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The Impact of Regulatory Heterogeneity on Agri-food Trade

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1. INTRODUCTION

Import conditions for food products defined by technical standards continue to differ between countries despite international coordination and the development of multilateral regulations and common conformity assessments by international institutions. Typically, standards prescribe requirements for product characteristics, production processes and/or conformity assessment and are used to address information problems, market failure externalities, or may be motivated by political economy considerations (see, for example, Sykes, 1995; Josling et al., 2004). In the context of agri-food trade, they aim to ensure food safety, animal and plant health, but also extend to other quality and technical aspects of food products.

Owing to concerns over food safety and market access in international trade, food standards have attracted much attention recently (e.g. Disdier et al., 2008; Jongwanich, 2009; Liu and Yue, 2012; Xiong and Beghin, 2012). Key challenges in quantitative analyses relate to the accounting, measurement and comparability of standards because of their often complex definitions and diverse

We acknowledge the considerable effort in data collection by partners in the NTM-Impact project at twelve institutions – Instituto Nacional de Tecnologia Agricola (Argentina), University of Sydney (Australia), University of São Paulo (Brazil), Université Laval (Canada), Centre for Chinese Agricultural Policy (China), University of Bonn (Germany), Osaka University and Keio University (Japan), Agricultural Economics Research Institute (LEI) (Netherlands), University of Otago (New Zealand), Institute for Agricultural Market Studies (Russia) and Virginia Tech University (USA). We wish to thank John Beghin, David Orden and an anonymous referee for helpful comments and suggestions. Remaining errors are our responsibility.
impacts. In particular, little work has focused on the measurement of the dispersion of non-numerical standards across countries. A possible way forward is the comparison of regulatory heterogeneity across countries using an index framework that combines numerical and non-numerical data. Such an approach has been applied by Kox and Lejour (2005) and Kox and Nordås (2007) to analyse the trade impacts of differences in services legislation, by Vigani et al. (2009) to evaluate the impact of differences in regulations for genetically modified organisms and by Drogué and DeMaria (2011) to evaluate the impact of differences in pesticide residue standards for apples.

We contribute to the research on non-tariff measures (NTMs) in two ways. First, we compute a heterogeneity index of trade regulations (HIT) specific to bilateral flows and a variant that takes into account whether the heterogeneity arises from more stringent regulations in the importing country. These indexes are constructed from a new database documenting the standards used by the EU and nine of its trading partners. The data were collected as part of a European research framework programme project entitled ‘Assessment of the impacts of NTMs on the competitiveness of the EU and selected trade partners’, hereafter referred to as the ‘NTM-Impact’ project. The NTM-Impact database contains information on sanitary, phytosanitary and conformity measures in the EU (treated as one entity), Argentina, Australia, Brazil, Canada, China, Japan, New Zealand, Russia and the United States. Eleven representative HS 4-digit level animal and plant products are covered in the database. The HIT was defined by Rau et al. (2010) and combines numerical, ordered and binary data to measure differences in NTM requirements between these trading partners that prevailed during the data collection period. The HIT can be disaggregated into sub-indexes so as to focus on certain standards or measures.

Our second contribution is measurement of the impact of NTMs on bilateral trade in plant products. We introduce HIT sub-indexes for import requirements in a gravity equation to examine the trade impact of differences in regulations across countries while accounting for tariff barriers.

The rest of this paper has five sections. Section 2 describes the NTM-Impact database. The heterogeneity index is defined in Section 3. Descriptive statistics about the heterogeneity indexes used in our trade flow analysis are presented in Section 4. Section 5 rationalises our gravity specification and presents the econometric results from different estimators. Section 6 concludes and discusses policy implications.

2. NTM-IMPACT DATA

The NTM data were collected by international partners of the NTM-Impact project. The NTM-Impact database includes import requirements concerning
food safety, labelling, traceability and animal and plant health, and follows a common framework so as to make the different information content of import requirements comparable across countries. Shutes and Mraz (2011) provide a detailed description of the database. Import requirement categories identified in the database, as detailed in Table 1, include product requirement (e.g. maximum residue limits (MRL) for pesticides), process requirements (e.g. quarantine regulations), presentation requirements (e.g. labelling), conformity assessment requirements (e.g. exporter certification) and country-level requirements (e.g. requiring countries to be free of a certain disease).

The NTM-Impact database targets HS 4-digit commodities, but information on HS 6-digit commodities was collected when there were specific regulations for such commodities. The HS 4-digit commodities for which data were collected (with commodity codes in brackets) include beef (0201), pigmeat (0203), cheese (0404), potatoes (0701), tomatoes (0702), fresh vegetables (represented by eggplants) (0709), other vegetables (represented by sweet peppers) (0710), apples and pears (0808), barley (1003), maize (1005) and rape and colza seed (1205). These products are the most commonly traded (in value terms) products between the EU and the nine countries in the database. The time dimension is limited to a single period (2009–10) so the data provide should be interpreted as providing a snapshot of the regulatory regime across the countries at that time.

### Table 1

<table>
<thead>
<tr>
<th>Categories</th>
<th>Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product requirements/food safety limits</td>
<td>MRLs for pesticides, contaminants, microbial criteria and veterinary drugs</td>
</tr>
<tr>
<td>Process requirements</td>
<td>Hygiene, Quarantine, Treatments, Traceability</td>
</tr>
<tr>
<td>Presentation requirements</td>
<td>Labelling, Publicity/marketing</td>
</tr>
<tr>
<td>Conformity assessment requirements</td>
<td>Approved third countries, Approved businesses, Certification, Border inspection, Laboratories, sampling and analysis</td>
</tr>
<tr>
<td>Country-level requirements</td>
<td>Pre-export checks on equivalence, Equivalence agreement on control system, Monitoring hazards, Animal health control, Plant health control</td>
</tr>
</tbody>
</table>

Note:
(i) MRL, maximum residue limits; NTM, non-tariff measure.

