Hidden Trade Costs? Maximum Residue Limits and US Exports to Trans-Atlantic and Trans-Pacific Trading Partners

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Abstract

Sanitary and phytosanitary (SPS) measures are not new, but their significance in international agri-food trade continues to grow. Despite recent data collection efforts, the current literature has not lead to a consensus about the impact of SPS measures on trade nor has it led to a prescribed framework for how to address SPS policy reforms in multilateral and bilateral trade negotiations. In this article we focus on a specific type of SPS measures that features prominently in the current mega-regional trade negotiations, namely food safety standards in the form of maximum residue limits. First, we construct a comprehensive database of country-and-product specific MRLs for global fresh fruit and vegetable trade and develop a novel bilateral stringency index to quantify the degree of MRL regulatory heterogeneity between trading nations for the years 2013 and 2014. Second, a formal econometric model is developed to investigate the trade restricting nature of these measures. The results suggest that for any given fresh fruit or vegetable product, importer MRL standards that are marginally stricter than exporter MRLs can impart significant reductions in bilateral trade. However, when MRL policies are roughly equivalent, as is the case between the US and some of its TPP trading partners, the actual restrictiveness of this SPS policy diminishes dramatically. The results have important implications for the current mega-regional negotiations.

Keywords: *fruit and vegetable trade, bilateral trade, maximum residue limits, non-tariff measures, Trans-Atlantic Trade and Investment Partnership, Trans-Pacific Partnership, Intensive and Extensive Margins of Trade.*

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Introduction

We have witnessed a significant shift in the focus of agricultural trade policy concerns from border related costs such as tariffs, quotas, and exports subsidies that dominated much of the research and policy agenda in the lead up to the historic Uruguay Round Agreement on Agriculture (URAA), to non-tariff measures (NTMs) and a plethora of "behind the border" policies in the form of regulatory measures and product standards. While tariffs remain high on a handful of agricultural sectors and tariff-rate quotas guarantee at least some access in certain markets, most agricultural economists agree that new 21st century obstacles to trade are more obscure in nature and have the potential to be more trade distorting (Beghin, Maertens and Swinnen 2015; Josling, Roberts, and Orden 2004; OECD 2005; WTO 2012). As Baldwin (1999) noted more than a decade ago: "…the lowering of tariffs has, in effect, been like draining a swamp. The lower water level has revealed all the snags and stumps of non-tariff barriers that still have to be cleared away" (pg 237).[1]

Broadly defined, NTMs are policy measures, other than ordinary customs tariffs, that can potentially have an economic effect on international trade in goods, changing quantities traded, or prices or both (UNCTAD 2010). Among the potential list of NTMs affecting agricultural and food trade, Sanitary and Phytosanitary (SPS) measures feature prominently. First, SPS measures are pervasive in agri-food trade because of the sensitive nature of issues such as food safety and the protection of plant and animal health from pest and disease risks. Second, the World Trade Organization (WTO) Agreement on the Application of SPS measures permits countries to adopt their own set of standards provided these measures are based on a risk assessment, not discriminatory between countries with similar conditions, and are minimally trade distorting to prevent the disingenuous use of these measures as instruments of disguised protectionism (Josling, Roberts and Orden, 2004). Third, SPS and TBT measures are the most frequently encountered NTMs according to data collected from official sources such as the United Nations Conference on Trade and Development's (UNCTAD) Trade Analysis and Information System (TRAINS) and the WTO's new Integrated Intelligence Portal (I-TIP). They are also considered among the most relevant impediments to exports, according to a small sample of NTM business surveys conducted by the World Bank.

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[1] Baldwin was not the only prominent Economist to highlight the increasing prevalence of NTMs. Lawrence (1996) noted that "… once tariffs are removed, complex problems remain because of differing regulatory policies among nations" (pg. 7) and Preeg (1998) concludes that: "…as border restrictions [tariffs] are reduced or eliminated, other policies become relatively more important in influencing trade flows and thus need to be assimilated in the trade relationship" (p. 50).

A major impediment to research progress on NTMs in agri-food trade is the difficulty in constructing NTM datasets suitable for empirical analyses because of the many different forms NTMs can be applied, when and how each measure is imposed, and on which country/commodity pairs. Although there is no complete global inventory of public and private NTM measures, multi-country and multi-institutional efforts to define, classify and categorize NTMs and their role in international trade have been undertaken the most recent being the UNCATD (2015) report culminating several years of effort by an expert committee termed the Multi-Agency Support Team (MAST). Despite these efforts, quantification of NTMs and in particular, those that represent significant obstacles to trade including case-studies and full-scale inventory approaches, has not lead to a consensus about the impact of NTMs on trade nor has it led to a prescribed framework of how to address NTM policy reforms in multilateral and bilateral negotiations. Difficulties arise because of the enormous amount of data collection that is required to obtain accurate empirical results that reflect economic outcomes and because of the wide range of channels by which NTMs can impact agricultural trade, commercial transactions, and even the ability of firms to establish new trading relationships.

The evidence to date has been mixed (see Li and Beghin 2013; Beghin, Maertens and Swinnen 2015; WTO 2012) and oftentimes the proverbial water has become muddied as more obscure measures are identified. While new information and improved NTM classification systems has increased our understanding of the nature of these measures it has simultaneously revealed a large and diverse universe of applicable measures whether justified or not. In principle, the United Nations Conference on Trade and Development (UNCTAD) maintains and periodically updates its Trade Analysis and Information System (TRAINS) database that covers well over 100 types of NTMs affecting agricultural and non-agricultural trade. However, the applicability of the TRAINS database has been subject to criticism for several reasons (Disdier, Fontagne and Mimouni 2008; Peterson et al. 2013; Grant et al., 2015). First, even if an NTM is notified in the TRAINs database very little information exists describing the type of measure affecting trade. Second, TRAINS does not contain a bilateral country-pair dimension which means researchers must assume that if an import measure is notified it applies to all exporters. Third, unlike agricultural tariffs for which WTO Members are required to notify rates and any changes in applicable duties, NTMs are not subject to such comprehensive reporting requirements. Further, the use of NTMs changes over time as new types of measures appear when new ingredients or supplements are registered for use or cost saving input technologies such as new pesticides becomes available.

While many SPS regulations are in place to protect animal and plant health from imported pests and disease, a particular type of SPS regulations known as Maximum Residue Limits (MRLs) or tolerances, are designed to safeguard human health. MRLs describe the maximum legal level of concentration of pesticides or feed additives that a country is willing to accept in or on the surfaces of food products. Although MRLs have become a key regulatory measure to limit human exposure to chemicals and veterinary drug residue, overly restrictive tolerances or limits set by importing countries that deviate significantly from international standards or those maintained by exporting countries may provide incremental reductions in human health and environmental hazards but will almost certainly increase compliance costs for foreign and domestic producers, consumer prices of food products in importing countries, and in some cases may shut off trade as products get rejected at the border (Xiong and Beghin, 2012a).

