect of PT and CB on trade of processed agrifood goods is greater for SSA countries. We conclude from this that there are untapped opportunities for value addition coming from e-trade facilitation, especially for SSA countries. These are important evidence because they corroborate our hypothesis #3 that e-trade facilitation has a greater impact on LMICs, which predominate in SSA. It is not, however, clear if the effect of CB implementation is stronger at the exporter or at the importer level for SSA countries.

Lastly, in theory, including a time trend and a term for country FE could absorb all the variation in the policy variables, incurring in multicollinearity. This happens because, in our dataset, countries only improve in their trade digitalization indexes – albeit some quite slowly or zero – , so we have either no variation, or positive variation, but no negative variation. In order to address this potential issue, we estimate additional models with and without the time trend and with different combinations of country FE terms (both importer and exporter and only the opposite vis-à-vis the policy variable of interest); the results remain robust[8].

5. Conclusions and Policy Implications

[8] These results are available upon request.

In this paper, we employ the gravity model of international trade to analyze the effect on bilateral agrifood trade flows of two key policy variables: (1) the introduction of standardized digital documentation and processes, or paperless trade; (2) the introduction of standardized digital documentation and processes related to cross-border non-tariff measures. In particular, we enrich our analysis by focusing on Sub-Saharan Africa and documenting the heterogeneity of the impacts by the degree of processing of the agrifood raw materials that are captured by our trade panel. Furthermore, we measure the impact and trade potential of varying levels of electronic bureaucratic paperwork and barriers to trade by using the data set from the UNTFS, merged and harmonized with two other secondary data sources, i.e., CEPII-BACI and UN Comtrade. Our methodology uses the gravity model because it has become the workhorse model to explain bilateral trade patterns in particular regarding its ability to deal with long-term and historical determinants as well as to its high explanatory power.

Our findings point to large and significant benefits of trade bureaucracy digitalization on agrifood exports, but with significant heterogeneities. While measures to digitize trade bureaucracy increase exports in our cross-country sample, this effect is even stronger in the case of Sub-Saharan Africa. The results are robust to the inclusion of time- and unobserved country-fixed effects. Once we break the sample down by degree of processing of the agrifood products, we observe that the positive effects are also stronger for processed products, which bodes well for an industrial policy focusing on adding value to local raw materials. This could happen because processed products tend to be more complex than unprocessed products in terms of their composition, thus requiring a larger amount of documentation and rules of origin. Furthermore, we observe that digitalization measures that facilitate non-tariff barriers at the destination (importers) play an important role in stimulating agrifood exports, which also bides well for LMICs.

We highlight from our results the following policy implications: (1) PT measures have a higher impact when they are implemented in exporting countries, so this is an important finding for LMICs to facilitate electronic trade bureaucracy; (2) this pattern is stronger in the SSA case, demanding policymakers to continue and deepen their efforts of facilitating trade via digitalization of bureaucratic procedures; (3) simply passing legislation to empower customs authorities and to create legal frameworks is not enough to foster trade, but the actual content of legislation as well as the effectiveness and implementation of trade institutions are crucial; (4) the costs of implementing e-facilitation measures, especially for LMICs, need to be considered. Generally, our findings also support the use of aid-for-trade programs for trade facilitation, particularly in digital form.

Although the COVID-19 pandemic led countries to retrench into domestic markets, the global and regional trade of agrifood products was less directly blocked as countries realized it is a lifeline to ensure domestic food security (Liverpool-Tasie et al., 2021). The momentum to deepen regional trade integration with the inception of the AfCFTA should be seized by SSA countries, which should take this opportunity to foster regional integration and improve their position in the agrifood trade markets.

6. References

Adaba, G. B., & Rusu, L. (2014). E-trade Facilitation in Ghana: A Capability Approach Perspective. *The Electronic Journal of Information Systems in Developing Countries*, *63*(1), 1–13. https://doi.org/10.1002/j.1681-4835.2014.tb00450.x

Anderson, J. E. (1979). A Theoretical Foundation for the Gravity Equation. *The American Economic Review*, *69*(1), 106–116.