Source: Rau et al. (2010).
The EU import requirements were taken as a reference point, and information for the corresponding import requirements in other countries in the sample was collected. In most cases, a requirement by one country applies to imports from all sources, but some measures with regard to animal and plant health are specific to exporting countries. Import requirements are expressed in a variety of formats. Table 2 presents examples of the different types of information available in the NTM-Impact database. Information may be binary (e.g. the importer regulates a particular substance and the exporter does not), ordered (from less stringent to most stringent) or quantitative (e.g. numerical values for MRLs). These classifications preserve the information content of each measure (e.g. a cardinal ranking of MRL regulations for a particular substance) rather than forcing all measures to fit a single data structure, which may result in a loss of information. In this way and due to its extensive coverage of standards, the NTM-Impact data differ from data on exporters’ complaints or WTO notifications, like the Trade Analysis and Information System (TRAiNS) database, built on count data.

3. THE HETEROGENEITY INDEX

The HIT, as defined by Rau et al. (2010), allows for the aggregation of diverse regulations involving binary, ordered or quantitative information and thus facilitates comparison of different requirements across regulatory elements, products and countries. The index is developed according to the Gower index of (dis)similarity (Gower, 1971). Specifically, the HIT is defined as the

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Table 2

<table>
<thead>
<tr>
<th>Type of measure</th>
<th>Binary</th>
<th>Ordered</th>
<th>Quantitative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Example</td>
<td>EU regulates (1) and Australia does not regulate (0)</td>
<td>(1) Argentina bans a product, (2) EU has a regulation of 2 ppm, and (3) China has no regulation</td>
<td>Maximum residue levels of a specific substance for a specific product</td>
</tr>
</tbody>
</table>

Note:
(i) HIT, heterogeneity index of trade; NTM, non-tariff measure.
Source: Adapted from Rau et al. (2010).
(dis)similarity of requirements between importing country \( j \) and exporting country \( k \) as follows:

\[
HIT_{jk} = \sum_{i=1}^{n} D_{ijk}^{HIT},
\]

where \( i \) denotes an import requirement, and \( D_{ijk}^{HIT} \) is a (dis)similarity measure, which is defined as:

\[
D_{ijk}^{HIT} = \frac{|x_{ij} - x_{jk}|}{\max(x_i) - \min(x_i)},
\]

where \( x_i \) is the observation on requirement \( i \) (which may be binary, ordered or quantitative information),\(^2\) and \( \max(x_i) \) and \( \min(x_i) \) are, respectively, the maximum and minimum value for requirement \( i \) across all countries considered. Intuitively, the dissimilarity measure scales the difference for requirement \( i \) between the exporting and the importing countries by the difference between the maximum and minimum of requirement \( i \) over all countries examined.

The HIT is calculated on a bilateral basis by comparing import requirements for each trading pair. The index depends on the benchmark for comparison, which is always the exporting country. As a result, the direction of trade matters and index values between pairs of trading countries are not necessarily symmetric (i.e. the index value for A’s imports from B does not necessarily equal the index value for B’s imports from A).\(^3\) The values of the HIT range between zero and one. An index value of zero indicates that there is no difference in requirements between importing and exporting countries, and a value of one indicates maximum dissimilarity in regulations.

The HIT provides information about (dis)similarity of requirements and, in its general form, does not measure the stringency of requirements, as it is difficult to determine relative stringency from qualitative information. In these cases, a detailed assessment and/or expert judgement (e.g. the interpretation of labelling requirements) is required to determine the relative restrictiveness of each measure. However, the relative restrictiveness of standards built on quantitative information, such as MRLs, can be determined easily. We exploit the information from quantitative standards, following Burnquist et al. (2011), by calculating HITs that convey the relative stringency of MRLs for pesticides, veterinary drugs and contaminants (stringency HITs). For each agent, if the

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\(^2\) Dissimilarity based on ordinal ranks is calculated using a Podani modification of the Gower index (Podani, 1999).

\(^3\) An index may not be symmetric if the importer and the exporter regulate different standards. If country A regulates substances 1, 2 and 3 and country B regulates substances 1 and 2, the HIT for exports from A to B will be based on differences in regulations for substances 1 and 2, and the HIT for exports from B to A will be based on regulations for substances 1, 2 and 3.
importer’s MRL is stricter (lower) than the exporter’s MRL, dissimilarity is calculated using the procedure described above. If the exporter’s MRL is stricter than the importer’s MRL, we assign a dissimilarity value of zero to reflect that the dissimilarity does not represent a barrier to the exporter.

As for the regular HIT, values for the stringency HIT are bounded between zero and one. A high stringency HIT value reflects stricter standards by the importing country. A high value can be obtained when an importing country is stricter than the exporting country on most standards entering the computation of the index and/or by being much stricter on a few standards. It should be noted that if country A is stricter than country B on some regulations and less so on others, then both the stringency HIT values for exports from A to B and exports from B to A will be positive.

