JAE Journal of Agricultural Economics

Journal of Agricultural Economics, Vol. 72, No. 1, 2021, 25–46
doi: 10.1111/1477-9552.12405

The Heterogeneous Effects of Standards on Agricultural Trade Flows

Dela-Dem Doe Fiankor, Oliver-Ken Haase and Bernhard Brümmer

(Original submitted March 2020, revision received August 2020, accepted August 2020.)

Abstract

This article uses a theory-based translog gravity model to investigate the heterogeneous effects of food standards on aggregate agricultural trade. We revisit the 'standards-as-barriers-to-trade' debate with a distinctive twist. In contrast to existing works, we show that standards reduce trade but even more so for countries that trade smaller volumes. Our identification strategy exploits the within-country variation in specific trade concerns. We confirm that stricter importer standards are indeed trade-restrictive. However, the estimated trade cost elasticity varies depending on how intensively two countries trade. Specifically, it decreases in magnitude with an increasing import share of the exporter in the importing country's total imports. The reason is simple but intuitive; bigger trading partners find it more profitable to invest in meeting the costs of importer-specific standards. This work is novel in showing that the standards–trade debate misses out on an important heterogeneity driven by existing import shares. Liberalising non-tariff measures will favour smaller trading partners more than well-established ones.

Keywords: *Agricultural trade*; *food standards*; *specific trade concerns*; *translog gravity model.*

JEL classifications: *F14, Q17, Q18.*

---

[1]Dela-Dem Fiankor, Oliver-Ken Haase, and Bernhard Brümmer are all in the Department of Agricultural Economics and Rural Development, while Dela-Dem Fiankor and Bernhard Brümmer are also in the Centre for Biodiversity and Sustainable Land Use (CBL), both at the University of Goettingen, Germany. Email: dfianko@agr.uni-goettingen.de for correspondence. This research was financially supported by the long-term EU–Africa research and innovation partnership on food and nutrition security and sustainable Agriculture LEAP-Agri (Project 'Agricultural Trade and Market Access for Food Security: Micro- and Macro-level Insights for Africa'). The project was also supported by funds of the Federal Ministry of Food and Agriculture (BMEL) based on a decision of the Parliament of the Federal Republic of Germany via the Federal Office for Agriculture and Food (BLE). We thank two anonymous reviewers and the Editor for their helpful and constructive comments on an earlier draft. We received valuable comments from Alessandro Olper, Daniele Curzi, Valentina Raimondi and Florian Unger. Open access funding enabled and organized by Projekt DEAL.

1. Introduction

'Food regulations in different countries are often conflicting and contradictory. Legislation governing [...] acceptable food standards often varies widely from country to country. New legislation not based on scientific knowledge is often introduced. [This] conflicting nature of food regulations may be an obstacle to trade in foodstuffs between countries. (WHO, 1950, p. 24).'

Custom tariffs and other traditional trade barriers have been negotiated down to near-zero. Concurrently, we have seen a surge in standard-like non-tariff measures (NTMs). While it may seem that countries are substituting NTMs for tariff protection, such a simple argument ignores the potential consumer or societal benefits that NTMs can entail, such as reducing information asymmetry, mitigating consumption risks and enhancing sustainability (Orefice, 2017; Beverelli *et al.*, 2019). However, NTMs can also be protectionist, or their associated costs may keep non-compliant countries out of global value chains. It is often challenging to know if a particular regulation serves genuine public interests or protectionist objectives because both motives are often combined in a single measure (Swinnen, 2016). Theoretically, the direction of the standards-trade effect is also ambiguous. Thus, how standards affect trade and welfare remain empirical questions. The result is a continuing 'standards as barriers or catalysts to trade' debate. Recent reviews (Beghin *et al.*, 2015) and meta-analyses (Santeramo and Lamonaca, 2019) in the agricultural trade literature confirm the ambiguity of the existing empirical estimates.

However, one thing is certain: public mandatory standards set by national governments usually vary across countries and often tend to hinder agricultural trade by increasing the cost of trading. As our opening quote suggests, this knowledge is as old as the first meeting of the Joint FAO/WHO Expert Committee on Nutrition in 1950. Yet, recent empirical findings – for example, public standards decrease the probability of trade (Ferro *et al.*, 2015; Crivelli and Gröschl, 2016), and reduce both the value of trade conditional on exports (Disdier *et al.*, 2008b; Curzi *et al.*, 2018; Kinzius *et al.*, 2019; Fernandes *et al.*, 2019) and the number of varieties traded (Fiankor *et al.*, forthcoming) – show that we have made little, if any progress, in addressing the negative effects of this regulatory heterogeneity across countries.[1]

Using the case of public mandatory food standards, we revisit this policy-relevant debate, but with a distinctive twist. Existing studies on the standards–trade effect share one thing in common: they are estimated using gravity equations – for example, the classical Anderson and Wincoop (2003) model – that impose the limiting assumption that the elasticity of trade with respect to trade costs is constant. This feature means that food standards have the same proportionate effect on trade regardless of *ex-ante* trade levels. For example, the point estimate of –0.15 in Disdier *et al.* (2008b) means that for OECD member states the introduction of a new standard decreases imports by 14% regardless of the origin of the product.[2] Even if some studies go further to assess the trade effects by income status of the exporting countries within the

[1]On the other hand, by harmonising standards across countries, private voluntary standards established by retailers, such as GlobalGAP standards or the International Featured Standards, enhance trade (Ehrich and Mangelsdorf, 2018; Fiankor *et al.*, 2020).

[2]Disdier et al. (2008b) capture the presence of standards using a dummy. The percentage change in trade flows from a change in a dummy variable is computed as $\exp\left(\beta - 1\right) \times 100$.

CES model (Disdier *et al*., 2008b; Xiong and Beghin, 2014), they estimate a uniform effect for the country groups. We test these 'onesize-fits-all' conclusions on the hypothesis that larger trading partners may find it worthwhile to invest in meeting importer-specific standards.

The main objective of our study is to examine the heterogeneous effects of food standards on agricultural trade at the aggregate level. To test our hypothesis, we combine theoretical predictions from the heterogeneous firms' literature (Melitz, 2003; Helpman *et al*., 2008) with a theory-founded translog gravity model (Novy, 2013) estimated at the country level. This is one of the first applications of the translog gravity framework in the agricultural trade literature.[3] Our empirical analysis uses data on the cross-country differences in Sanitary and PhytoSanitary (SPS) measures using a panel of aggregate agricultural trade flows between 66 importing and exporting countries over the period 1998 to 2017. Because we focus in this paper on standards that are trade-restrictive, our measure of standards is from the specific trade concerns (STC) database. It records any concerns raised at the WTO against an SPS measure introduced by an importing country. If an exporter raises an STC on an SPS measure imposed by an importer, it follows that the former considers that particular measure to be overly stringent or even protectionist. This is particularly relevant for the agricultural sector where about 94% of STCs related to SPS measures apply (WTO, 2012). Our empirical model specifications include a host of bilateral and country-time fixed effects that control for supply and demand shocks but also unobserved country characteristics. Hence, our identification strategy exploits the within-country variation in STCs.

We contribute three main novelties to the existing standards and trade literature. Our first contribution is to the empirical literature that assesses the standards-trade effect using the gravity model (Disdier *et al*., 2008b; Ferro *et al*., 2015; Crivelli and Gröschl, 2016). Like many demand-side theoretical gravity equations, the models estimated in this literature assume constant elasticity of substitution (CES) expenditure functions (e.g., Anderson and Wincoop, 2003). This class of models limits the elasticity of trade to changes in standards to be constant. Another implication of the CES model is that some volume of the product is purchased no matter how high the selling price. Hence, it is not straightforward to justify zero trade observations, unless we assume fixed costs of exporting on the supply side (e.g., Helpman *et al*., 2008). In this paper, we overcome these limitations by using a much more flexible translog functional form of the gravity model (Novy, 2013) that addresses the issue of zero trade observations while also allowing for variable trade cost elasticities. Extensions of our modelling approach allow us to show country-pair specific estimates of the effects of the introduction of an SPS measure for which an STC is raised. Our analysis is the first to present country-pair specific effects of stricter food safety standards across a panel of bilateral trade relations.[4] Our contribution is important from both an analytical and a public policy point of view. Working with country-pair specific estimates of

[3]In the international trade literature, the translog gravity model has been employed to study the heterogeneity of the custom unions effect (Chen and Novy, 2018). In agricultural trade, Meng et al. (2018) use the translog gravity model to assess China's agricultural trade-cost elasticity and to analyse its heterogeneity across different types of trading partners.