Anderson, J. E., & van Wincoop, E. (2003). Gravity with Gravitas: A Solution to the Border Puzzle. *American Economic Review*, *93*(1), 170–192. https://doi.org/10.1257/000282803321455214

Anderson, J. E., & van Wincoop, E. (2004). Trade Costs. *Journal of Economic Literature*, *42*(3), 691–751. https://doi.org/10.1257/0022051042177649

Arvis, J.-F., Duval, Y., Shepherd, B., Utoktham, C., & Raj, A. (2016). Trade Costs in the Developing World: 1996–2010. *World Trade Review*, *15*(3), 451–474. https://doi.org/10.1017/S147474561500052X

Arvis, J.-F., & Shepherd, B. (2013). The Poisson quasi-maximum likelihood estimator: A solution to the 'adding up' problem in gravity models. *Applied Economics Letters*, *20*(6), 515–519. https://doi.org/10.1080/13504851.2012.718052

Avery, E., Baragwanath, T., Deuss, A., Marlet, E., Sorescu, S., & van Tongeren, F. (2021). *Digital Opportunities for Sanitary and Phytosanitary (SPS) Systems and the Trade Facilitation Effects of SPS Electronic Certification* (Working Paper No. 152; OECD Food, Agriculture and Fisheries Paper). OECD.

Barrett, C. B., Reardon, T., Swinnen, J., & Zilberman, D. (2020). Agri-food Value Chain Revolutions in Low- and Middle-Income Countries. *Journal of Economic Literature*. https://doi.org/10.1257/jel.20201539

Bergstrand, J. H. (1985). The Gravity Equation in International Trade: Some Microeconomic Foundations and Empirical Evidence. *The Review of Economics and Statistics*, *67*(3), 474–481. https://doi.org/10.2307/1925976

Bouët, A., Tadesse, G., & Zaki, C. (2021). *Africa Agriculture Trade Monitor 2021*. AKADEMIYA2063 & IFPRI. https://doi.org/10.54067/9781737916406

Brakman, S., Garita, G., Garretsen, H., & van Marrewijk, C. (2010). Economic and financial intervention and the rise of cross-border M&As. In *The Gravity Model in International Trade. Advances and Applications.* Cambridge University Press.

Brun, J.-F., Carrère, C., Guillaumont, P., & de Melo, J. (2005). Has Distance Died? Evidence from a Panel Gravity Model. *The World Bank Economic Review*, *19*(1), 99–120. https://doi.org/10.1093/wber/lhi004

Burger, M., Oort, F. van, & Linders, G.-J. (2009). On the Specification of the Gravity Model of Trade: Zeros, Excess Zeros and Zero-inflated Estimation. *Spatial Economic Analysis*, *4*(2), 167–190. https://doi.org/10.1080/17421770902834327

Cheng, I.-H., & Wall, H. J. (2005). Controlling for Heterogeneity in Gravity Models of Trade and Integration. *Federal Reserve Bank of St. Louis Review*, *87*(1), 49–63. https://doi.org/10.20955/r.87.49-64

Cipollina, M., De Benedictis, L., Salvatici, L., & Vicarelli, C. (2016). *Policy Measurement and Multilateral Resistance in Gravity Models* (Working Papers LuissLab No. 16130). Dipartimento di Economia e Finanza, LUISS Guido Carli. https://econpapers.repec.org/paper/luilleewp/16130.htm

Civelek, M. E., Çemberci, M., Uca, N., Çelebi, Ü., & Özalp, A. (2017). Challenges of Paperless Trade: Redesign of the Foreign Trade Processes and Bundling Functions of Traditional

