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Abstract

Constructing an original panel on Maximum Residue Levels (MRLs) in pesticides for 50 countries over 2006-2012, this paper studies the effect of heterogeneity in MRL regulation on bilateral trade. We find evidence of regulatory heterogeneity diminishing trade at the extensive margin when the exporter faces more stringent regulation abroad, suggesting compliance costs in entering the destination market. Significantly, however, we also find strong evidence of regulatory heterogeneity increasing trade at the intensive margin for exports coming from countries that set the strictest standards, alluding to the positive informative effect of such regulation.

JEL classification: I18, F13, F14

Key words: Sanitary and Phytosanitary Measures, MRLs, Regulation, Heterogeneity, Trade

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1 Introduction

The continual decline of tariffs through successive rounds of multilateral trade negotiations has increased the relative importance of non-tariff measures (NTMs). Sanitary and phytosanitary (SPS) standards and technical barriers to trade (TBT) are two such NTMs, which though imposed for legitimate reasons, can also be instruments of disguised protectionism.

Standards prescribe requirements for product characteristics, production processes and/or conformity assessment to address information problems, market failure externalities and societal concerns. However, country-specific standards effectively create additional costs for foreign producers by forcing them to adjust their product and production process so as to meet individual national standards. Further costs emanate from the need for subsequent conformity assessment with these standards (for instance see Wilson and Otsuki, 2004; Baldwin et al., 2000; Chen and Mattoo, 2008; Chen et al., 2006).

Public and private standards for food imports continue to differ between countries despite international coordination, development of multilateral regulations and common conformity assessments by international institutions. Such heterogeneity in standards creates two main negative side effects. One, foreign producers are hurt by the increased production and transaction costs that emanate from the requirement to meet different regulations in different markets. Such costs may even become prohibitive and are especially burdensome for developing countries trying to access developed country markets. Two, by creating uncertainty about changing regulations, heterogeneous country-specific standards have a negative effect on productive efficiency by preventing firms from being able to take advantage of economies of scale. When markets remain segmented by such asymmetries, firms are also able to raise mark-ups, implying less allocative efficiency than could be reached with homogeneous standards.

"Additionally, Baldwin et.al. (2000) point to a "magnification effect of globalization": the greater the freeness of trade, the greater the effect of any remaining barriers especially from an economic geography point of view. In other words, a reduction in distortion arising from tariff barriers, will lead to an increased impact of regulatory differences on the location of production." (Baller, 2007)

Heterogeneity in regulations and standards also implies additional costs for the government, as SPS authorities need to provide support to the export sector to meet different standards in different markets. Finally, regulatory heterogeneity has also led to greater negotiations costs and a possible "stumbling block" effect on the multilateral trading system by generating the need for bilateral/plurilateral negotiations with one's most important trading partners, especially those with more stringent standards. SPS Chapters are a "standard" feature of all post-2000 trade agreements, including the ongoing TPP and TTIP negotiations.

A commonly used standard in agricultural products restricts the maximum residue level (MRL) from pesticides. A pesticide residue is a tiny trace of pesticide that sometimes remains on the treated crop. An MRL is the maximum amount of residue legally permitted on food products. Once residues are demonstrated to be safe for consumption, MRLs are set by independent scientists, based on rigorous evaluation of each legally authorized pesticide. Countries choose the products they regulate, the pesticides they regulate for each product, as well as the MRL for a given product-pesticide pair.

In this paper, we examine the effect of heterogeneity in MRL regulation on bilateral trade using original data on pesticide MRLs over 2006-2012 for 50 countries (details in Section 4.2).

In doing so, we make several original empirical contributions to the impact assessment of standards literature. We assemble an original panel on pesticide MRLs and bilateral trade flows to investigate the effects for agri-trade both on the probability of exporting and on the value of exports. We construct two indices of regulatory heterogeneity, which departing from existing literature, also examine the effect of heterogeneity on exports when the exporting country is bound to stricter regulation at home than in the destination market. Other studies analyzing the effect of sanitary measures on trade either assume no effect from regulatory dissimilarity when the exporter is stricter (Burnquist et al., 2011) or that all regulation heterogeneity leads to compliance costs for the exporter in the destination market, whether or not regulations are stricter in the exporter market (Achterbosch et al., 2009; Drogué and DeMaria, 2012; Winchester et al., 2012). Finally, our analyses are based on a more comprehensive product-pesticide coverage (118 products and 1193 pesticides) compared to previous work on agricultural trade in this literature[1], which studies the effects of standards on one product, one pesticide, one product-pesticide pair or at best, few selected products-pesticides pair.

We find evidence in our empirical results of trade reduction at the extensive margin due to MRL regulatory heterogeneity when the importer has stricter regulation, suggesting that the exporter has to absorb compliance costs to enter the destination market. More striking though, is the evidence that differences in MRL standards have a strong and persistent positive effect at the intensive margin for exports coming from countries with stricter regulation, alluding to the positive signalling effect of the latter.

The rest of the paper is structured as follows. The following section reviews the existing

[1] The following section provides a detailed review of the existing literature.

literature while Section 3 describes the measures of heterogeneity we construct, comparing them with others that have been proposed in this literature. Section 4 presents the empirical methodology and data used to estimate the trade effects of MRL regulation heterogeneity, with results discussed in Section 5 before concluding.

2 Literature review

The main strand of the standards-literature has generally been more concerned with the link between standards and innovation and standards and growth. The link between harmonization of standards and trade has generated academic and research interest only in the last decade.

Even so, most work is empirical in nature and theoretical literature on this subject remains scant. Ganslandt and Markusen (2001) have modeled TBTs formally (though not their liberalization). Baldwin et al. (2000) and Chen and Mattoo (2008) have modeled both TBTs and their harmonization, cautioning against the discriminatory effects that the latter may entail.

The empirical analysis in Chen and Mattoo (2008) focused on harmonization directives and mutual recognition initiatives in manufacturing industries in a sample of 42 OECD and developing countries over 1986-2001. They found these to raise both intra-regional trade as well as trade with excluded developed countries, though their results also indicated that such harmonization diverted trade away from developing countries.

Other work on diverging standards in the manufacturing sector included: Moenius (2006) who estimated the effects of importer-/exporter-specific and internationally harmonized standards on trade between Canada and its major trading partners in electricity-dependent products over 1980-1995 for 471 four-digit SITC industries; Baller (2007) who examined trade effects of the regional liberalization of TBTs for testing procedures in telecoms and medical devices; and Shepherd (2007), who used a new database of EU product standards in the textiles, clothing and footwear sectors to show that international standards harmonization is associated with increased partner country export variety. All these studies found a negative impact of regulatory heterogeneity on trade, especially for exporters from low income countries.

Moving away from studies on the manufacturing sector, de Frahan and Vancauteren (2006) studied the trade effects of harmonization of food regulations in the EU on intra-EU trade in food products over 1990-2001 by considering harmonization initiatives in EC Directives. They found this harmonization to have a large and positive effect on import intensity both at the aggregate level and for individual food sectors. The authors not only use very different data from us, but they also only investigate intra-EU trade effects and only at the intensive margin.

Achterbosch et al. (2009) studied the impact of differences in pesticide MRLs on Chilean fruits exports to the EU15 over 1996-2007 and found a 5% reduction in the EU's regulatory tolerance levels for MRLs to lead to a 14.8% decline in export volumes, with grapes being twice as sensitive as the other fruits. Our focus is also on MRL harmonization, but unlike Achterbosch et al. (2009), we include all agriculture and processed food sectors, a wider sample of trading partners and also study the extensive margin of trade.

