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Abstract

The agri-food trade has expanded considerably over decades, with a remarkable increase in the market share of developing countries. The upward trend in trade flows has been parallel to the proliferation of non-tariff measures, particularly of sanitary and phytosanitary (SPS) measures in the agri-food sector. SPS measures may have a dual impact on trade, i.e. standards as catalysts *versus* standards as barriers, and the net effect is likely to depend on the level of economic development of countries involved. We investigate whether the trade effects of SPS measures is correlated with the economic development of trading partners. In particular, we disentangle the trade effects of SPS measures implemented by developed and developing countries and look at differential impacts due to a mismatch in the economic development of trading partners. Using a structural gravity approach on bilateral trade and regulation data, we conclude that SPS measures are catalysts for developing importers, whereas no evidence is found for developed importers. We also find a pro-trade effect of SPS measures when traders have different levels of economic development. Our findings have important policy implications: sharing SPS measures is strategic for economies characterised by different abilities to alter trade terms.

Keywords: Agri-food trade; Economic development; Gravity model; Non-tariff measure; Trade pattern.

JEL CODES: F13, O24, O57, Q17, Q18.

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1. Introduction

International trade in the agri-food sector has considerably expanded, particularly for developing countries (Martin 2018). The new trade dynamics are likely to be influenced by the progressive reduction of tariffs and proliferation of non-tariff measures (NTMs) which occurred starting from the negotiations of the World Trade Organisation (WTO) (Bacchetta and Beverelli, 2012). Since the mid-1990s the number of NTMs in force has tripled and sanitary and phytosanitary (SPS) measures have grown exponentially in terms of products coverage and number of implementing countries[1] (Curzi et al. 2020). The growth and spread of NTMs has stimulated both academic and policy debates on the effects on international trade and development.

Whether food safety regulations serve the public or protectionist's interest and whether they have a dual impact on trade ('standards as catalysts' *versus* 'standards as barriers') are still debated questions (Herghelegiu, 2018; Peci and Sanjuán 2020). SPS measures may have either: "*a substantial positive impact [… or] a significant negative impact*" (Schlueter et al. 2009, p. 1489), and the empirical evidence makes generalisations not easy. Indeed, the literature is not conclusive on the net effects of SPS measures, with the 'standards as barrier' and the 'standards as catalyst' views being supported by contrasting empirical evidence. Some studies depict SPS as trade-impeding measures (e.g. Henson and Loader, 2001; Olper and Raimondi 2008; Yue and Beghin

[1] According to the UNCTAD data, between 1995 and 2015 SPS measures adopted by developed countries have doubled (from 32.6 to 60.5 thousand), but the growth in the number of SPS measures implemented by developing countries has been impressive (from 0.8 to 65.8 thousand). Since 1995 until 2015, also the number of countries implementing SPS measures has more than doubled: in addition to the United States, China, New Zealand, Brazil, and Argentina, since 2015 several emerging economies have implemented SPS measures (i.e. Bolivia, Russian Federation, Indonesia, Peru). While the share of SPS measures imposed by the United States has decreased from 96% (1995) to 35% (2015), it remains the largest share. During the same period, the number of SPS measures implemented has approximately doubled in China (from 684 to 1,247) and in the United States (from 32,096 to 43,982), and it has grown exponentially in Argentina (from 4 to 915), Brazil (from 112 to 10,207), and New Zealand (from 551 to 12,947).

2009), while others conclude on both positive and negative effects on trade (e.g. Vollrath et al. 2009; Schlueter et al. 2009; Dal Bianco et al. 2016). Several previous studies deepen on the effects of regulations on developing countries and conclude that regulations may have a dual effect (e.g. Jouanjean et al., 2015). While higher costs of compliance may keep developing countries out of international market and affect pattern of specialisation, foreign standards may foster less developed economies to improve production processes and obtain productivity gains (e.g. Maertens and Swinnen, 2009). We get the point raised by Swinnen (2016, p. 11), who concluded that "*it would be interesting to analyse how strong the relationship between food standards and economic development is*", and disentangle the effects of SPS measures implemented by developed and developing countries. The effects of regulations on trade are likely to depend on the relative economic relevance of countries implementing measures: while more developed economies are able to influence the trade terms, less developed economies are unable to alter trends in international trade (Swinnen, 2016). However, a few questions remain underinvestigated. We try to answer to a couple of specific questions: to what extent do the trade effects of the SPS measures differ according to the economic development of implementing countries? Also, is there a role played by the mismatch in the economic development of trading partners?

Our study focuses on the effects of the SPS measures considering the level of economic development of the trading partners. The dataset includes bilateral trade flows and SPS measures for the most regulated agri-food products among the major developed and developing trading countries. We cover a long period, from 1996 to 2017. Using a structural gravity approach and addressing empirical issues of trade models (i.e. potential endogeneity of trade policies, heteroskedasticity in the error term, zero values in the dependent variable), we are able to contribute to the debate and provide policy implications for the economic growth of developing countries. More precisely, our contribution is two-fold: differently from the (numerous) empirical studies that provide case-specific analyses (e.g. Melo et al., 2014; Medin, 2019), we provide a more general assessment on the trade effects of SPS measures, a focus that is a less common in the existing literature and builds on the contributions by Disdier et al. (2008) and Crivelli and Gröschl (2016). We complement the analysis by Crivelli and Gröschl (2016) by focusing on the differences implied by heterogeneous levels of economic development of the implementing country. We also extend the contribution of Disdier et al. (2008) in two ways: first, we use a finer disaggregation level of data, and rely on a long panel data so as to capture the evolution of SPS measures and to conclude on the changes in imports overtime; second, and more importantly, we analyse whether the effects of SPS measures implemented by developed or developing importers diverge. A further contribution of our study is to disentangle the effect of SPS measures shared between trading partners across different trade patterns (e.g. between countries with similar or different level of economic development).

This analysis has important implications for the debate on the political economy of trade regulations: countries intensification of food safety regulations may be pushed by the need of meeting public interests, although such a policy may be suboptimal at the global level (Josling et al., 2010; Martin 2018). The feasibility of globally superior policy options depends on the ability of governments to identify trade-offs and politically feasible packages that allow them to efficiently achieve a global equilibrium (Beghin et al., 2006). Thus, a better understanding of the global gains would help the coordination of international policies (Bagwell and Staiger 2011), and analyses such as the present one may provide valuable insights to the policymakers involved in debates on international cooperation.

2. The 'SPS measures and development' debate in literature

SPS measures, often subject to negotiations, tend to have significant economic impacts on the agri-food trade[2]. In the domestic market, a non-discriminatory SPS measure is likely to produce an expansion of the demand, due to a reduction of market failures (e.g. asymmetric information,

[2] As NTMs, SPS measures are policy instruments that may have an economic effect on international trade in goods, changing traded quantities, or prices or both (UNCTAD 2012).

externalities), and a contraction of the supply, due to increased costs of compliance to implement a more stringent regulation. As a consequence, SPS measures may boost trade by reducing transaction costs and market failures but may also hinder trade if their protectionist scopes prevail (Crivelli and Gröschl 2016).

A recent meta-analysis on the trade effects of trade measures by Santeramo and Lamonaca (2019) suggests that the level of development of countries involved in trade relationships may generate specific geo-economic patterns of regulations. SPS measures tend to be detrimental for countries with similar levels of economic development. For instance, the removal of SPS measures would increase Australian imports of apples from New Zealand (Yue and Beghin 2009) and the trade of meat between the United States (US) and the European Union (EU) (Beckman and Arita 2016). Similarly, Arita et al. (2017) find that EU-US trade of meat, fruit and vegetables, cereals and oilseeds is significantly lowered by SPS measures. In addition, Webb et al. (2019) demonstrate that the number of countries exporting agri-food products to the US reduces by 35% if exporters have to face SPS compliance measures. SPS measures are also found to be trade-impeding for exports of fruits between developing countries (Melo et al. 2014). Mixed effects are found for trade involving countries with different levels of economic development. Trade from developing to developed countries tends to be hampered by SPS measures, while trade is favoured once the required standards of developed countries are met by developing countries (Chevassus-Lozza et al. 2008). For instance, Jongwanich (2009) and Peterson et al. (2013) conclude that SPS measures implemented by developed countries tend to hinder imports of fresh and processed food from developing countries. Similarly, Chen et al. (2008) found that the effect of food safety standards, implemented by developed countries on China's export of vegetables and aquatic products, is much larger than that of the import tariff. The variability in trade effects may reflect divergences among countries' food safety regulations and standards, differences in consumers' preferences across countries, ability (or limited capacity) to produce safe food, and willingness to pay for risk-reducing technology (Jongwanich 2009) that, in general, differ between developing and developed countries

(Maertens and Swinnen, 2009). Given the vast heterogeneity of findings, studies that provide overall assessments and disentangle differences between developed and developing countries should be encouraged.

The implications of regulations for countries' development are particularly relevant in the agri-food sector (Maertens and Swinnen 2015). SPS measures are pervasive in the agri-food sector[3], in which developing countries tend to have a comparative advantage. Agri-food exports, a potential source of growth for developing countries (Winters, 2003, 2004), can be stimulated by regulations pursuing quality upgrade and reduction of market failures (Jaffee and Henson 2005). However, developing countries tend to be standards takers due to an implicit divide between food safety standards in countries with different levels of economic development (Curzi et al. 2020). Although food safety regulations in developed countries have stiffened over decades, SPS measures are increasingly being adopted also by developing countries, which tend to affirm their role in the WTO consultations (Barrett et al., 2020). Bown and Crowley (2007) argue that the proliferation of trade measures may induce countries to respond to external pressures by implementing other trade measures.

3. Estimating the effects of SPS measures

3.1 Structural Gravity model

The gravity model is the workhorse in international economics for investigating the effects of various determinants of bilateral trade (e.g. Weidner and Zylkin, 2021). It is frequently used for counterfactual analysis, such as quantifying the effects of trade policies (e.g. Costinot and

[3] SPS measures have been frequently implemented to regulate trade of perishable agri-food products and those exposed and vulnerable to diseases and pests (Dal Bianco et al. 2016). In fact, according to the definition proposed in the WTO SPS Agreement, SPS measure are applied to protect human, animal or plant life or health from risks arising from the entry, establishment or spread of pests, diseases, disease-carrying organisms or disease-causing organisms in foods, beverages or feedstuffs. The sensitive nature of covered issues explains the pervasiveness of SPS measures in the agri-food sector (Sumner and Tangermann, 2002).

Rodríguez-Clare, 2014; Yotov et al., 2016). Analogously to the Newtonian theory of gravitation, the gravity model predicts that international trade between two countries (i.e. gravitational force between two objects in the Newton's Law) is directly proportional to the product of their sizes (i.e. objects' masses in the Newton's Law) and inversely proportional to the trade costs (i.e. the square of distance in the Newton's Law) between them (e.g. Tinbergen, 1962). In the trade literature, the term 'gravity model' refers to different models explaining the determinants of bilateral trade. Head and Mayer (2014) classify them in three categories: naïve, general, and structural gravity models.

The naïve gravity model provides that bilateral trade is proportional to the product of the importer and exporter sizes, while imposes that the bilateral trade costs are constant and inversely related to the bilateral trade flows. This category of gravity models ignores the multilateral resistances predicted by Anderson and van Wincoop (2003) and, as argued by Baldwin and Taglioni (2007), the empirical analyses based on these models are characterised by the 'gold medal mistake' of gravity equations that consists in the correlation between omitted terms and the trade-cost term. The 'general' gravity model relaxes the assumption of constant bilateral trade costs and assumes that bilateral trade is proportional to the size of the exporter (importer) as a supplier to (consumer from) all destinations (sources): the countries' sizes include the multilateral resistance terms. However, the drawback of these models is that the trade effect of bilateral trade costs cannot be isolated from the multilateral terms embedded in countries' sizes. In the structural gravity model, countries' sizes (i.e. the value of exporter's production and the value of importer's expenditure on all source countries) are separated from the countries' multilateral resistances. This additional condition allows for a clearer identification of the trade effect of bilateral trade costs, thus overcoming the limits of the general gravity models (e.g. Head and Mayer, 2014, Fally, 2015; Weidner and Zylkin, 2021).