Documents. *International Business Research*, *10*(2), 74. https://doi.org/10.5539/ibr.v10n2p74
Correia, S., Guimarães, P., & Zylkin, T. (2020). Fast Poisson estimation with high-dimensional fixed effects. *The Stata Journal*, *20*(1), 95–115. https://doi.org/10.1177/1536867X20909691
Czubala, W., Shepherd, B., & Wilson, J. S. (2009). Help or Hindrance? The Impact of Harmonised Standards on African Exports†. *Journal of African Economies*, *18*(5), 711–744. https://doi.org/10.1093/jae/ejp003
Duval, Y., & Mengjing, K. (2017). *Digital Trade Facilitation: Paperless Trade in Regional Trade Agreements* (Working Paper No. 747; ADBI Working Paper Series, p. 43). Asian Development Bank Institute. https://www.econstor.eu/bitstream/10419/179203/1/adbi-wp747.pdf
Duval, Y., Utoktham, C., & Kravchenko, A. (2018). *Impact of implementation of digital trade facilitation on trade costs* (Working Paper No. 174; ARTNeT Working Paper Series, p. 58). UNESCAP. https://www.econstor.eu/bitstream/10419/177771/1/AWP174.pdf
Duval, Y., Wang, T., Utoktham, C., & Kravchenko, A. (2019). Next-generation Trade Facilitation for Asian Integration: Cross-border Paperless Trade. *Journal of Asian Economic Integration*, *1*(1), 11–31. https://doi.org/10.1177/2631684618821473
Eichengreen, B., & Irwin, D. A. (1998). The role of history in bilateral trade flows. In J. Frankel (Ed.), *The Regionalization of the World Economy*. University of Chicago Press.
Engman, M. (2009). The Economic Impact of Trade Facilitation. In *Overcoming Border Bottlenecks: The Costs and Benefits of Trade Facilitation* (pp. 81–112). OECD. https://doi.org/10.1787/9789264056954-4-en
Fally, T. (2015). Structural gravity and fixed effects. *Journal of International Economics*, *97*(1), 76–85. https://doi.org/10.1016/j.jinteco.2015.05.005
Feenstra, R. C. (2015). *Advanced International Trade: Theory and Evidence* (Second Edition). Princeton University Press.
Frankel, J. A., & Romer, D. H. (1999). Does Trade Cause Growth? *American Economic Review*, *89*(3), 379–399. https://doi.org/10.1257/aer.89.3.379
Frankel, J., Stein, E., & Wei, S. (1995). Trading blocs and the Americas: The natural, the unnatural, and the super-natural. *Journal of Development Economics*, *47*(1), 61–95. https://doi.org/10.1016/0304-3878(95)00005-4
Freund, C. L., & Weinhold, D. (2004). The effect of the Internet on international trade. *Journal of International Economics*, *62*(1), 171–189. https://doi.org/10.1016/S0022-1996(03)00059-X
Fukase, E., & Martin, W. (2020). Economic growth, convergence, and world food demand and supply. *World Development*, *132*, 104954. https://doi.org/10.1016/j.worlddev.2020.104954
Gaulier, G., & Zignago, S. (2010). *BACI: International Trade Database at the Product-Level. The 1994-2007 Version* (Working Paper 2010=23; CEPII Working Paper). CEPII. http://www.cepii.fr/PDF_PUB/wp/2010/wp2010-23.pdf
Goedhuys, M., & Sleuwaegen, L. (2016). International standards certification, institutional voids and exports from developing country firms. *International Business Review*, *25*(6), 1344–1355. https://doi.org/10.1016/j.ibusrev.2016.04.006
Grainger, A. (2011). Trade Facilitation: A Conceptual Review. *Journal of World Trade*, *45*(1), 39–62.
Grant, J. H., & Lambert, D. M. (2008). Do Regional Trade Agreements Increase Members' Agricultural Trade? *American Journal of Agricultural Economics*, *90*(3), 765–782.

Haq, Z. U., Meilke, K., & Cranfield, J. (2013). Selection bias in a gravity model of agrifood trade. *European Review of Agricultural Economics*, *40*(2), 331–360. https://doi.org/10.1093/erae/jbs028

Haveman, J., & Hummels, D. (2004). Alternative Hypotheses and the Volume of Trade: The Gravity Equation and the Extent of Specialization. *The Canadian Journal of Economics / Revue Canadienne d'Economique*, *37*(1), 199–218.