Melo et al. (2014) examined regulatory harmonization in a range of SPS and quality (SPSQ) measures (including MRLs) on Chilean fresh fruit exports in 16 destination markets based on the number of regulations and exporters perception of the stringency of SPSQ measures over 2005-09. However, their research design, methodology and country focus are completely different from ours.

The papers closest to ours are Winchester et al. (2012) and Drogué and DeMaria (2012).

Winchester et al. (2012) study the impact of regulatory heterogeneity on the EU's agri-food export intensity in the year 2009-10 by using the NTM -Impact database that was assembled under a European research framework programme. Their results indicate that differences in most regulations weakly reduce trade, but that stricter MRLs for plant products in one country relative to others reduces exports to that country. Unlike Winchester et al. (2012), we only focus on MRLs in pesticides in our paper but this enables us to include more products and trading partners and also give a panel dimension to our analysis, which is also conducted at both margins of trade.

Drogué and DeMaria (2012) construct an alternative index of regulatory heterogeneity in MRLs (following that in Vigani et al., 2010) to examine its effect on bilateral export intensity of fresh and processed apples and pears among 40 trading partners over 2000-09. Once again, our paper is different from theirs along several dimensions – sample, heterogeneity index and treatment of margins of trade.

Finally, a contemporaneous paper by Ferro et al. (2013) uses the same data on pesticide MRLs as ours to study the effects of standards restrictiveness on agri-exports in importing countries over 2006-11. Like us, the authors find more restrictive standards in the destination market to advsersely affect the probability of exporting, but unlike us, they do not consider the case where the exporting country has more stringent regulation. Our heterogeneity index is also different from their measure of standards restrictiveness.

Since one original contribution of this paper is our use of two measures of regulatory heterogeneity, we devote the next section to describing how we construct our measures and to contrasting them with the other measures used in the reviewed literature.

3 Measures of MRL regulation heterogeneity

Drogué and DeMaria (2012) use a similarity index based on the Pearson correlation coefficient which is the covariance of two random variables divided by the product of their standard deviations. The Pearson correlation coefficient is then subtracted from 1 to create the "respective distance" ranging between 0 (very similar) and 2 (very different). This approach however speaks only of the linear relationship between the two MRL regulations and does not consider differences in levels: two countries might have perfectly collinear regulation but at different levels, thus having a similarity index of 0 and yet be very different in terms of stringency.

Moreover, the Pearson correlation coefficient could be sensitive to outliers (which Drogué and DeMaria (2012) remove by fixing a maximum level in their data for MRLs) and to skewness of the random variables[2], which is a problem since the distribution of MRL regulation are highly positively (right) skewed. Furthermore, they do not distinguish the effect that heterogeneity of regulation can have depending on whether it is the importer or the exporter that is stricter. In other words, they assume that all dissimilarity implies compliance, even when exporting to a less stringent market than your own. Their results foreshadow a probable need to differentiate as they don't find that "regulatory distance does not *per se* impede trade. The values of the marginal effects of the interaction term between the similarity index and the exporting countries fixed effects are more ambiguous" (Drogué and DeMaria, 2012).

The heterogeneity index in Winchester et al. (2012) is based on the Gower index of similarity[3] which has three particularities : *i)* the dissimilarity measure is scaled by the maximum dissimilarity between all countries considered; *ii)* it assumes that compliance costs arise even when the exporter has stricter standards; and *iii)* it allows for the comparison of binary, ordered and quantitative measures. The third point is interesting for their paper since they consider multiple standards (not only MRLs) which are not quantitatively measured like

[2] Kowalski (1972)
[3] Gower (1971)

MRLs. The two former points however, make their index uninteresting for our approach; we see no reason for scaling the bilateral dissimilarity by the largest possible dissimilarity across countries since it confuses the interpretation of results in our opinion, and we believe that heterogeneity has asymmetric effects on trade depending on which of the trading partners is stricter.

Burnquist et al. (2011) build on Winchester et al. (2012) by introducing a modified version of their Heterogeneity Index of Trade with an Actual Heterogeneity Index which only considers cases in which the importer is stricter. In other words, to deal with the criticism that the dissimilarity might not produce compliance costs for stringent exporters they set the index at 0 (very similar).

The index in Achterbosch et al. (2009) is constructed by taking the difference in MRL regulation and normalizing it through the division of the sum of the levels in both countries. Following Achterbosch et al. (2009), we construct a heterogeneity index of MRLs as follows:

$$r_{ijpkt} = \frac{MRL_{jpkt} - MRL_{ipkt}}{MRL_{jpkt} + MRL_{ipkt}} \tag{1}$$

The index, r, measures the degree of heterogeneity of MRL regulation between importer i and exporter j, regarding the maximum residue level of pesticide k allowed to remain on product p. The value of the index ranges between -1 and 1, where $r = 0$ indicates that for the same pesticide and crop, the importer and exporter have equal MRLs and there is therefore no heterogeneity.

Negative values of the index imply that for the country-pair product-pesticide combination, the exporter is stricter than the importer. The opposite is true when the index value is positive (see Figure 1). Because the main concern about these sanitary measures is that they create significant compliance costs for exporting countries irrespective of the source of such costs, we will test this claim by separating the index into two indices: f and m, the former corresponding to heterogeneity emanating from cases in which the importer has more stringent regulation, and the latter to cases in which the exporter is more stringent.

$$f_{ijpkt} = \begin{cases} \frac{MRL_{jpkt} - MRL_{ipkt}}{MRL_{jpkt} + MRL_{ipkt}} & \text{if } MRL_{jpkt} > MRL_{ipkt} \\ 0 & \text{otherwise} \end{cases} \tag{2}$$

$$m_{ijpkt} = \begin{cases} \frac{MRL_{jpkt} - MRL_{ipkt}}{MRL_{jpkt} + MRL_{ipkt}} & \text{if } MRL_{jpkt} < MRL_{ipkt} \\ 0 & \text{otherwise} \end{cases} \quad (3)$$

The value of f is positive (importer more restrictive) or zero, while that of m is negative (exporter more restrictive) or zero. This distinguishes us from the approach of simply ignoring heterogeneity when the exporter is stricter (Burnquist et al., 2011) and from the approach that heterogeneity always imposes compliance costs (Achterbosch et al., 2009; Drogué and DeMaria, 2012; Winchester et al., 2012).

If we consider our index F, a strong negative effect at the extensive margin suggests that having dissimilar MRL regulations between countries is a fixed cost that producers have to overcome before being able to export towards a more stringent destination. The same effect at the intensive margin suggests that the costs of complying with different MRL regulations is variable and increases with the value of exports. Literature suggests that harmonization initiatives affect both fixed and variable costs (Baldwin et al., 2000; Chen and Mattoo, 2008).

On the other hand, the positive effect of standards could be due to an increased demand in the destination market thanks to the positive signalling of strict standards, or due to more efficient and productive techniques used in markets where regulations are stricter[4]. We thus examine the potential asymmetric impact of regulatory heterogeneity between exports from stringent countries and imports into stringent ones.

A few cases must be noted. Not all countries set MRLs for the same pesticide/crop combination; it can therefore be the case that the importer country sets an MRL for a k, p pair for which the exporting country has not set a limit and we would therefore have to drop this observation as no comparison is possible. To minimize this from happening, and without imputing values arbitrarily, we resort to *default MRL values*[5]. Some countries set default MRLs for any k, p combination that is not explicitly cited in their MRL regulation, such as the EU that sets an MRL of 0.01 mg/kg for any pesticide on any crop that is not listed in the European Commission Regulation No 396/2005. Another example is Egypt since it has three levels of "default": if no national MRL exists, the Codex MRL for the same crop-pesticide applies, if that is also missing, then the EU harmonized MRL holds, and finally if even that is missing, the default 0.01 mg/kg applies.