In the March 2014 *Report on SPS Measures* (USTR 2014), the Office of the US Trade Representative highlighted a number of discriminatory SPS measures affecting US fruit and vegetable (FV) and animal product trade. A common theme in this report was the concern of overly burdensome maximum residue limits (MRLs), particularly regarding pesticides and aflatoxins in tree nuts and restrictions or bans concerning biotechnology, ractopamine, trichinosis, bovine spongiform encephalopathy (BSE), avian influenza (AI) and certain veterinary drugs imposed on US exports of animal products. Perhaps not surprisingly, many of the country-product examples of SPS restrictions listed in the report lie in Asia and Europe – two continents that are part of the large mega-regional trade deals with the US.

While broad-based approaches to quantify the effect of NTMs on trade are useful for developing a “big picture”, simply put, NTMs include a very diverse array of policies that can have heterogeneous impacts on trade (Beghin, Maertens and Swinnen 2015). Given persistent difficulties in constructing suitable NTM datasets, this article adopts a targeted approach investigating a specific type of SPS regulation in a particular product class of US trade, namely maximum residue limits affecting fresh fruits and vegetable (FV) exports. More specifically, the purpose of this article is threefold. First, we develop a bilateral stringency index of MRL heterogeneity between trading partners. Following Li and Beghin’s (2013) index work, we modify their index which is designed to evaluate the stringency of members’ MRLs with respect to the international standard, to incorporate an explicit bilateral dimension. The decision to export and the intensity of exports with a given bilateral partner likely depends more on the stringency of MRL standards in the importing nation as opposed to the international standard. Second, we develop a bilateral trade flow equation to test the degree to which MRLs reduce both the probability and intensity of trade.[2] Finally, we use the bilateral stringency indices and the empirical model to shed light on key regulatory differences between the US and its main trading partners in the Trans-Pacific and Trans-Atlantic trade negotiations.

MRL Policy Setting

While the SPS Agreement allows WTO Members to adopt their own set of regulations, it encourages countries to apply internationally accepted science-based standards established by the Codex Alimentarius Commission (henceforth CAC or Codex).[3] The Codex Committee on Pesticide Residues (CCPR) is the primary body responsible for establishing MRLs for pesticide residues. While the CCPR's responsibility is to establish MRLs for pesticides in specific food items or in groups of food, the Joint Food and Agricultural Organization (FAO)/World Health Organization (WHO) Meeting on Pesticide Residues (JMPR) is responsible for reviewing the appropriate toxicology and residue field data, conducting dietary risk assessments, and recommending specific MRLs to the CCPR. Thus, human health risk assessments must be conducted to ensure food safety before a Codex MRL can be established (Epstein, 2013; Madden, 2014; WHO 2009).

The CCPR follows a three-step process to establish a Codex MRL. First, a member country nominates a chemical/commodity to the CCPR. Second, the JMPR reviews the data provided for this chemical/commodity. Finally, according to the WHO (2009), the establishment of the MRL will be considered by the CCPR, if the JMPR's review confirms that there are no issues or concerns. Although the CAC sets the MRLs for most agricultural and livestock products, WTO members are not legally bound to adopt such standards and there is no means to enforce equivalency with the international standard. As such, MRLs vary widely across countries as discussed shortly because of differences in residue definitions, usage patterns, formulations used in the residue field experiments that may differ from pesticide use in actual production settings, and in the procedures used to determine MRL

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[2] The extensive margin describes as the emergence of new trade flows (i.e. the probability of having strictly positive trade flows), and the intensive margin introduces as the value of these positive flows (Besedeš and Prusa, 2011).

[3] The Codex Alimentarius Commission (CAC) "develops harmonized international food standards to protect health of consumers and ensure fair practices in food trade" (http://www.fao.org/fao-who-codexalimentarius/en/).

levels (Madden, 2014). In such circumstances, countries can adopt standards that differ from Codex as long as they are science-based, non-discriminatory, and minimally trade-distorting (Beghin, 2014).

Thus, no official harmonized level of MRL exists globally (Achterbosch et al., 2009; Drogue and DeMaria, 2010; Van der Meulen and van der Velde, 2004). For example, the European Union (EU) and the United States (US) have established different MRLs for the chemical Methidathion - a widely used organophosphate insecticide used in the production of oranges and other citrus fruits. Because the insecticide can be toxic to humans, avian species, and honeybees, the EU's harmonized SPS policy sets a more stringent residue limit of 0.02 parts per million (ppm), compared to the US which establishes a less stringent standard of four ppm. For comparison, the CAC international standard for Methidalthion in oranges is two ppm.[4]

In the US, the Environmental Protection Agency (EPA) is responsible for establishing residue limits on pesticides that have been registered and approved for use (e.g., have been determined with "reasonable certainty" not to pose a harmful threat to human or environment health). In setting the tolerance, the EPA considers: the toxicity of the pesticide and its break-down products, how much of the pesticide is applied and the frequency of application; and how much of the pesticide (i.e., the residue) remains in or on the surfaces of food by the time it is prepared for retail markets. Pesticide manufacturers, or registrants, are required to submit a variety of scientific trials that identify possible harmful effects the chemical could have on humans (its toxicity), and the amount of the chemical (or breakdown products) likely to remain in or on the surface of food. This information is then used in the EPA's risk assessment and determination of the tolerance. Once an EPA tolerance is established, the limit applies both to domestically produced and imported products. In addition, established MRLs can be updated if new information regarding toxicity or residue data warrants a revision to the existing tolerance (EPA website, 2014).

In the EU, MRLs apply to 315 fresh and processed agricultural products. In cases where pesticides have not been registered, the EU maintains a default MRL of 0.01 mg/kg. The EU's standard setting MRL process first involves estimating residue levels in or on a crop when the pesticides are applied under the Good Agricultural Practice (GAP). Second, the

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[4] It should be noted that international and country-specific MRL standards for a given chemical differ depending on the product. For example, the CAC international MRL standard for pears and table grapes is 1 ppm compared to 0.1 ppm for onions and tomatoes and 0.01 ppm for Macadamia nuts. In the empirical exercise, we develop an index to measure dissimilarities in two trading partners MRL standards for a given product.

total daily intake of the specific pesticide is estimated using consumer intake models and the established residue level. Third, an acceptable daily intake (ADI) is established using information based on toxicological tests. Sensitive groups of consumers such as children are considered in order to determine a safe ADI limit as well as a second limit referred to as the Acute Reference Dose[5] (ARFD). Once these intake limits are computed, the European Commission (EC) establishes a new MRL or revises the existing MRL based on the condition that the daily consumer intake of residues is less than the ADI. For crops and chemicals produced and used outside of the EU, MRLs are established upon request of the exporting country (EC website, 2014; Smolka, 2006).