Ibrahim, G., Simbanegavi, W., Prakash, A., Davis, W., Wasike, W., & Patel, A. (2019). *Industrial Development and ICT in Africa: Opportunities, Challenges and Way Forward* (p. 15). JICA. https://www.jica.go.jp/jica-ri/publication/booksandreports/l75nbg000017wb6r-att/TF5_web_0603_0006.pdf

Janssens, C., Havlík, P., Krisztin, T., Baker, J., Frank, S., Hasegawa, T., Leclère, D., Ohrel, S., Ragnauth, S., Schmid, E., Valin, H., Van Lipzig, N., & Maertens, M. (2020). Global hunger and climate change adaptation through international trade. *Nature Climate Change*, *10*(9), 829–835. https://doi.org/10.1038/s41558-020-0847-4

Kornher, L., & von Braun, J. (2020). *EU Common Agricultural Policy—Impacts on Trade with Africa and African Agricultural Development* (No. 294; ZEF Discussion Papers on Development Policy No. 204, p. 65). University of Bonn: ZEF.

Kumar Roy, C., & Xiaoling, H. (2020). Effects of Paperless Trade Policy and Aid for Trade on Export Performance: Evidence from SASEC And CAREC Countries. *Asian Development Policy Review*, *8*(1), 61–74. https://doi.org/10.18488/journal.107.2020.81.61.74

Lambert, D., & McKoy, S. (2009). Trade Creation and Diversion Effects of Preferential Trade Associations on Agricultural and Food Trade. *Journal of Agricultural Economics*, *60*(1), 17–39. https://doi.org/10.1111/j.1477-9552.2008.00184.x

Laryea, E. (2005). Facilitating paperless international trade: A survey of Law and Policy in Asia. *International Review of Law, Computers & Technology*, *19*(2), 121–142. https://doi.org/10.1080/13600860500131200

Lewis, G. (2009). *The Impact of ICT on Customs*. *3*(1), 3–11.

Liverpool-Tasie, L. S. O., Reardon, T., & Belton, B. (2021). "Essential non-essentials": COVID-19 policy missteps in Nigeria rooted in persistent myths about African food supply chains. *Applied Economic Perspectives and Policy*, *43*(1), 205–224. https://doi.org/10.1002/aepp.13139

Ma, A., & Van Assche, A. (2011). Global Production Networks in the Postcrisis Era. In M. Haddad & B. Shepherd, *Managing Openness: Trade and Outward-oriented Growth After the Crisis*. World Bank.

Melo, J. de, & Shepherd, B. (2018). The Economics of Non-Tariff Measures: A Primer. In *Non-Tariff Measures: Economic Assessment and Policy Options for Development* (pp. 121–157). UNCTAD. https://unctad.org/system/files/official-document/ditctab2018d3_en.pdf

Milner, C., Morrissey, O., & Rudaheranwa, N. (2000). Policy and Non-Policy Barriers to Trade and Implicit Taxation of Exports in Uganda. *Journal of Development Studies*, *37*(2), 67–90. https://doi.org/10.1080/713600069

Moenius, J. (2004). *Information Versus Product Adaptation: The Role of Standards in Trade* (SSRN Scholarly Paper ID 608022). Social Science Research Network. https://doi.org/10.2139/ssrn.608022

Mujahid, I., & Kalkuhl, M. (2016). Do Trade Agreements Increase Food Trade? *The World Economy*, *39*(11), 1812–1833. https://doi.org/10.1111/twec.12324

Otsuki, T., Wilson, J. S., & Sewadeh, M. (2001). Saving two in a billion: Quantifying the trade effect of European food safety standards on African exports. *Food Policy*, *26*(5), 495–514. https://doi.org/10.1016/S0306-9192(01)00018-5