[4] Xiong and Beghin (2012) find that Canadian exports benefit from having MRL regulation stricter than the international standard, Codex. Portugal-Perez (2012) et al. also find this result for exports from China.

[5] Drogué and DeMaria (2012) also resort to default values, and to the best of our knoweldge they are the only ones doing so apart from us.

Table 1 summarizes the pertinent default MRL cases. Thus, in cases where one of the partner countries was missing the MRL, we resort to the missing country's default value (if any) to compute the heterogeneity index. If the importer has an MRL and the exporter does not, and has no default MRL in place either, we impute $f_{ijpkt} = 1$ and $m_{ijpkt} = 0$[6]. We in fact assume that the exporter is being more lenient since not only does it have no regulation, but no default one either[7].

<Insert Table 1 here>

Just as in Achterbosh et. al. (2009), we proceed to aggregating the index for each product by constructing the following, where K is the total number of pesticides for which there is an MRL on product p:

$$F_{ijpt} = \frac{1}{K} \sum_{k=1}^{K} f_{ijpkt} \tag{4}$$

$$M_{ijpt} = \frac{1}{K} \sum_{k=1}^{K} m_{ijpkt} \tag{5}$$

4 Estimating trade flows

Our empirical analysis is conducted in the framework of the gravity model as laid down by Anderson (1979) which is based on identical consumer preferences modelled by Constant Elasticity of Substitution (CES) utility functions and with Armington assumption of preference for domestically produced goods. Following Anderson and van Wincoop (2004), the value of exports from country j to country i of product p can be written as follows:

$$X_{ij}^{p} = \frac{E_i^p Y_j^p}{Y^p} \left(\frac{T_{ij}^p}{P_i^p \Pi_j^p} \right)^{(1-\sigma^p)}, \tag{6}$$

[6] We impute $f_{ijpkt} = 0$ and $m_{ijpkt} = -1$ when the importer is missing an MRL that the exporter has set.

[7] Winchester et al. (2012) also assume that the lack of regulation that exists elsewhere is considered to be less stringent a regulation. Drogué and DeMaria (2012) also assume that the lack of MRL is due to the exemption of the substance-product combination by the country and thus they arbitrarily impute the missing MRL with 75 mg/kg, a level that corresponds to the highest MRL in their dataset. Ferro et al. (2013) replace missing MRLs with the maximum MRL for the concerned product across countries in their sample at any point of time. Thus, they also associate absence of regulation to leniency.

where X_{ij}^p denotes the value of exports, E_i^p are the expenditure in the destination country i of product p, Y_j^p denotes the total sales of exporter j towards all destinations, Y^p is the total world output of product p, T_{ij} are the iceberg transport costs and σ^p is the elasticity of substitution across products. Multilateral Resistance Terms (MRTs) are the inward and outward relative resistance of a country's exports towards *all* destinations and from *all* origins and are represented by P_i^p and Π_j^p[8]. Because these terms are difficult to construct directly as national price indices are needed, applications of the gravity model have resorted to using dummy variables to control for them instead. At the sectoral level, time-varying importer-product and exporter-product fixed effects control for the MRTs (Anderson and Yotov, 2012).

We proxy transport costs by bilateral distance between trading partners, $ln(Dist_{ij})$, as well as the usual gravity model controls which include dummy variables identifying whether the trading partners share a border, $Contig_{ij}$, had a colonial relationship, $Colony_{ij}$, share a common language, $ComLang_{ij}$, and whether they were ever part of the same country, $Smctry_{ij}$.

Introducing tariffs, τ_{ijpt}, membership of trade agreements, PTA_{ijt}, and our variables of interest, F_{ijpt} and M_{ijpt} as additional determinants of trade, substituting the MRTs with the appropriate fixed effects, adding the proxies for transport costs and taking the logarithm of this transformed version of equation (6) yields the following[9]:

$$ln(X_{ijpt}) = \beta_1 F_{ijpt} + \beta_2 M_{ijpt} + \beta_3 ln(1+\tau_{ijpt}) + \beta_4 ln(Dist_{ij}) + \beta_5 Contig_{ij} + \beta_6 ComLang_{ij} + \beta_7 Smctry_{ij} + \beta_8 PTA_{ijt} + \mu_{ipt} + \mu_{jpt} + \epsilon_{ijpt} \quad (7)$$

where μ_{ipt} and μ_{jpt} are the fixed effects that proxy the MRTs.

4.1 Estimation issues

Estimating equation (7) using an OLS estimator would result in biased results due to the large frequency of zeroes in the dependent variable, X_{ijpt}. This is because even if the model allows for all countries to export everywhere, this is obviously not the case, especially when dealing with product-level bilateral trade data as in our case. In fact, in the agricultural trade sample we focus on, X_{ijpt} is equal to 0 in 86% of all observations (details in sub-section 4.2). Dropping the observations with zero trade would bias the results and thus we turn to

[8] The MRTs are derived theoretically in Anderson and Van Wincoop (2003).

[9] The notation, regarding the subscripts, is slightly modified hereinafter to accommodate the time dimension, t.

the Heckman two-step estimation method proposed by Helpman et al. (2008) which involves controlling for the probability of the export-line $ijpt$ to be non-zero before estimating the coefficients of equation (7)[10].

The Heckman two-step estimation involves running a Probit in stage one ("selection equation"), with a dichotomous variable identifying non-zero exports between country i and j of product p at time t as dependent variable, and our MRL heterogeneity indices along with the standard controls explained above. From this first step estimation or selection equation, we construct the Inverse Mills Ratio[11] (IMR), $\eta(\mathbf{x}\hat{\beta})$, from the fitted values of our dependent variable. By including $\eta(\mathbf{x}\hat{\beta})$ in the outcome equation (7), η_{ijpt}, we effectively control for the probability of having positive trade flows (Helpman et al., 2008). In other words, we correct for the selection bias that would have been present in our coefficients had we dropped observations with zero trade.

Stage two of the Heckman ("outcome equation") is an OLS with the natural logarithm of exports as dependent variable on the same set of control variables as in stage one with the exclusion of at least one variable that should ideally affect trade only at the extensive margin[12]. In the spirit of Chen and Mattoo (2008), our selection variable is a dummy identifying whether exports were non-zero five years ago[13]. Araujo et al. (2012) however question the validity of this variable as an exclusion condition as they find that exporters will trade larger amounts and for longer periods of time with partners with whom they have already had a successful match because the quality of the institutions that enforce commercial contracts is revealed to exporters. Our sample, however, makes this issue less important since most of the importers in our sample are developed countries and exporters have a clear idea of the type of contractual enforcement they will find in the importing country.

The use of fixed effects in Probit estimations has come under intense scrutiny due to the

[10] We could not resort to the Pseudo-Maximum Likelihood estimator proposed by Silva and Tenreyro (2006) due to the very large number of fixed effects *ipt* and *jpt* in estimation that led to non-convergence.

[11] $\eta(\mathbf{x}\hat{\beta}) = \frac{\phi(\mathbf{x}\hat{\beta})}{\Phi(\mathbf{x}\hat{\beta})}$, where $\phi(\cdot)$ and $\Phi(\cdot)$ are the standard normal density function and the standard normal cumulative function, respectively.

[12] In order to correctly identify the selection equation of the Heckman estimation, the selection equation must have additional explanatory variables than the outcome equation. These explanatory variables must satisfy the criterion that they affect the probability of having positive exports (therefore setting up a trading relationship) but that once the relationship has been set, the volume/value of exports is not affected.