The structural gravity model has solid theoretical foundations derived from both the demand-side (e.g. the Armington-CES model of Anderson, 1979) and the supply side (e.g. the Ricardian structure with intermediate goods of Eaton and Kortum, 2002). It is widely supported in recent empirical applications (e.g., Tobin and Busch, 2019; Hayakawa et al., 2020; Kox and Rojas-Romagosa, 2020).

3.1.1 Theoretical framework

We consider a world economy comprising multiple countries engaged in bilateral trade and indexed by *i* (importing country) and *j* (exporting country). Each country produces a variety of goods in the *k*-th sector, differentiated by *J* origins and internationally traded. Following Eaton and Kortum (2002), we assume perfect competition, homothetic consumer preferences across countries and sectors, and countries' specialisation in different sectors. Consistent with the theoretical gravity equation, bilateral trade flows, $X_{ijk,t}$, are explained as follows:

$$X_{ijk,t} = \frac{E_{ik,t}}{\Phi_{ik,t}} \frac{Y_{jk,t}}{\Omega_{jk,t}} \theta_{ijk,t} \quad (1)$$

The size term of equation (1), $E_{ik,t}Y_{jk,t}$, is time-specific (*t*) and considers the sectoral preferences in *i* and the specialisations of *j*. It includes the *i*-th total expenditure on *k* ($E_{ik,t}$) and the *j*-th value of production of *k* ($Y_{jk,t}$)[4]. The size term indicates that large importing economies tend to import more from all sources, large producing economies tend to export more to all destinations, and trading partners with a similar size tend to share larger trade flows. The trade cost term of equation (1), $\frac{t_{ijk,t}}{\Phi_{ik,t}\Omega_{jk,t}}$, is sector- and time-specific, and includes the structural terms ($\Phi_{ik,t}$ and $\Omega_{jk,t}$) and the bilateral trade costs ($t_{ijk,t}$). As defined in Anderson and van Wincoop (2003), $\Phi_{ik,t}$ and $\Omega_{jk,t}$ are multilateral resistances; they proxy the competitiveness of *i* and *j*, depend on relative price indexes, and are based on market clearing conditions. The term $\theta_{ijk,t}$ includes both time-invariant (e.g.

[4] The term $Y_{jk,t}$ equals the sum of all bilateral shipments from *j* at time *t* ($Y_{jk,t} = \sum_I X_{ijk,t} \ \forall \ i$).

distance, common language, contiguity) and time-varying (e.g. SPS measures, tariffs, the presence of regional trade agreements –RTAs– between *i* and *j*) determinants of transaction costs.

3.1.2 Empirical strategy

The empirical specification of the model in equation (1) can be expressed as a structural gravity in its exponential function[5]:

$$X_{ijk,t} = e^{\{\boldsymbol{\beta}_{ikt}+\boldsymbol{\beta}_{jkt}+\boldsymbol{\beta}_{ijk}+t_{ijk,t}\boldsymbol{\gamma}\}}\varepsilon_{ijk,t} \qquad (2)$$

The term $X_{ijk,t}$ is the nominal, sector-specific trade flow between *i* and *j* at time *t*. The term $\boldsymbol{\beta}_{ikt}$ is a vector of importer-product-time fixed effects which control for multilateral resistances in i (i.e. $\Phi_{ik,t}$ in 1) and countries' total expenditure (i.e. $E_{ik,t}$); the term $\boldsymbol{\beta}_{jkt}$ is a vector of exporter-product-time fixed effects which control for multilateral resistances in *j* (i.e. $\Omega_{jk,t}$) and countries' output shares (i.e. $Y_{jk,t}$). The use of $\boldsymbol{\beta}_{ikt}$ and $\boldsymbol{\beta}_{jkt}$ allows us to control for unobservable country-specific characteristics that vary over time for each sector[6] (Yotov et al., 2016). The terms $\boldsymbol{\beta}_{ijk}$ and $t_{ijk,t}$ capture the bilateral part of the trade cost term explaining bilateral trade in equation (1) (i.e. $\theta_{ijk,t}$). The term $\boldsymbol{\beta}_{ijk}$ is the vector of sector-specific country-pair fixed effects which account for the unobservable linkages between the endogenous trade policy covariates and the error term, solving for the problem of endogeneity of trade policy variables (Baier and Bergstrand, 2007). They absorb all bilateral time-invariant determinants of trade (e.g. distance, common language, contiguity) without precluding the estimation of the effects of time-varying bilateral trade policies (Egger and Nigai, 2015). The time varying bilateral trade costs term is defined as $t_{ijk,t} =$

[5] A comparison between the theoretical gravity model in equation (1) and the empirical specification in equation (2) is reported in the Appendix A.1 to clarify why certain variables are included in the model.

[6] Country-specific fixed effects also vary by sector to accommodate sectoral differences in importers and exporters.

$\{SPS_{ijk,t}, \tilde{\tau}_{ijk,t}, RTA_{ij,t}\}$. The term $SPS_{ijk,t}$ proxies time- and sector-specific SPS measures implemented by i; the term $\tilde{\tau}_{ijk,t}$ accounts for bilateral tariffs[7]; the dummy $RTA_{ij,t}$ controls for the presence of an RTA between i and j at time t. The term $\boldsymbol{\gamma}$ is the vector of parameters. We focus on the effects of the SPS measures on the imports of the implementing country but control other relevant trade policies such as tariffs and regional trade agreements. We use different proxies for $SPS_{ijk,t}$, synthesised in table 1, to distinguish the average effect of the SPS measures from the effect of implementing a different number of SPS.

A dummy variable ($SPS_{dummy_{ijk,t}}$) discriminates country-pairs sharing at least one SPS measure. This allows us to test if the presence of regulations affects imports. Commonly used in literature (e.g. Disdier et al., 2008; Crivelli and Gröschl, 2016), this index captures the average effect of having a regulation in place, and controls for the effects of SPS measures before and after their introduction (time dimension) and across countries (panel dimension)[8].

In order to account for the intensity of regulations, we use a count variable ($SPS_{count_{ijk,t}}$) equal to the sum of all country-pair SPS measures. This indicator, also used in Schlueter et al. (2009), allows us to assess the impacts of introducing an additional SPS measures[9]. In order to examine if the regulation intensity affect bilateral trade, we use dummy variables for each time-specific quartile of the distribution of SPS measures (excluding country-pairs without SPS measures in place): low ($SPS_{\text{low}_{ijk,t}}$), low-mid ($SPS_{\text{low-mid}_{ijk,t}}$), mid-high ($SPS_{\text{mid-high}_{ijk,t}}$) and high ($SPS_{\text{high}_{ijk,t}}$)[10]. For

[7] The term $\tilde{\tau}_{ijk,t}$ is defined as $\tilde{\tau}_{ijk,t} = \ln(1 + tariff_{ijk,t})$, where $tariff_{ijk,t}$ is the tariff that i imposes on imports from j at time t in the k-th sector.

[8] Let consider trade relationships between an importing country A and its trading partners B and C. Suppose that A implements a SPS measures on imports from B but not on imports from C. The panel dimension allows to disentangle the effects between A-B and A-C.

[9] This variable counts only the number of shared SPS measures between two trading partners and captures the effect of the additional match of SPS measures between the two countries.

[10] The baseline is the pool of country-pairs without SPS measures in place.

instance, if the number of SPS measures in a country-pair is above the 50th percentile and below the 75th percentile of the distribution, than $SPS_{\text{mid-high}_{ijk,t}}$ takes value 1, whereas the other dummies (i.e. $SPS_{\text{low}_{ijk,t}}$, $SPS_{\text{low-mid}_{ijk,t}}$, $SPS_{\text{high}_{ijk,t}}$) equal 0. These indicators are a relative measure of the intensity of regulations across countries.

Table 1. Proxies for SPS measures and investigated effects.

Proxies for $SPS_{ijk,t}$	
$SPS_{dummy_{ijk,t}} = \begin{cases} = 1\ if\ i\ and\ j\ share\ SPS\ measures \\ = 0 \text{ otherwise} \end{cases}$	Presence of SPS measures
$\widetilde{SPS}_{ijk,t} = \ln\left(1 + SPS_{count_{ijk,t}}\right)$	Number of shared SPS measures in place
$SPS_{\text{low}_{ijk,t}} = \begin{cases} = 1\ if\ SPS_{dummy_{ijk,t}} = 1\ \wedge\ SPS_{count_{ijk,t}} \leq 25^{\text{th}}\ percentile_t \\ = 0 \text{ otherwise} \end{cases}$	Relative low intensity of regulation
$SPS_{\text{low-mid}_{ijk,t}} = \begin{cases} = 1\ if\ SPS_{dummy_{ijk,t}} = 1\ \wedge\ 25^{\text{th}}\ percentile_t < SPS_{count_{ijk,t}} \leq 50^{\text{th}}\ percentile_t \\ = 0 \text{ otherwise} \end{cases}$	Relative low-mid intensity of regulation
$SPS_{\text{mid-high}_{ijk,t}} = \begin{cases} = 1\ if\ SPS_{dummy_{ijk,t}} = 1\ \wedge\ 50^{\text{th}}\ percentile_t < SPS_{count_{ijk,t}} \leq 75^{\text{th}}\ percentile_t \\ = 0 \text{ otherwise} \end{cases}$	Relative mid-high intensity of regulation
$SPS_{\text{high}_{ijk,t}} = \begin{cases} = 1\ if\ SPS_{dummy_{ijk,t}} = 1\ \wedge\ SPS_{count_{ijk,t}} > 75^{\text{th}}\ percentile_t \\ = 0 \text{ otherwise} \end{cases}$	Relative high intensity of regulation

3.2 Sectoral and economic development heterogeneities

SPS measures are negotiated and applied at sectoral level, thus their trade effects are likely to be heterogeneous across sectors. To capture sectoral heterogeneity, we account for the level of aggregation that is the target of the specific trade policy. Accordingly, our model (equation 1) is a sectoral-level gravity system where all products of the *k*-th sector are differentiated by origins and consumer preferences are weakly separable: trade expenditures are separable from domestic expenditures (Anderson and van Wincoop, 2004). The sectoral-level gravity model in equation (1) also posits that the trade costs are sector specific. The model in equation (2) is estimated on sectoral data and the SPS measures vary across sectors (Yotov et al., 2016).

The trade effects of SPS measures are also likely to differ between developed and developing countries for several reasons: consumer preferences for quality and safety standards differ across countries (e.g. Jongwanich, 2009), the quality of institutions for enforcement and control of standards is higher in developed economies (e.g. Swinnen, 2016), due to low wages and lower land rents less developed countries have cost advantages in production of raw materials (e.g. Curzi et al., 2020), different levels of economic development imply a different organisation and structure of the media –the main source of information on food risks for many people– (e.g. McCluskey and Swinnen, 2004), larger rural/urban population ratio in developing countries has less asymmetric information (e.g. McCluskey et al., 2016). Indeed, it is likely to observe differences in trade effects for developed and developing importers. We investigate these dynamics, and also examine trade relationships between countries with a similar level of economic development (horizontal trade, i.e. developed-developed and developing-developing countries), or with a gap in the economic development (transversal trade, i.e. developed-developing, developing-developed).

3.3 Endogeneity, heteroskedasticity and trade data issues

Empirically, three econometric issues may affect gravity-type estimations: endogeneity of trade policies, heteroskedasticity in the error term, and problems in the trade data such as zero values in the dependent variable and the use of values *versus* quantities.

As for the endogeneity, the level of trade may justify the adoption of trade measures, and the measures tend to influence trade flows: countries may tend to liberalise trade with significant trade partners (Trefler, 1993). Endogenous trade policies may be correlated with unobservable trade costs implying unreliable estimates of the effects of trade policies (Yotov et al., 2016). To circumvent the endogeneity problems, Baier and Bergstrand (2007) suggest using country-pair fixed effects. First, they allow to account for unobservable relationships between covariates proxying trade policies (i.e. SPS measures) and the error term. Second, the country-pair fixed effects are a good measure of bilateral trade costs and do not prevent the estimation of the effects of time-varying bilateral trade policies (Egger and Nigai, 2015). In order to test if the use of country-pair fixed effects properly accounts for potential reverse causality between imports and SPS measures, we add a forwarded variable, $SPS_{ijk,t+3}$, as suggested in Baier and Bergstrand (2007). The argument is that although import penetration may be endogenous with the concurrent implementation of new (or additional) SPS measures, it will not be endogenous with future decisions on the implementation of SPS measures. If SPS measures are exogenous to trade flows, the parameter associated with the variable $SPS_{ijk,t+3}$ should be statistically not different from zero[11].