Previous NTM and MRL Work

A growing body of empirical literature has emerged exploring the relationship between NTMs and international trade. Because of data limitations, most empirical investigations of NTMs employ either broad-based inventory approaches which attempt to cover the widest possible scope of notified NTMs, or focus on a single case-study where better information is available for a specific type of measure. Swann et al. (1996) found that non-tariff standards generally promoted trade in the United Kingdom (UK). Their results initially challenged the predominant view that standards restrict trade. Subsequent studies have often found negative effects of NTMs on trade. Examining the trade impacts of country specific and bilaterally shared standards in 12 OECD countries and 471 industries over the period 1985-1995, Moenius (2004) finds a negative effect of national standards on trade in non-manufacturing sectors. Using frequency and converge ratios for 61 product groups, including some agri-food commodities, Fontagné, Mimouni and Pasteels (2005) find that SPS and TBT measures have a negative impact on agri-food trade but not necessarily on trade in industrial products. Disdier, Fontagne, and Mimouni (2008) use notification frequencies on NTMs and the *ad valorem* tariff-equivalents estimated by Kee, Nicita and Olarreaga (2008) to estimate broad-based impacts of NTM regulations on agri-food trade. They find that NTMs have a negative influence on trade in cut flowers, processed food products (e.g. beverages) and meat, but a strong positive influence on trade in cereals, wool and albuminoids/starch.

Jayasinghe, Beghin and Moschini (2009) depart from broad-based inventory approaches and focus on a particular product – US corn seed exports. Making use of the EXCERPT database, the authors use a count variable to determine the number of SPS measures affecting

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[5] ARFD is the pesticide dose that can be consumed during one day (short time), without considerable health hazard (Smolka, 2006).

corn seed exports and find that trade is decreasing in the number of foreign SPS/TBT standards required. Similarly, Peterson et al. (2013) and Grant et al. (2015) focus on phyto-sanitary treatments (i.e., Methyl Bromide, Cold and refrigeration treatments, etc.) impacting US fresh fruit and vegetable trade. Both studies find that SPS measures tend to reduce US trade initially. However, an innovation in their study is that exporters can overcome the fixed costs of establishing treatment facilities once exporters accumulate product treatment experience in the global market place such that the negative phyto-sanitary trade effect vanishes.

Equally important broad-based and case-study approaches have been conducted in the context of standards and residue limits related to food safety. In terms of broad-based approaches, an important empirical assessment of the trade effects of NTM regulatory heterogeneity was accomplished in the NTM-IMPACT project (see Orden, Beghin and Henry 2012 for a summary). An aggregate data set of regulations and standards measured on a comparable basis for the EU and nine of its trade partners were assembled by collaborators at twelve institutions. The vast array of NTMs covered by the project are technically complex and difficult to evaluate, aggregate, and quantify. Winchester et al. (2012) articulated these challenges and described the procedures followed to develop a comprehensive snapshot of EU regulatory heterogeneity in 2008-09 including measures for import requirements concerning food safety, animal and plant health, labeling, traceability, conformity assessment and certification requirements. Indices of the heterogeneity of trade regulation (HIT) were computed in each of these areas. Concluding evidence from this project indicates that regulatory differences in NTMs negatively impact EU trade.

Case-study approaches have offered a number of additional insights. Otsuki et al. (2001) finds a negative effect of the EU's aflatoxin standard on African groundnut exports. Moving from the CAC standard established by the FAO and the WHO to the more stringent European Commission standard decreases African exports of cereals, dried fruits, and nuts to Europe by $670 million. Xiong and Beghin (2012a) recently overturned the estimated effect in Otsuki et al. (2001), by considering possible demand enhancing effects of SPS regulations. However, other case-studies addressing many of the econometric criticisms raised in Xiong and Beghin (2012a) tend to corroborate the significant negative effects of MRL stringency. Examples include Wilson and Otsuki (2004) for MRLs on chlorpyrifos in banana exports; Wilson, et al. (2003) on the effect of residue limit standards on tetracycline in beef exports; Chen, et al. (2008) on food safety standards impacting China's exports of vegetables, fish and aquatic products; Drogué and DeMaria (2012) on MRLs affecting apples and pears; and Disdier and Marette (2010) on antibiotics impacting crustaceans exports.

While the focus of these studies tends to be narrower in terms of commodity coverage, the results tend to show more stringent maximum residue limits and food safety standards negatively impact trade, particularly for developing nations. Comparing the stringency of MRLs between trade partners is complicated because there are often numerous residue limits that apply to any given product.[6] First, many of the aforementioned studies tend to compare an importers MRL policy with the Codex established international standard without paying much attention to regulatory differences between origin and destination countries. Even if an importer's MRL policy is more stringent than the international standard there are cases where an exporter's MRL policy may be the most restrictive. If exporting firms face a more stringent domestic MRL policy than either the international or importer's standard, it is not likely that the importer's MRL policy could be considered overly trade distorting even if the importer's MRL policy is more stringent than the international standard. Second, a drawback with case-study approaches that focus on one chemical class such as Aflatoxins is that if other MRLs are operating, the empirical analysis may overstate the impacts of the targeted Aflatoxin MRL.

An alternative approach is to consider a targeted stringency index that captures and summarizes the full spectrum of a country's MRL standard for a given product. Such an approach has several advantages. First, the index is bilateral in the sense that we can pay attention to hidden trade obstacles facing exporters in the proposed mega-regional agricultural negotiations. Second, the index can be computed on a product-by-product basis (i.e., apples, pears, grapes, lettuce, etc.) for each exporting partner thereby capturing only those chemicals registered for use for a given product. Finally, the index is targeted at a specific type of SPS policy – namely MRLs. An important drawback in the construction of indices in studies such as Winchester et al. (2012) and the NTM-Impact project for the EU is that the index assigns equal weight to all types of NTMs covered regardless of the importance and/or intensity of their use in the underlying production process (Winchester et al., 2012; Li and Beghin, 2013; Achterbosch et al., 2009; Burnquist et al., 2011; Drogue and DeMaria, 2012; Winchester et al., 2012; Li and Beghin (2013); Ferro et al., 2013; Foletti and Shingal,

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[6] For example, the US has established tolerances for 131 chemicals for apples. However, the same number of registered tolerances is not identical across countries. For apples, the number of established tolerances for chemicals varies from 45 in China, 79 in Canada, to 112 in Japan. This compares to 68 MRLs registered by Codex.