[13] Helpman et al. (2008) propose using common religion between trading partners as a proxy for the costs of regulation as a selection variable in the first step. Although the majority of papers use common religion as an exclusion variable because data on it are easily-collected and Helpman et al. (2008) vouch for it with country-level data, it is hard to imagine how common religion between two countries can realistically affect the fixed cost of establishing a trading relationship when using disaggregated product data such as ours. We therefore use past exporting experience, in the same way that Chen and Mattoo (2008) do. This said, we also used common religion as a robustness check and found weaker but consistent results.

problem of incidental parameters. Incidental parameters are nuisance (not of primary interest) parameters whose number increase as the sample size increases[14] and which bias estimates of coefficients derived from non-linear estimations, such as the Probit. Using a Linear Probability model, estimated with OLS instead of a Probit, when the explanatory variable matrix contains dummy variables for mutually exclusive and exhaustive categories is equivalent and yields estimated probabilities within the unit interval[15]. We do not have a perfectly saturated model, but as Wooldridge (2010) reiterates, because we care about the partial effect of the explanatory variables on the response probability on average across the explanatory variables, then even if some estimated probabilities lie outside the unit interval it is not so important. We therefore resort to the LPM for stage one of the Heckman estimator.

Formally, we have the following empirical specifications:

Selection equation:

$$Pr(X_{ijpt} > 0) = \alpha_0 + \alpha_1 F_{ijpt} + \alpha_2 M_{ijpt} + \alpha_3 ln(1 + \tau_{ijpt}) + \alpha_4 ln(Dist_{ij}) + \alpha_5 Contig_{ij} + \alpha_6 ComLang_{ij} + \alpha_7 Smctry_{ij} + \alpha_8 PTA_{ijt} + \alpha_9 X_{ijp,t-5} + \mu_{ipt} + \mu_{jpt} + \epsilon_{ijpt}$$

Outcome equation:

$$ln(X_{ijpt}|X_{ijpt} > 0) = \beta_1 F_{ijpt} + \beta_2 M_{ijpt} + \beta_3 ln(1 + \tau_{ijpt}) + \beta_4 ln(Dist_{ij}) + \beta_5 Contig_{ij} + \beta_6 ComLang_{ij} + \beta_7 Smctry_{ij} + \beta_8 PTA_{ijt} + \eta_{ijpt} + \mu_{ipt} + \mu_{jpt} + \epsilon_{ijpt}$$

Because of the very large number of fixed effects that we include to control for multilateral resistance terms, we resort to a novel estimation method proposed and coded[16] by Guimaraes and Portugal (2010)[17] that makes use of a full Gauss–Seidel algorithm - the 2WFE estimator. The main advantage of using this "zig-zag" algorithm is that it reduces the amount of RAM needed since it partitions the calculation of the OLS estimator[18] in a way that avoids calculating $(X'X)^{-1}$ which becomes extremely large when high-dimensional fixed effects are included.

Finally, there may be concerns about endogeneity in our estimating equations. In Foletti (2014), it is argued that the level and stringency of MRLs does not depend solely on scientific

[14] Lancaster (2000)

[15] Wooldridge (2010)

[16] reg2hdfe in STATA

[17] Paulo Guimaraes and Pedro Portugal. "A Simple Feasible Alternative Procedure to Estimate Models with High-Dimensional Fixed Effects", Stata Journal, 10(4), 628-649, 2010.

[18] $\hat{\beta} = (X'X)^{-1}X'Y$

and health concerns regarding the pesticide but also on economic and political determinants. In fact, the author finds strong evidence that agro-chemical industries have an influence on the setting of these residue limits since when the pesticide is produced domestically, the regulation is more lenient. Looking for evidence of protection of agriculture products through MRLs, Foletti (2014) empirically tests the Protection for Sale (Grossman and Helpman, 1994) model using MRLs as a proxy for protection instead of tariffs. She finds very weak evidence for MRL levels being determined by import penetration, thus negating the concern about the indices F_{ijpt} and M_{ijpt} being endogenous.

4.2 Data

We use data on MRL regulation covering the period between 2006 and 2012 in Argentina, Australia, Brazil, Canada, Chile, China, Colombia, Egypt, India, Israel, Japan, Korea, Mexico, Malaysia, Norway, New Zealand, Russia, Singapore, South Africa, Switzerland, Thailand, Turkey, Taiwan, Ukraine, USA and the EU-27 members[19]. We only include those countries in our analyses that set MRL regulation independently. The data on MRL regulation were acquired from a private company, Homologa, that updates MRL regulation from these countries on a monthly basis. The data are intended mainly for agricultural producers wishing to export their crops.

However, the richness of the data received from Homologa that covers 243 products could not be fully exploited because a large amount of crops are too specific compared to Harmonized System (HS) 6-level data. To enable an empirical trade analysis of these MRLs, it becomes impossible to use these specific observations since they would introduce MRL variation within the HS code that cannot be matched by trade variables. We therefore only keep those crops specified in Homologa that were either a perfect match (e.g. avocados are listed separately in Homologa and have the HS code 080440), broader than the HS 6 category (e.g. Brassicas, for which we proceeded to apply the MRL to all HS codes that had this description) and in very few cases, we took the average of no more than two crops listed within the HS code (e.g. plantains and bananas)[20]. In view of these limitations, we could only include 118 of the 243 Homologa products in our analyses.

Creating the indices meant creating comparisons at the pesticide-product level between importers and exporters and a main challenge was the diversely named pesticide active in-

[19] In our data, EU-27 includes 25 countries because Belgium and Luxembourg are merged into one in the BACI database and there were no data for Romania

[20] These last exceptions were made considering the economic importance of these crops.

gredients present in cross-country regulation. For this purpose, the names were matched to their CAS[21] number, which is an international nomenclature to identify chemicals. We matched 1,193 pesticides with their respective CAS number out of the overall 1,426 pesticides regulated.

We conduct our analyses at the product level, focusing on trade in HS Chapters 7 to 12 over 2006-12 at level 6 of disaggregation; these HS Chapters correspond to the agriculture and non-processed food sectors where pesticide MRLs are relevant. These sectors accounted for approximately 17% of the 691 agricultural products included in the WTO Agriculture Agreement. The list of HS codes is reported in Tables 2 and 3.

<Insert Tables 2 and 3 here>

Export data come from the BACI database, which is constructed from UN COMTRADE trade data after reconciling exporter and importer declarations and thus expanding the availability of bilateral trade data. BACI is available at the HS6 level and records exports per USD thousands, in current prices. The bilateral variables distance, common border and colonial relationship are also taken from BACI.

Descriptive statistics are provided in Table 4. The full sample has more than 2.4 mn observations but export value is positive for only 14% of these. For both the "full" and the "restricted" sample (the latter only comprises those countries that actually set MRL regulations or use a default value and for which we do not need to impute values), the mean value of F_{ijpt} is larger than that of M_{ijpt} (in absolute terms), which suggests that the relative magnitude of importer stringency exceeds that of exporter stringency. This finding can also be explained by our data set, which is dominated by OECD countries, where the MRL values are typically lower, so that the construction of m_{ijpkt} would result in a lot more zero values compared to that of f_{ijpkt}.

<Insert Table 4 here>

The mean values of F_{ijpt} and M_{ijpt} by country averaged over 2006-2012 are shown in Figures 2 and 3, respectively. Figure 2 shows that USA, Australia and Japan are the strictest importers (on average) relative to their exporters. Thus, developed countries (USA, Australia, Japan) exhibit larger magnitudes of relative importer stringency compared to the developing

[21] Chemical Abstracts Service, a division of the American Chemical Society that has as objective the collection and organization of information on chemical substances worldwide.

world (Colombia, Chile, Singapore, India). Figure 3 shows that Mexico, Malaysia, China, and Taiwan are the four strictest exporters in our sample (on average) relative to their importers. Thus, when it comes to the magnitude of relative exporter stringency (Figure 3), the distribution is more even - Mexico, Malaysia, China, Taiwan exhibit the largest relative exporter stringency; Egypt, Argentina, Greece, Portugal show the smallest relative exporter stringency; and Germany, Austria, Netherlands, Australia, USA, and Japan lie in the middle.