Our priority is that a higher value on the stringency HIT should, more often than not, reduce trade. We expect the regular HIT to have a more ambiguous effect. A high regular HIT value signals regulatory heterogeneity between trade partners, but this may result from stricter regulations in the exporting country. When firms in the exporting country have little problems adjusting to stricter domestic regulations, they are expected to penetrate the importing market more easily. However, one should keep in mind that there could be thresholds for standard differences below which differences are inconsequential and that regulatory enforcement for domestic firms may be tighter or looser than for foreign firms. If the standards are enforced more systematically on domestic firms, then having stricter standards may actually result in more imports and/or less exports by domestic firms.

4. APPLICATION OF THE NTM DATABASE TO CALCULATE THE HETEROGENEITY INDEX

The heterogeneity indexes are calculated for 11 different categories of regulations. In the aggregation of requirements within each category, each requirement is assumed to be equally important. A weighting of importance was not considered as this would have required expert knowledge about the specific characteristics of what is regulated and common production methods.

Table 3 lists the indexes of regulatory heterogeneity that are calculated using the NTM-Impact database. There are three stringency HITs (pesticides, veterinary drugs and contaminates) and nine regular HITs (traceability, product, process, monitoring, labelling, conformity assessment, certification, plant and veterinary requirements). The table provides an overview of import requirements included in each index (see column 3). Table 3 also summarises the number of items regulated or asked about in the questionnaires used to collect the data.
### TABLE 3
Indexes of Regulatory Heterogeneity

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Name</th>
<th>Overview of Requirements Included</th>
<th>Scope</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pesticide</td>
<td>Stringency index for pesticides (MRLs)</td>
<td>Numerical residue limits</td>
<td>610 pesticides</td>
</tr>
<tr>
<td>Vetdrug</td>
<td>Stringency index for veterinary drugs (MRLs)</td>
<td>Numerical residue limits</td>
<td>130 veterinary drugs</td>
</tr>
<tr>
<td>Contam</td>
<td>Stringency index for contaminants (MRLs)</td>
<td>Combination of counts and numerical information</td>
<td>24 contaminants</td>
</tr>
<tr>
<td>Trace</td>
<td>Traceability requirements index</td>
<td>Tracking and tracing, documentation, record-keeping</td>
<td>1,674 questions</td>
</tr>
<tr>
<td>Product</td>
<td>Product requirements index</td>
<td>Product approval, packaging, vaccination</td>
<td>1,770 data points</td>
</tr>
<tr>
<td>Process</td>
<td>Process requirements index</td>
<td>Hygiene, quarantine, treatments to prevent and combat diseases and pests</td>
<td>919 data points</td>
</tr>
<tr>
<td>Monitor</td>
<td>Monitoring requirements index</td>
<td>Monitoring hazards, bans, laboratories, sampling and analysis</td>
<td>397 data points</td>
</tr>
<tr>
<td>Label</td>
<td>Labelling requirements index</td>
<td>Country of origin, information provided, specific claims, information about daily allowance</td>
<td>279 data points</td>
</tr>
<tr>
<td>Conform</td>
<td>Conformity assessment index</td>
<td>Pre-export checks, equivalence agreement, animal and plant health control, border controls</td>
<td>1,779 data points</td>
</tr>
<tr>
<td>Certify</td>
<td>Certification requirements index</td>
<td>Testing, inspection, auditing, certificates, establishment approval (prelisting)</td>
<td>1,105 data points</td>
</tr>
<tr>
<td>Plant</td>
<td>Plant requirements index</td>
<td>Phyto sanitary export certificates, pest-free status, invasive species</td>
<td>1,077 data points</td>
</tr>
<tr>
<td>Vetreq</td>
<td>Veterinary requirements index</td>
<td>Veterinary export certificates, disease-free status</td>
<td>278 data points</td>
</tr>
</tbody>
</table>

MRL, maximum residue limit.
Source: Adapted from Shutes et al. (2011).
When calculating the HITs, some rules are systemically applied. Specifically, bans of products or substances are considered to be the most stringent regulation, and the absence of a requirement that is regulated elsewhere is considered to be the least stringent regulation. Index calculations also differentiate between situations where there is no requirement from situations where no information is available. If no information is available for a requirement, the requirement is not included in index calculations.

Each index is constructed for each product and each exporter–importer combination included in the database. To summarise the NTM data, for each index, we calculate the average for each importer across all exporters for two categories of products: (i) animal products (an aggregate of beef, pigmeat and cheese); and (ii) plant products (an aggregate of remaining products in the database). The data summary averages are shown in Figures 1–3.

Figure 1 displays average stringency HIT values for pesticides, contaminants and (for animal products only) veterinary drugs. A high average stringency HIT value indicates that, compared to other countries in the sample, the importer has stricter MRLs on a large number of substances and/or has

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**FIGURE 1**

Stringency Heterogeneity Index (HIT) for Maximum Residue Levels (MRLs), Average Index Values by Importing Country (Presented on the x-axis)

Notes:
(i) The stringency HIT for contaminants for the United States (plant and animal products), for Canada (plant and animal products) and Japan (animal products) could not be calculated because of missing information.
(ii) Veterinary drugs are only relevant for animal products.
(iii) As there are MRLs for pesticides in meat products and cheese, the stringency HIT for pesticides is also available for animal products.

Source: Authors’ calculations using the NTM-Impact database.