2014a and b). Indeed, Winchester et al. (2012) argue that the general nature of the index makes it difficult to determine the importance of individual (or groups of) NTMs for a given product and country pair. The authors state further that it is difficult to know without expert evaluation which standards matter and which do not for a given product and country pair.

Indices of Regulatory Heterogeneity

Constructing a measure encapsulating the degree of regulatory MRL heterogeneity remains an open empirical issue. Achterbosch et al. (2009) constructed stringency levels of MRLs affecting Chile's exports of fruits to the EU over the period of 1996-2007 using averages of the actual difference in MRLs for each pesticide divided by the sum of the limits for the two trading partners. Foletti and Shingal (2014a) build on Achterbosch et al.'s (2009) framework by separate the stringency index into two measures – one when the exporter maintains a stricter limit and the second when the importer maintains a stricter limit – with the goal of testing the claim that regulatory heterogeneity always creates compliance costs for countries no matter where this heterogeneity comes from. Drogue and DeMaria (2012) compute the respective distance between each country's MRL standards by subtracting the Pearson's coefficient correlation from one, which gives an index with domain [0, 2]. When the index value is close to zero (two), the two trading partners have the same (dissimilar) MRL standards. However, a major shortcoming of the Pearson index is that it does not provide information about which trading partner (importer or exporter) has the stricter MRL. For reasons discussed previously, we believe such information is crucial to the question of whether differences in MRLs represent barriers or catalysts to trade.

Winchester et al. (2012) develop directional and non-directional heterogeneity indices of trade regulation (DHIT and HIT respectively), as defined by Rau et al. (2010), based on the Gower index of (dis)similarity (Gower 1971). The standards investigated, however, include import requirements concerning food safety, animal and plant health, labeling, traceability, conformity assessment, process requirements and certification requirements. Thus, the number of measures involved in the computation of the DHIT is very large, and they weight all NTMs including MRLs equally in their index, arguing that using all of the information is a better alternative than focusing on just a few NTMs or pesticides in the case of MRLs, which is equivalent to putting a weight of zero on all but those few. Indices over a large number of NTMs, however, makes it difficult to determine which measures are responsible for trade disruptions.

With this in mind, the starting point in our analysis is a modification of Li and Beghin's (2013) non-linear exponential index that takes into account the dissimilarity of MRL policies *between country-pairs* rather than between and importer's standard relative to the international Codex limit. Formally, the bilateral stringency index (*BSI*) between origin region *o* and destination region *d* for the *c* classes of chemicals used in the production of product *k* is defined as follows:

$$BSI_{codk} = \left(\frac{1}{N_{ck}}\right) \sum_{p \in N_{ck}} exp\left(\frac{MRL_{opk} - MRL_{dpk}}{MRL_{opk}}\right) \tag{1}$$

where N_{ck} is the number of chemicals in chemical class *c* used in the production of commodity *k*, MRL_{opk} is the maximum residue limit for the p^{th} chemical in class *c* for commodity *k* in region *o* and MRL_{dpk} is the maximum residue limit for the p^{th} chemical in class *c* for commodity *k* in region *d.* We consider three broad classes of pesticides - herbicides, insecticides, and fungicides – to identify whether MRL policy dissimilarities between the destination and origin regions vary systematically across different classes of chemicals (*c*).

The advantages of the exponential function are that it maps heterogeneous *BSI* differences onto the range zero ($\exp(-\infty)$) and 2.72 ($\exp(1)$) and penalizes larger MRL differences between *o* and *d* relatively more. For example, if the destination region has a much stricter MRL for chemical *p* in class *c* (i.e., 0.1 ppm) compared with the origin region (i.e., 5 ppm), reflecting a heterogeneous regulatory situation, then the ratio of MRLs will approach a value of unity and the BSI function will approach its upper limit of *exp*(1) = 2.72. Conversely, if the origin region has a much stricter MRL for chemical *p* in class *c* compared to the destination region, then the ratio of MRLs will be negative and in the limit the exponential function will approach zero, reflecting the fact that the destination region MRL is not likely to represent a "barrier" to trade because exporting firms are already required to meet a more stringent domestic tolerance. Finally, if the origin and destination regions have the same MRL for chemical *p* in class *c*, then the ratio equals zero and the BSI is *exp*(0) = 1, reflecting an equivalent or harmonized SPS situation.

As described shortly, the *BSI* is calculated for all countries with established MRL standards and the requirement that the chemical is used in production based on data provided by the USDA/NASS surveys of pesticide use for 26 fruits and 25 vegetable crops across producers in the United States. All else constant, stricter MRLs in the destination country relative to the origin country are expected to have a negative impact on trade. The extent to which trade falls for incremental increases in the *BSI*, however, is clearly an open empirical question.

Empirical Approach

In order to quantify the extent to which MRL policy dissimilarities reduce fruit and vegetable trade between trading partners, a product-level model of bilateral trade is developed based Anderson and van Wincoop (2003), Baldwin and Taglioni (2006), Peterson et al. (2013) and Grant et al. (2015) and augmented to focus in particular on U.S. exports to the EU and TPP markets. The model assumes all varieties of commodity *k* (e.g., apples, broccoli, etc.) are differentiated by their source and consumer preferences' in destination region *d* for commodity *k* are weakly separable and can be represented by a CES sub-utility function:

$$U_{dk} = \left\{ \sum_{o=1}^{R} \alpha_{odk}^{\frac{1}{\sigma_k}} x_{odk}^{\frac{\sigma_k - 1}{\sigma_k}} \right\}^{\frac{\sigma_k}{\sigma_k - 1}} \tag{2}$$

where U_{dk} is the level of utility from the consumption of commodity *k* by the representative consumer in *d*, *R* is the number of countries/regions, α_{odk} is a preference parameter for commodity *k* supplied by region *o* to region *d*, x_{odk} is the quantity of commodity *k* supplied by *o* and consumed in *d*, and σ_k is the elasticity of substitution between all varieties of commodity *k*. Time period subscripts are suppressed as discussed further below due to the limited time-series nature of the MRL data.