Philippidis, G., Resano-Ezcaray, H., & Sanjuán-López, A. I. (2013). Capturing zero-trade values in gravity equations of trade: An analysis of protectionism in agro-food sectors. *Agricultural Economics*, *44*(2), 141–159. https://doi.org/10.1111/agec.12000
Porter, M. E. (1985). *The Competitive Advantage: Creating and Sustaining Superior Performance*. Free Press.
Reil, S., Hamdani, K., Barreiros, L. E., Berger, A., Huerta, R. C., Kagan, Y., Sauvant, K. P., Steneri, P., & Zhao, Q. (2022). *What Foreign Investors Want: Findings From an Investor Survey of Investment Facilitation Measures in Latin America and the Caribbean*. International Trade Centre. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4018005
Santos Silva, J. M. C., & Tenreyro, S. (2010). On the existence of the maximum likelihood estimates in Poisson regression. *Economics Letters*, *107*(2), 310–312. https://doi.org/10.1016/j.econlet.2010.02.020
Santos Silva, J. M. C., & Tenreyro, S. (2011). Further simulation evidence on the performance of the Poisson pseudo-maximum likelihood estimator. *Economics Letters*, *112*(2), 220–222. https://doi.org/10.1016/j.econlet.2011.05.008
Sarker, R., & Jayasinghe, S. (2007). Regional trade agreements and trade in agri-food products: Evidence for the European Union from gravity modeling using disaggregated data. *Agricultural Economics*, *37*(1), 93–104. https://doi.org/10.1111/j.1574-0862.2007.00227.x
Shepherd, B., & Duval, Y. (2016). Estimating the benefits of cross-border paperless trade in Asia and the Pacific. In A. Saggu, C. Utoktham, & Y. Duval, *Reducing Trade Costs in AsiaPacific Developing Countries*. UNESCAP. https://www.unescap.org/sites/default/files/publications/STI84_Final.pdf
Shepherd, B., & Wilson, N. L. W. (2013). Product standards and developing country agricultural exports: The case of the European Union. *Food Policy*, *42*, 1–10. https://doi.org/10.1016/j.foodpol.2013.06.003
Silva, J. M. C. S., & Tenreyro, S. (2006). The Log of Gravity. *The Review of Economics and Statistics*, *88*(4), 641–658. https://doi.org/10.1162/rest.88.4.641
Sun, D., Liu, Y., Grant, J., Long, Y., Wang, X., & Xie, C. (2021). Impact of food safety regulations on agricultural trade: Evidence from China’s import refusal data. *Food Policy*, *105*, 102185. https://doi.org/10.1016/j.foodpol.2021.102185
Sun, L., & Reed, M. R. (2010). Impacts of Free Trade Agreements on Agricultural Trade Creation and Trade Diversion. *American Journal of Agricultural Economics*, *92*(5), 1351–1363.
Tinbergen, J. (1962). *Shaping the World Economy; Suggestions for an International Economic Policy*. Twentieth Century Fund. https://repub.eur.nl/pub/16826
United Nations. (2019). *Digital and Sustainable Trade Facilitation: Global Report 2019*. UNESCAP. https://untfsurvey.org/report
Were, M. (2015). Differential effects of trade on economic growth and investment: A cross-country empirical investigation. *Journal of African Trade*, *2*(1), 71–85. https://doi.org/10.1016/j.joat.2015.08.002
Westerlund, J., & Wilhelmsson, F. (2011). Estimating the gravity model without gravity using panel data. *Applied Economics*, *43*(6), 641–649. https://doi.org/10.1080/00036840802599784
World Bank. (2008). *World Development Report 2008: Agriculture for Development*. The World Bank. https://doi.org/10.1596/978-0-8213-6807-7
World Bank. (2020). *Trading for Development in the Age of Global Value Chains* (world; World Development Report 2020). World Bank. https://elibrary.worldbank.org/doi/pdf/10.1596/978-1-4648-1457-0

Yang, J. (2009). *Small and Medium Enterprises (SME) Adjustments to Information Technology (IT) in Trade Facilitation: The South Korean Experien* (Working Paper No. 61; ARTNeT Working Paper Series, p. 40). Asia-Pacific Research and Training Network on Trade (ARTNeT). https://www.econstor.eu/bitstream/10419/64260/1/601134532.pdf