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some MRLs that are much stricter. On the other hand, a low average stringency HIT value indicates that the importer has stricter MRLs on a small number of substances, and/or for substances with stricter MRLs, there is only a small difference between the importer MRL and those in other countries. In general, there is more heterogeneity in pesticide and contaminant MRLs for animal products than for plant products (the exceptions are pesticide MRLs for Australia and contaminant MRLs for China and Russia). Comparing pesticide MRLs across countries, relative high index values are recorded for China, Russia and Argentina for animal products, indicating that other countries may find it difficult to export animal products to these countries. For plant products, pesticide index values are high for Argentina, Australia and the United States. Examining country differences in pesticide MRLs at the product level (not reported in Figure 1) reveals that MRLs are relatively strict for cheese exports to China, beef exports to Argentina and Russia, eggplant (aubergine) exports to Argentina, barley exports to Australia and exports of sweet peppers, apples, pears and maize to the United States.

Turning to contaminant MRLs, the stringency HITs for Argentina for both plant and animal products are higher than in other countries. The high index values are driven by Argentina imposing relatively strict contaminant MRLs on beef (for animal products) and tomatoes and barley (for plant products). The contaminant index is also relatively high for EU imports of animal products, which is mainly because of relatively strict EU MRLs for cheese. The descriptive statistics for veterinary drugs reveal that Brazil, Japan and Russia impose relative strict MRLs for these products.

Figures 2 and 3 display the average HIT values for other (non-MRL) regulations for animal and plant products, respectively. A high average HIT value indicates a large difference between regulations in the importing country and regulations in other countries. Most HIT values range between 0.2 and 0.5. The largest HIT values are observed for Russia for plant products, indicating that there are relatively large differences between Russian regulations and regulations in other countries. Comparing average indexes in Figures 1–3, indicates that there is greater heterogeneity in MRL regulations than in other non-MRL regulations.

Although we have discussed NTM indexes for plant and animal products, we focus on plant products for our gravity analysis in Section 5. This is motivated by the fact that plant products are somewhat more homogenous and hence more suited for data pooling. This is an important consideration given that we do not have several observations/years for each trade flow. Animal products, and in particular cheese, are subject to complex and severe trade barriers such as tariff-rate quotas (TRQs). Ideally, such products would be analysed individually.
5. GRAVITY ANALYSIS

To assess the impact of cross-country regulatory differences on trade flows, we estimate a gravity model with a specification augmented by several heterogeneity indexes. The most common empirical specification of the gravity model was developed by Anderson and van Wincoop (2003) who introduced multilateral trade resistance indexes, commonly proxied by importer–exporter fixed effects, in the gravity equation. Several authors have proposed applications focused on agricultural products (e.g. Jayasinghe et al., 2010; Sun and Reed, 2010; Tamini et al., 2010). We consider the following log-linear gravity specification:

$$\ln x_{ijq} = \alpha_0 + \ln prod_{iq} + \ln prod_{jq} + \alpha_i + \alpha_j + \delta D_{ijq} + e_{ijq},$$

where $x_{ijq}$ is the value of sales from exporting country $i$ to importing country $j$ of commodity $q$, $\alpha_0$ is the constant, $prod_{iq}$ and $prod_{jq}$ are production of commodity $q$ in countries $i$ and $j$, respectively, $\alpha_i$, and $\alpha_j$ are exporter and importer fixed effects, respectively, $D_{ijq}$ is a matrix of observable trade cost determinants and $e_{ijq}$ is the error term.

Agricultural production and marketing decisions are often separated by several months because of biological constraints that make production highly
inelastic in the short run. Accordingly, when export and import decisions are made, they are conditioned on production levels. As a result, production levels are often included in gravity equations for trade in agricultural products.

The trade cost matrix includes the relevant measure-specific heterogeneity indexes described in Table 3, the log of distance between countries $i$ and $j$, the log of one plus the applied import tariff and a binary variable equal to one if two nations share a common official language ($clang$). The NTM indexes displayed in Table 3 measure the degree of regulatory heterogeneity for different aspects of food safety. For regular HITs, whether or not differences in regulations influence trade can be determined using two-sided hypothesis tests. For stringency HITs, as noted above, our priority is that trade is likely to be reduced when the importing country’s standards are more stringent than those in the importing country.\(^4\) Whether a higher stringency HIT values impedes

\(^4\) A positive sign is plausible, but perhaps not as likely. As noted above, if domestic producers in the importing country have more difficulty than their foreign counterparts in meeting their country’s standards or if their products and production processes are more scrutinised, then the stricter standards in the importing country can increase imports. In many industrialised countries, domestic firms often complain that they face at home higher effective standards than their foreign rivals. The reverse cannot be ruled out, at least on a temporary basis, but overzealous standard enforcement on foreign firms is inconsistent with GATT Article III on national treatment.
trade or not can be tested with a one-sided test with the null (alternative) of a zero (negative) coefficient.

Before estimating our gravity equation, we investigated correlation between our NTM indexes. This analysis revealed that indexes for product and plant requirements and conformity assessment were highly correlated with other indexes. These indexes and indexes for veterinary drugs and veterinary requirements, which are not relevant for plant products, were excluded from our analysis.