<Insert Figures 2 and 3 here>

Figure 4 shows the average number of pesticides regulated per product in each country at two points in time (2006, 2012). Figure 4 reveals that developed countries (EU, Switzerland) regulate a much larger number of pesticides per product and even though there have been significant changes within the overall distribution, the broad picture is fairly constant over time, with developing countries regulating far fewer pesticides per product. Figure 5, which shows the average number of products for which MRLs are set in each country (again across 2006, 2012), reveals the same pattern. Thus, developed countries are also far more active in setting pesticides standards.

<Insert Figures 4 and 5 here>

5 Results and analysis

Columns (1) and (2) of Table 5 report the results of the Heckman two-step estimations of our baseline specification. All estimations include time-varying importer-product and exporter-product fixed effects to control for multilateral resistance. Standard errors are clustered by trading partner pair.

We find that MRL heterogeneity decreases the probability of having positive exports when the importer is stricter than the exporter implying compliance costs imposed on exporters. No significant effect appears at the intensive margin. On the other hand, greater difference of MRLs between trading partners increases the value of exports when the exporters have to comply with stricter regulations in their domestic market. Thus, stringency in exporter market is positively correlated with the value of exports. This is a hitherto unexplored result for as large a sample of exporting and importing countries as ours.

The coefficients on the gravity control variables are consistent with existing gravity estimates. Countries with a common language or membership of a trade accord or which are adjacent to each other have higher probabilities of exporting to each other and also export larger values. Distance is found to reduce both the probability of trading and the value of trade between partners. We also find higher tariffs to reduce exports, both at the intensive and extensive margins, which is an expected result.

The exclusion variable, $X_{ijp,t-5}$, in the selection equation and the inverse mills ratio, η_{ijpt}, in the outcome equation, are both found to be statistically significant.

<Insert Table 5 here>

5.1 Sensitivity analysis

We made some assumptions about the data regarding missing MRLs that can be tested by relaxing the assumptions and running the same econometric analysis as a robustness check.

When constructing the two indices of heterogeneity, F_{ijpt} and M_{ijpt}, we needed data on both importer and exporter MRLs and when one of them was missing we took various steps to ensure using the most data possible, without compromising the information in the data. The first assumption was the use of default MRLs to fill in missing MRLs when the country in question had a known default MRL (like the European Union with a default of MRL equal to 0.01 mg/kg for any pesticide that is not regulated by the EU). The second assumption made regarding those MRLs that were still missing was that if the country in question had no default MRL as well, then not having an MRL was equivalent to being more lenient with respect to the partner country that did set an MRL.

To test these assumptions and provide a robustness check, while constructing F_{ijpt} and M_{ijpt} we stopped at the first assumption, and avoided imputing 1, and -1, for the f_{ijkpt}, and m_{ijkpt}, respectively, according to the second assumption. Columns (3) and (4) of Table 5 show the results from estimations when using this "restricted" sample. Although magnitudes of the coefficients of F_{ijpt} and M_{ijpt} are lower, qualitatively the results are robust to removing the imputations mentioned above.

Finally, we also estimated our selection and outcome equations for both the full and restricted samples using an alternative exclusion variable: a dummy identifying whether exports were non-zero in the preceding year. These results, reported in Table 6, were qualitatively similar to those reported in Table 5 and even more statistically significant in the case of the restricted sample.

<Insert Table 6 here>

6 Conclusion

Using two measures of MRL heterogeneity that, departing from existing literature, also include cases when the exporting country is stricter compared to the importing country, we have identified the effect that dissimilarity in MRL regulation can have on bilateral trade.

We find some evidence that regulatory heterogeneity in MRL regulation is detrimental to trade. This result is precisely estimated at the extensive margin when the regulation in the destination market is stricter. Thus, trade between countries that actively invest in regulating pesticide residues is hurt by compliance costs of achieving lower levels of residues to comply with stricter destination-market regulation. This result is in line with the work of others Drogué and DeMaria (2012), Achterbosch et al. (2009), Burnquist et al. (2011).

A novel result, and a pertinent contribution to the empirical literature on the trade effects of harmonization of sanitary measures, is the strong evidence that heterogeneity in regulation is beneficial to exporters setting stricter standards than the trading partner. The result is robust to changes in the construction of the heterogeneity index.

Having strong heterogeneity in regulations and standards between trading partners induces additional costs on both exporting firms and public institutions that have to provide the support for the exporting sector as well as leading to the use of financial resources to negotiate and resolve probable trade disputes. Our analysis however provides an answer as to why some countries might prefer to remain relatively stricter than the rest, including international standards: their exports are boosted by signalling higher-quality more efficient products emanating from the stricter standards.

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Figure 1: Illustration of the heterogeneity indices