Conditional on the level of expenditure allocated to consumption of commodity *k* in region *d* (E_{dk}), expenditure on commodity *k* from country *o* in region *d* (V_{odk}) is:

$$V_{odk} = p_{odk} x_{odk} = \frac{\alpha_{odk} p_{odk}^{1-\sigma_k} E_{dk}}{\sum_{r=1}^{R} \alpha_{rdk} p_{rdk}^{1-\sigma_k}}, \tag{3}$$

where p_{odk} is the price of commodity *k* from region *o* in region *d*. Note that the denominator in equation (3) can be expressed in terms of the price index (PI_{dk}) for the CES sub-utility function:

(4) $$PI_{dk} = \left\{ \sum_{r=1}^{R} \alpha_{rdk} p_{rdk}^{1-\sigma_k} \right\}^{\frac{1}{1-\sigma_k}}.$$

If t_{odk} represents all trade costs of selling commodity *k* from region *o* in region *d* then producer prices in the origin country (pp_{ok}) are linked to destination prices via the price linkage equation, $p_{odk} = t_{odk}pp_{ok}$. Substituting this expression, along with equation (4) in equation (3) yields:

(5) $$V_{odk} = \frac{\alpha_{odk} \left(t_{odk} pp_{ok} \right)^{1-\sigma_k} E_{dk}}{PI_{dk}^{1-\sigma_k}}.$$

If all markets for commodity *k* clear, the quantity of commodity *k* produced in region *o* will equal the quantity demanded across destination regions, including domestic consumers in country *o*. Total sales of commodity *k* produced in region *o* (Y_{ok}) will equal the sum of consumer expenditures (evaluated at the producer price in region *o*) across demand regions:

(6) $$Y_{ok} = \sum_{d=1}^{R} V_{odk} = \sum_{d=1}^{R} \frac{\alpha_{odk} \left(t_{odk} pp_{ok} \right)^{1-\sigma_k} E_{dk}}{PI_{dk}^{1-\sigma_k}}$$

Solving for $pp_{ok}^{1-\sigma_k}$ in equation (6) and substituting into equation (5) yields an extended version of Baldwin and Taglioni (2006), that incorporates an explicit commodity dimension:

(7) $$V_{odk} = \frac{\alpha_{odk} t_{odk}^{1-\sigma_k} Y_{ok} E_{dk}}{\left[\sum_{d=1}^{R} \frac{\alpha_{odk} t_{odk}^{1-\sigma_k} E_{dk}}{PI_{dk}^{1-\sigma_k}} \right] PI_{dk}^{1-\sigma_k}} = \frac{\alpha_{odk} t_{odk}^{1-\sigma_k} Y_{ok} E_{dk}}{\Omega_{ok} PI_{dk}^{1-\sigma_k}}.$$

Trade costs (t_{odk}) consist of all factors required to get commodity *k* from producers in region *o* to consumers in region *d.* We assume that the trade cost function is multiplicative function of transportation margins as proxied by geographical distance, an indicator of free trade agreements and the bilateral stringency index of MRL policy:

(8) $$t_{odk}^{1-\sigma_k} = dist_{od}^{\delta_1} \exp\left(RTA_{od} \right) \prod_{c} BSI_{odk}^{\theta_c} z_{odk}^{\theta_0}$$

where, $dist_{od}$ is the geographical distance between regions *o* and *d*, RTA_{od} is an indicator of free trade agreements, BSI_{odk} is the bilateral stringency index defined in previous section (equation 1) noting that we define $c = 3$ classes of pesticide MRL categories (herbicides, insecticides, and fungicides), and z_{odk} are other potentially unobserved determinants of trade costs.

To complete the product line model, some further refinements are necessary. First, because the CES sub-utility function is homothetic, an increase in E_{dk} will yield a proportional increase in V_{odk}, all else constant. However, E_{dk} is not directly observable. While in general, E_{dk} is a function of the price indices for each partition (commodity) and income, the price indices are also not observable. Baldwin and Taglioni (2006), Anderson and van Wincoop (2003), Feenstra (2004) and many others suggest the use of time varying, country-specific fixed effects. However, because MRL data availability limits our analysis to two years of data, we adopt an alternative approach that involves dummy variables for origin, destination and commodity fixed effects (*o*, *d* and *k*) as a consistent alternative to control for production levels in the exporting country, expenditure in importing countries and the unobserved price indices (Grant et al., 2015).

The second refinement is the prevalence of zero trade flows. Recent papers by Santos-Silva and Tenreyro (2006), Pham and Martin (2008), Helpman, et al. (2008) and Jayasinghe, et al. (2009) show that omitting zero trade flows leads to biased estimates due to sample selection issues, particularly if the reason for the existence of zero trade is correlated with right-hand side variables such as MRL policies. One approach to incorporate zero trade flows is the Poisson pseudo-maximum likelihood (PPML) estimation framework as discussed in Santos-Silva and Tenreyro (2006). Substituting equations (8) and (1) into equation (7) along with E_{dk} yields our baseline model of product line trade flows:

$$
\begin{aligned}
X_{odk} = \exp\Bigg[& \pi_o + \pi_d + \pi_k + \sum_c \theta_c BSI_{codk} + \delta_1 \ln Dist_{od} + \delta_2 RTA_{od} \\
& + \sum_c \theta_{c_{US-EU}} BSI_{codk} I_{US-EU} + \sum_c \theta_{c_{US-TPP}} BSI_{codk} I_{US-TPP} \Bigg] \varepsilon_{odk}
\end{aligned} \tag{9}
$$

where X_{odk} is the export value of bilateral fresh fruit and vegetable trade between *o* and *d*, $I_{US\text{-}EU}$ and $I_{US\text{-}TPP}$ are indicator variables equal to one if *o* is the US and *d* belongs to the EU or TPP countries, respectively. By including these terms, we allow the EU and TPP MRL policies with respect to US exports to have potentially different trade impacts. π_o, π_d and π_k are exporter, importer and commodity fixed effects, and ε_{odkt} is the multiplicative error term.

While equation (9) describes the PPML estimation framework, an important consideration of MRL policies is whether exporting nations facing stringent MRL policies in destination markets actually export at all. Thus, the final objective of the empirical model is to investigate the impact of regulatory heterogeneity of MRL standards on both the extensive (i.e., probability of exporting) and intensive (intensity of exports) margins of trade while controlling for sample selection issues. Heckman's (1979) model retains the log-linear transformation of the model and treats zero trade flows as censored observations. The model includes both a selection and outcome equation as follows:

$$(10) \qquad Y^*_{odk} = \pi_o + \pi_d + \pi_k + \sum_c \theta_c BSI_{codk} + \delta_1 \ln Dist_{od} + \delta_2 RTA_{od} + \mu_{odk}$$

$$(11) \qquad \ln X^*_{odk} = \pi_o + \pi_d + \pi_k + \sum_c \theta_c BSI_{codk} + \delta_1 \ln Dist_{od} + \delta_2 RTA_{od} + \varepsilon_{odk}$$

where Y^*_{odk} is a latent variable predicting whether or not bilateral trade between o and d is observed and ln (X^*_{odk}) is the natural logarithm of the intensity of bilateral trade. Y^*_{odk} and lnX^*_{odk} are not observable in the selection and outcome equations, respectively, but we do observe $Y_{odk} = 1$ if $Y^*_{odk} > 0$ and $Y_{odk} = 0$ if $Y^*_{odk} \leq 0$ and $lnX_{odk} = lnX^*_{odk}$ if $Y^*_{odk} > 0$ and lnX_{odk} is not observed if $Y^*_{odk} \leq 0$. The model can be estimated by a two-step procedure suggested by Heckman (1979) or the one-step maximum likelihood estimation where the selection and outcome equation are estimated simultaneously. The two-step procedure first estimates the bivariate selection equation using a Probit model and generates the standard inverse of the Mills ratio which is subsequently included as an additional regressor in the outcome equation.