Trade data are sourced from the United Nation’s Commodity Trade Statistics Database; tariff data are taken from the TRAINS database; and distance and common language are sourced from the Centre d’Etudes Prospectives et d’Informations Internationales (Disdier and Head, 2008). Our chosen distance measure is the log of the harmonic mean of population-weighted distances between major cities in the countries of interest. Data on domestic production are obtained from FAOSTAT of the Food and Agricultural Organization (FAO). We denote the log of exporter and importer production as, respectively, \( \ln \text{prode} \) and \( \ln \text{prodm} \), and log of distance as \( \ln \text{distance} \). The tariffs used in our analysis, denoted \( \ln \text{tariff} \), are the log transformation of the sum of one and the ad valorem or ad valorem equivalent MFN applied tariffs: \( \ln(1 + t) \).\(^5\)

The data set is a panel data set and includes bilateral trade between the EU and the nine countries in the NTM-Impact database, for two years (2008 and 2009) and HS 6-digit commodities for fruits (080810 and 080820), vegetables (070110, 070190, 070200, 070930, and 070960) and cereals-grains (100300, 100510, 100590, 120510, and 120590). We pooled plant products to have a large enough sample for which the assumption of homogenous effects across products for heterogeneity indexes would not be too heroic.\(^6\) Still, we allow for some product heterogeneity through HS4 product dummies. As heterogeneity indexes are calculated at the HS 4-digit level for a single year, HS 6-digit commodities sharing the same first four digits have the same index values in both years of our sample. Observations with missing heterogeneity indexes were discarded.

Data about bilateral trade flows are notorious for having many zero observations. The zeros raise several issues. An immediate problem is that the log of zero is undefined. Excluding zero observations creates a selection bias, and

\[ \frac{y_1}{y_0} = \frac{t_1}{t_0} \]

As a result, the trade elasticity with respect to the tariff is only a fraction of the estimated coefficient. For example, for a 5 per cent tariff, the scaling factor is 0.0476 while it is 0.167 for a 20 per cent tariff.

\(^5\) We also experimented with dummy variables to signal the presence of specific tariffs and TRQs. They were not always significant and the other coefficients were quite robust whether they were added or not. The fact that our tariff variable is \( \ln(1+t) \) makes the interpretation of the regression coefficient a bit more complex. When the coefficient is the elasticity: \( \frac{\ln(y_1) - \ln(y_0)}{\ln(1+t) - \ln(1)} \sim \frac{\ln(y_1) - \ln(y_0)}{\ln(1+t) - \ln(1)} = \beta \),

the denominator does not give us the percentage change in the tariff. However, it is easy to verify that \( \frac{\ln(y_1) - \ln(y_0)}{\ln(1+t) - \ln(1)} = \beta \frac{t_1}{t_0} \). As a result, the trade elasticity with respect to the tariff is only a fraction of the estimated coefficient. For example, for a 5 per cent tariff, the scaling factor is 0.0476 while it is 0.167 for a 20 per cent tariff.

\(^6\) If we had more time variation and/or more countries in our data set, we could have estimated product-specific gravity equations.
adding one to all trade flows introduces a deliberate measurement error. A better alternative is to use an estimator that handles zeros. For instance, the Tobit estimator advocated by Eaton and Tamura (1994) has been used in many studies, but Tobit estimators perform poorly when errors are non-normal and heteroscedastic. Tobit estimators also restrict the selection and value equations to be generated from the same probability mechanism. Hurdle-like models are generalisations of Tobit estimators by allowing for zero trade flows to be generated from a separate process. However, little has been done in this area (Anderson, 2010). One exception is the contribution by Helpman et al. (2008), or HMR, which posits that firms must be able to overcome a fixed cost to be able to export. The productivity of potential trading firms is drawn from a Pareto distribution, and when the most productive firm from country \(i\) is not productive enough to export to country \(j\), then a zero trade flow ensues. The HMR theoretical model lends itself to a two-step empirical specification that allows for selection and firm heterogeneity effects to be estimated on aggregate data. One of the drawbacks of this estimator is that an explanatory variable is usually excluded from the gravity equation to prevent the selection and gravity equations from having identical specifications and hence facilitate identification. The choice of an exclusion variable is not obvious and if inadequate can introduce a misspecification bias.

Santos Silva and Tenreyro (2006) take a different approach, which we adopt, to address the zeros by advocating the estimation of the gravity equation in levels with a Poisson pseudo-maximum likelihood (PPML) estimator, a poisson estimator which uses a robust estimate of the variance–covariance matrix. The PPML estimator is shown to be more efficient than a non-linear least square (NLS) estimator in the presence of heteroscedasticity, a common occurrence in trade data. The Poisson estimator assumes that the mean and variance are the same. Overdispersion is often found when a test rejects the assumed equality between the mean and the variance. A generalised negative binomial (GNegB) estimator can then be seen as a logical alternative as it models overdispersion in the trade data as a function of explanatory variables which may also condition the level of trade. Finally, Martin and Pham (2008) and Burger et al. (2009) showed that the efficiency of the PPML approach is sensitive to the proportion of zeros in trade flows. Zero-inflated Poisson and negative binomial

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7 The variables entering both the selection and value equations must have parameters with the same sign.
8 The Poisson estimator is typically used on count data. It is nevertheless appealing in a trade context because it remains consistent when the data are not actually Poisson distributed, provided that the gravity function is correctly specified.
9 Formally, the null of \(\text{Var}(y|x) = \mu \text{Var}(y|x)\) is pitted against \(\text{Var}(y|x) = \mu^2 \text{Var}(y|x); \mu > 0\) by regressing \(\{y - \hat{\mu}\}^2 - y\)/\(\hat{\mu}\) on \(\hat{\mu}\) without an intercept. Overdispersion (or the absence of) is detected with a \(t\) test on \(\hat{\mu}\) (Cameron and Trivedi, 2005, pp. 670–1).
10 Using Monte Carlo simulations, Santos Silva and Tenreyro (2011) show that the PPML estimator can perform well even when the proportion of zeros is very high.
models provide flexibility in dealing with the zeros by linking a process explaining zero and non-zero observations to another that explains the level of trade, which includes zero as a potential level. Thus in zero-inflated models, zeros can be the outcome of two different processes. For example, it could be that an importing country’s standard make it impossible for some exporting countries to enter the market regardless of the production levels observed. Alternatively, a frequent exporter may cease to export when its domestic production is much lower than typically observed. For our analysis, we rely on the PPML estimator and its extensions to evaluate the manner and extent by which trade is affected by tariffs, heterogeneity in regulatory standards, common language, distance, and production levels.