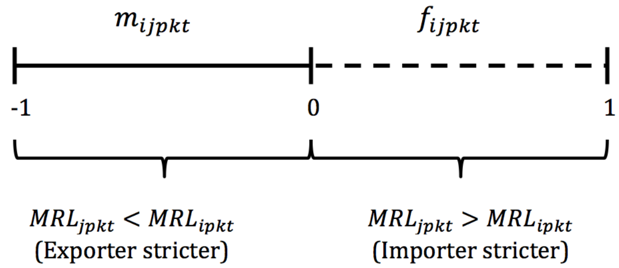


Figure 2: Mean F_{ijpt}

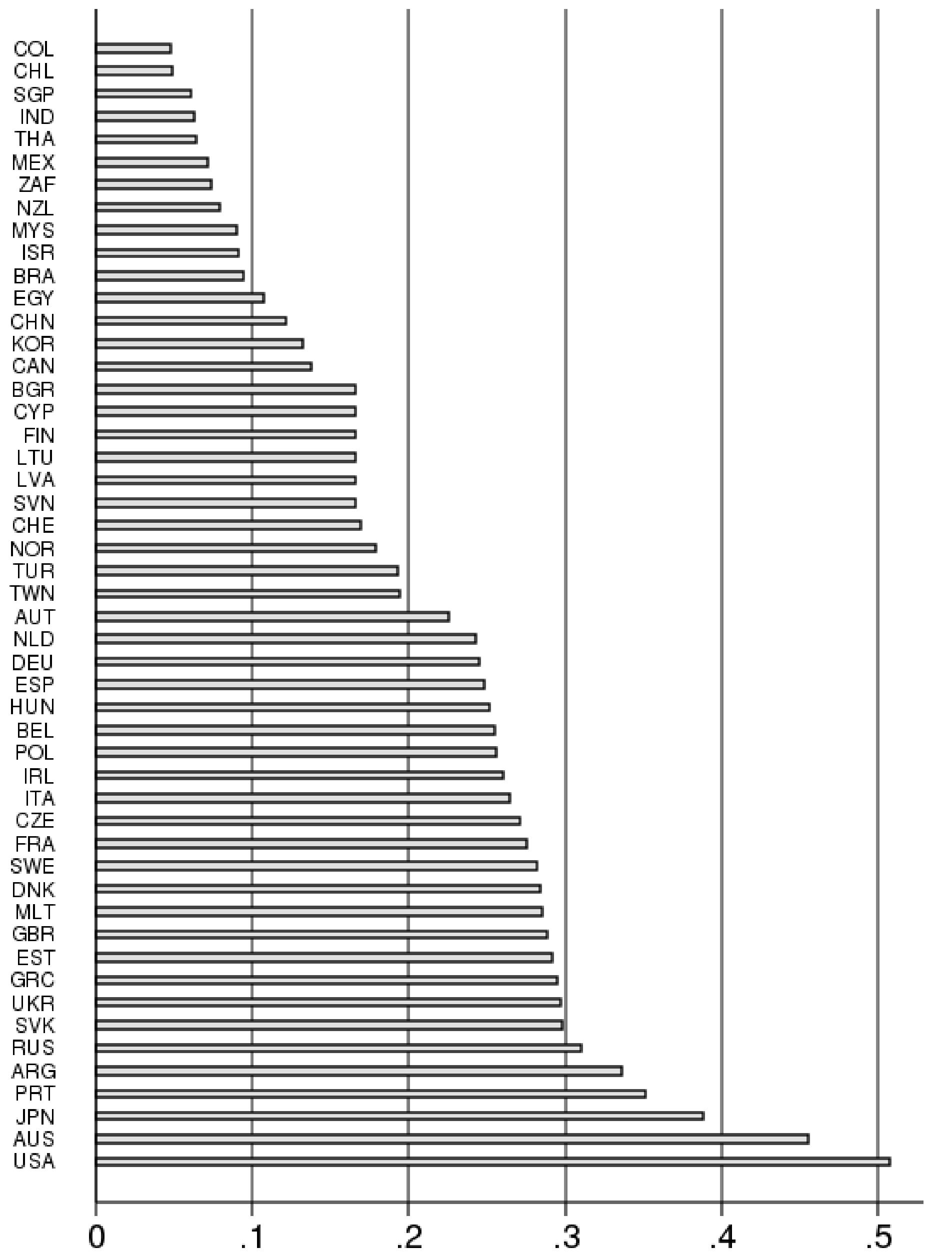


Figure 3: Mean M_{ijpt}

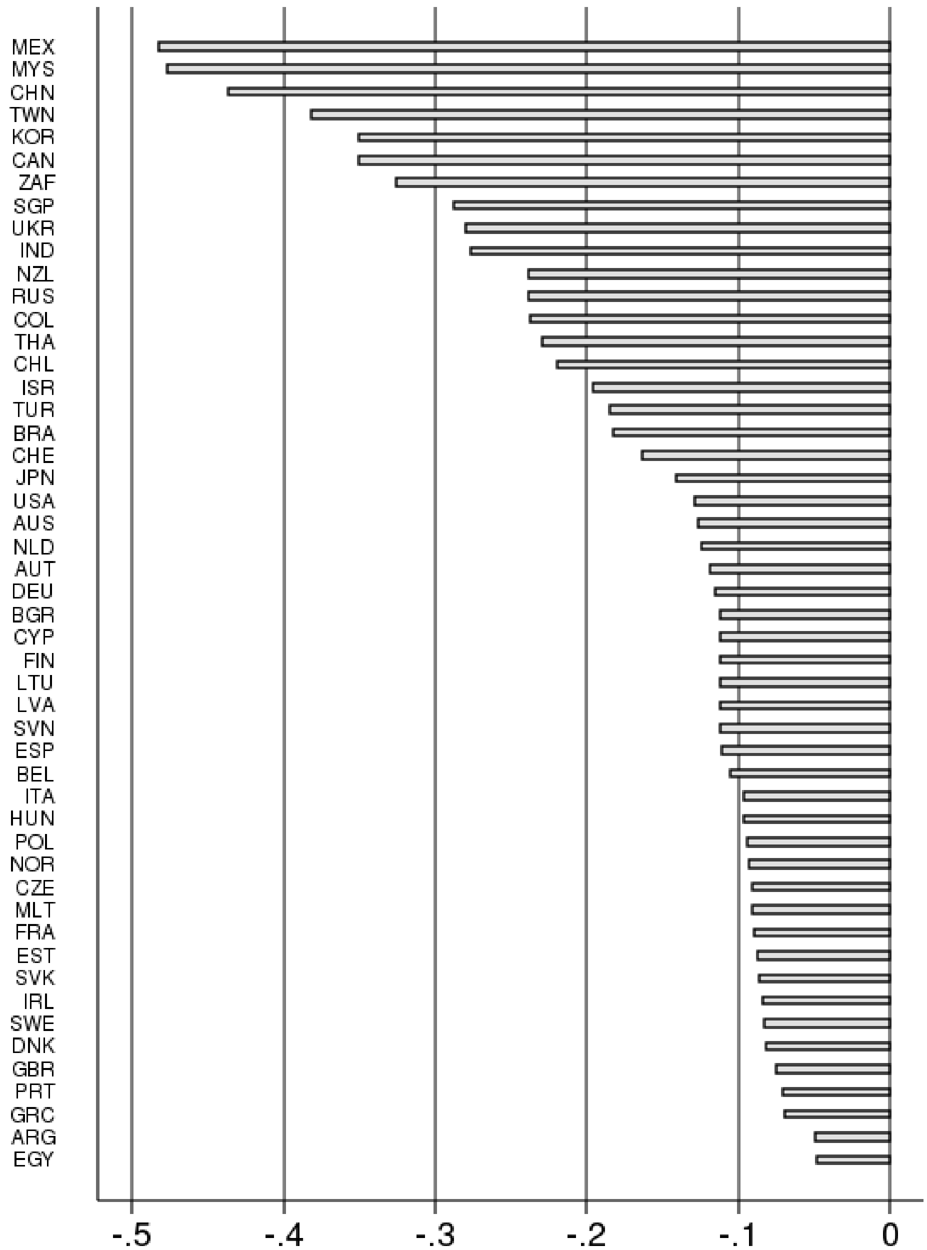
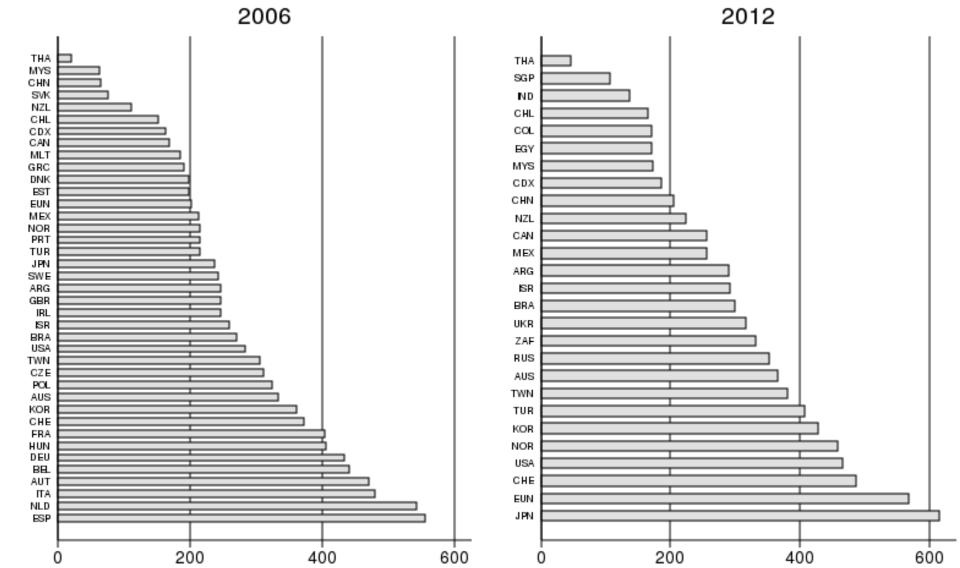
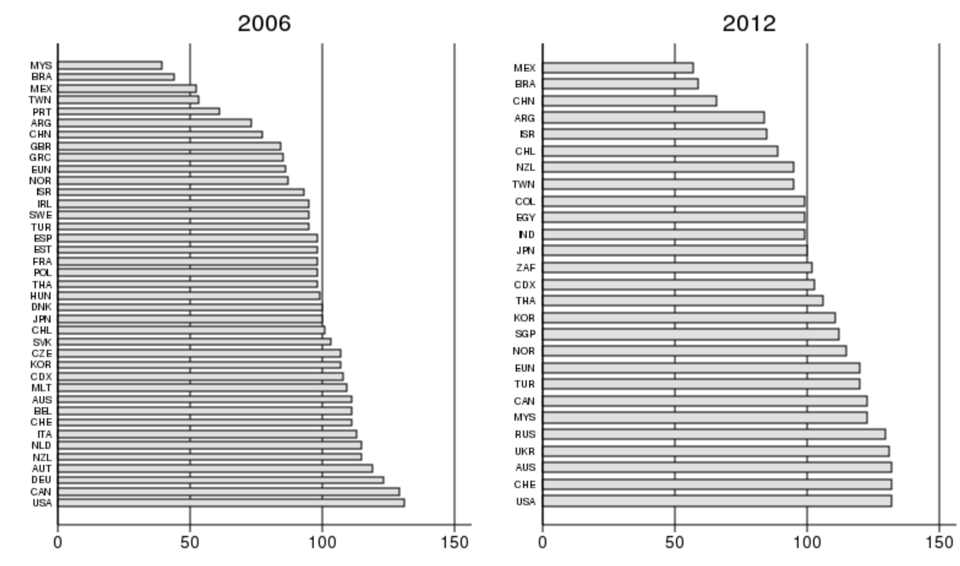