However, as noted in Cheng and Wall (2005), fixed-effects estimation applied to data pooled over consecutive years is sometimes criticised due to the fact that the phenomena captured in the dependent (i.e. bilateral trade) and independent variables (i.e. policy measures, SPS measures in particular) may not fully adjust in a single year. In fact, it may be expected that the adjustment of trade flows in response to trade policy changes is not instantaneous. To address this concern, in a sensitivity analysis, we use panel data with intervals (i.e. a 3-years gap) instead of data pooled over

[11] The results, reported in table A.1 in the Appendix A.2, confirm the absence of reverse causality between imports and SPS measures.

consecutive years[12]: this approach is frequently use in empirical trade analyses (e.g. Trefler, 2004; Olivero and Yotov, 2012; Anderson and Yotov, 2016).

A further challenge in the estimation of gravity-type models is the existence of heteroskedasticity which may imply inefficient and inconsistent estimates (Silva and Tenreyro, 2006). Heteroskedasticity is a common feature of trade data and occurs when trade flows tend to be zero, especially for small and remote countries, causing the conditional variance of the trade flow variable to lean towards zero[13] (Schlueter et al., 2009). Silva and Tenreyro (2006) suggest using the Poisson Pseudo-Maximum-Likelihood (PPML) estimator which is robust to heteroskedastic errors: it allows us to estimate the model in equation (2) in levels with a multiplicative error term[14] and assuming proportionality between the conditional variance and conditional mean.

A third challenge is related to the management of trade data. One of the issues is to deal with zero trade flows that lead to inconsistent estimates (Head and Mayer, 2014). Zero values in trade data may be structural or statistical zeros. Structural zeros are associated with trade expected to be low, for instance between small and distant countries for which trade is frictioned by large transaction costs. Statistical zeros are due to rounding errors or missing observations, wrongly recorded as zeros. Both sources of statistical zeros are more likely to occur for small and distant countries. The presence of zeros[15] may be dealt with several ways[16]. In our case, the estimation of the model in

[12] The results are reported in table A.2 of the Appendix A.2.

[13] While the conditional variance from low trade flows tends to zero due to the inability to offset between positive and negative dispersions from the conditional mean, the conditional variance from large trade flows tends to be larger as the dispersion from the conditional mean may be both positive and negative (Schlueter et al., 2009).

[14] Accordingly, after log-transformation, the model in equation (2) is estimated in a linear form as follows: $X_{ijk,t} = \alpha + \boldsymbol{\beta}_{ikt} + \boldsymbol{\beta}_{jkt} + \boldsymbol{\beta}_{ijk} + \ln(t_{ijk,t})\boldsymbol{\gamma} + \varepsilon_{ijk,t}$, where the dependent variable is in level.

[15] A detailed analysis of zero trade flows in our sample is reported in the Appendix A.3.

[16] Helpman et al (2008) develop a two-part estimation procedure to handle the existence of zero trade between country-pairs: a first equation discriminating between the existence or not of trade between country-pairs, and a standard gravity equation to explain non-zero trade flows. The drawback of this approach is the assumptions of normality and homoskedasticity, the latter being in contrast with heteroskedasticity characterising trade data.

equation (2) in multiplicative rather than logarithmic form, through the PPML estimator, allows us to handle zero observations for the left-hand-side variable[17] (Silva and Tenreyro, 2006).

A further issue is about measuring trade flows in quantity *versus* value and, in the latter case, in current prices *versus* constant prices. Datasets of trade data at the national level, covering trade flows among several trading partners, frequently aggregate separately quantities and values. But, in some cases, quantity data are available for a limited number of products. As a consequence, empirical analyses tend to rely on trade flows measured in value. The reliability of trade flows measured in value is highly dependent on the techniques used to harmonise and make comparable national datasets. In particular, if trade flows are measured in current prices and the empirical analysis covers a long time period, potential issues related to the inflation rate and the exchange rate across different currencies may lead to misinterpreted results. Our empirical analysis relies on trade data expressed in current US dollar values[18]. To control for the potential role of the inflation and the exchange rates on the trade values, we estimate the model in equation (2) introducing the average Consumer Price Index for the US as a proxy of the inflation rate and the domestic currency per USD (as a proxy of the exchange rate [19].

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[17] The large share of zeros in the trade variable (see Appendix A.3) suggests the use of the PPML to estimate the model in equation (2).

[18] As explained in section 4.2, trade data (in current USD) are from the UN Comtrade database. As explained in the methodological note of the United Nations (UN) database (more details at unstats.un.org), the national values when sent by reporters to the UN Statistics Divisions are sometimes in dollars but mostly in national currency. After validating the data, the UN Statistics Divisions applies the exchange rate and upload them to the Comtrade database. The UN Statistics Divisions uses the US dollar series of the International Monetary Fund, which is based on the monthly average of the official daily exchange rates. The average annual exchange rates are obtained separately for imports and for exports by taking into account the monthly value of imports (or exports) and the monthly average of the official daily exchange rates.

[19] The average Consumer Price Index for the US is collected from the International Monetary Fund World Economic Outlook Database; the domestic currency per USD (period average) is collected from the International Finance Statistics (IFS). Recall that the inflation and the exchange rates are country-time specific. To allow for the estimation of the effect of the inflation and the exchange rates, we use a different combination of fixed effects to avoid collinearity problems. In the empirical specification we drop the time

3.4 Trade volume and tariff equivalent effects of SPS measures

Following Yotov et al. (2016), we translate our estimates into trade volume effects and tariff equivalent effects. The trade volume effects (TVE_{dummy}) for the dummy capturing the presence of SPS measures ($SPS_{dummy_{ijk,t}}$) can be calculated in percentage terms as follows: $TVE_{dummy} = \left(e^{\hat{\gamma}_{SPS}} - 1\right) * 100$, where $\hat{\gamma}_{SPS}$ is the coefficient of interest. Similar procedure applies to the specification of quartiles of the distribution of SPS measures ($SPS_{\text{low}_{ijk,t}}$, $SPS_{\text{low-mid}_{ijk,t}}$, $SPS_{\text{mid-high}_{ijk,t}}$, $SPS_{\text{high}_{ijk,t}}$). As for continuous variables (i.e. the number of SPS measures in place, $\widetilde{SPS}_{ijk,t}$), the estimated coefficient is the elasticity of the value of trade flows with respect to the number of SPS measures. The trade volume is computed as follows: $TVE_{count} = \hat{\gamma}_{SPS} * 100$.

We also compute tariff equivalents or *ad-valorem* tariff (AVE) that would generate effects comparable with those of the SPS measures: $AVE = \left(e^{\hat{\gamma}_{SPS}/-\hat{\gamma}_{tariff}} - 1\right) * 100$, where $\hat{\gamma}_{SPS}$ and $\hat{\gamma}_{tariff}$ are the coefficients respectively associated with proxies of SPS measures and tariffs, as specified in equation (2).

4. Data

4.1 Sample description

Our empirical analysis covers a long period, from 1996 to 2017. We select the year 1996 as starting date due to the massive adoption of non-tariff measures, and in particular SPS measures, to regulate trade of agri-food products after the Uruguay Round. In order to investigate the trade effects of the SPS measures across trading partners with different level of economic development, we analyse a sample of major developed and developing trading countries. The developed economies are

dimension and use the following set of fixed effects: i.e. importer-product, exporter-product, country-pair-product fixed effects. The results are reported in table A.3 of the Appendix A.4. The overall effect of SPS measures on trade flows does not change.

Australia, Canada, France, Germany, Italy, New Zealand, Spain, the United Kingdom, the United States; the developing economies are Argentina, Brazil, China, Egypt, Indonesia, India, Libya, Morocco, Peru, Russian Federation[20], South Africa. The classification of each country in the sample of developed or developing economies is based on the well-established country classification of the United Nations (2017). The selected countries account for more than two-third of the global gross domestic product in 2015, according to the CEPII data. Within the group of developing countries we can distinguish developing countries with upper middle income (i.e. Argentina, Brazil, China, Peru, Russian Federation, South Africa) from developing countries with lower middle income (i.e. Bolivia, Congo, India, Indonesia, Egypt, Libya, Morocco, Tunisia), according to their income levels in 2015. Table 2 lists countries and presents their trade and policy characteristics in strategic sectors, i.e. meat, fish, vegetables, fruit, preparation of meat and fish.

[20] Russian Federation is listed as economy in transition. Here, for argument's sake, we consider it as developing country.

Table 2. Trade and policy profile of countries at the sector level.

Country (ISO3)	Level of development	Class of income	Product category (HS2-digit)	Avg. import value (mln USD, 2015-17)	Trade balance (mln USD)		Bilateral SPS in force	Avg. bilateral SPS per trading partner	Multilateral SPS in force
Australia	Developed	High	Meat	494	-8,509	Net exporter	0	0	2,090
(AUS)			Fish	799	-210	Net exporter	0	0	5,803
			Vegetable	259	-1,564	Net exporter	0	0	1,840
			Fruit	833	-529	Net exporter	0	0	1,919
			Preparation of meat and fish	734	600	Net importer	0	0	1,278
Canada	Developed	High	Meat	2,081	-2,676	Net exporter	15,646	10	1,060
(CAN)			Fish	1,994	-2,351	Net exporter	15,633	10	3,219
			Vegetable	3,041	-1,503	Net exporter	0	0	803
			Fruit	4,546	3,978	Net importer	1	1	705
			Preparation of meat and fish	1,459	544	Net importer	1,624	8	643
Germany	Developed	High	Meat	7,122	-1,388	Net exporter	0	0	1,293
(DEU)			Fish	4,398	2,688	Net importer	0	0	3,581
			Vegetable	6,555	5,381	Net importer	0	0	1,387
			Fruit	10,500	8,398	Net importer	0	0	1,414
			Preparation of meat and fish	2,893	-279	Net exporter	0	0	711
Spain	Developed	High	Meat	1,462	-4,323	Net exporter	0	0	1,293
(ESP)			Fish	5,976	2,985	Net importer	0	0	3,581
			Vegetable	1,269	-5,171	Net exporter	0	0	1,387
			Fruit	2,961	-6,187	Net exporter	0	0	1,414
			Preparation of meat and fish	1,469	-176	Net exporter	0	0	711
France	Developed	High	Meat	4,688	1,286	Net importer	0	0	1,293
(FRA)			Fish	4,851	3,525	Net importer	0	0	3,581
			Vegetable	3,228	1,000	Net importer	0	0	1,387
			Fruit	5,376	3,474	Net importer	0	0	1,414
			Preparation of meat and fish	2,112	1,063	Net importer	0	0	711
United Kingdom	Developed	High	Meat	5,614	3,652	Net importer	0	0	1,293
(GBR)			Fish	2,660	665	Net importer	0	0	3,581
			Vegetable	4,208	3,709	Net importer	0	0	1,387
			Fruit	6,265	5,957	Net importer	0	0	1,414
			Preparation of meat and fish	4,546	4,033	Net importer	0	0	711
Italy	Developed	High	Meat	4,915	2,600	Net importer	0	0	1,293
(ITA)			Fish	4,600	4,157	Net importer	0	0	3,581
			Vegetable	1,737	66	Net importer	0	0	1,387
			Fruit	3,493	-475	Net exporter	0	0	1,414
			Preparation of meat and fish	1,746	617	Net importer	0	0	711
New Zealand	Developed	High	Meat	178	-4,355	Net exporter	19,052	11	1,096
(NZL)			Fish	77	-951	Net exporter	47,971	11	3,613
			Vegetable	73	-227	Net exporter	8,003	13	1,101
			Fruit	316	-1,485	Net exporter	10,560	11	1,090
			Preparation of meat and fish	107	-161	Net exporter	22,335	11	707