In interpreting results for regular HITs, recall that a value of zero for an index indicates that regulations are the same in both the exporting and importing countries, while a value of one indicates that regulations are very dissimilar. The effect of the HIT index is a priori ambiguous. On the one hand, highly dissimilar regulations can make it more costly for a country to export to a given market because of additional costs to comply with different regulations. On the other hand, greater dissimilarity may also be associated with increased trade, for example, if higher standards in one country increase that country’s ability to export to other countries. In the case of stringency HITs, our priority is that mainly it is easier for firms based in a country with stricter regulations (e.g. low MRLs) to meet other countries’ regulations, so we expect that trade would be reduced when the importing country is more stringent.

Table 4 shows our estimation results. The PPML results are in the first column. The coefficients for importer, exporter and commodity fixed effects are not reported. The coefficient for distance has the expected negative sign and it is significant. It can be interpreted as an elasticity: a 1 per cent increase in distance decreases trade by 1.19 per cent. Put another way, if distance increases by 1,000 km from its mean of 8,777 km, trade would be reduced by a factor of 0.88.\textsuperscript{11} The coefficient on the production level in the exporting country is expected to be positive as it reflects a greater capacity to export, all else constant including the level of domestic consumption. The coefficient is positive and statistically significant. All else being equal, a higher level of production in the importing country should decrease imports and this is what the negative and significant coefficient on lnprodm indicates. Having a common language does not have a significant impact on trade according to the PPML estimator. In contrast, higher tariffs adversely impact on trade, as one would expect. The stringency index for pesticide MRLs is negative and highly significant. This variable varies

\begin{equation}
\frac{y_1}{y_0} = e^{(\sum \beta_{x_i} + \beta_D \ln D_1)} / e^{(\sum \beta_{x_i} + \beta_D \ln D_0)} = e^{\beta_D (\ln D_1 - \ln D_0)} , \text{all else equal.}
\end{equation}

\textsuperscript{11} The ratio of trade at different distances is
between 0 and 1 and has a mean of 0.385 in our sample. We can then infer that if the index increased by 0.01, from its mean to 0.395, trade would be reduced by a factor of $e^{(-5.0391*0.01)} = 0.95$ (i.e. there would be 5 per cent less trade).

Table 4
Gravity Estimates from Competing Estimators

<table>
<thead>
<tr>
<th></th>
<th>(1) PPML</th>
<th>(2) GNegB</th>
<th>(3) GNegBe</th>
<th>(4) ZIP</th>
</tr>
</thead>
<tbody>
<tr>
<td>ln distance</td>
<td>-1.1936***</td>
<td>-1.6860***</td>
<td>-1.7394***</td>
<td>0.9770a</td>
</tr>
<tr>
<td></td>
<td>(0.1855)</td>
<td>(0.2041)</td>
<td>(0.2054)</td>
<td>(0.5015)</td>
</tr>
<tr>
<td>ln prode</td>
<td>1.0858***</td>
<td>0.8264***</td>
<td>0.8436***</td>
<td>-0.1956*</td>
</tr>
<tr>
<td></td>
<td>(0.1372)</td>
<td>(0.0700)</td>
<td>(0.0714)</td>
<td>(0.0841)</td>
</tr>
<tr>
<td>ln prodm</td>
<td>-0.2937***</td>
<td>-0.6083***</td>
<td>-0.7324***</td>
<td>0.1491**</td>
</tr>
<tr>
<td></td>
<td>(0.0493)</td>
<td>(0.0561)</td>
<td>(0.0755)</td>
<td>(0.0498)</td>
</tr>
<tr>
<td>Clang</td>
<td>-0.9322</td>
<td>0.8894a</td>
<td>0.7351</td>
<td>-0.7474</td>
</tr>
<tr>
<td></td>
<td>(0.6267)</td>
<td>(0.5232)</td>
<td>(0.5248)</td>
<td>(1.3717)</td>
</tr>
<tr>
<td>ln tariff</td>
<td>-5.9692**</td>
<td>-12.1476***</td>
<td>-30.0149***</td>
<td>-2.6417</td>
</tr>
<tr>
<td></td>
<td>(1.9069)</td>
<td>(2.4364)</td>
<td>(7.5587)</td>
<td>(2.0088)</td>
</tr>
<tr>
<td>Tariff endog. correction</td>
<td>22.1054*</td>
<td>(8.8041)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pesticide</td>
<td>-5.0391***</td>
<td>-3.2857***</td>
<td>-2.7911***</td>
<td>-0.3046</td>
</tr>
<tr>
<td></td>
<td>(1.1950)</td>
<td>(0.8580)</td>
<td>(0.8785)</td>
<td>(1.1945)</td>
</tr>
<tr>
<td>Contam</td>
<td>0.6661</td>
<td>0.0696</td>
<td>0.0381</td>
<td>-0.0905</td>
</tr>
<tr>
<td></td>
<td>(0.6116)</td>
<td>(0.5412)</td>
<td>(0.5410)</td>
<td>(1.7109)</td>
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<td>Trace</td>
<td>1.8268</td>
<td>-1.0582</td>
<td>-1.7105</td>
<td>-3.9476</td>
</tr>
<tr>
<td></td>
<td>(2.0740)</td>
<td>(1.7515)</td>
<td>(1.7553)</td>
<td>(3.5292)</td>
</tr>
<tr>
<td>Process</td>
<td>-3.7250*</td>
<td>0.0647</td>
<td>1.0832</td>
<td>0.6175</td>
</tr>
<tr>
<td></td>
<td>(1.6655)</td>
<td>(1.2582)</td>
<td>(1.3348)</td>
<td>(1.9720)</td>
</tr>
<tr>
<td>Monitor</td>
<td>1.2682</td>
<td>0.7355</td>
<td>1.2880</td>
<td>1.8936</td>
</tr>
<tr>
<td></td>
<td>(0.9980)</td>
<td>(0.7762)</td>
<td>(0.7874)</td>
<td>(1.1733)</td>
</tr>
<tr>
<td>Label</td>
<td>-9.8708*</td>
<td>-0.2003</td>
<td>1.5829</td>
<td>-11.0003</td>
</tr>
<tr>
<td></td>
<td>(4.0494)</td>
<td>(3.0823)</td>
<td>(3.1557)</td>
<td>(8.4107)</td>
</tr>
<tr>
<td>Certify</td>
<td>2.8193</td>
<td>-0.5250</td>
<td>-1.8468</td>
<td>2.3182</td>
</tr>
<tr>
<td></td>
<td>(1.9564)</td>
<td>(1.5573)</td>
<td>(1.6452)</td>
<td>(3.8251)</td>
</tr>
<tr>
<td>N</td>
<td>1530</td>
<td>1530</td>
<td>1530</td>
<td>1530</td>
</tr>
</tbody>
</table>