Figure 4: Average number of pesticides regulated per product in each country



Source: Authors' calculations based on data on MRL regulation from Homologa, S.A.

Figure 5: Average number of products for which MRLs are set in each country



Only products with Harmonizeed System concordance included in this paper.
From 2009 all EU members have harmonized MRL regulation thus they appear as one observation in the right panel
Source: Authors' calculations based on data on MRL regulation from Homologa, S.A.

Table 1: Many countries use Codex MRLs as default values if national regulation is missing

Country	First Default	Second Default	Third Default
European Union	0.01		
Argentina	Codex	0.01	
Australia	0.01		
Brazil	Codex		
Canada[a]	0.01		
Egypt	Codex	EU	0.01
India	Codex		
Israel	Codex		
Japan	0.01		
New Zealand	Codex		
Singapore	Codex		
South Africa	Codex	EU	
Thailand	Codex		
USA[b]	LOD[c]	0.01	

Default MRL information from mrldatabase.com (US FDA) except otherwise stated.
[a]Health Canada Information note “Information Note: Progress on Minimizing Reliance on the 0.1 Parts per Million as a General Maximum Residue Limit for Food Pesticide Residue”, 2010.
[b]"When no Limit of Determination is present in the data, we use 0.01 mg/kg as the LOD since it is the most common level at which pesticides are detected." Pesticide Monitoring Program, 2009 Pesticide Report, US FDA.

[c]Limit of Determination

Table 2: Agricultural products included in the sample

HS070190 Other potatoes fresh or chilled	HS081090 Other fruit fresh nes
HS070200 Tomatoes fresh or chilled	HS081310 Dried apricots
HS070310 Onions and shallots fresh or chilled	HS081330 Dried apples
HS070320 Garlic fresh or chilled	HS081340 Other dried fruit nes
HS070390 Leeks and other alliaceous vegetables nes	HS090111 Coffee not roasted or decaffeinated
HS070410 Cauliflowers and headed broccoli fresh or chil	HS090121 Roasted coffee not decaffeinated
HS070420 Brussels sprouts fresh or chilled	HS090230 Black tea (fermented) and partly fermented tea
HS070490 White and red cabbages kohlrabi kaleetc f	HS090300 Mate
HS070511 Cabbage lettuce fresh or chilled	HS090500 Vanilla
HS070521 Witloof chicory fresh or chilled	HS090610 Cinnamon and cinnamon-tree flowers neither cru
HS070610 Carrots and turnips fresh or chilled	HS090700 Cloves (whole fruit cloves and stems)
HS070690 Beetrootradishes and other similar edible ro	HS090810 Nutmeg
HS070700 Cucumbers and gherkins fresh or chilled	HS090820 Mace
HS070810 Peas fresh or chilled	HS090830 Cardamoms
HS070820 Beans fresh or chilled	HS090910 Seeds of anise or badian
HS070910 Globe artichokes fresh or chilled	HS090920 Seeds of coriander
HS070920 Asparagus fresh or chilled	HS090930 Seeds of cumin
HS070930 Aubergines fresh or chilled	HS090940 Seeds of caraway
HS070940 Celery fresh or chilled	HS090950 Seeds of fennel; juniper berries
HS070951 Mushrooms fresh or chilled	HS091010 Ginger
HS070952 Truffles fresh or chilled	HS091020 Saffron
HS070960 Fruits of genus Capiscum or Pimenta fresh or c	HS091030 Turmeric (curcuma)
HS070970 Spinach fresh or chilled	HS091040 Thyme bay leaves
HS070990 Other vegetables fresh or chilled nes	HS091091 Spice mixtures
HS071090 Mixtures of vegetables frozen	HS100110 Durum wheat
HS071130 Capers provisionally preserved not for immedia	HS100200 Rye
HS071220 Dried onions	HS100300 Barley
HS071310 Dried peas shelled	HS100400 Oats
HS071320 Dried chickpeas shelled	HS100510 Maize seed
HS071331 Dried beans shelled	HS100590 Maize (excl. seed)
HS071340 Dried lentils shelled	HS100610 Rice in the husk (paddy or rough)
HS071410 Manioc fresh or dried	HS100620 Husked (brown) rice
HS071420 Sweet potatoes fresh or dried	HS100630 Semi-milled or wholly milled rice
HS080110 Coconuts fresh or dried	HS100640 Broken rice

Table 3: Agricultural products included in the sample (contd.)

HS080120 Brazil nuts fresh or dried	HS100700 Grain sorghum
HS080130 Cashew nuts fresh or dried	HS100810 Buckwheat
HS080211 Almonds in shell fresh or dried	HS100820 Millet
HS080212 Almonds without shells fresh or dried	HS100830 Canary seed
HS080221 Hazlenuts in shell fresh or dried	HS100890 Other cereal nes
HS080222 Hazlenuts without shells fresh or dried	HS110100 Wheat or meslin flour
HS080232 Walnuts without shells fresh or dried	HS110210 Rye flour
HS080240 Chestnuts fresh or dried	HS110220 Maize (corn) flour
HS080250 Pistachio fresh or dried	HS110230 Rice flour
HS080290 Other nuts fresh or dried nes	HS110290 Other cereal flour nes
HS080300 Bananas including plantains fresh or dried	HS120100 Soya beans
HS080410 Dates fresh or dried	HS120210 Ground-nuts in shell not roasted or otherwise
HS080420 Figs fresh or dried	HS120300 Copra
HS080430 Pineapples fresh or dried	HS120400 Linseed
HS080440 Avocados fresh or dried	HS120500 Rape or colza seeds
HS080450 Guavas mangoes and mangosteens fresh or dried	HS120600 Sunflower seeds
HS080510 Oranges fresh or dried	HS120710 Palm nuts and kernels
HS080520 Mandarins clementines wilkingsetc fresh o	HS120720 Cotton seeds
HS080530 Lemons and limes fresh or dried	HS120730 Castor oil seeds
HS080540 Grapefruit fresh or dried	HS120740 Sesamum seeds
HS080590 Citrus fruit fresh or dried nes	HS120750 Mustard seeds
HS080610 Fresh grapes	HS120760 Safflower seeds
HS080620 Dried grapes	HS120791 Poppy seeds
HS080710 Melons and watermelons fresh	HS120792 Shea nuts (karite nuts)
HS080720 Papaws (papayas) fresh	HS120810 Soya bean flour and meal
HS080810 Apples fresh	HS120921 Lucerne (alfalfa) seed of a kind used for sowi
HS080820 Pears and quinces fresh	HS120926 Timothy grass seed of a kind used for sowing
HS080910 Apricots fresh	HS121120 Ginseng roots of a kind used in perfumery pha
HS080920 Cherries fresh	HS121291 Sugar beet fresh or dried
HS080930 Peaches including nectarines fresh	HS080940 Plums and sloes fresh
HS081010 Strawberries fresh	HS081020 Raspberries blackberries mulberries and logan
HS081030 Black white or red currants and gooseberries	HS081040 Cranberries milberries etc fresh