United States (USA)	Developed	High	Meat	8,491	-6,609	Net exporter	125,246	21	2,746
			Fish	16,500	11,741	Net importer	224	6	6,482
			Vegetable	9,960	6,100	Net importer	73,590	35	2,160
			Fruit	16,700	3,600	Net importer	91,592	21	2,126
			Preparation of meat and fish	5,181	2,927	Net importer	44,352	24	2,174
Argentina (ARG)	Developing	Upper middle	Meat	84	-1,471	Net exporter	144	6	903
			Fish	69	-1,618	Net exporter	310	6	1,942
			Vegetable	29	-612	Net exporter	219	7	1,008
			Fruit	340	-620	Net exporter	165	6	1,018
			Preparation of meat and fish	123	31	Net importer	253	6	568
Brazil (BRA)	Developing	Upper middle	Meat	323	-12,877	Net exporter	24	4	1,098
			Fish	1,173	950	Net importer	0	0	3,401
			Vegetable	645	561	Net importer	19,356	10	1,489
			Fruit	687	-147	Net exporter	460	7	1,227
			Preparation of meat and fish	70	-1,206	Net exporter	0	0	547
China (CHN)	Developing	Upper middle	Meat	8,850	7,891	Net importer	2,236	9	741
			Fish	6,777	-6,423	Net exporter	1,696	8	1,227
			Vegetable	2,166	-8,034	Net exporter	116	5	741
			Fruit	6,092	764	Net importer	131	5	912
			Preparation of meat and fish	511	-8,063	Net exporter	103	5	293
Peru (PER)	Developing	Upper middle	Meat	130	115	Net importer	2,548	9	1,286
			Fish	169	-532	Net exporter	0	0	988
			Vegetable	90	-558	Net exporter	237	6	909
			Fruit	111	-1,974	Net exporter	1,369	8	893
			Preparation of meat and fish	99	-145	Net exporter	150	6	473
Russia (RUS)	Developing	Upper middle	Meat	2,690	2,470	Net importer	15,966	10	1,940
			Fish	1,456	-1,539	Net exporter	44,759	11	4,344
			Vegetable	1,698	1,239	Net importer	156	6	1,254
			Fruit	4,159	4,070	Net importer	549	7	1,319
			Preparation of meat and fish	410	166	Net importer	9,732	10	961
South Africa (ZAF)	Developing	Upper middle	Meat	587	299	Net importer	0	0	0
			Fish	251	-184	Net exporter	0	0	0
			Vegetable	104	-91	Net exporter	0	0	0
			Fruit	143	-2,922	Net exporter	0	0	0
			Preparation of meat and fish	154	27	Net importer	0	0	0
Egypt (EGY)	Developing	Lower middle	Meat	1,747	1,742	Net importer	0	0	0
			Fish	535	499	Net importer	0	0	0
			Vegetable	536	-519	Net exporter	0	0	0
			Fruit	536	-667	Net exporter	0	0	0
			Preparation of meat and fish	181	173	Net importer	0	0	0
Indonesia (IDN)	Developing	Lower middle	Meat	466	445	Net importer	35,313	11	1,649
			Fish	229	-2,611	Net exporter	267,036	15	6,444
			Vegetable	697	588	Net importer	31,758	11	764
			Fruit	881	73	Net importer	31,284	11	837
			Preparation of meat and fish	49	-1,001	Net exporter	50,187	13	861
India	Developing	Lower middle	Meat	3	-4,204	Net exporter	0	0	630

(IND)			Fish	68	-5,382	Net exporter	0	0	1,132
			Vegetable	3,888	2,732	Net importer	0	0	675
			Fruit	3,091	1,450	Net importer	0	0	785
			Preparation of meat and fish	3	-316	Net exporter	0	0	311
Libya (LBY)	Developing	Lower middle	Meat	52	52	Net importer	0	0	0
			Fish	10	10	Net importer	0	0	0
			Vegetable	9	9	Net importer	0	0	0
			Fruit	63	63	Net importer	0	0	0
			Preparation of meat and fish	43	43	Net importer	0	0	0
Morocco (MAR)	Developing	Lower middle	Meat	28	27	Net importer	0	0	0
			Fish	153	-851	Net exporter	0	0	0
			Vegetable	111	-875	Net exporter	0	0	0
			Fruit	180	-624	Net exporter	0	0	0
			Preparation of meat and fish	27	-839	Net exporter	0	0	0

Notes: As for Libya, the average import value (mln USD) refers to the period 2008-2010; the trade balance for Libya is computed considering average exports of meat in 2009-2010, average exports of fish in 2007-2009; exports of preparation of meat and fish in 2007. Multilateral SPS measures for Germany, Spain, France, United Kingdom, Italy are the number of multilateral SPS measures implemented at the European level.

Countries tend to adopt different strategies in trade policy. The United States has the highest level of regulation, both bilateral and multilateral SPS measures: on average, 21 measures per partner, with heavier regulation in the vegetable sector (35 bilateral SPS measures per partner on average) and milder in the fish sector (6 bilateral SPS measures per partner, on average). High levels of bilateral and multilateral SPS measures are adopted also by New Zealand (with 11-13 bilateral SPS measures per partner, on average) and Canada (with 8-10 bilateral SPS measures per partner adopted, on average, in meat and fish sectors and for preparation of meat and fish). Differently, the European countries and Australia do not have bilateral SPS measures in force, but several multilateral SPS measures in place. As for developing countries, the upper middle income economies (exception made for South Africa) tend to implement bilateral SPS measures, whereas the lower middle income economies do not have bilateral SPS measures in force, exception made for Indonesia with 12 bilateral SPS measures per partner, on average.

As for sectoral differences, the meat-based products are heavily regulated in developed countries (e.g. the United States has 21 bilateral SPS measures per partner, on average) and in the upper middle income economies (e.g. on average, the bilateral SPS measures per partner are 10 for Russian Federation and 9 for China and Peru). Trade of fish and of preparation of meat and fish in developed countries is mostly regulated by multilateral SPS measures (a few exceptions are Canada and New Zealand); differently, the use of bilateral SPS measures is frequent among developing countries. Fruit and vegetables are highly regulated both in developed and developing countries.

Overall, differences in trade balance and trade policy emerge at the sectoral level and such differences seem to be affected by countries' economic development. Trade policies tend to be more similar in developing countries and to differ from the strategies adopted in developed countries.

4.2 Data sources and descriptive analyses

Following Baldwin and Taglioni (2006, p. 13), who state *"there is an old tradition in the gravity literature of using only import data on the grounds that nations spend more on measuring imports than exports"*, we opt for bilateral imports data, collected from the UN Comtrade database. We consider the two-digit level of the Harmonised System classification (HS 2-digit)[21], and select the most regulated agri-food sectors, i.e. meat, fish, vegetables, fruit, preparation of meat and fish[22]. According to the UNCTAD data, SPS measures currently in force account for 22.8% in fish sector, 13.0% in meat sector, 9.2% in fruit sector, 8.8% in vegetables sector, 7.2% in preparation of meat and fish sector. The annual data on bilateral SPS measures have been collected from the UNCTAD's global database on non-tariff measures, which provides information on official measures implemented at country and product level. Our analysis focuses on bilateral SPS measures; differently from multilateral SPS measures implemented by a country against all its trading partners[23], bilateral SPS measures are country-pair specific and, as indicated in the WTO SPS Agreement, are often applied on the basis of bilateral agreements or protocols. Information about the number of SPS measures that regulates bilateral trade are available at the HS 6-digit level[24]. This feature is important to compute a count variable of SPS measures for country-pairs and sectors. The UNCTAD's database also provides, for each measure, information on the date of entry into force and on the expiry date; this allows us to track the validity of SPS measures. We control for tariffs, downloaded from the World Bank's World Integrated Trade Solution (WITS) database, and for the presence of RTAs between country-pairs, an information retrieved from the CEPII database. The descriptive statistics of key variables are presented in table 3.

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[21] Working at the HS 2-digit level allows us to capture the variance among groups of products (Disdier et al., 2008).

[22] The HS 2-digit categories selected are 'Meat and edible meat offal' (HS 1996: 02), 'Fish and crustaceans, molluscs and other aquatic invertebrates' (HS 1996: 03), 'Edible vegetables and certain roots and tubers' (HS 1996: 07), 'Edible fruit and nuts' (HS 1996: 08), 'Meat, fish or crustaceans, molluscs or other aquatic invertebrates; preparations thereof' (HS 1996: 16).

[23] In our empirical analysis, multilateral SPS measures are absorbed by importer-product-time fixed effects included in the model in equation (2).

[24] In order to facilitate the match between trade and SPS data, we aggregate the information on SPS measures at the HS 2-digit level.

Table 3. Average values of key variables (standard deviation in parentheses).

Variables		All importers	Developed importers	Developing importers
Imports (billion USD)		.04 (± .16)	.07 (± .21)	.01 (± .09)
	Meat	.05 (± .21)	.08 (± .26)	.03 (± .15)
	Fish	.04 (± .17)	.08 (± .22)	.01 (± .09)
	Vegetables	.03 (± .14)	.06 (± .20)	.01 (± .06)
	Fruit	.05 (± .16)	.09 (± .23)	.01 (± .05)
	Preparation of meat and fish	.02 (± .07)	.03 (± .09)	.001 (± .01)
SPS_{dummy}		.14 (± .35)	.20 (± .40)	.10 (± .30)
	Meat	.19 (± .39)	.23 (± .42)	.15 (± .36)
	Fish	.08 (± .27)	.11 (± .31)	.05 (± .23)
	Vegetables	.14 (± .34)	.22 (± .42)	.07 (± .25)
	Fruit	.17 (± .38)	.22 (± .42)	.13 (± .34)
	Preparation of meat and fish	.13 (± .34)	.20 (± .40)	.08 (± .27)
SPS_{count} (hundreds)		.56 (± 2.33)	1.00 (± 3.12)	.20 (± 1.27)
	Meat	.93 (± 3.58)	1.81 (± 5.09)	.21 (± .94)
	Fish	.44 (± 1.91)	.53 (± 1.93)	.37 (± 1.89)
	Vegetables	.63 (± 2.37)	1.04 (± 2.83)	.29 (± 1.85)
	Fruit	.55 (± 2.02)	1.15 (± 2.89)	.06 (± .29)
	Preparation of meat and fish	.27 (± .90)	.51 (± 1.25)	.08 (± .37)
SPS_{count} (if SPS_{dummy} is 1) (hundreds)		4.00 (± 4.98)	5.15 (± 5.33)	2.09 (± 3.59)
	Meat	5.00 (± 6.96)	7.98 (± 8.09)	1.40 (± 2.04)
	Fish	5.63 (± 4.16)	4.89 (± 3.58)	6.86 (± 4.74)
	Vegetables	4.58 (± 4.79)	4.68 (± 4.37)	4.31 (± 5.76)
	Fruit	3.22 (± 3.90)	5.17 (± 4.08)	0.49 (± .66)
	Preparation of meat and fish	2.03 (± 1.60)	2.58 (± 1.59)	.93 (± .92)
$SPS_{low\ intensity}$ (dummy)		.04 (± .19)	.06 (± .23)	.03 (± .16)
	Meat	.06 (± .24)	.08 (± .27)	.02 (± .15)
	Fish	.01 (± .07)	.02 (± .15)	.00 (± .00)
	Vegetables	.01 (± .12)	.08 (± .28)	.003 (± .06)
	Fruit	.07 (± .25)	.02 (± .13)	.07 (± .25)
	Preparation of meat and fish	.05 (± .21)	.08 (± .28)	.03 (± .17)