[4]Anders and Caswell (2009) provide estimates of the country-specific impacts of stricter food safety standards across a panel of bilateral trade relations with the US as an importer.

a trade policy restriction – instead of the usual average effect across all country-pairs – will enhance evidence-based policy-making in the agricultural sector.[5]

Second, our work is closely related to the literature on the heterogeneous effects of standards across production units depending on their sizes. Much of this work has been done at the firm level. Fontagné *et al.* (2015), using a panel of French exporting firms, show that restrictive SPS measures in the importing country decrease both the extensive and the intensive margin of trade, but these negative effects are mitigated for larger firms. Fernandes *et al.* (2019) show that smaller exporting firms are more affected in their market entry and exit decisions by the relative stringency of destination standards than larger exporters. Using data on Peruvian firms, Curzi *et al.* (2020) show that larger firms are less affected by STCs. At the macro-level, few studies have considered the heterogeneous effects of standards in terms of export volume. The exceptions include Anders and Caswell (2009) who find that regardless of development status, leading seafood exporters generally experienced a positive HACCP effect, while most other smaller trading partners faced a negative effect. Ehrich *et al.* (2017) apply a quantile regression procedure within the gravity framework to show that maximum residue limits impede bilateral trade of selected agricultural products between country pairs with relatively low trade volumes but have positive trade effects at the 90th decile. Our paper differs from this literature in three respects. (1) We consider the whole agricultural sector. (2) We define size as exporter-specific market shares in an importing country, contrary to absolute trade volumes regardless of destination as done in the existing literature (Anders and Caswell, 2009; Fontagné *et al.*, 2015; Ehrich *et al.*, 2017; Fernandes *et al.*, 2019; Curzi *et al.*, 2020). Admittedly, in the agricultural trade literature, a few papers that study the nexus between standards and quality upgrading also regress price-adjusted market shares in the destination countries on standards (e.g., Fiankor *et al.*, forthcoming; Curzi *et al.*, 2020). The difference is that our size measure originates from the underlying theoretical framework in which the demand side of the general equilibrium condition is represented by a translog expenditure function. Heterogeneous trade responses are thus endogenous to the translog gravity equations that we estimate. (3) Our estimation of heterogeneous effect of standards on trade flows at the country-level based on the CES gravity model yields results that are consistent with the predictions from the translog gravity framework.

Our third contribution is to the literature that assesses the heterogeneity of the standards–trade effect across the development status of the exporting countries. These studies usually report bigger trade-reducing effects for developing countries compared to developed countries. For example, considering OECD imports, Disdier *et al.* (2008a) show that OECD exporters are not significantly affected while exports of developing countries are reduced by SPS regulations. Similar conclusions are reached for maximum residue limits (Fiankor *et al.*, forthcoming; Xiong and Beghin, 2014; Ferro *et al.*, 2015; Curzi *et al.*, 2018) and HACCP standards (Anders and Caswell, 2009).

The rest of the paper proceeds as follows. Section 2 discusses our empirical framework. This is followed in section 3 by a discussion of the data used in the analysis with a focus on specific trade concerns. In section 4 we discuss the results of our translog gravity model estimations. In section 5 we conduct various sensitivity analyses to

[5]Analytically, James Anderson argues 'more general translog treatments [of the gravity model] are feasible and desirable' (Anderson, 2011, p. 147).

confirm the robustness of our findings. Section 6 concludes and offers policy implications.

2. Empirical Approach

To guide our empirical analysis, we estimate a theory-consistent structural gravity model. The gravity model in economics was until the early 2000s disconnected from the rich family of economic theory (Anderson, 2011), but can now be derived from several theoretical foundations, including the Ricardian model (Eaton and Kortum, 2002), the CES/Armington demand framework (Anderson and Wincoop, 2003), or models with heterogeneous firms (Melitz, 2003; Chaney, 2008; Helpman *et al*., 2008). Inherent in these model classes is the assumption that the elasticity of trade with respect to trade costs is constant. For instance, the trade cost elasticity is fixed at $1-\sigma$ in Anderson and Wincoop (2003), equal to the Pareto shape parameter, γ in Chaney (2008) or the Frechet shape parameter, θ in Eaton and Kortum (2002). This feature means that in our specific case *ceteris paribus*, the presence of a food standard or an increase in its stringency has the same proportionate effect on bilateral trade regardless of product origin and existing trade levels. Our aim is to provide further insights into this simple one-size-fits-all narrative.

Since our interest is to assess the heterogeneity of the standards-trade effect, we follow Novy (2013) and employ a flexible specification for our gravity model to allow for variable trade effects from food standards. The estimating equation is derived from a general equilibrium framework – which features multiple countries endowed with an arbitrary number of differentiated goods – where linear homogeneity and symmetry of parameters according to Feenstra (2003) is imposed on a translog type expenditure function.[6] Imposing market clearance and solving for general equilibrium results, the general structural translog gravity reads as:

$$\frac{x_{ij}}{y_j}=\frac{y_i}{y^w}+\gamma n_i \ln\left(T_j\right)-\gamma n_i \ln\left(\tau_{ij}\right)+\gamma n_i \sum_{s=1}^{J}\frac{y_s}{y^w}\ln\left(\frac{\tau_{is}}{T_s}\right) \tag{1}$$

where x_{ij} denotes bilateral trade flows in US\$1000 from exporter i to importer j, and y_j is the gross annual imports by j. The two variables are in levels such that the dependent variable reflects i's import share in the total of j's imports which depends on total production in the exporting country y_i, normalised by global production, y^w. Import shares are further linked to the inward multilateral resistance term, $\ln(T_j)$, which represents a weighted average of logarithmic trade costs over trading partners of importer j. The number of goods produced and exported by country i, n_i, reflects a measure for the extensive margin and γ denotes the translog parameter. The bilateral costs of trading are captured in τ_{ij}. At first glance, equation (1) looks distinct from standard CES gravity equations (Eaton and Kortum, 2002; Anderson and Wincoop, 2003) since the dependent variable is measured as import shares in levels and not the log of trade. As a result, the translog gravity relationship is not log-linear in trade costs, which implies a variable trade cost elasticity (Novy, 2013). It is this property that we exploit to study the heterogeneity of the standards–trade effect. Nevertheless, on second glance, equation (1), is just like the traditional CES gravity equations, relating bilateral trade to bilateral trade costs and other country-specific variables.

[6]A full derivation of the translog gravity model is presented in the Online Appendix.

As the first and the last term on the right-hand side of equation (1) are invariant over the importing partner j, they can be parsimoniously captured by an exporter's fixed effect ψ_i. In the same vein, inward multilateral resistance does not vary over the exporting partner i and thus can be captured by an importer's fixed effect λ_j. Accordingly, reformulating equation (1) and dividing both sides of the equation by n_i yields the estimation equation:[7]

$$\frac{x_{ij}/y_j}{n_i} = -\gamma \ln(\tau_{ij}) + \psi_i + \lambda_j + e_{ij}. \tag{2}$$

Following Chen and Novy (2018), we adapt the original specification in (2) and specify our aggregate panel data model as follows:[8]

$$\frac{x_{ijt}/y_{jt}}{n_{it}} = -\gamma \beta' \mathbf{w}_{ijt} + \psi_{it} + \lambda_{jt} + \alpha_{ij} + e_{ijt}. \tag{3}$$

The dependent variable is import shares. They are set equal to zero when no imports in the respective destination-year are reported.[9] We define the extensive margin n_{it} as a time-varying count of HS2 digit categories exported within the class of agricultural products, that is, HS01 to HS24.[10] We define the costs of trading $\ln(\tau_{ijt}) = \beta' \mathbf{w}_{ijt}$ as the following function of different dyadic time-varying observables:

$$\ln(\tau_{ijt}) = \beta_1 \mathrm{SPS}_{ijt} + \beta_2 \ln\mathrm{Tariff}_{ijt} + \beta_3 \mathrm{RTA}_{ijt} \tag{4}$$

where our variable of interest SPS_{ijt} is a dummy variable that takes the value of 1 if an exporting country i raises or supports a specific trade concern against an SPS measure that an importing country j maintains in year t. Tariff_{ijt} are applied bilateral tariffs and RTA_{ijt} is a regional trade agreement dummy.