Yasui, T., & Engman, M. (2009). The Role of Automation in Trade Facilitation. In *Overcoming Border Bottlenecks: The Costs and Benefits of Trade Facilitation* (pp. 141–172). OECD. https://doi.org/10.1787/9789264056954-6-en

Yotov, Y., Piermartini, R., Monteiro, J.-A., & Larch, M. (2016). *An advanced guide to trade policy analysis: The structural gravity model.* World Trade Organization (WTO). https://www.wto.org/english/res_e/publications_e/advancedguide2016_e.htm

7. Appendix

Table A1 List of trade digitalization policy variables

Policy variable	Mechanisms and components
Paperless trade	Automated Customs System
	E-Payment of Customs Duties and Fees
	Internet connection available to Customs and other trade control agencies
	Electronic Single Window System
	Electronic submission of Customs declarations
	Electronic application and issuance of import and export permit
	Electronic Submission of Sea/Air Cargo Manifests
	Electronic application and issuance of Preferential Certificate of Origin
	Electronic Application for Customs Refunds
Cross-border NTMs	Laws and regulations for electronic transactions
	Recognized certification authority
	Electronic exchange of Customs Declaration/Certificate of Origin
	Electronic exchange of Sanitary & Phyto-Sanitary Certificate
	Paperless collection of payment from a documentary letter of credit
Transparency	Publication of existing import-export regulations on the internet
	Stakeholders' consultation on new draft regulations (prior to their finalization)
	Advance publication/notification of new trade-related regulations before their implementation
	Advance ruling on tariff classification and origin of imported goods
	Independent appeal mechanism
Formalities	Risk management
	Pre-arrival processing
	Post-clearance audits
	Separation of release from final determination of customs duties, taxes, fees and charges
	Establishment and publication of average release times
	Trade facilitation measures for authorized operators
	Expedited shipments
	Acceptance of copies of original supporting documents required for import, export or transit formalities
Institutional	National Trade Facilitation Committee or similar body
	National legislative framework and/or institutional arrangements for border agencies cooperation
	Government agencies delegating controls to Customs authorities

	Alignment of working days and hours/formalities and procedures with neighbouring countries at border crossings

Table A2 List of gravity and socio-cultural control variables of the gravity model

Variables	**Source**
GDP PPP (in current thousands USD)	CEPII-BACI / UN Comtrade
Contiguity/shared border	CEPII-BACI
Common official or primary language	CEPII-BACI
Language is spoken by at least 9% of the population	CEPII-BACI
Common colonizer post 1945	CEPII-BACI
Pair in colonial relationship post 1945	CEPII-BACI
Origin of the legal system	CEPII-BACI
Catholics/Muslims/Protestants/other religions as % of population in 1980	CEPII-BACI
Pair current or former hegemon	CEPII-BACI
Pair ever/currently in colonial or dependency relationship	CEPII-BACI
WTO membership	WTO
EU membership	CEPII-BACI
RTA type between trading pair	WTO

Table A3 List of sub-regions

Acronym	**Sub-region**
SSA	Sub-Saharan Africa
MENA	Middle East & North Africa
SA	South Asia
LAC	Latin America & Caribbean
EAP	East Asia & Pacific
ECA	Europe & Central Asia
NA	North America

Table A4 List of products classified by processing category

Agrifood product sub-category	**SITC 3-digit product code**
Unprocessed	001, 034, 035, 036, 041, 043, 044, 045, 054, 057, 071, 072, 073, 075, 081, 222
Lightly processed	011, 012, 016, 017, 025, 037, 042, 046, 047, 048, 056, 058, 061, 073, 223, 411, 421, 422

Highly processed	022, 023, 024, 059, 062, 091, 098, 111, 112, 431

Table A5 Summary of effects of e-paperless trade digitalization on agrifood trade in SSA