$SPS_{low\text{-}mid\ intensity}$ (dummy)		.03 (± .18)	.04 (± .20)	.03 (± .16)
	Meat	.05 (± .21)	.03 (± .16)	.05 (± .22)
	Fish	.02 (± .15)	.02 (± .13)	.002 (± .04)
	Vegetables	.05 (± .21)	.02 (± .14)	.02 (± .14)
	Fruit	.01 (± .12)	.07 (± .25)	.05 (± .22)
	Preparation of meat and fish	.04 (± .20)	.09 (± .28)	.02 (± .13)
$SPS_{mid\text{-}high\ intensity}$ (dummy)		.03 (± .18)	.05 (± .21)	.02 (± .15)
	Meat	.02 (± .15)	.01 (± .12)	.05 (± .23)
	Fish	.02 (± .14)	.06 (± .24)	.02 (± .13)
	Vegetables	.04 (± .19)	.06 (± .24)	.02 (± .13)
	Fruit	.05 (± .21)	.07 (± .26)	.01 (± .08)
	Preparation of meat and fish	.04 (± .21)	.03 (± .16)	.02 (± .14)
$SPS_{high\ intensity}$ (dummy)		.03 (± .18)	.05 (± .21)	.02 (± .14)
	Meat	.06 (± .23)	.11 (± .31)	.03 (± .16)
	Fish	.03 (± .17)	.01 (± .07)	.03 (± .18)
	Vegetables	.04 (± .19)	.06 (± .23)	.03 (± .17)
	Fruit	.04 (± .20)	.06 (± .25)	.003 (± .05)
	Preparation of meat and fish	.003 (± .05)	.00 (± .00)	.01 (± .11)

In our sample only a low percentage of imports (14%) is regulated by bilateral SPS measures; if regulations are in place, country-pairs share on average four hundreds SPS measures, with the fish and preparation of meat and fish being the most and the least regulated sectors (respectively, 563 and 203 SPS measures on average). Differences are observed between developed and developing importers. First the developed countries regulate more than the developing countries (table 3). The intensity of SPS measures implemented by developing importers tends to be lower as compared to that of developed importers[25]; on average, the high-income level countries implement 515 measures as compared to the 208 measures of developing countries: this gap occurs in all but one sector, i.e. fish (on average, 686 measures of developing countries as compared to 489 measures of developed countries) (table 3). Second, the import values are greater in magnitude for developed countries and

[25] The distribution of SPS measures in the sample is reported in figure A.2 in the Appendix A.4.

increase faster for country-pairs that have measures in place (figure 2). The average value of imports in our sample is 70 million USD for high-income countries and 10 million USD for less developed economies[26].

5. Results

The results of the Poisson Pseudo-Maximum Likelihood (PPML) estimates are reported in table 4[27]. We disentangle the effects of SPS measures implemented by developed and developing countries and compare the impacts of SPS measures across trade patterns. The trade route specific results allow us to disentangle potential differences in the influence of SPS measures between exporters with different levels of economic development. The table synthesises the results of three specifications. The first specification includes a dummy variable for country-pairs with and without SPS measures in place. The second specification includes a count variable (i.e. the number of shared SPS measures between country-pairs). The last specification considers different intensity of regulation (i.e. low, low-mid, mid-high, high). We use dummy variables for each time-specific quartile of the distribution of SPS measures, the latter obtained excluding country-pairs without SPS measures in place that we treat as the baseline.

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[26] Trends in average import values of country-pairs with and without SPS measures in place are reported in figure A.3 in the Appendix A.4.

[27] The structure of fixed effects used to estimate the specifications of the model in table 4 is quite stringent but allows us to isolate the effect of a sector-specific SPS measures implemented in a certain year between two trading partners. In a sensitivity analysis, we propose more flexible structures of fixed effects to test if the effect of the variable of interest (i.e., SPS measures, expressed as dummy variable) is potentially absorbed by multilateral resistances and unobserved heterogeneity defined at the three dimensions of the panel (i.e., importer-product-time, exporter-product-time, country-pair-product). In a specification, we control for importer-time, importer-product, exporter-time, exporter-product, country-pair fixed effects. In a further specification, we add product-time fixed effects. In both specifications, the standard errors are clustered by importer-product. The results, reported in table A.4 of the Appendix A.5 for the sample of all importers, developed importers, and developing importers, confirm the main results of table 4, indicating that the overall effect of SPS measures is a true null effect.

Next, we use the point estimates of variables of interest (reported in table 4) to derive the trade volume and tariff equivalent effects and the implied change in import values. The implied change in import values is computed by multiplying the trade volume effect of SPS measures (when available) by the average import value. The trade volume and tariff equivalent effects of SPS measures as well as trade-weighted average change are reported in table 6.

Table 4. Estimated effects of SPS measures.

Variables		All importers	Developed importers	Developing importers	Developed-developed	Developed-developing	Developing-developed	Developing-developing
Specification 1		-.114	-.006	.268	-.087	.240***	.271***	-.101
		(.156)	(.124)	(.221)	(.247)	(.010)	(.093)	(.356)
Specification 2		-.046	.014	.041	-.019	-.031	.004	.011
		(.042)	(.029)	(.107)	(.059)	(.097)	(.099)	(.133)
Specification 3	Low intensity	-.114	-.009	.057	-.085	.228***	0.141	-.658***
		(.176)	(.124)	(.178)	(.245)	(.010)	(.118)	(.204)
	Low-mid intensity	-.108	.075	.667***	-.019	.397***	.538***	.586**
		(.135)	(.144)	(.207)	(.307)	(.016)	(.126)	(.257)
	Mid-high intensity	-.161	.159	1.043***	.226	.432***	.939***	1.450**
		(.189)	(.160)	(.369)	(.274)	(.017)	(.106)	(.597)
	High intensity	-.118	.061	.582	.105	.364***	.719***	.558
		(.193)	(.156)	(.429)	(.276)	(.037)	(.109)	(.592)

Notes: Poisson Pseudo-Maximum Likelihood (PPML) estimates of gravity-type model in equation (2). The table synthesises the results of three specifications: the first one tests for the effect of the introduction of a new regulation (SPS measures modelled as a dummy variable); the second one tests for the marginal impact of the introduction of an additional SPS measure (SPS measures modelled as a count variable); the third one tests for the effects of SPS measures with low, low-mid, mid-high, high intensity, given the presence of SPS measures (SPS measures modelled as dummy variables for each time-specific quartile of the distribution of SPS measures obtained excluding pairs without SPS measures in place treated as the baseline). Each specification uses the value of imports as dependent variable and is estimated for the samples of all importers (N = 34,399), developed importers (N = 17,533), and developing importers (N = 16,429) –exporters are all countries in the sample–, and for the samples of developed importers and developed exporters (N = 7,920), developed importers and developing exporters (N = 9,551), developing importers and developed exporters (N = 8,845), and developing importers and developing exporters (N = 7,471). All the specifications include a constant, importer-product-time, exporter-product-time and country-pair-product fixed effects, and control for tariff levels (log) and the presence of RTAs (dummy). Robust standard errors are in parentheses, clustered at the product level.

*** Significant at the 1 percent level.

** Significant at the 5 percent level.

All coefficients in the first column of table 4 are statistically not different from zero. Similar conclusions are achieved when considering only the SPS measures implemented by the developed importers. Differently, we find that a higher intensity of SPS measures implemented by developing countries corresponds to a larger magnitude of imports from any trading partners (table 4). Imports of developing countries are 94.8% higher if country-pairs share a few SPS measures (low-mid intensity), and 183.8% higher if they share numerous measures (mid-high intensity). The greater the intensity of regulation, the larger the trade-enhancing effects of SPS measures. In dollar terms, the imports of developing countries increase by an amount ranging between 13 and 26 million US$ (28 and 55 million US$ in 2017 only) when a mid level of regulations is in place. In terms of tariff equivalence, the introduction of about 100 SPS measures corresponds to eliminating tariffs (table 6)..

As suggested in Santeramo and Lamonaca (2019), the heterogeneous impacts of SPS measures are likely to occur not only across different geo-economic areas but also across different products, due to different costs of compliance (Crivelli and Gröschl, 2016) and specific political objectives (Schlueter et al., 2009). In a sensitivity analysis, we control for differences in the impact of SPS measures on trade of different products (table 5). We find mixed effects of regulations on imports of developed and developing countries. In developed countries, SPS measures favour imports of meat, vegetable and preparation of meat and fish, whereas they are detrimental for imports of fish and fruit. Developing countries take advantage of regulations for the fruit and vegetables sector.

Table 5. Estimated effects of SPS measures across product categories and differences between regulations implemented by developed and developing countries.

	Developed importers		Developing importers	
Variables	Specification 1	Specification 2	Specification 1	Specification 2
SPS	.5276***	.2033***	-.274***	-.209***
(meat)	(.0176)	(.0048)	(.032)	(.024)
SPS	-.0179***	-.0007***	-2.219***	-.439***
(fish)	(.0005)	(.0001)	(.005)	(.001)
SPS	Omitted	.0360***	1.139***	.266***
(vegetable)		(.0016)	(.013)	(.002)
SPS	-.1891***	-.1813***	.183***	-.014***
(fruit)	(.0057)	(.0076)	(.007)	(.004)
SPS	.3740***	.0485***	-.877***	-.031
(preparation of meat and fish)	(.0053)	(.0027)	(.059)	(.037)

Notes: Poisson Pseudo-Maximum Likelihood (PPML) estimates of gravity-type model in equation (2). The table synthesises the results of two specifications: the first one tests for the effect of the introduction of a new regulation (SPS measures modelled as a dummy variable); the second one tests for the marginal impact of the introduction of an additional SPS measure (SPS measures modelled as a count variable). Each specification uses the value of imports as dependent variable and is estimated for the samples developed importers (N = 17,533) and developing importers (N = 16,429); exporters are all countries in the sample. All the specifications include a constant, importer-product-time, exporter-product-time and country-pair-product fixed effects, and control for tariff levels (log) and the presence of RTAs (dummy). Robust standard errors are in parentheses, clustered at the product level.
*** Significant at the 1 percent level.

As for differences across trade patterns, the SPS measures seem to not impact on trade among developed countries. Conversely, the trade between partners with different levels of economic development tends to be positively correlated with trade regulations. In particular, the presence of SPS measures in place matters for trade among developed and developing countries (table 4). The trade volume effect due to the introduction of a new regulation is lower in the developed-developing case (+27.1%) with respect to the developing-developed case (+31.1%). In economic terms, the effects are almost twice higher for developed (+9 million US$) than for developing (+5 million US$) importers, due to differences in the average magnitude of trade flows (table 6). As suggested in Fiankor et al. (2021, p. 205), "*bigger trading partners find it more profitable to invest in meeting the costs of importer-specific standards*". An increasing intensity of SPS measures tends to be beneficial although up to a certain level after which the increase in magnitude of imports occurs at a slower pace. In fact, the change in imports of developed countries from developing exporters associated with a low intensity of regulation (+8 million US$) is twice larger with a low-mid intensity of regulation (+16 million US$), however slightly raises with a mid-high (+18 million US$) or a high (+14 million US$) intensity of regulation. Similarly, the level of imports of the developing countries from developed exporters is 11 million US$ larger with a low-mid intensity of regulation, 23 million US$ larger with a mid-high intensity of regulation, but only 16 million US$ larger if developing importers have many SPS measures in place (table 6). A different trend is observed among developing countries, for which the effects of SPS measures is detrimental for bilateral trade if the intensity of regulation is low (-6 million US$), but turns out to be beneficial with a mid intensity of regulation. A mid-high intensity of SPS measures among developing countries increases the level of imports by 326.3% (+42 million US$).

Table 6. Trade volume and tariff equivalent effects of SPS measures and related trade-weighted average change.