To control for a range of potentially omitted variables affecting bilateral trade, country-specific time-varying fixed effects, ψ_{it} and λ_{jt}, are included in equation (3). They control for supply and demand shocks (i.e., the total agricultural production in country i, and the total expenditure by country j on foreign goods), and other country-specific (un)observables (e.g, institutional quality, comparative advantages in agriculture and other unilateral trade policy measures).[11] They also control for

[7]An alternative estimation strategy is to maintain nit on the right hand as a multiplicative factor. We prefer to divide through equation (1) by nit so that all possible measurement errors associated with nit are passed on to the left-hand side. This also allows us to estimate our models with the usual country-time fixed effects as is standard in the gravity literature.

[8]While the structural gravity model can be estimated at the product level (e.g., the Armington CES model of Anderson and Wincoop, 2004), the translog gravity model is derived at the aggregate level. Sticking closely to the theoretical model of Novy (2013) we estimate our translog gravity equations in this paper at the aggregate level. Deriving a product-specific translog gravity model goes beyond the scope of the present paper.

[9]Depending on the countries' reporting practices, this could signify that imports were of a negligible size and are therefore not reported. The reporting practices are controlled for by using an appropriate fixed effects structure in the empirical model.

[10]We also use other definitions of the extensive margins as a form of robustness check. For example, the count of HS6 digit categories exported or defining the extensive margin according to Hummels and Klenow (2005). These different definitions yield qualitatively similar results.

[11]To deal with the high-dimensional fixed effects in our model specifications, we use the user-written commands reghdfe and ppmlhdfe (Correia, 2016) in Stata.

multilateral resistance terms which are necessary for proper specifications of the gravity model (Anderson and Wincoop, 2003; Feenstra, 2004).

The panel structure of our dataset allows us to control for time-invariant heterogeneity in equation (3) by including country-pair time-invariant fixed effects, α_{ij}. Since equation (3) is in principle a gravity equation, traditional gravity variables such as distance, contiguity and language could be included in the model in place of the country-pair fixed effects. However, the country-pair fixed effects are better measures of bilateral trade costs than the standard set of bilateral varying gravity variables (Egger and Nigai, 2015; Agnosteva *et al.*, 2019). Furthermore, public food standards imposed by the importing countries may be endogenous to bilateral trade volumes. By including the full set of three-way fixed effects in our analysis we reduce endogeneity concerns to a large extent. Including α_{ij} also means we exploit fully the within-country variation in our control variables. e_{ijt} is the random error term, which we cluster at the country-pair level to account for heteroskedasticity. We estimate equation (3) using ordinary least squares (OLS). Because the dependent variable is measured as market shares in levels, the OLS translog gravity model can deal with zero trade observations. The elasticities in the translog gravity model are not constant between country pairs. The variable trade cost elasticity can be retrieved by deriving equation (3) with respect to our variable of interest:

$$\varepsilon_{ijt} \approx \frac{d\ln \frac{x/y_{jt}}{n_{it}}}{d\mathrm{SPS}_{ijt}} = -\frac{\gamma\beta_1}{\frac{x/y_{jt}}{n_{it}}}. \tag{5}$$

Since $\beta_1 > 0$ in equation (4) – due to the trade cost-increasing effect of stringent standards – we expect an overall negative effect of SPS_{ijt} on bilateral trade in equation (3). But more importantly from equation (5), the magnitude of the negative food standard effect on trade flows is supposed to be larger for trade relations where the exporter only governs a small market share in the destination market.

3. Data

In many high-value markets, export success is now conditional on compliance with NTMs as export competition has shifted from prices to quality (Curzi *et al.*, 2015). In agricultural markets, SPS measures, such as food standards, are often the most important NTMs driven among other things by increasing consumer awareness of food safety, shifting liability for food safety from governments to retailers, and growing public concern for consumer and environmental protection. Even though the Codex Alimentarius Commission sets international standards, the WTO's agreement on SPS measures allows countries to set their own national standards that protect human, animal or plant health. To prevent the abuse of this provision for protectionist intents, the national standards must be based on a scientific risk assessment, not discriminatory toward countries with similar conditions, and are minimally trade-distorting. These principles are not always achieved, in which case standards can be abused for mercantilist trade policy objectives. SPS measures are also the most frequently encountered NTM in agrifood trade (Grant and Arita, 2017).

While we are broadly focused on SPS measures in the agricultural sector, our identification strategy exploits specifically the time and country differences in specific trade concerns (STCs) raised against SPS measures maintained by an importing country. STCs are issues raised at the WTO by exporting countries affected by SPS measures, which they consider unjustified and particularly restrictive (Olper, 2016). Raising an STC is a formal mechanism by which a country can introduce a complaint against another country's SPS policies regulating imports. Standards may be barriers to trade, but can also be measures for market creation. As a result, measures which form strong barriers to trade and are motivated by protectionism – rather than preventing legitimate health risks – are likely to be raised as a concern by other members at the WTO.[12] Grant and Arita (2017) call this a 'revealed concern' approach. Likewise, we would expect legitimate measures to receive fewer complaints. Hence, we can expect that measures that exporters consider as overly restrictive will attract an STC. Furthermore, policy-makers may have little incentive to notify their own SPS measures but all kinds of incentives to notify the unjustified barriers of their partners (Grant and Arita, 2017). This nature of STCs makes them *de facto* restrictive and thus appropriate to study the standards–trade effect if the focus, as in our case, is on the standards-as-barriers angle (see also Fontagné *et al.*, 2015; Grant and Arita, 2017; Orefice, 2017; Beverelli *et al.*, 2019; Curzi *et al.*, 2020).

The data we use on SPS STCs come from Ghodsi *et al.* (2017). The original source of the data is the compilation of NTMs notified to the WTO, accessible via the Integrated Trade Intelligence Portal (I-TIP). The I-TIP provides information compiled by the WTO on all trade policy measures. One major limitation of this otherwise rich dataset is that it is not readily available in a form necessary for econometric analysis or quantitative assessment. For instance, the dataset does not follow a panel structure where NTMs are distinctly assigned to products according to product classifications such as the Harmonised System (HS) or the International Standard Industrial Classification. This limitation is addressed in Ghodsi *et al.* (2017). They enhance the value of the WTO I-TIP database for econometric analysis of NTMs by imputing missing product codes at the HS 6-digit level. Since we treat the agricultural sector as one unit, we aggregate this HS6 digit STCs to the country level. We limit our sample to only bilateral pairs where an STC was active at least once over the length of the panel. This brings our sample to 66 importing countries (including the EU15 as a group) and 66 exporting countries over the period 1998 to 2017 with a total of 87,120 ($66 \times 66 \times 20$) observations. The list of countries in the sample is included in the Appendix S1 (Table S1).

Figure S1 offers further insights into our trade concerns data. Over the period 2001 to 2010, we observe a steep increase in both the number of countries maintaining a restrictive SPS measure and the number of countries raising or supporting concerns

---

[12]This idea that exporting countries raise STCS when NTMs imposed by an importer becomes an effective trade barrier is motivated by the timing of some STCs raised at the WTO. Orefice (2017) offers many such examples. For one, in 2003 the Chinese government raised an STC complaining about an NTM imposed by the EU that restricted the imports of natural honey from China as a food safety measure due to the presence of chloramphenicol, a toxic antibiotic. The consumers' protection aim of this NTM is clear, but its timing raises eyebrows. This concern was raised in 2003, just before the EU enlargement towards the east in 2004. Among the new EU member states, Poland and Slovenia had in 2003 a high tariff protection on Chinese honey (applied tariff on natural honey respectively 89% and 45%) – to be necessarily reduced the year after the accession to the EU at 17.3% (EU tariff protection on honey). Hence, using STCs allows us to sort through the host of SPS measures introduced annually to identify those which likely constitute unjustified measures or a significant trade barrier, as opposed to justified measures which may be of little concern to exporters.