The advantage of the Heckman model is that it can effectively estimate both the extensive and intensive margins of trade by explicitly modeling zero trade flows. That is, it allows us to determine if stringent MRL policies impact the probability of exporting, the intensity of exporting or both. The drawback of this model is that appropriate exclusion restrictions are often required although Cameron and Travedi (2010) note that the system is just-identified through the non-linearity of the inverse mills ratio.

Data Description

Information on MRLs during 2013 and 2014 are obtained from the global MRL database maintained by the Foreign Agricultural Service (FAS) (see mrldatabase.com). Since the global MRL database is frequently updated and without archives, we extracted the MRL data first in December 2013 and then again in December 2014. The established MRL data for each fruit and vegetable by each individual country including CODEX standards were retrieved. The total number of pesticides with established MRLs reported in the global MRL database is 256 chemicals. However, not all pesticides with established MRLs are approved for use. Therefore, we have retrieved data from the National Agricultural Statistics Service (NASS) producer surveys that report 162 chemicals used in fruit and vegetable production. NASS develops surveys to determine on-farm chemical use and pest management information for agricultural commodities. Each chemical's biological name is then matched with the chemical identifier reported in the global MRL database.

Once the list of active chemicals is created, it is then merged with the global MRL data, leaving us with a three-dimensional database of MRLs that varies by country, commodity, and the pesticide chemical name. Our product sample includes 51 fruit and vegetable products (FVs) (see appendix table A) at the 6-digit level of harmonized system for 85 countries with reported MRL tolerances for 162 pesticides used in production over the sample period 2013 and 2014. The raw unbalanced dataset has 678,252 observations consisting of a year, country, commodity and pesticide dimension. However, around 42% of observations are missing because an MRL is not registered for use in a given country or an established MRL has not been registered. While some countries maintain default values (e.g. the EU introduces a default value of 0.01 ppm) if no MRL is reported, replacing these missing values with default values does not add much information to our sample (35% of the observations are still missing).

Reported MRLs can be divided into six categories – Codex standards, European Union standards, United States standards, Gulf Cooperation Council (GCC) standards, other countries with their own standards, and countries deferring to exporting countries' standards. Among the 88 countries listed in Table 1 for which we collected MRL information, 27 countries adopt the Codex standard for all products and 31 countries set their own standards. Sixteen countries defer to the EU's standard, seven countries use their trading partners' (exporting countries) standards, four countries adopt the GCC standards, and Mexico defers to the US standards. With the exception of Peru (Codex deferral) and Mexico (US deferral), all of the Trans-Pacific Partnership (TPP) and T-TIP members (Australia, Brunei, Canada, Chile, Japan, Malaysia, Mexico, New Zealand, Peru, Singapore, United States and Vietnam and the EU) set their own MRL standards. Importantly as shown in Table 2, some countries establish a default MRL, which can be used if a specific MRL is not reported, a pesticide has not been registered for use, or is in the process of being registered for use. The default values demonstrate the lowest residue concentration that is permitted.[7]

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[7] Further information available at www.MRLdatabase.com.

Table 3 provides a comparison of the MRL data for countries that set their own standards relative to the international standard (Codex) and the United States. It also presents for each country the Codex-based stringency index scores defined in Li and Beghin (2013). Column (1) (Table 3) illustrates the share of each country's MRLs that are stricter (i.e., a tighter limit) than Codex. Relative to the international standard, Brazil's MRL standards appear to be the most stringent among all countries in Table 3 with 61 percent of its standards being set at stricter limits than those advocated by Codex. Column (2) presents similar results but instead of the Codex we compare MRL stringencies to the United States. Here, Russia appears to set the most restrictive tolerances with 68 percent of established MRLs being more stringent than the corresponding values set by the United States.[8] Following Russia, Brazil, Turkey, Iceland and Norway with 64 percent and the EU with 63 set their MRLs more stringent than the United States.

Columns (3) and (4) summarizes the degree of MRL policy dissimilarity as measured by the bilateral stringency index (BSI) relative to Codex. Interestingly, our Codex-based BSI calculation reveals that Thailand, Malaysia, Saudi Arabia, Canada, India, Singapore, South Africa, China, the US, New Zealand, Japan and the GCC all have BSI values less than one indicating a less stringent MRL policy compared to Codex. Conversely, the remaining countries from Brazil to Brunei have Codex-based BSI levels above unity indicating a more stringent level of MRL policy. Also of interest are the Codex-based BSI's for EU and TPP countries. Among TPP countries, Chile and Australia have the highest MRL stringency index levels at 1.07 and 1.05, respectively which indicates only a slightly more restrictive MRL policy compared to Codex, whereas many other TPP members including Japan and New Zealand have indices that are much less stringent than Codex and the United States. On the other hand, with an MRL index of 1.25 the EU ranks eighth in terms of its MRL stringency compared to Codex. The final two columns in Table 3 report the number of established and non-established MRLs in our database. As shown, the US has the highest number of established MRLs (14,311), while Indonesia has the lowest number of established MRLs (384).

Also of interest is the fact that MRL tolerances differ widely across products for the same chemical. For instance, Acetamiprid is an odorless neonicotinoid insecticide, which controls for sucking insects on some fruits such as citrus, pome, and grapes and leafy

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[8] While Russia reports a limited number of established MRLs, those established MRLs have the most stringent values compared to the US standards.

vegetables. Codex has established 12 different tolerances for this chemical depending on the fruit or vegetable product being traded. However, the EU, Japan and the US set 19, 15 and 14 unique values for this chemical, respectively, and their values are consistent with Codex ranging from 0.01 to around 5 ppm (with the exception of 15 ppm for the United States). While it is conceivable that biological and production factors necessitate 19 different tolerance levels for a given pesticide (as in the EU), it could also be the case that countries are creating MRL policy flexibility similar to the way in which countries set different tariff rates for the same product depending on the country of origin. At the other extreme, more generic pesticides such as 2,4-D have a much lower range of Codex tolerances across products ranging from a low of two ppm to a high of ten ppm (and the only other unique tolerances are two and five ppm). Similar ranges exist for 2,4-D MRLs in the EU, Japan and the US.