	Average imports (million US$)	Average bilateral SPS measures (%, number)	Estimated coefficient	Trade volume effect (%)	Change in average imports (million US$)	Tariff equivalent effect (%)
Developing importers	14 (30 in 2017)					
Low-mid intensity of regulation		75	0.667	+94.8	+13 (+28 in 2017)	-99.6
Mid-high intensity of regulation		137	1.043	+183.8	+26 (+55 in 2017)	-100.0
Developed-developing trade	33 (56 in 2017)					
New regulation		19.5%	0.240	+27.1	+9 (+15 in 2017)	-72.5
Low intensity of regulation		143	0.228	+25.6	+8 (+14 in 2017)	-70.6
Low-mid intensity of regulation		307	0.397	+48.7	+16 (+27 in 2017)	-87.6
Mid-high intensity of regulation		513	0.432	+54.0	+18 (+30 in 2017)	-89.7
High intensity of regulation		1,172	0.364	+43.9	+14 (+25 in 2017)	-85.3
Developing-developed trade	15 (33 in 2017)					
New regulation		11.1%	0.271	+31.1	+5 (+10 in 2017)	-
Low-mid intensity of regulation		68	0.538	+71.3	+11 (+24 in 2017)	-
Mid-high intensity of regulation		134	0.939	+155.7	+23 (+51 in 2017)	-
High intensity of regulation		644	0.719	+105.2	+16 (+35 in 2017)	-
Developing-developing trade	13 (27 in 2017)					
Low intensity of regulation		10	-0.658	-48.2	-6 (-13 in 2017)	-
Low-mid intensity of regulation		83	0.586	+79.7	+10 (+22 in 2017)	-
Mid-high intensity of regulation		140	1.450	+326.3	+42 (+88 in 2017)	-

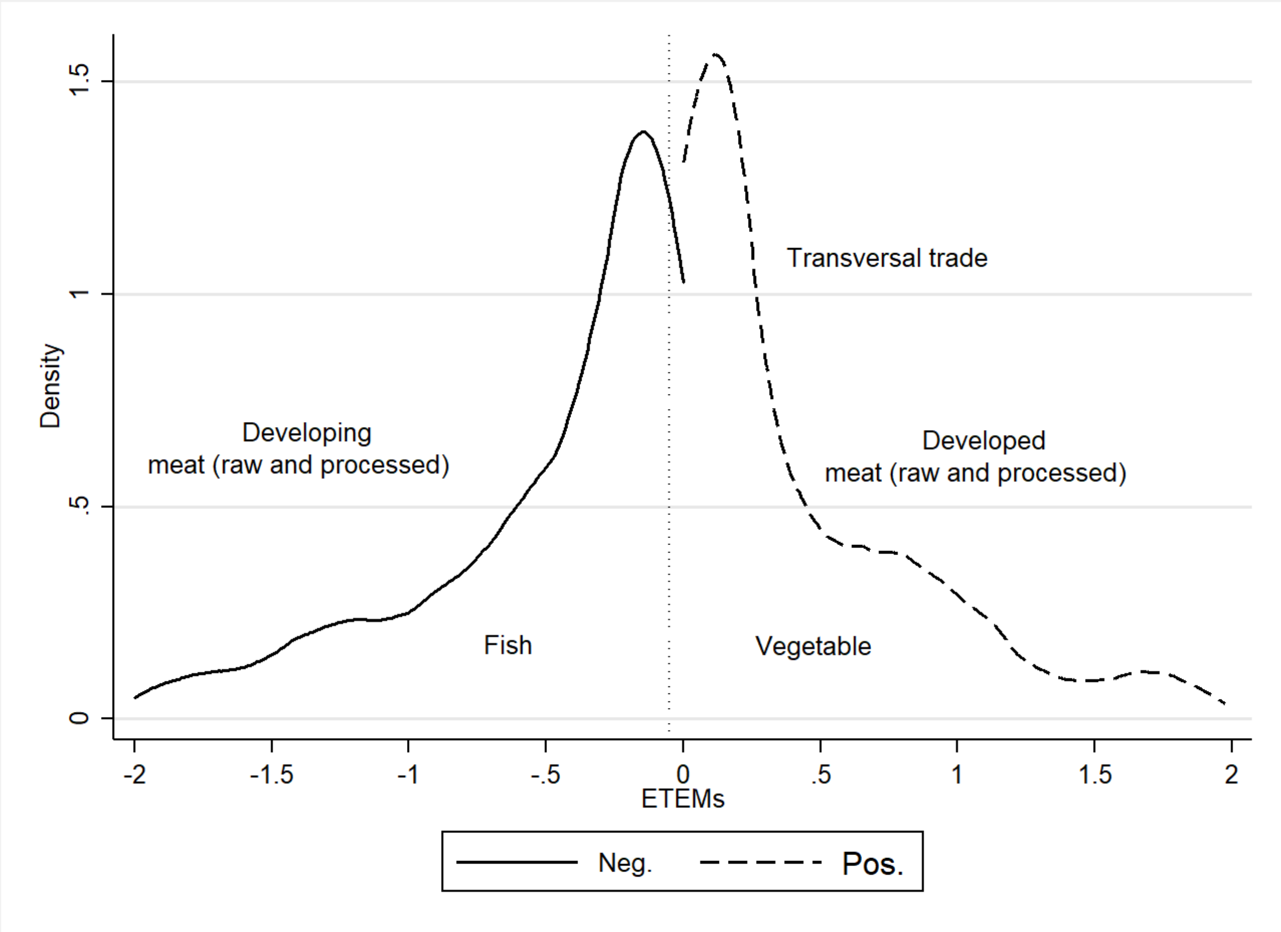
Notes: The table reports only available trade volume and tariff equivalent effects of SPS measures and related trade-weighted average change.

6. Discussion

Overall, the bilateral SPS measures tend to have limited effects on imports. As argued in Schlueter et al. (2009), at an aggregate level a strong tendency cannot be determined and, as a result, SPS measures may have no trade impact at all in a global picture. In support of this evidence, Santeramo and Lamonaca (2019) conclude that, overall, regulations may be both trade-impeding and trade-enhancing, with a consequent offset of these impacts. In fact, their meta-analysis shows how the estimated effects of non-tariff measures on agri-food trade are distributed around the zero, with differences observable across geo-economic areas and markets of the agri-food sector. In figure 1, we propose the distribution of the estimated trade effect of measures (ETEMs) arranged by direction (i.e. negative *versus* positive estimates) presented in Santeramo and Lamonaca (2019, p. 606, figure 1) and allocate the trade effects of SPS measures found in our analysis. Santeramo and Lamonaca (2019) find that non-tariff measures have a dual effect on the agri-food trade whose overall effect approaches to zero (figure 1). Consistent with these findings, in our analysis we show that the trade effect of SPS measures is almost null, and differences have to be found at a more disaggregated level. For instance, at the sectoral level, SPS measures are catalysts for trade of vegetables, but barriers for trade of fish. SPS measures regulating trade in the meat supply chain behave differently depending on the levels of economic development of importers: they favour imports of developed countries, but friction imports of developing countries (figure 1).

Our results conclude that SPS measures are catalysts for developing importers, whereas no evidence is found for developed importers. Accordingly, developing countries tend to have a relative advantage in facilitating imports, that may be due to the emergence of new origins or to the expansion of existing trade routes. As noted by Martin (2018), over the last decades, in developing countries we observed a rapid growth in the market share, as compared to developed countries, a substantial increase in the level of regulations in the agri-food sector, and their greater turmoil in trade negotiations.

Figure 1. Estimated trade effect of measures: a comparison with the literature.



Source: Authors' elaboration on figure 1 in Santeramo and Lamonaca (2019, p. 606).

Notes: The distribution of the estimated trade effect of measures (ETEMs) and the overall median value (dot horizontal line set on -0.05) are from Santeramo and Lamonaca (2019). Categories are allocated in the positive (i.e. transversal trade, developed-meat (raw and processed), vegetable) and in the negative (i.e. developing-meat (raw and processed), fish) halves of the graph according to the trade effects of SPS measures estimated in this article (see tables 4 and 5).

Differences in the level of economic development of trading partners matter. Our results expand the findings of Disdier et al. (2008) who, based on a cross-sectional analysis, conclude that SPS measures implemented by developed countries have an insignificant impact on OECD exports. The trade route specific results also reveal the dual effect of SPS measures in the agri-food trade: regulations may have no effects on trade or be even beneficial as they carry information on the safety of products, but they may also be trade-impeding if exporters are unable to meet SPS requirements (Peci and Sanjuán 2020). Transversal trade is favoured (figure 1). Adhering to SPS requirements is a strategy to compete against other countries with lower cost of production. This is particularly true for developing exporters for which developed markets are relevant destinations; the compliance with requirements of SPS measures implemented by developed importers is relevant to secure and maintain exports (Neeliah et al. 2013). It is noteworthy how the rapid spread of regulations in high value sectors, such as fruits, vegetables, meat, seafood and fish, has been associated with a substantial growth in exports from developing countries (e.g. +40% in Asia and Latin America) during the past 25 years (Swinnen 2016). Although SPS requirements make production more costly, they boost the value of production and increase the likelihood of higher profits; thus, the compliance with SPS requirements may be a strategy that countries adopt to (re)position themselves in global markets (Jaffee and Henson 2005). This strategy however demonstrates successful only if accompanied by an improvement of domestic supply chains in developing countries, also through the introduction of standards (Swinnen 2016). While the increased production costs implied by SPS requirements tend to be barriers for trade, regulations may also reduce transaction costs and act as catalysts for trade once the required standards are met (Chevassus-Lozza et al. 2008). This is what we observe in trade relationships between developing countries. It is plausible that exporters find less affordable changing production processes to comply with a few SPS measures (e.g. covering specific products or selected stage of production chains) than with more spread safety requirements (e.g. involving several products of a certain category or the entire production process). Put differently, SPS measures, by imposing sunk costs, may act as entry barriers (Crivelli and Gröschl 2016), especially if the exporter suffers the lack of adequate financial and technical capacity to comply with SPS requirements (Athukorala and Jayasuriya 2003).

7. Conclusions

Over the last decades, the growing trend in trade flows has been parallel to the increase in trade policy interventions and in non-tariff measures. Sanitary and phytosanitary (SPS) measures have grown exponentially, in terms of products coverage and number of implementing countries, with effects on global agri-food trade that have not been sufficiently examined. By focusing on the most regulated product categories of the agri-food sector, we investigated the trade effects of SPS measures, and how they differ according to the level of economic development of countries implementing regulations.

We found that SPS measures have limited effects on agri-food trade at the global level. Such evidence suggests that, in a global picture, the 'standards as catalysts' and the 'standards as barriers' effects may offset each other and, consequently, a strong tendency cannot be determined. Different types of SPS measures, in fact, entail different costs of compliance, with each instrument pursuing specific political objectives (Crivelli and Gröschl, 2016; Schlueter et al., 2009). The economic relevance of countries implementing regulations may be determinant in orienting the effect of SPS measures on trade (Maertens and Swinnen, 2015). We found a positive relationship between number of SPS measures implemented by developing countries and magnitude of imports. We concluded that developing countries tend to have a relative advantage in facilitating imports, the latter likely related to the emergence of new origins or to the expansion of existing trade routes. As noted by Martin (2018), we are observing a rapid growth in the market share of developing countries as compared to developed countries, and a substantial increase in the level of regulations in the agri-food sector. The greater importance of developing countries in the global arena and their increasing use of regulations highlight the relevance of developing countries in trade negotiations.

Empirical results also showed that the level of development of countries involved may generate specific geo-economic patterns of regulations. The SPS measures regulating trade between countries with different levels of development (i.e. developed-developing and developing-developed trade relationships) do matter. Trade measures have mixed effects on trade between developing countries: while a limited intensity of regulations tends to be detrimental for trade, a mid-high intensity of regulations favours imports of developing countries. Differently, regulations have no effect on trade between developed countries. Our results build upon findings of Disdier et al. (2008) and of Crivelli and Gröschl (2016) by highlighting differences in the trade effects of SPS measures implemented by countries with different levels of economic development and involved in different trade patterns. Our findings also confirm conclusions of Jongwanich (2009) and Chevassus-Lozza et al. (2008): food safety standards may be *"an impediment to trade in developing countries"* (Jongwanich, 2009, p. 453), however advantages from regulation may occur once required standards are met (Chevassus-Lozza et al. 2008). Adhering to SPS requirements is costly and may be not viable if only specific products or selected stage of production chains are involved. A few SPS measures may be an entry barrier (Barrett, 2008; Crivelli and Gröschl 2016). This evidence implies that sharing a less intense regulation may be a sort of protection for still slightly thriving markets.