Table 1
Summary statistics

Variable	Mean	Std. Dev.	Min.	Max.	N
SPS_{ijt} dummy	0.149	0.356			87,120
RTA_{ijt} dummy	0.205	0.403			87,120
$Tariff_{ijt}$ (logs)	2.320	1.228	0	7.786	87,120
Import shares (%)	1.515	4.369	0	84.618	87,120
Extensive margin (n_{it})	23.803	0.904	15	24	87,120
Trade value (US$m)	0.171	1.391	0	65.212	87,120

against such measures. We also see (Figure S2) that not all countries are active in maintaining or raising specific trade concerns. The most active countries both maintaining and contesting concerns are the EU and the USA with the former more frequently raising concerns against the latter (Figure A2). Emerging markets maintain relatively few concerns – partly due to political-economy reasons – notwithstanding the fact that standards are thought to pose larger challenges on producers in poorer countries.

It seems clear that the rise in SPS measures coincides with a fall in tariffs though whether this relationship is causal remains an empirical question. The evidence thus far confirms both substitutionary and complementary effects (Orefice, 2017; Beverelli *et al*., 2019; Niu *et al*., 2020). To account for potential trade policy substitution, we control for applied tariffs and bilateral trade agreements in our empirical analyses. The tariff data comes from the World Integrated Trading System and data on regional trade agreements are from De Sousa (2012).

The remaining standard gravity variables are derived from different sources. The bilateral trade data is taken from the Base pour l'Analyse du Commerce International (BACI) database developed by the Centre d'Etudes Prospectives et d'Informations Internationales (CEPII) which reports the bilateral value of trade by product, origin and destination (Gaulier and Zignago, 2010). The advantage of the BACI dataset over that in the UNCOMTRADE database is that the former reconciles discrepancies in bilateral trade flows between CIF import values and FOB export values. To allow us to focus on the agricultural sector, we aggregate trade data on HS01 to HS24. Summary statistics on our dependent and control variables are reported in Table 1.

4. Results and Discussions

Our baseline empirical findings are presented in Table 2. Columns (1)–(2) present results using the OLS estimator (equation 3). The number of observations differs across the different estimations because in column (1) we exclude zero trade shares but include them in column (2). The high R^2 values we obtain reflect the typical good fit of gravity models. Our control variables and the time-varying country and time-invariant bilateral fixed effects explain about 93% of the variation in the bilateral import shares per good. Given our identification strategy, the estimated coefficient of the SPS dummy is to be interpreted as the average change in annual bilateral imports caused by the introduction of at least one restrictive measure (i.e., an SPS measure raising a specific trade concern) by the importing country. In column (1) and (2), the SPS_{ijt} coefficient is −0.013. The coefficient estimates are statistically significant at the

Table 2
The effect of standards on agricultural trade: translog gravity model

	$\frac{x_{ijt}/y_{jt}}{n_{it}}>0$	$\frac{x_{ijt}/y_{jt}}{n_{it}}$
Dependent variable	(1)	(2)
SPS_{ijt}	−0.013***	−0.013***
	(0.002)	(0.002)
$\text{Log}(1+\text{Tariff}_{ijt})$	−0.001	−0.001
	(0.001)	(0.000)
RTA_{ijt}	0.003	0.003
	(0.003)	(0.003)
SPS estimates		
Mean	−0.187	−0.183
30th percentile	−5.167	−5.060
50th percentile	−1.194	−1.170
90th percentile	−0.075	−0.073
R^2	0.930	0.927
Observations	76,219	87,120

Note: Robust country-pair-product clustered standard errors in parentheses. ***, **, * denote significance at 1%, 5% and 10%, respectively. Importer-time, exporter-time, and importer-exporter fixed effects included in all regressions. Intercepts included but not reported. Columns (2) excludes zero trade shares. The dependent variable are import shares measured as the aggregate of agricultural trade (i.e., HS01–HS24). Except for tariffs all explanatory variables enter the regression as dummy variables.

1% level. As shown in the lower part of Table 2, this corresponds to an estimate of −0.19 at the mean value of import shares. This implies that on average, aggregate agricultural exports from a country raising a specific trade concern fall by 17% (i.e., [exp(−0.187) − 1] × 100) if at least one concern is raised against an SPS measure implemented by the importer. This finding contrasts those of Crivelli and Gröschl (2016) – that STCs constitute obstacles to agrifood trade, but conditional on market entry affect trade flows positively – but are in line with the firm level findings of Fontagné *et al.* (2015) and Curzi *et al.* (2020) that STCs restrict trade even at the intensive margin.

What is new in our contribution is that we are able to show that these average effects mask a substantial amount of heterogeneity across exporting countries. This is the major advantage that our analysis has over existing works. The lower part of Table 2 shows that the trade effect at the 30th percentile of import shares is 99%. This reduces to 70% at the 50th percentile and further down to 7% at the 90th percentile.[13] This implies that for countries trading large volumes, even contested standards have limited negative effects. This is a conclusion that is overlooked in the existing literature since the estimated CES gravity models yield estimates that are constant. To see the essence of our contribution, we plot in Figure 1 the estimated trade cost elasticities

[13]The SPSijt estimates at the 10th and 20th percentiles are extremely large. The reason is that the translog imposes a hyperbolic functional form on the way our elasticities of interested are computed (Chen and Novy, 2018). Because import shares at low percentiles are very close to zero, the implied elasticities tend to become very large.

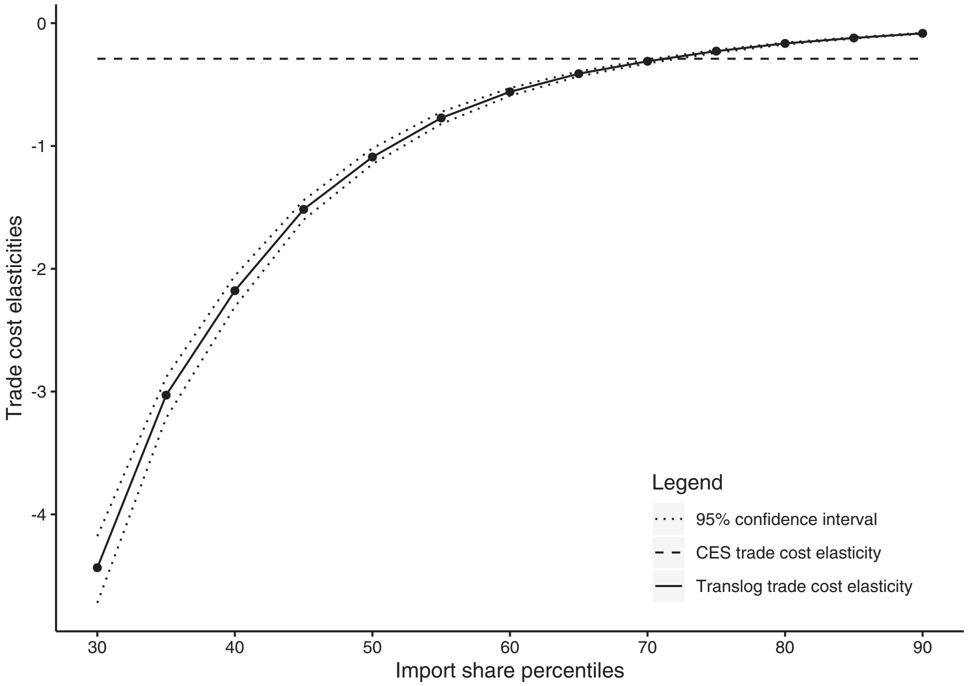

Figure 1. Trade cost elasticities plotted against import shares

reported in columns (2) along with their 95% confidence intervals across percentiles of the trade share values. We observe that the estimated effects are heterogeneous across import shares. At the 90th percentile of predicted import shares, where imports are large, the standard-trade effect is relatively small at near 0. However, as we move to lower percentiles (where import shares are small), the estimated trade effects become larger. For comparison, we also plot the constant elasticity from the traditional log-linear CES OLS gravity model which yields an average effect of −0.313 in the same graph (see Table S2).[14]

An added advantage of the translog modelling framework is that it enables us to retrieve country-pair specific estimates of the contested SPS effects. Consider the case of STCs raised or supported against SPS measures maintained by the EU in 2017. The EU has a reputation for setting overly stringent standards and is the leading country maintaining the most restrictive SPS trade measures for which concerns are raised. Table 3 shows that the magnitude of the trade effect induced by EU standards increase as the import shares in the EU15 decreases. We report the bilateral trade effects for the 20 years in Table S4 of the Appendix S1.