Notes:
(i) Heteroscedastic robust standard errors in parentheses.
(ii) GNegB, generalised negative binomial; PPML, Poisson pseudo-maximum likelihood.
(iii) * Signals that the t-ratio exceeds the 1.65 critical value for a one-tailed test.
(iv) **p < 0.05, ***p < 0.01, ****p < 0.001 probability levels based on two-tailed tests.

between 0 and 1 and has a mean of 0.385 in our sample. We can then infer that if the index increased by 0.01, from its mean to 0.395, trade would be reduced by a factor of $e^{(-5.0391*0.01)} = 0.95$ (i.e. there would be 5 per cent less trade).

The number of measures involved in the computation of an index can be very large. This is particularly true in the case of MRLs for pesticides. It is difficult to know without expert evaluation in each case which pesticide MRLs matter and which do not for a given product and country pair. As noted above, all pesticides are equally weighted in the stringency HIT. While a weakness, we feel that using all of the information is a better alternative than focusing on just a few pesticides, which is equivalent to putting a weight of zero on all but those few. Our aggregate analysis should be complemented by specific case studies to ensure a robust understanding.
The stringency index for contaminants does not significantly impact on trade of plant products and the same can be said about the HIT capturing heterogeneity in standards about traceability, monitoring and certification. Differences in labelling and process regulations, however, exert negative impacts on trade. Thus, we can conclude that heterogeneity in standards has a weakly negative effect on trade.

Even though the PPML has a great fit according to the pseudo-R^2 (0.71, not shown in Table 4) and many of the coefficients are significant with the expected sign, it may not be the best estimator. The fact that the test about the absence of overdispersion produced a t statistic of 11.13 suggests that overdispersion is an issue and that a GNegB model might be more appropriate.

The coefficients for the GNegB model appear in the second column of Table 4. The commodity fixed effects were used as factors conditioning dispersion and most were significant, confirming that the variance varies across commodities. Importer and exporter fixed effects were used to condition the level of trade, these coefficients being of little interest, we do not report them. The coefficient for distance is negative and significant, but it is larger in magnitude than in the PPML. For comparison purposes, the distance coefficient in McCallum’s (1995) classic study was −1.42, which implied that doubling distance would reduce trade by a factor of 2^{1.42} = 2.67.13 Given that our application pertains to agricultural products and that transport costs are relatively more important for agricultural products than manufactured ones, the distance coefficient for the GNegB model is more plausible than its PPML counterpart. The same can be said about common language since it has the anticipated sign in the GNegB column and not in the PPML column. Common language is significant in the GNegB when a one-tailed test is used. The coefficient for exporter production is still positive and significant, but it is now closer in magnitude to the coefficient for importer production, which doubles from the PPML to the GNegB estimation. The coefficient on exporter production remains larger than the one for importer production in absolute value. This implies that generalised increases in world-wide production translates into increases in world trade, as one would expect. Tariffs decrease trade by a greater extent in the GNegB than in the PPML, but the effect of the stringency pesticide index is more muted than in the PPML gravity equation. The effects of the other indexes are not significant at conventional levels.

We investigated the possibility that tariffs might be endogenous. We regressed the tariff variable on the variables of the trade equation, minus ln(tariff), but augmented by a TRQ dummy variable, a specific tariff dummy

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13 Grossman (1997) brought attention to McCallum’s distance coefficient and inspired several papers on the so-called ‘distance puzzle’, like Disdier and Head (2008) who report a median distance elasticity of 0.9.
variable and a dummy variable for regional trade agreements. We do not report the results of this regression in Table 4, but the fit was good with a $R^2$ of 0.41. The estimation confirms that ad valorem tariff equivalents tend to be lower when countries participate in a regional trade agreement. Production in the importing country and the specific tariffs dummy exert also a negative influence. The former result indicates that tariff protection is higher where domestic production is low. The trade flow results are presented in the third column (GNegBe) of Table 4. The correction term is significantly positive, and not surprisingly, the tariff coefficient is more negative than when endogeneity is not taken into account. The stringency pesticide index remains highly significant and negative, but its coefficient is somewhat lower (in absolute value) than when tariff is not endogenised.¹⁴ The interpretation of other coefficients is not affected, as they are not statistically different from zero whether tariffs are endogenised or not.