Finally, annual bilateral trade of fresh fruits and vegetable products are merged with the constructed MRL database. The bilateral annual export flows of FVs between trading partners are obtained from the United Nations Commodity Trade Statistics Database at 6-digit level of harmonized system. Geographical distance is taken from the *Centre d'Etudes Prospectives et d'Informations Internationales* (CEPII) geo-distance dataset (Mayer and Zignago 2006).[9] Information on Regional Trade Agreements (RTAs) data is obtained from Grant (2013). Table 4 presents the summary statistics for the variables in our econometric model. Our sample contains 95 exporters and 96 importers, 51 FVs and two years of trade and MRL data. It should be noted that the unbalanced panel includes zero trade flows in our sample, which is common when working with individual product level trade flows.[10] The final sample includes 257,647 observations, of which 65% observations are zero trade flows.

Results

The results are organized as follows. In section one we present qualitative illustrations of the MRL bilateral stringency index across countries, products and classes of chemicals focusing our attention on the EU and TPP markets. While these results illustrate basic trends and bilateral stringency levels across countries and products, they do not establish a more

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[9] CEPII is an independent European research institute on the international economy stationed in Paris, France. CEPII's research program and datasets can be accessed at www.cepii.com. CEPII uses the great circle formula to calculate the geographic distance between countries, referenced by latitudes and longitudes of the largest urban agglomerations in terms of population.

[10] In order to explore if a country has the potential to export a given commodity, we assume if an exporter did not export a given commodity at least 3 times over a period of 10 years (2004-2014), we consider that the exporter does not have the potential to export a given commodity. We make this assumption because retrieving data at 6-digit level of FVs from Food and Agricultural Organization (FAO) is not feasible.

casual link between MRL policy dissimilarities and trade. Thus, section two presents the formal econometric results to test and quantify the extent to which regulatory heterogeneity in MRL policies disrupt bilateral trade in fresh fruits and vegetables.

Bilateral Stringency Index

Table 5 presents the simple and trade-weighted averages of the BSI overall and across four different classes of pesticides. Columns (1) and (2) illustrate the simple and trade-weighted averages across partner countries assuming the US is the exporting nation.[11]

Among the countries listed in Table 5, Iceland, Norway, Switzerland, the EU, Russia, Turkey, Brazil and the United Arab Emirates have the highest stringency index based on simple averages of the BSI. These countries have a stringency index above 1.5, which shows a potentially high level hidden trade costs in the form of strict food safety tolerances. Iceland has the highest trade weighted BSI against the United States. Commodities with high stringency indices between the US and Norway include brussels sprouts, cauliflower, broccoli, spinach, avocado and leeks with stringency levels between 1.91 and 2.01. The top imported commodities such as apples and grapes have more moderate stringency levels of 1.45 and 1.29, respectively, but still above one indicating the US faces greater MRL stringency for exports compared to exporting firms that serve the domestic market. Russian melons and cherries, for example, have MRL tolerances of 2.17 and 1.92, respectively. The BSIs for the rest of the countries listed in Table 5 show moderate stringency levels between one and 1.5. It is also worth mentioning that major importers of US FVs such as Canada, Mexico and Japan have the least stringent MRLs on average.

Table 5 also displays BSIs for many of the Trans Pacific Partnership (TPP) countries. Among TPP countries, Chile and Australia have higher equally weighted stringency level of BSIs of approximately 1.29. However, Chile’s trade weighted BSI is much higher than its unweighted BSI, suggesting that commodities sourced from the US with greater values of imports tend to have stricter MRL tolerances. Conversely, for the EU, the trade-weighted BSI is lower than the equally weighted BSI, indicating that US export intensity is higher in less stringent MRL product categories.

Columns (3) through (8) of Table 5 also report the stringency level of tolerances for different classes of chemicals. Turkey’s BSI for herbicides and fungicides has the highest stringency indices above two, while it has a moderate level of stringency for insecticides on

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[11] Recall the BSI is not symmetric and thus the direction of trade flow matters.

average. In order to simplify these results, Figure 1 plots the average trade-weighted bilateral stringency indices for different classes of chemicals, where the vertical axis shows the average stringency level when the US is the exporting country. Again, Brazil, the EU, Iceland, Norway and Russia rank the highest (> 1.5) in stringency among all US trading partners for the insecticides index. Switzerland has an insecticide index around 1.5 and the remaining countries have moderate levels below 1.5 for insecticides. A broader range of countries/regions, including some in the TPP and T-TIP, have herbicide BSIs above 1.5, including Chile, the EU, Indonesia, Norway, Peru, Saudi Arabia, Switzerland, Turkey and Vietnam. BSI-insecticides and BSI-herbicides for China and Japan, and the BSI-fungicides for New Zealand are the only countries with indices below one. It is also apparent that BSI-fungicides generally have a stricter stringency index compared to other classes of chemicals. While the highest level of stringency belongs to BSI-herbicide for Turkey, the BSI-fungicides are consistently close to or above 1.5.

Figure 2 displays a distribution plot (boxplot) of the range of the BSIs across commodities within a given country and is useful to decipher the variability of MRL policies for select destination countries. The figure shows that although China has a relatively less stringent MRL policy overall, it has the highest variation among the three pesticide indices compared to other countries (the exception being fungicides for Indonesia). On the other hand, Canada, Japan, Australia and Korea have a much narrower MRL policy span.

Table 6 and Figure 3 illustrate average and the variability of BSI levels across commodities. Table 6 illustrates that vegetables have stricter BSI levels using both equally and trade weighted averages across US trading partners. Specifically, brussels sprouts, broccoli, cauliflower, avocados and celery are five commodities facing the most restrictive MRL tolerances globally. Among fresh fruits and vegetables, apples, leaf lettuce, strawberries and grapes rank the highest among US exports in 2013 and 2014, but on average face moderate stringency levels ranging between 1.14 (grapes) to 1.32 (strawberries). In figure 3 fresh tomato exports face the smallest range and lowest level of MRL tolerances for each pesticide class and commodity. For cherries, broccoli, leaf lettuce and onions, however, not only the level but also the variability of MRLs is relatively high.