Overall, the results are in line with our expectations. Consistent with much of the existing literature, we confirm that stricter importing country standards are indeed

[14]Note that direct comparison of the estimates is not feasible, for one, because the dependent variable in the translog model denotes shares whereas the standard gravity model denotes volumes as the dependent variable. For another, the estimate obtained from the translog model is not an elasticity as it is for the standard gravity framework.

trade-restrictive (Fiankor *et al.*, forthcoming; Disdier *et al.*, 2008b; Curzi *et al.*, 2018; Kinzius *et al.*, 2019; Fernandes *et al.*, 2019) at least when they raise objections as an STC. In line with Melitz (2003) and Helpman *et al.* (2008) type models, a stringent importing country standard induces a selection effect by raising fixed and variable trade costs that discriminate against non-compliant producers. But consistent with findings at the firm (Fontagné *et al.*, 2015; Fernandes *et al.*, 2019; Curzi *et al.*, 2020) and country-product levels (Anders and Caswell, 2009; Ehrich *et al.*, 2017) we see that the negative effects reduce with exporter size which we measure as import shares. Nonetheless, there are also some notable differences in our results compared to others. At the country-product level, Anders and Caswell (2009) find that for HACCP standards neither the 'standards as barriers/catalyst' hypothesis fits developing countries as a whole. Among developing countries increased standards act as a catalyst for larger, more established exporting countries and a barrier for smaller exporters. Ehrich *et al.* (2017) also report positive effects of food standards at high deciles of the trade flow distribution and negative effects at lower deciles. At the firm-product level, Curzi *et al.* (2020) also show that in Peru the trade-reducing effects of stringent standards are especially strong for small and medium firms, but have the tendency to turn positive for very large firms. We, on the other hand, find that for SPS STCs, the standards-as-barriers effect prevails for all countries – developed and developing – and trade volumes, but with magnitudes that are smaller for more established trading partners who have high import shares regardless of their development status.[15]

Another implication of our results is that while the standard's effect on trade is mainly discussed from a North-South perspective – with countries in the South finding it more difficult to comply – these generalisations may not necessarily be the whole story. Even in developing countries, some producers will make the effort to meet importing-country specific standards if those firms command a relatively large market share in that importing country. For example, in Table 3 we see that developing countries such as Indonesia, Côte d'Ivoire, Ecuador, Thailand and Peru are relatively less affected by stringent standards in the EU-15 than developed countries such as Australia, Russia, Israel and Uruguay.

So why may standards affect smaller trading partners more than larger ones? Standards impose both fixed costs (e.g., investing in new production techniques or adjustments to existing ones) and variable trade costs (e.g., costly inputs, recurrent costs of quality control, and product testing) for producers. The fixed cost component of a standard will affect mainly the extensive margin as increased production costs induce

[15]The fact that our conclusions on the standards–trade effect differ from the country-level conclusions of Anders and Caswell (2009) and Ehrich et al. (2017) is not surprising and may just offer insights into some underlying mechanisms driving our results. These two studies focus on specific standards (HACCP and maximum residue limits) that may not necessarily be trade-restrictive. Even if their stringency levels change intermittently, producers may suffer in the short term until they adjust completely to the standard and can then increase trade volumes. This is not necessarily the case for the broad SPS measures we focus on, and especially regarding the fact that we select out overly stringent measures which have raised at least one specific trade concern. Nevertheless, even at the firm-product level, our conclusions differ in this one regard with Curzi et al. (2020) who also use specific trade concerns as a standard. The difference may arise from the fact that we work at the very aggregate country-level and our results may still be missing some important between firm heterogeneities that we are unable to capture in our paper.

Table 3
Country-pair specific estimates of the effects of EU-15 standards in agricultural trade in 2017

Exporting country	Trade value (US$ m)	Import share (in %)	Trade cost elasticity	Income status
Fiji	107	0.027	−11.950	Low
Cuba	368	0.091	−2.896	Low
Tanzania	413	0.103	−3.090	Low
Senegal	459	0.114	−2.781	Low
Uruguay	663	0.164	−1.927	High
Israel	1,033	0.256	−1.236	High
Egypt	1,080	0.268	−1.183	Low
Phillipines	1,416	0.351	−0.902	Low
Russia	1,622	0.403	−0.787	High
Colombia	2,236	0.555	−0.571	Low
Australia	2,440	0.606	−0.524	High
Peru	2,767	0.687	−0.462	Low
Thailand	3,050	0.757	−0.419	Low
Ecuador	3,115	0.773	−0.410	Low
South Africa	3,752	0.931	−0.340	Low
Côte d'Ivoire	4,215	1.046	−0.303	Low
India	4,755	1.180	−0.269	Low
Indonesia	5,198	1.290	−0.246	Low
Argentina	5,881	1.460	−0.217	Low
China	7,467	1.853	−0.171	Low
Brazil	12,600	3.126	−0.101	Low
USA	12,800	3.184	−0.100	High

Note: Estimates are based on exporting countries that raised or supported a Specific Trade Concern maintained against the EU-15 in 2017. Also note that import shares do not add up to 100% as shares are given by the exporter country's market share per good in the importing country. Here we kept the importer (EU-15) fixed and show the variation in shares across export partners.

market exit for non-compliant firms, while the effect on the intensive margins is *a priori* undetermined. Standards increase production costs and may reduce export volumes but the extra costs may be compensated by increased market access due to quality upgrading and/or more consumer information. It is intuitive to assume that for more established trading relationships, exporters would have already invested in meeting the fixed costs imposed by the importer. For smaller trading partners the fixed cost component is very high and thus affects to a large degree their trade flows to the country maintaining the standard. It is also possible that bilateral relationships with higher import shares will imply that the particular exporter involved in that trading relationship has a lot of importer-specific experience. This is consistent with Grant *et al*. (2015) who show that the negative effects of SPS standards diminish as US exporters accumulate treatment experience. The underlying mechanism is consistent with a 'learning-by-doing' framework whereby bilateral trading relationships with higher trade volumes are able to treat shipments more efficiently as their cumulative experience grows (Grant *et al*., 2015).

Regarding the other control variables, bilateral tariffs and regional trade agreements have the expected negative and positive effects on bilateral trade flows, respectively. By construction, tariffs and SPS measures cannot be compared directly. Although tariffs are by nature trade reducing, NTMs can be measures for market creation. So, even though our results show that tariffs and standards have qualitatively similar effects on trade flows, these two trade policy instruments may affect market structure differently. For instance, standards, unlike tariffs, affect both domestic producers and foreign exporting firms. As a result, standards displace smaller firms – both domestic and foreign – in favour of larger firms although cooperation may overcome some difficulties for smaller firms (Asprilla *et al.*, 2019). The estimated coefficient for the RTA dummy is positive. This is consistent with the theoretical prediction that trade preferences enhance trade flows. However, the estimated effects are not statistically significant, probably because the extensive fixed effects in our model specifications absorb most of the variations in the RTA variable. Not controlling for bilateral fixed effects yields a statistically significant RTA effect (Table 4). It is possible that these other control variables also have heterogeneous effects on agricultural trade. However, these go beyond the scope of our paper. We refer the interested reader to Chen and Novy (2018) for the case of trade agreements.

Table 4
The effect of standards on agricultural trade: unilateral SPS measure

	$\frac{x_{ijt}/y_{jt}}{n_{it}}>0$	$\frac{x_{ijt}/y_{jt}}{n_{it}}$
Dependent variable	(1)	(2)
SPS_{jt}	−0.003***	−0.003***
	(0.002)	(0.001)
$\text{Log}(1+\text{Tariff}_{ijt})$	−0.006***	−0.009***
	(0.002)	(0.000)
RTA_{ijt}	0.062***	0.059***
	(0.008)	(0.008)
Log Distance_{ij}	−0.057***	−0.034***
	(0.005)	(0.004)
Colony_{ij}	0.092***	0.091***
	(0.031)	(0.031)
Language_{ijt}	0.011	0.028***
	(0.013)	(0.011)
Contiguity_{ijt}	0.215***	0.254***
	(0.039)	(0.039)
SPS estimates		
Mean	−0.041	−0.038
30th percentile	−1.132	−1.052
50th percentile	−0.262	−0.243
90th percentile	−0.016	−0.015
Observations	76,270	87,120

Note: Robust country-pair-product clustered standard errors in parentheses. ***, **, * denote significance at 1%, 5% and 10% respectively. Exporter-time, importer, and time fixed effects included in all regressions. Intercepts included but not reported. Columns (2) excludes zero trade shares. The dependent variable are import shares measured as the aggregate of agricultural trade (i.e., HS01 – HS24).