A high proportion of zeros in the dependant variable suggests that a zero-inflated model might be warranted, but a high proportion of zeros is by no means a sufficient condition (Cameron and Trivedi, 2005). However, Vuong’s test ($z = 4.53$) suggests that zero-inflation should be explicitly addressed. The last two columns display the coefficients associated with the inflated and level equations of a zero-inflated Poisson model (ZIP).¹⁵ The logit coefficients relate the effect of explanatory variables on the probability of no trade. Hence, they have the reverse sign than they would if they were conditioning the probability of trade.

The decomposition of the effects of explanatory variables into two distinct processes is enlightening. For instance, distance has a neutralising effect through the process governing the probability of no trade and through the process defining the size of the trade flow. The $t$-statistic for distance in the inflating equation is 1.95, just slightly below the 1.96 critical value routinely used by computer software. However, because the alternative hypothesis is that distance increases the likelihood of zero trade, we could argue that in this instance 1.65 is a more appropriate critical value. In contrast, tariffs do not have a significant impact on the probability of no trade, but this variable has a significant and negative effect on the value of trade. The coefficients for the production level in the exporting and importing country have the expected signs and are significant in both equations. Higher production in the exporting (importing) country makes it less (more) likely that no trade will be observed.

¹⁴ It is less likely that NTM indexes are endogenous because the gap between applied and bound tariffs makes it easy to increase or decrease tariffs. Data for Canadian and US pesticide MRLs, for example, show few changes over time (Larue and Gervais, 2010). We did not examine endogeneity between trade and NTM indexes.

¹⁵ We experienced convergence problems when we tried to estimate a zero-inflated negative binomial model.
and increases (decreases) the expected value of trade through the level equation. Having a common language has no effect on the probability of trade or on the level of trade. Interestingly, the stringency pesticide index which was significant in the PPML and negative binomial gravity equations is not significant in the logit equation but has a significant and negative impact on the level of trade. The stringency contaminant index remains insignificant as in the other gravity equations. Finally, heterogeneous regulations on labelling have no significant impact on the probability of no trade, but the heterogeneity does impede the level of trade.

6. CONCLUDING REMARKS

We describe new detailed data on NTMs on agricultural trade collected as part of the NTM-Impact project that covered import requirements for agricultural and food products for the EU and nine of its major trade partners. The database includes qualitative and quantitative information on an extensive array of import requirements for eleven representative HS 4-digit level animal and plant products. We created two kinds of heterogeneity indexes (called HITs), which aggregate diverse regulations. The HITs assess the degree of diversity in the rules used by pairs of importing and exporting countries for each product. The stringency HITs capture relative stringency and are based on the hypothesis that trade is likely to be reduced when importing countries have more stringent rules than exporting countries. Indexes for several different regulatory aspects were included in gravity equations to estimate the impact of differences in standards and regulations on trade of plant products. Our results indicate that differences in most regulations weakly reduce trade (i.e. they have no effect or negative effects). However, stricter pesticide MRLs for plant products in one country relative to other countries reduce exports to that country. This suggests that regulators should invest time in revising pesticide MRLs to attenuate cross-country differences, for example, by adopting internationally agreed MRLs like those suggested by the Codex Alimentarius. On the positive side, the fact that several indexes about regulation heterogeneity do not have a negative and significant impact on trade is encouraging even though our sample covered only a small number of plant products. This may suggest that differences are not wide enough to act as trade impediments.

The results across estimators are quite robust. Most of the coefficients had the expected signs, and the ones for which there are comparable estimates reported in other studies appear quite plausible. Our main concern is with the generalisation of our results to other commodities, like animal products. Appropriately accounting for specific trade distortions and interactions between these distortions and the heterogeneity indexes will be key to the further analysis. To
tackle these issues, the analysis may need to focus on narrowly defined commodities. In our analysis, we assumed that the impact of each index was the same for all plant products, but impacts may differ across commodities. Future research may also focus on a subset of NTMs, which have been identified as important by external sources.

We close by noting that coordination and convergence on regulatory standards would generally increase trade flows, and policymakers and regulators are encouraged to pursue such endeavours. This is particularly true for pesticide MRLs in our analysis. However, complete NTM harmonisation may not be politically feasible or desirable from a national welfare perspective, given that different countries face different food safety problems and consumer safety demand. Tariff reductions remain a sure way to increase trade even in the presence of regulatory heterogeneity. The conclusion of the Doha Round of multilateral negotiations or other negotiations achieving such results would definitely be helpful in this regard.

AUTHORS’ CONTRIBUTION

Senior authorship is equally shared between Rau and Winchester, who coordinated the research. Goetz, Larue, Otsuki, Rau, Shutes, Wieck, and Winchester calculated the indexes of NTMs, analysed the NTM data, conducted the gravity analysis and wrote the paper. The stringency indexes used in the gravity analysis are based on a procedure developed by Burnquist, Pinto de Souza and Nunes de Faria.

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Cameron, A. C. and P. K. Trivedi (2005), Microeconometrics: Methods and Applications (New York: Cambridge University Press).

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