Log of Agrifood Trade	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
PT, destination	1.652***		1.826***		0.466		2.053***		0.609	
	(0.438)		(0.437)		(0.577)		(0.357)		(0.520)	
PT, origin		4.692***		3.422***		5.107***		2.708***		4.573***
		(0.419)		(0.449)		(0.512)		(0.390)		(0.429)
Transparency, destination					-0.133				0.211	
					(1.243)				(0.957)	
Transparency, origin						4.503***				4.200***
						(1.049)				(0.828)
Formalities, destination					2.688***				2.403***	
					(0.829)				(0.772)	
Formalities, origin						-6.008***				-6.115***
						(1.061)				(0.864)
Institutions, destination					3.086**				4.497***	
					(.1381)				(1.157)	
Institutions, origin						-8.831***				-6.767***
						(1.027)				(0.777)
Constant	-10.031***	-12.166***	-12.072***	-12.879***	-12.261***	-12.582***	-9.332***	-6.416**	-9.593***	-4.881*
	(0.574)	(1.078)	(0.636)	(0.789)	(0.668)	(0.721)	(1.276)	(2.580)	(1.302)	(2.589)
Time trend	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Country FE										
Gravity Variables	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Socioeconomic Controls	NO	NO	YES	YES	YES	YES	YES	YES	YES	YES
Fixed Effects	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES
Observations	714,748	500,894	680,938	481,344	680,938	481,344	620,402	437,828	620,402	437,828
No. of countries	25	25	25	25	25	25	25	25	25	25
R^2	0.057	0.041	0.093	0.086	0.093	0.091	0.300	0.284	0.302	0.290
AIC	2.02e+6	1.42e+6	1.90e+6	1.24e+6	1.89e+6	1.23e+6	1.71e+06	1.14e+06	1.71e+6	1.13e+6

Standard errors in parentheses and significance levels: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. For fixed-effects model, R^2 captures the Pseudo-R^2.

Table A6 Summary of effects of e-cross-border NTMs digitalization on agrifood trade in SSA

Log of Agrifood Trade	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
CB, destination	5.065***		3.950***		2.926***		4.142***		2.915***	
	(0.644)		(0.609)		(0.653)		(0.475)		(0.548)	
CB, origin		5.511***		2.949***		6.490***		2.947***		5.931***
		(0.853)		(0.816)		(0.938)		(0.637)		(0.721)
Transparency, destination					-0.640				-0.359	
					(1.248)				(0.948)	
Transparency, origin						5.032***				4.434***
						(1.069)				(0.846)
Formalities, destination					2.273***				2.107***	
					(0.729)				(0.653)	
Formalities, origin						-3.047***				-3.396***
						(1.103)				(0.903)
Institutions, destination					2.041				3.455***	
					(1.379)				(1.163)	
Institutions, origin						-13.295***				-10.600***
						(1.173)				(0.908)
Constant	-9.497***	-12.122***	-11.760***	-13.156***	-11.865***	-13.271***	-9.313***	-7.789***	-9.424***	-6.662**
	(0.559)	(1.081)	(0.614)	(0.827)	(0.648)	(0.749)	(1.312)	(2.574)	(1.314)	(2.591)
Time trend Country FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Gravity Variables	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Socioeconomic Controls	NO	NO	YES	YES	YES	YES	YES	YES	YES	YES
Fixed Effects	NO	NO	NO	NO	NO	NO	YES	YES	YES	YES
Observations	714,748	500,894	680,938	481,344	680,938	481,344	620,402	437,828	620,402	437,828
No. of countries	25	25	25	25	25	25	25	25	25	25
R^2	0.058	0.040	0.093	0.084	0.093	0.092	0.302	0.283	0.303	0.290
AIC	2.01e+6	1.42e+6	1.89e+6	1.25e+6	1.89e+6	1.23e+6	1.71e+06	1.14e+06	1.71e+6	1.13e+6

Standard errors in parentheses and significance levels: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. For fixed-effects model, R^2 captures the Pseudo-R^2.