5. Sensitivity Analyses

5.1. Endogeneity of SPS measures

Our identification strategy controls for endogeneity concerns arising from selection and bilateral heterogeneity due to omitted variable bias. However, if importing countries introduce restrictive SPS measures in reaction to a sudden growth in imports of a product from a particular exporting country, then endogeneity due to reverse causality (e.g., due to political economy arguments) could bias our estimates.[16] The optimal solution to address this form of endogeneity is to estimate instrumental variable regressions. However, in the absence of appropriate instruments at the country-level, we proceed in two steps to mitigate the bias.[17]

First, SPS measures are unilateral – that is, if an importer introduces a standard it affects all exporters – but SPS-related STCs are bilateral. Yet, an exporter may not complain about a measure simply because it considers the importer's market as irrelevant (Beverelli *et al.*, 2019). Low-income countries may also not have enough resources to raise concerns, likely because of high political and opportunity costs. In both cases, we would not observe an STC, although the importer may have a trade-restrictive measure in place. To account for this possibility, we consider the SPS measure as trade restrictive for all potential exporting countries (Curzi *et al.*, 2020). This approach has the advantage that it mitigates endogeneity due to political economy reasons. If the SPS measure affects all exporting countries, there is no reason to suggest that importers target particular exporters as is the case for bilateral measures. The results are presented in Table 4. Because our variable of interest is now unilateral (i.e., SPS_{jt}), there is no country-pair variation in the SPS measure. As a result, we replace the country-pair fixed effects with country-pair specific controls (i.e., bilateral distance, colonial relationships, sharing a common language and sharing a common border). Our main findings are confirmed. However, the estimated effects are smaller in economic magnitude. This gives further weight to our estimate for the bilateral SPS measure underlining the fact that exporters legitimately raise concerns on overly restrictive standards.

Second, our baseline models use the contemporaneous values of our SPS variables. However, STCs may also target new SPS measures which are to come into force in the near future. As a consequence, Fontagné *et al.* (2015) and Crivelli and Gröschl (2016) argue that a contemporary SPS measure inadequately captures the 'true' variation and they use the first lag of the variable on SPS to circumvent the attenuation

[16]This is to a large extent not problematic in our aggregate country-level analysis. Importing countries are more likely to introduce a restrictive measure that targets a particular product or group of products from an exporting country but not the whole agricultural sector of the exporting country. Hence this sort of endogeneity should be minimised in our specific case.

[17]At the firm-product level, Fontagné and Orefice (2018) use as an instrument a dummy variable that takes the value of 1 if two conditions hold: (i) if country j has an active concern on at least one product other than s and (ii) if at least one third country (other than j) has an active concern over product s at time t. A similar instrument is used at the country-product level in Crivelli and Gröschl (2016). We are unable to apply this instrument in our country-level study for two reasons: (i) our aggregate agricultural sector analysis means that our dataset has no product s dimension; and (ii) this lack of product variation also means that at least one third country other than j always has an active concern at time t. As a result, our instruments are almost perfectly collinear with the SPS variable.

Table 5
Heterogeneity across trade routes

	Exports to the North		Exports to the South	
	South–North (1)	North–North (2)	South–South (3)	North–South (4)
SPS_{ijt}	−0.007**	−0.014***	−0.006	0.002
	(0.003)	(0.005)	(0.004)	(0.012)
$\text{Log}(1+\text{Tariff}_{ijt})$	−0.000	0.000	−0.002	−0.001
	(0.001)	(0.001)	(0.001)	(0.002)
RTA_{ijt}	0.006**	0.008	−0.003	0.023
	(0.003)	(0.008)	(0.007)	(0.013)
SPS estimates				
Mean	−0.159	−0.153		
30th percentile	−3.213	−2.990		
50th percentile	−0.871	−0.729		
90th percentile	−0.070	−0.057		
Observations	18,352	22,123	19,968	15,770

Note: Robust country-pair-product clustered standard errors in parentheses. ***, **, * denote significance at 1%, 5% and 10% respectively. Importer-time, exporter-time, and importer-exporter fixed effects included in all regressions. Intercepts included but not reported. The dependent variables are import shares. We only report the elasticities for the SPS estimates whenever they are statistically significant.

bias. In the spirit of these papers, we use the 1-year lag of SPS. Doing this further bolsters our estimations against the potential problem of reverse causality between import shares and SPS measures. The results are presented in column (1) of Table A3. Our main findings remain qualitatively the same and the magnitudes differ only slightly. The lagged SPS coefficient, SPS_{ijt-1} is equal to −0.012. As shown in the lower part of the table, this corresponds to an estimate of −0.165 at the mean value of import shares. This implies that on average, aggregate agricultural imports from a country raising a specific trade concern fall by 15% if at least one SPS is implemented by the importer. This implies a two percentage point decrease from using the contemporaneous SPS measure in Table 2. If there would be an attenuation bias then our estimate for SPS_{ijt-1} should be in fact larger in terms of magnitude.

The two results from this section further enhance confidence in our results. Even though endogeneity concerns may remain, we have taken different steps to mitigate their effect and our main findings remain unchanged.

5.2. *Trade route specific heterogeneity*

One other form of heterogeneity that is receiving increased attention in the agri-food standards and trade discussion is the potential difference across trade routes (Santeramo and Lamonaca, 2019). Building on these insights derived from CES gravity models, we assess our results from the translog gravity model across two broad routes: (i) exports to the North; and (ii) exports to the South. We define the South as all countries classified as non-high income in the World Bank Income classifications. Consistent with the literature, the results presented in Table 5 show that the trade-reducing effects are important for exports to the North but not for exports to the South (Fiankor *et al.*,

Table 6
The heterogeneous effect of standards on agricultural trade: standard CES gravity model

	(1)	(2)
SPS_{ijt}	−0.051** (0.026)	
SPS_{ijt} × predicted shares (First interval)		−3.470*** (0.145)
SPS_{ijt} × predicted shares (Second interval)		−1.174*** (0.066)
SPS_{ijt} × predicted shares (Third interval)		−0.471*** (0.045)
SPS_{ijt} × predicted shares (Fourth interval)		−0.028 (0.026)
Log (1 + $Tariff_{ijt}$)	−0.021 (0.016)	−0.015 (0.015)
RTA_{ijt}	0.008 (0.034)	0.007 (0.034)
Observations	85,200	85,200

Note: Robust country-pair-product clustered standard errors in parentheses. ***, **, * denote significance at 1%, 5% and 10% respectively. Importer-time, exporter-time, and importer-exporter fixed effects included in all regressions. Intercepts included but not reported. The dependent variables are observed trade values. All models are estimated using PPML. The dummy for predicted shares is omitted due to perfect collinearity with the importer-time fixed effects.

forthcoming; Xiong and Beghin, 2014; Curzi *et al.*, 2018). Without loss of generality the heterogeneous effect of SPS is more pronounced for developing countries as a group because standards required in both production and trade are becoming more complex. As a result, we report the SPS elasticity estimates for exports to the North where the effects are statistically significant. What we then see is that the average effects at the mean are bigger in magnitude for South–North trade than for North–North trade. We find a similar result if we also focus on the effects at the different percentiles of the trade flow distributions. Even though the results from this section coincide with those from the CES gravity literature, what we show in Table 3 is that these general larger effects for developing countries relative to their developed country counterparts hide the country-pair specific estimates that we can derive from the translog model.