8. Policy implications

The differences we found for developed and developing countries may be partly explained by different standards on food safety, which depend on available technologies, plant and livestock host factors, food production practices, cultural background, and pedo-climatic conditions. The divergences in food safety regulations and standards may exacerbate the differences. Adopting international standards would allow countries to avoid redundant costs and potential obstacles to trade (Barrett et al., 2020). As our results suggest, partners with different economic relevance that agree on SPS issues and set measures to regulate their trade relationships benefit of improved market access conditions: the greater the intensity of SPS matching between developed and developing partners, the lower the trade frictions between them. Sharing standards on SPS issues is of utmost importance for economies characterised by different abilities to alter trade terms.

A few words of caution are needed. A drawback of the present analysis is that, by estimating overall effects, we can only cautiously conclude on the drivers of the relationships that we found. However, the present analysis may represent a benchmark for country-specific evidence. Furthermore, it would represent valid support to derive a general framework on the effects of SPS measures on trade of agri-food products. Future research should also duly consider the quality of data used in the empirical application (e.g. trade flows in quantity *versus* value, trade flows in constant prices *versus* current prices) to reach a consistent interpretation of results.

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A. Appendix

A.1 Comparing theoretical and empirical gravity models

We compared the theoretical gravity model in equation (1) with the empirical specification in equation (2) to clarify why certain variables are included in the model. Recall that *i* is the importer, *j* is the exporter, *k* is the product, *t* is time.

Theoretical model, equation (1)	Empirical model, equation (2)
$X_{ijk,t} = \frac{E_{ik,t}}{\Phi_{ik,t}} \frac{Y_{jk,t}}{\Omega_{jk,t}} \theta_{ijk,t}$	$X_{ijk,t} = e^{\{\boldsymbol{\beta}_{ikt} + \boldsymbol{\beta}_{jkt} + \boldsymbol{\beta}_{ijk} + t_{ijk,t}\gamma\}} \varepsilon_{ijk,t}$

The gravity model explains bilateral trade (i.e., $X_{ijk,t}$ in equations 1 and 2) as a function of the total expenditure of *i* on *k* (i.e., $E_{ik,t}$ in equation 1), the value of production of *k* in *j* (i.e., $Y_{jk,t}$ in equation 1), and the multilateral resistances proxying the competitiveness of *i* and *j* (i.e., $\Phi_{ik,t}$ and $\Omega_{jk,t}$ in equation 1). In the structural gravity model, these terms are traditionally proxied by a set of fixed effects: importer-product-time fixed effects (i.e., $\boldsymbol{\beta}_{ikt}$ in equation 2) control for total expenditure of *i* and multilateral resistances in *i* (i.e., $E_{ik,t}$ and $\Phi_{ik,t}$ in equation 1); exporter-product-time fixed effects (i.e., $\boldsymbol{\beta}_{jkt}$ in equation 2) control for value of production and multilateral resistances in *j* (i.e., $Y_{jk,t}$ and $\Omega_{jk,t}$ in equation 1).

The term of interest in the theoretical model is the bilateral trade cost between *i* and *j* (i.e., $\theta_{ijk,t}$ in equation 1), which consists of time-invariant (i.e. geographical and cultural distance between pairs) and time-varying (i.e. trade policy distance between pairs) determinants of transaction costs. In the empirical model, the time-invariant determinants of transaction costs are captured by country-pair-product fixed effects (i.e., $\boldsymbol{\beta}_{ijk}$ in equation 2); the time-varying determinants of transaction costs are proxied by country-pair and product-specific trade policies, defined as $t_{ijk,t} = \{SPS_{ijk,t}, \tilde{\tau}_{ijk,t}, RTA_{ij,t}\}$.

A.2 Testing for endogeneity

We evaluate the strict exogeneity of SPS measures by adding to the model in equation (2) a forwarded variable, $SPS^{k}_{ij,t+3}$, capturing the future level of SPS measures, to test if the use of country-pair fixed effects properly accounts for potential reverse causality between imports and SPS measures in our model (Baier and Bergstrand 2007). The results, reported in table A.1, confirm the absence of reverse causality between imports and SPS measures; in fact, the parameter associated with the variable $SPS^{k}_{ij,t+3}$ is statistically not different from zero confirming that SPS measures are exogenous to trade flows.

Table A.1. Testing for the absence of reverse causality between imports and SPS measures.

Variables	All importers New regulation
New regulation (*t*)	0.149
	(0.198)
New regulation (*t+3*)	-0.261
	(0.324)

Notes: Poisson Pseudo-Maximum Likelihood (PPML) estimates of gravity-type model in equation (2). The dependent variable is the value of imports; the explanatory variables are SPS measures at time t and t+3 (test for endogeneity of trade policies) modelled as a dummy variable. The specification, estimated for the samples developed importers (N = 29,286), includes a constant, importer-product-time, exporter-product-time and country-pair-product fixed effects, and control for tariff levels (log) and the presence of RTAs (dummy). Robust standard errors are in parentheses, clustered at the product level.

Trade estimations pooled over consecutive years are sometimes criticised (e.g. Trefler, 2004; Cheng and Wall, 2005). After policy changes, trade flows may not fully adjust in a single year. To address the critique, we leave three years between our observations, to check the robustness of our results. We find that estimates obtained with data pooled over consecutive years (baseline results in table A.2) and with 3-year gaps (sensitivity analysis in table A.2) are comparable. We further detect a positive relationship between trade and SPS measures implemented by developing importers. This effect is stronger if these measures regulate trade from developed exporters.

Table A.2. Testing for the adjustment of trade flows to policy changes.

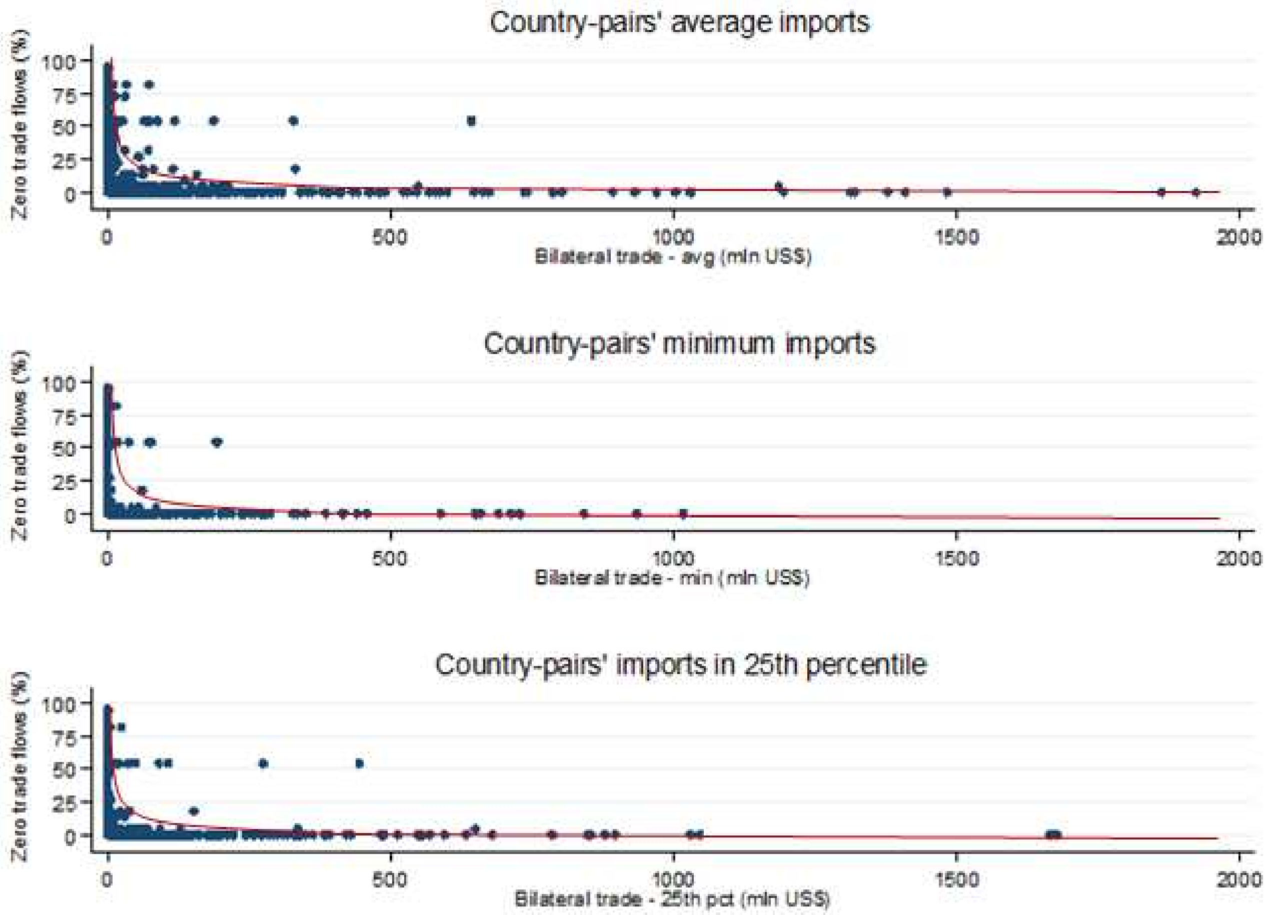
Variables	All importers	Developed importers	Developing importers	Developed-developed	Developed-developing	Developing-developed	Developing-developing
Baseline results							
SPS (dummy)	-.114	-.006	.268	-.087	.240***	.271***	-.101
	(.156)	(.124)	(.221)	(.247)	(.010)	(.093)	(.356)
Sensitivity analysis							
SPS (dummy)	-.038	.027	.382***	-.086	.154***	.462***	.173
	(.100)	(.113)	(.106)	(.210)	(.021)	(.043)	(.515)

Notes: Poisson Pseudo-Maximum Likelihood (PPML) estimates of gravity-type model in equation (2). In the specification 'baseline results' estimates are obtained with data pooled over consecutive years; in the specification 'sensitivity analysis' estimates are obtained with with 3-year gaps. Each specification uses the value of imports as dependent. All the specifications include a constant and control for tariff levels (log) and the presence of RTAs (dummy). Robust standard errors are in parentheses, clustered at the product level.

A.3 Analysis of zero trade flows

Trade data collected for the sample of 20 countries[28] over the period between 1996 and 2017 exhibit fractions of zero values; in our sample country pairs that do not trade with each other account for 32.5%. A detailed analysis shows that zero trade flows tend to occur for country-pairs with scarce trade flows.

Figure A.1. Correlation between zero trade flows and level of bilateral trade.



As shown in figure A.1 (upper panel), the percentage of zero trade flows increases as the average values of bilateral trade tend to zero. This evidence is also stronger considering the correlation