Table 4: Descriptive statistics

Full sample

Variable	Obs	Mean	Std. Dev.	Min	Max
Export value	341696	3424.89	64800.52	1	15200000
Export quantity	338921	6121.98	161633.70	0	26200000
F	2020023	0.47	0.41	0	1
M	1996287	-0.42	0.40	-1	0
Tariffs	2084607	10.90	34.86	0	800.3
Contiguity	2427535	0.04	0.19	0	1
Common language	2427535	0.12	0.32	0	1
Colony	2427535	0.03	0.17	0	1
Smctry	2427535	0.01	0.10	0	1
Distance	2427535	7089.93	4938.27	6.69	19747.4
PTA	2427535	0.40	0.49	0	1
lnX	341696	4.30	2.63	0	16.53
X_t	2427535	0.14	0.35	0	1
ln(distance)	2427535	8.46	1.10	1.90	9.89
X_{t-1}	2427535	0.14	0.35	0	1
X_{t-5}	2427535	0.13	0.33	0	1

Restricted sample

Variable	Obs	Mean	Std. Dev.	Min	Max
Export value	261799	3473.87	60749.72	1	11100000
Export quantity	259301	6411.24	163426.50	0	24100000
F	1839414	0.51	0.40	0	1
M	1773473	-0.35	0.36	-1	0
Tariffs	1617254	11.26	36.40	0	800.3
Contiguity	1839414	0.04	0.19	0	1
Common language	1839414	0.12	0.33	0	1
Colony	1839414	0.03	0.17	0	1
Smctry	1839414	0.01	0.10	0	1
Distance	1839414	7185.23	4864.44	59.62	19747.4
PTA	1839414	0.38	0.48	0	1
lnX	261799	4.36	2.64	0	16.22
X_t	1839414	0.14	0.35	0	1
ln(distance)	1839414	8.51	1.01	4.09	9.89
X_{t-1}	1839414	0.14	0.35	0	1
X_{t-5}	1839414	0.13	0.34	0	1

The restricted sample includes only those countries that actually set MRL regulation or use a default value so that we do not need to impute values.

Table 5: Exporters benefit from regulation heterogeneity when their country sets stricter standards than the destination country

	Full sample		Restricted sample	
	(1)	(2)	(3)	(4)
	$Pr(X_{ijpt}>0)$	$ln(X_{ijpt})$	$Pr(X_{ijpt}>0)$	$ln(X_{ijpt})$
F_{ijpt}	-0.013**	0.017	-0.010#	0.021
	(0.005)	(0.088)	(0.005)	(0.093)
M_{ijpt}	0.006	0.238**	0.006	0.211*
	(0.005)	(0.087)	(0.005)	(0.090)
$ln(1+\tau_{ijpt})$	-0.012***	-0.293***	-0.012***	-0.291***
	(0.001)	(0.029)	(0.001)	(0.030)
$ln(Dist_{ij})$	-0.048***	-0.597***	-0.048***	-0.606***
	(0.003)	(0.049)	(0.003)	(0.051)
$Contig_{ij}$	0.109***	0.672***	0.110***	0.675***
	(0.013)	(0.113)	(0.013)	(0.116)
$Colony_{ij}$	0.020#	0.095	0.016	0.090
	(0.010)	(0.124)	(0.010)	(0.128)
$Smctry_{ij}$	0.024	0.070	0.023	0.067
	(0.023)	(0.206)	(0.024)	(0.214)
$ComLang_{ij}$	0.014**	0.343***	0.014**	0.362***
	(0.005)	(0.091)	(0.005)	(0.094)
PTA_{ijt}	0.023***	0.299***	0.024***	0.326***
	(0.004)	(0.074)	(0.005)	(0.078)
X_{ijpt-5}	0.468***		0.472***	
	(0.004)		(0.004)	
η_{ijpt}		-3.136***		-3.141***
		(0.090)		(0.094)
N	1760000	262000	1600000	245000
r2	0.586	0.671	0.592	0.671
Fixed effects				
Importer-product-year	Yes	Yes	Yes	Yes
Exporter-product-year	Yes	Yes	Yes	Yes

Columns (3) and (4) use F_{ijpt} and M_{ijpt} constructed only with observations in which both importer and exporter had an explicit MRL or a default.
#p<0.1 *p<0.05 **p<0.01 ***p<0.001.

Robust standard errors, clustered by importer-exporter pair, included in parantheses.

Table 6: Qualitatively similar results with a different exclusion variable in the selection equation

	Full sample		Restricted sample	
	(1)	(2)	(3)	(4)
	$Pr(X_{ijpt}>0)$	$ln(X_{ijpt})$	$Pr(X_{ijpt}>0)$	$ln(X_{ijpt})$
F_{ijpt}	-0.010**	0.019	-0.008*	0.026
	(0.003)	(0.089)	(0.004)	(0.094)
M_{ijpt}	0.004	0.262**	0.004	0.235**
	(0.003)	(0.088)	(0.004)	(0.091)
$ln(1+\tau_{ijpt})$	-0.008***	-0.308***	-0.008***	-0.306***
	(0.001)	(0.029)	(0.001)	(0.030)
$ln(Dist_{ij})$	-0.034***	-0.645***	-0.034***	-0.653***
	(0.002)	(0.050)	(0.002)	(0.052)
$Contig_{ij}$	0.082***	0.767***	0.083***	0.770***
	(0.008)	(0.115)	(0.009)	(0.118)
$Colony_{ij}$	0.011#	0.121	0.009	0.116
	(0.007)	(0.126)	(0.007)	(0.130)
$Smctry_{ij}$	0.008	0.092	0.007	0.088
	(0.015)	(0.214)	(0.015)	(0.221)
$ComLang_{ij}$	0.011***	0.361***	0.011***	0.378***
	(0.003)	(0.093)	(0.003)	(0.096)
PTA_{ijt}	0.017***	0.325***	0.017***	0.356***
	(0.003)	(0.076)	(0.003)	(0.080)
X_{ijpt-1}	0.596***		0.598***	
	(0.004)		(0.004)	
η_{ijpt}		-2.949***		-2.975***
		(0.070)		(0.073)
N	1760000	262000	1600000	245000
r2	0.662	0.673	0.667	0.672
Fixed effects				
Importer-product-year	Yes	Yes	Yes	Yes
Exporter-product-year	Yes	Yes	Yes	Yes

The exclusion variable used in the selection equation is a dummy variable indicating non-zero exports in the preceding year. Columns (3) and (4) use F_{ijpt} and M_{ijpt} constructed only with observations in which both importer and exporter had an explicit MRL or a default.
#p<0.1 *p<0.05 **p<0.01 ***p<0.001.

Robust standard errors, clustered by importer-exporter pair, included in parantheses.