5.3. CES gravity model with heterogeneous SPS effects on trade

Another concern with our findings is whether the results are model-driven. To refute this argument we estimate a CES gravity model with the exporter's market share per good in importing country *j* as the dependent variable and incorporate heterogeneous effects of SPS measures.[18] Our baseline regression in the translog framework is estimated using OLS. This is because the dependent variables are in levels and so our regressions retain zero trade shares. This is not the case for the CES model which will require that we log transform the dependent variable. As a result, in this part of the analysis we employ the non-linear Poisson-pseudo maximum likelihood (PPML) estimator (Santos Silva and Tenreyro, 2006) which has become the gold standard in the CES gravity model. This estimator's log-linear objective function allows us to specify

[18]Unlike the translog gravity model, the CES gravity equation estimated using PPML is log-linear in trade costs. Since variations of the extensive margin nit and the importer size term (i.e., total imports or GDP) yjt of the dependent variable are absorbed by the exporter-year and importer-year fixed effects the remaining variation in market shares is derived from trade volumes between i and j. Therefore, we effectively regress trade volumes in logs.

our estimation equation in its multiplicative form without log-transforming the dependent variable as follows:

$$\frac{x_{ijt}/y_{jt}}{n_{it}} = \exp\left[-\beta' \mathbf{w}_{ijt} + \psi_{it} + \lambda_{jt} + \alpha_{ij}\right] + e_{ijt}. \tag{6}$$

To account for heterogeneous standards-trade effects, we include the interaction between our variable of interest and quartiles of predicted market shares per good into equation (6). If the trade effect of standards falls with higher exporter's market share as predicted by the translog gravity model, we would expect the trade effect to be pronounced for lower quartiles of predicted market shares. We use predictions according to Novy (2013) to circumvent simultaneity between the dependent variable and the effects of the standard. Our estimation equation in which the standards-trade effect is estimated for different intervals of market shares becomes:

$$\frac{x_{ijt}/y_{jt}}{n_{it}} = \exp\left[-\gamma \mathbf{r} \beta^{\mathbf{w}_{ijt}} + \delta_{int}\mathrm{SPS}_{ijt} \times D_{int} + \psi_{it} + \lambda_{jt} + \alpha_{ij} + D_{int}\right] + e_{ijt}. \tag{7}$$

Quartile dummies D_{int} enter the estimation as indicators interacted with SPS_{ijt} to obtain the corresponding heterogeneous coefficients δ_{int} across quartiles and also as quartile fixed effects. The first term on the right-hand side includes a (1×3) vector $\mathbf{r}$ which selects out bilateral tariffs and regional trade agreements from the initial trade cost vector $\mathbf{w}_{ijt}$.

The results are presented in Table 6. In column (1) we estimate the homogeneous effect of standards on agricultural trade (equation 6). The coefficient of −0.051 implies that an increase or introduction of standards are associated with a decrease in bilateral trade of 5% on average. Because the CES utility function is homothetic, the presence of a specific trade concern will yield a proportional decrease in trade, all else being equal. In column (2) we show the estimated effects for each quartile of predicted market share per good (equation 7). The first quartile refers to the interval with the lowest import shares. As expected, the standards coefficient is largest (−3.470) in magnitude for the first quartile and continues to fall with higher quartiles. Consistent with the predictions from the translog gravity framework, the estimated negative trade effect of stricter importing country food standards varies depending on how intensively two countries trade. The negative trade effect of stricter standards is more pronounced for lower market shares. The results in this section further enhance confidence in the main conclusions we draw from the translog modelling approach.

5.4. Further robustness checks

We have so far captured the presence of an STC as a dichotomous variable. Keeping in mind the limitations of using the counts of STCs present, we test our findings using the counts of cumulative STCs in place in year t. Here the interpretation of our SPS variable of interest changes to the average change in imports following the implementation of one additional protectionist policy. Our main conclusions remain unchanged. See column (2) of Table S3 of the Appendix S1. Finally, our translog models control adequately for zeroes. However, to see how robust our specification is to other estimators, we employ the PPML estimator within the translog gravity framework. Our main findings remain the same, but the estimated magnitudes in the PPML are higher (Column (4) of Table S3). Furthermore, we observe in Figure S2 that the most active countries in terms of raising and maintaining STCs are the US and the

EU. To see whether this drives our results, we re-estimate our baseline equation with a sample that excludes trade between the EU and the US. Our main findings remain the same. However, the elasticity estimates at the mean and across different percentiles of the trade share distribution become larger in magnitude.

6. Conclusion

How standards affect agricultural trade has been a subject of intense scrutiny. The rapid increase in the number of published studies assessing the standards-trade nexus – from about 14 in the year 2000 to about 140 studies in 2017 (Santeramo and Lamonaca, 2019) – is a good case in point. A limitation of this strand of literature is that the existing estimates are all from gravity models that impose the limiting assumption that the estimated trade effect is constant. These led to the one-size-fits-all type of conclusions, which this paper contests.

In this paper, we use a theory-based gravity model to provide the first set of empirical evidence on the heterogeneous effects of standards in agricultural trade considering import shares. The estimation is performed on a panel of aggregate bilateral agricultural trade flows between 66 countries from 1998 to 2017. Our empirical strategy exploits the within-country variation in specific trade concerns raised against strict standards introduced by an importing country. Consistent with existing research, we confirm that contested importing country standards are indeed trade-restrictive. However, unlike existing works, we show that the estimated trade cost elasticity varies depending on how intensively two countries trade. This means that for countries trading large volumes, contested standards have only limited negative effects. Thus, standards-related trade costs have heterogeneous trade-reducing effects depending on trade volumes. This result is robust to the inclusion and exclusion of zero trade values and holds even if we extend the theoretical Armington CES specification of the gravity model to account for this source of heterogeneity. While these results are specific to food standards, the insights may be general to other trade costs in the agricultural sector.

Our finding that there is a significant heterogeneity underlying the simple 'standards-as-barriers' argument – that goes beyond the typical developed-developing country-specific effects – has far-reaching policy implications. This is important from a public policy point of view; for one, working with country-pair specific estimates of a trade policy shock – instead of the usual average effect across country-pairs – will enhance evidence-based policy-making. As tariff barriers have gone down, liberalising NTMs must be the top priority. Even more important is that smaller trading partners will benefit more from further NTM liberalisation or harmonisation of standards. In terms of the overall standards-trade effect, we need to ensure that NTMs are appropriate, transparent and based on science. The multinational trading system is weakening; strengthening it will ensure that intergovernmental bodies like the Codex Alimentarius Commission have the scientific capacity and resources to develop standards acceptable for most, if not all, member countries.

Our work is not without its limitations. By focusing on SPS measures which cover a broad range of policy instruments we provide general results on the effects of standards in the agricultural sector. However, we do not provide precise estimates on the effects of a specific standard on trade, for example, maximum residue limits. We also provide results that refer to the general agricultural sector and do not provide product-specific findings. To better understand the mechanisms driving our results, extensions of our analysis should consider specific standards and specific products. Further analysis could also focus on firm-level transactions and customs data. Thus, extensions of our analysis should consider applications of the translog gravity model at the product-level or using firm-level data. The former will allow us to understand if the observed heterogeneity exists even at the product level. Furthermore, our measure of standards measures the prevalence of standards, but not their stringency. This makes it difficult to compare the stringency of standards between countries. Further studies could employ continuous measures of relative stringency set on specific products, such as maximum residue limits, to compare differences in country-pair specific standards.

Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Appendix S1. Appendix.

References

Agnosteva, D. E., Anderson, J. E. and Yotov, Y. V. 'Intra-national trade costs: Assaying regional frictions', *European Economic Review*, Vol. 112, (2019) pp. 32–50.

Anders, S. M. and Caswell, J. A. 'Standards as barriers versus standards as catalysts: assessing the impact of HACCP implementation on US seafood imports', *American Journal of Agricultural Economics*, Vol. 91, (2009) pp. 310–321.

Anderson, J. E. 'The gravity model'. *Annual Review of Economics*, Vol. 3, (2011) pp. 133–160.

Anderson, J. E. and Van Wincoop, E. 'Gravity with Gravitas: a solution to the border puzzle', *American Economic Review*, Vol. 93, (2003) p#. 170–192.

Anderson, J. E. and Van Wincoop, E. 'Trade costs', *Journal of Economic Literature*, Vol. 42, (2004) pp. 691–751.

Asprilla, A., Berman, N., Cadot, O. and Jaud, M. 'Trade policy and market power: Firm-level evidence', *International Economic Review*, Vol. 60, (2019) pp. 1647–1673.