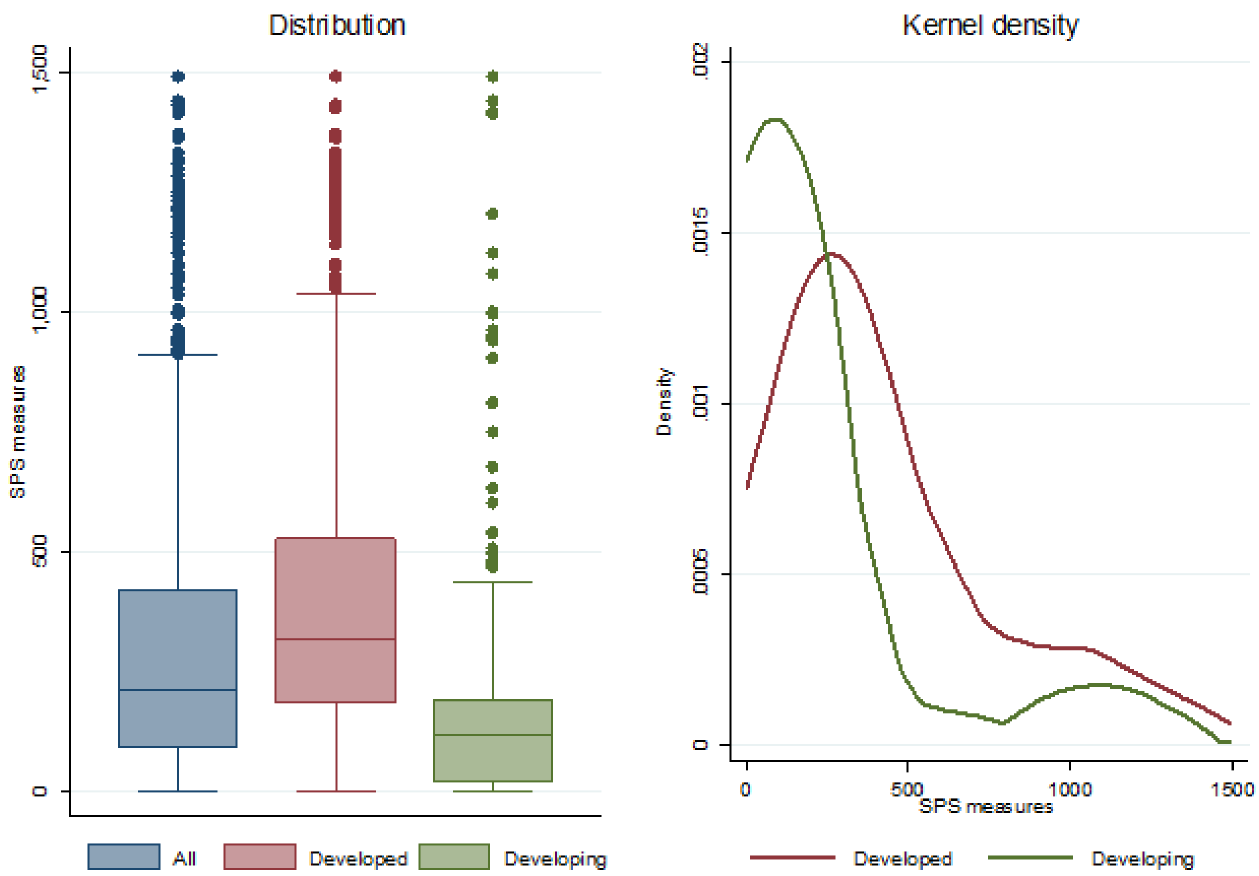
[28] Australia, Canada, France, Germany, Italy, New Zealand, Spain, the United Kingdom, the United States, Argentina, Brazil, China, Egypt, Indonesia, India, Libya, Morocco, Peru, Russian Federation, South Africa.

between zero trade flows and minimum import values (mid-panel, figure A.1) as well as between zero trade flows and import values within the first quartile of the distribution of bilateral trade (lower panel, figure A.1). The relevant presence of zero trade flows justifies the use of the PPML estimator to investigate the relationship between imports and SPS measures.

A.4 Sample description

Figure A.2 shows the distribution of SPS measures in our sample (excluding observations related to country-pairs without SPS measures in place). The intensity of SPS measures implemented by developing importers tends to be lower as compared to that of developed importers.

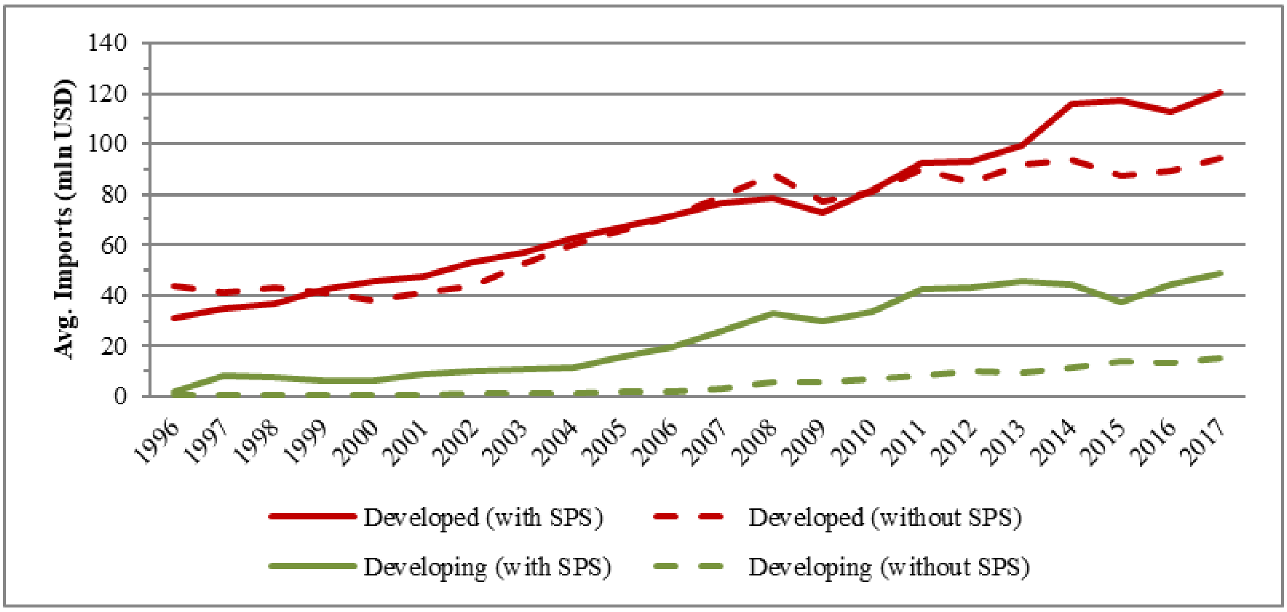
Figure A.2. Distribution of SPS measures.



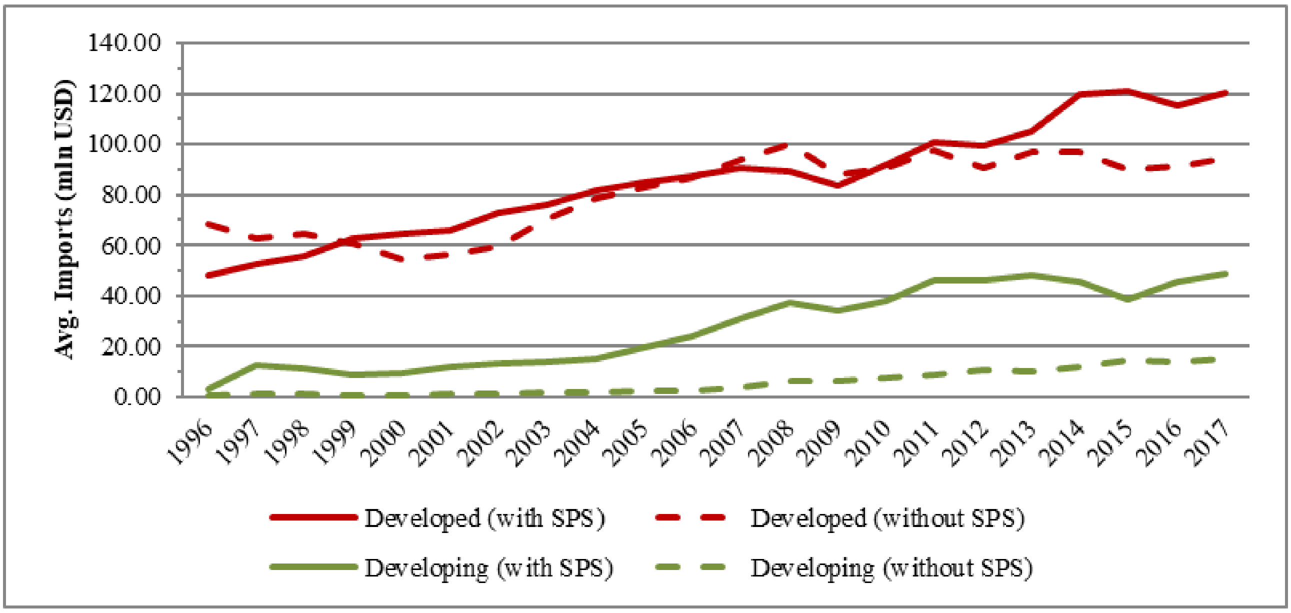
Trends in in the value of imports may be affected by the inflation, due to the long time period analysed (i.e., since 1996 until 2017). To address this issue, we collected data on the average Consumer Price Index (CPI) for the US during the period 1996-2017 from the International Monetary Fund. Data are expressed in averages for the year, not end-of-period data. We considered the US as reference country since trade values are expressed in USD. We used the average CPI to convert trade values expressed in USD of each year of the sample (i.e., 1996-2016) in trade values expressed in USD of 2017. The figure A.3 compares trends in average import values in current prices in panel A and in constant prices in panel B. There are no marked differences between import values in current and constant prices. In both cases, the import values are greater in magnitude for developed countries and increase faster for country-pairs that have measures in place.

Figure A.3. Trends in average import values of country-pairs with and without SPS measures in place.

Panel B – Average import values at current price



Panel B – Average import values at constant price



Notes: Country-pairs with and without SPS measures in place are considered regardless of the year of implementation. In panel B, trade values expressed in USD of each year of the sample (i.e., 1996-2016) are converted in trade values expressed in USD of 2017 using the average Consumer Price Index in the US.

To control for the potential role of the inflation and the exchange rates on the trade values, we estimated the gravity model introducing the average Consumer Price Index for the US as a proxy of the inflation rate and the domestic currency per USD as a proxy of the exchange rate. To allow for the estimation of the effect of the inflation and the exchange rates (which are country-time specific), we use a different combination of fixed effects to avoid collinearity problems (i.e. importer-product, exporter-product, country-pair-product fixed effects). The overall effect of SPS measures on trade flows does not change.

Table A.3. Controlling for the effect of the inflation and exchange rates.

Variables	Specification i (baseline)	Specification ii	Specification iii
SPS (dummy)	-.114	.239	.249
	(.156)	(.152)	(.153)
Inflation rate	No	Yes	Yes
Exchange rate	No	No	Yes

Notes: Poisson Pseudo-Maximum Likelihood (PPML) estimates of gravity-type model in equation (2). Each specification uses the value of imports as dependent. All the specifications include a constant and control for tariff levels (log) and the presence of RTAs (dummy). In the specification i fixed effects used are importer-product-time, exporter-product-time, country-pair-product; in the specification ii and iii fixed effects used are importer-product, exporter-product, country-pair-product. Robust standard errors are in parentheses, clustered at the product level.

A.5 Sensitivity analyses: flexible structures of fixed effects

In a sensitivity analysis, we propose the more flexible structures of fixed effects. The table A.2 provides a comparison between the baseline results (i.e., table 4) and the results of the sensitivity analyses. In a specification, we control for importer-time, importer-product, exporter-time, exporter-product, country-pair fixed effects (sensitivity analysis 1 in table A.2). In a further specification, we add product-time fixed effects (sensitivity analysis 2 in table A.2). In both specifications, the standard errors are clustered by importer-product.

Table A.4. Estimated effects of SPS measures: controlling for different structures of fixed effects.

Variables	All importers	Developed importers	Developing importers
Baseline results			
SPS (dummy)	-.114	-.006	.268
	(.156)	(.124)	(.221)
Importer-product-time FE	Yes	Yes	Yes
Exporter-product-time FE	Yes	Yes	Yes
Country-pair-product FE	Yes	Yes	Yes
Sensitivity analysis 1			
SPS (dummy)	-.070	-.115	-.042
	(.079)	(.116)	(.186)
Importer-time FE	Yes	Yes	Yes
Importer-product FE	Yes	Yes	Yes
Exporter-time FE	Yes	Yes	Yes
Exporter-product FE	Yes	Yes	Yes
Product-time FE	No	No	No
Country-pair FE	Yes	Yes	Yes
Sensitivity analysis 2			
SPS (dummy)	-.054	-.072	-.104
	(.082)	(.149)	(.179)
Importer-time FE	Yes	Yes	Yes
Importer-product FE	Yes	Yes	Yes

Exporter-time FE	Yes	Yes	Yes
Exporter-product FE	Yes	Yes	Yes
Product-time FE	Yes	Yes	Yes
Country-pair FE	Yes	Yes	Yes

Notes: Poisson Pseudo-Maximum Likelihood (PPML) estimates of gravity-type model in equation (2). Each specification uses the value of imports as dependent. All the specifications include a constant and control for tariff levels (log) and the presence of RTAs (dummy). Robust standard errors are in parentheses, clustered at the product level in the baseline results and at the importer-product level in the sensitivity analyses.

The results of the sensitivity analyses confirm the baseline results, indicating that the overall effect of SPS measures is a true null effect.