Beghin, J. C., Maertens, M. and Swinnen, J. 'Nontariff measures and standards in trade and global value chains', *Annual Review of Resource Economics*, Vol. 7, (2015) pp. 425–450.

Beverelli, C., Boffa, M. and Keck, A. 'Trade policy substitution: Theory and evidence', *Review of world economics*, Vol. 155, (2019) pp. 755–783.

Chaney, T. 'Distorted gravity: the intensive and extensive margins of international trade', *The American Economic Review*, Vol. 98, (2008) pp. 1707–1721.

Chen, N. and Novy, D. *Currency Unions, Trade, and Heterogeneity*. CEPR Discussion Paper, 2018.

Correia, S. *REGHDFE: Stata module to perform linear or instrumental-variable regression absorbing any number of high-dimensional fixed effects*. Statistical Software Components, Boston College Department of Economics, 2016.

Crivelli, P. and Gröschl, J. 'The impact of sanitary and phytosanitary measures on market entry and trade flows', *The World Economy*, Vol. 39, (2016) pp. 444–473.

Curzi, D., Luarasi, M., Raimondi, V. and Olper, A. 'The (lack of) international harmonization of EU standards: import and export effects in developed versus developing countries', *Applied Economics Letters*, Vol. 25, (2018) pp. 1–5.

Curzi, D., Raimondi, V. and Olper, A. 'Quality upgrading, competition and trade policy: Evidence from the agri-food sector', *European Review of Agricultural Economics*, Vol. 42, (2015) pp. 239–267.

Curzi, D., Schuster, M., Maertens, M. and Olper, A. 'Standards, trade margins and product quality: Firm-level evidence from Peru', *Food Policy*, Vol. 91, (2020) pp. 101834.

De Sousa, J. 'The currency union effect on trade is decreasing over time', *Economics Letters*, Vol. 117, (2012) pp. 917–920.

Disdier, A.-C., Fontagné, L. and Mimouni, M. 'The impact of regulations on agricultural trade: evidence from the SPS and TBT agreements', *American Journal of Agricultural Economics*, Vol. 90, (2008) pp. 336–350.

Disdier, A. C., Fontagné, L. and Mimouni, M. 'The impact of regulations on agricultural trade: Evidence from the SPS and TBT agreements', *American Journal of Agricultural Economics*, Vol. 90, (2008) pp. 713–726.

Eaton, J. and Kortum, S. 'Technology, geography, and trade', *Econometrica*, Vol. 70, (2002) pp. 1741–1779.

Egger, P. H. and Nigai, S. 'Structural gravity with dummies only: Constrained ANOVA-type estimation of gravity models', *Journal of International Economics*, Vol. 97, (2015) pp. 86–99.

Ehrich, M., Brümmer, B. and Martínez-Zarzoso, I. Exporter size matters — heterogeneous effects of food standards on agricultural trade. Unpublished thesis chapter. Available at: https://ediss.uni-goettingen.de/handle/11858/00-1735-00000023-3DFB-3 (last accessed 30 July 2019). 2017.

Ehrich, M. and Mangelsdorf, A. 'The role of private standards for manufactured food exports from developing countries', *World Development*, Vol. 101, (2018) pp. 16–27.

Feenstra, R. C. 'A homothetic utility function for monopolistic competition models, without constant price elasticity', *Economics Letters*, Vol. 78, (2003) pp. 79–86.

Feenstra, R. C. *Advanced International Trade: Theory and Evidence* (Princeton: Princeton University Press, 2004).

Fernandes, A. M., Ferro, E. and Wilson, J. S. 'Product standards and firms' export decisions'. *The World Bank Economic Review*, Vol. 33, (2019) pp. 353–374.

Ferro, E., Otsuki, T. and Wilson, J. S. 'The effect of product standards on agricultural exports', *Food Policy*, Vol. 50, (2015) pp. 68–79.

Fiankor, D.-D. D., Curzi, D. and Olper, A. 'Trade, price and quality upgrading effects of agri-food standards'. *European Review of Agricultural Economics*, (forthcoming).

Fiankor, D.-D. D., Flachsbarth, I., Masood, A. and Brümmer, B. 'Does GlobalGAP certification promote agrifood exports?', *European Review of Agricultural Economics*, Vol. 47, (2020) pp. 247–272.

Fontagné, L. and Orefice, G. 'Let's try next door: Technical Barriers to Trade and multidestination firms', *European Economic Review*, Vol. 101, (2018) pp. 643–663.

Fontagné, L., Orefice, G., Piermartini, R. and Rocha, N. 'Product standards and margins of trade: firm-level evidence', *Journal of International Economics*, Vol. 97, (2015) pp. 29–44.

Gaulier, G. and Zignago, S. BACI: International Trade Database at the Product-Level. the 1994-2007 Version. CEPII Working Paper 2010-23, October, (2010).

Ghodsi, M., Grübler, J., Reiter, O. and Stehrer, R. The evolution of non-tariff measures and their diverse effects on trade. wiiw Research Report No 419, Vienna Institute for International Economic Studies, May (2017).

Grant, J. and Arita, S. Sanitary and phyto-sanitary measures: Assessment, measurement, and impact. IATRC Commissioned Paper No. CP-21, 2017. Available at: https://ageconsearch.umn.edu/record/259417 (last accessed 21 September 2020).

Grant, J. H., Peterson, E. and Ramniceanu, R. 'Assessing the impact of SPS regulations on US fresh fruit and vegetable exports', *Journal of Agricultural and Resource Economics*, Vol. 40, (2015) pp. 144–163.

Helpman, E., Melitz, M. and Rubinstein, Y. 'Estimating trade flows: Trading partners and trading volumes', *Quarterly Journal of Economics*, Vol. 123, (2008) pp. 441–487.

Hummels, D. and Klenow, P. J. 'The variety and quality of a nation's exports', *American Economic Review*, Vol. 95, (2005) pp. 704–723.

Kinzius, L., Sandkamp, A. and Yalcin, E. 'Trade protection and the role of non-tariff barriers', *Review of World Economics*, Vol. 155, (2019) pp. 603–643.

Melitz, M. J. 'The impact of trade on intra-industry reallocations and aggregate industry productivity', *Econometrica*, Vol. 71, (2003) pp. 1695–1725.

Meng, D., Maeda, K. and Wang, X. 'China's agricultural trade cost elasticity: Estimates from using translog gravity model', *Journal of the Faculty of Agriculture, Kyushu University*, Vol. 63, (2018) pp. 177–184.

Niu, Z., Milner, C., Gunessee, S. and Liu, C. 'Are nontariff measures and tariffs substitutes? Some panel data evidence', *Review of International Economics*, Vol. 28, (2020) pp. 408–428.

Novy, D. 'International trade without CES: Estimating translog gravity', *Journal of International Economics*, Vol. 89, (2013) pp. 271–282.

Olper, A. 'The political economy of trade-related regulatory policy: Environment and global value chain', *Bio-based and Applied Economics*, Vol. 5, (2016) pp. 287–324.

Orefice, G. 'Non-tariff measures, specific trade concerns and tariff reduction', *The World Economy*, Vol. 40, (2017) pp. 1807–1835.

Santeramo, F. G. and Lamonaca, E. 'The effects of non-tariff measures on agri-food trade: A review and meta-analysis of empirical evidence', *Journal of Agricultural Economics*, Vol. 70, (2019) pp. 595–617.

Santos Silva, J. M. C. and Tenreyro, S. 'The log of gravity', *The Review of Economics and Statistics*, Vol. 88, (2006) pp. 641–658.

Swinnen, J. 'Economics and politics of food standards, trade, and development', *Agricultural Economics*, Vol. 47, (2016) pp. 7–19.

WHO. Joint FAO/WHO Expert Committee on Nutrition: report on the first session, Geneva, 24–28 October 1949. WHO Technical Report Series (1950), pp. 1–24.

WTO. *World Trade Report 2012: Trade and Public Policies: a Closer Look at Non-tariff Measures in the 21st Century* (World Trade Organization, 2012).

Xiong, B. and Beghin, J. 'Disentangling demand-enhancing and trade-cost effects of maximum residue regulations', *Economic Inquiry*, Vol. 52, (2014) pp. 1190–1203.