Given the sensitive nature of NTMs and food safety issues in the T-TIP and TPP negotiations, we next analyze the BSI indices with respect to these markets to assess current regulatory heterogeneity faced by US exporters (Figures 4 and 5). For TPP markets (Figure 4), our results indicate that eight commodities (apples, oranges, leaf lettuce, pears and quinces, lemons and limes, tomatoes, grapefruits, peaches and nectarines) out of 48 commodities with significant exports rank in the top 20 *least* stringent indices to TPP countries in 2013 and 2014. Apples, which ranked 17 out of the 20 of the least stringent MRL tolerances, is the top export of US fruits and vegetables to TPP countries. Here the BSIs are close to one which illustrates that TPP MRLs are closer to equivalent with the US compared to those faced in the EU. The top fruit and vegetable exports to the EU are grapefruit, apples, grapes, onions, raspberries and blackberries, strawberries, and cherries. According to our results, three commodities (apples, grapes, and mushrooms and truffles) rank in the top 10 least stringent indices to the EU in 2013 and 2014. On the other hand, avocados and cauliflower rank among the most stringent MRL commodities exported to the EU. Comparing the EU and TPP markets indicates that the stringency levels for the EU are much stricter than those in TPP markets, with values frequently exceeding 1.5 for certain commodities and pesticide classes in the former, compared to values much closer to unity in the latter.

Figure 6 also plots the variations of BSI indices for each chemical class for the EU and TPP markets. The boxplot of the EU indices shows stricter indices and wider dispersion compared to TPP markets, particularly among fungicides indicating room for negotiations over MRLs in this class of pesticides. In addition, we conducted a non-parametric two-sample Wilcoxon rank-sum test to test whether differences between the indices across the EU and TPP markets are significantly different. The equality of the BSI indices was easily rejected.

Finally, Table 7 simplifies the analysis further by categorizing commodities into bin ranges: less than one, between one and 1.5, and greater than 1.5.[12] Interestingly, the majority of BSIs for TPP markets fall into the middle category, with a smaller but still significant number of commodities – 15, 11 and 5 for insecticides, herbicides and fungicides, respectively – exhibiting BSIs less than one. This underscores the important point that for most fruit and vegetable products, TPP countries have roughly similar BSIs to those of the US. In the EU, the majority of BSIs fall into the last category - greater than 1.5 – indicating a more stringent MRL policy environment and the potential for MRL harmonization in the trade negotiations.

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[12] Note that, some fruits and/or vegetables do not have BSI indices across all the classes of chemicals. Therefore, the total numbers of commodities across different classes of chemicals for the EU and/or TPP markets are not equal.

Econometrics Results

The econometric estimates reported here shed light on the degree to which differences in MRL regulatory stringencies affect bilateral exports of fruits and vegetables between trading partners. The results discussion is organized as follows. First, we discuss aggregate BSI impacts on trade flows. Second, we discuss the results by augmenting the model with indicators for US exports to TPP and T-TIP markets and the interaction of these with the BSI. In the third section, we distinguish between the different classes of chemicals to determine if the negative and significant trade flow effects of the aggregate BSI results are systematically driven by a particular class of chemicals. Finally, we examine the effects of MRL policy dissimilarities on the probability of exporting and the intensity of exports using a Heckman model. In all regressions, importer, exporter and commodity fixed effects are included and standard errors are clustered by country-pairs.

Table 8 considers the aggregate BSI effects across all countries and between the US-EU and US-TPP. The results for geographical distance and belonging to a mutual regional trade agreement are of the correct sign and statistically significant across all specifications. In terms of MRL policy, the BSI showcases a negative and statistically significant sign across all model specifications in columns (1)-(6) suggesting that higher BSIs – indicative of a more stringent tolerance in the destination compared to the origin market – significantly reduces bilateral fresh fruit and vegetable exports. Thus, overall, the impact of MRL tolerances is trade impeding because it likely requires more careful production, testing and compliance costs to serve international markets with stricter food safety guidelines. The economic interpretation is similar to a semi-elasticity since the dependent variable is in logs while the BSI is in levels. A stricter BSI equivalent to an increase in the index of 0.1 at the mean reduces fruit and vegetable exports by 7% in the OLS model (column 1) and 8.8% in the Poisson model (Column 2). However, these results are across all countries and products in the database. When we introduce individual controls for US exports to the EU and TPP markets, the results paint a contrasting picture of MRL effects on US exports. Here, the BSI coefficient is more negative and statistically significant for US exports to the EU but has a positive and statistically significant interaction coefficient for US trade with TPP partners. Quantitatively, the estimates imply that stricter bilateral stringencies of MRLs (by 0.1 at mean) declines US export of FVs to the EU members by a striking 23.6% in OLS model (column 4). Thus, the effect of stricter MRLs is quite elastic with respect to its effect on US-EU trade.

In addition to the baseline estimations, we also allow the BSI effect to vary over fungicides, herbicides and insecticides (table 9).[13] In a similar format to table 8, columns (1)-(3) report the results of chemical class-specific BSIs across all trading partners, while columns (4)-(6) distinguish between US-EU and US-TPP markets. The results are robust. With the exception of fungicides in the Poisson model, more restrictive MRL policies tend to impose negative and statistically significant trade distortions (Columns 1-3). In columns (4)-(6), the impact of BSIs for different classes of chemicals on US-EU and the US-TPP markets are more sensitive and fragile given the low number of observations in these categories making identification challenging. However, some interesting findings emerge. First, the mostly negative BSI effect reported in columns (4)-(6) turns out to be driven almost entirely by fungicides and insecticides for the US-EU and insecticides for the US-TPP markets suggesting specific chemical classes on which trade negotiators can focus attention. Second, herbicide indices of MRL stringency appear to enhance US exports. Because the BSIs measure the stringency of MRL heterogeneity for the US-TPP markets, the results for herbicides suggest that stricter MRL tolerances of the US may serve as a demand enhancing effect on trade.

Finally, we turn to the results of the Heckman model as presented in Table 10. Overall the results are illuminating and suggest that MRL stringency decreases both the probability of exports (selection equation) as well as the intensity of exports (outcome equation). Thus, MRL policies likely impart significant fixed and variable trade costs of exporting judging by the negative and significant extensive and intensive margin results.

Conclusions

This paper introduced the bilateral stringency index to assess how regulatory heterogeneity (and convergence) for pesticide tolerances used in the production process of fresh fruits and vegetables impacts trade between the US and its partner countries in the proposed mega-regional trade deals. We developed the aggregated bilateral stringency index based on different classes of chemicals, which provides further insight as to the types of pesticides that influence trade flows. In particular, previous studies in this line of work often employ an aggregate measure of stringency or dissimilarity over all chemicals with established MRLs relative to the international standard, whereas we develop a bilateral

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[13] The last category of chemical class “Other” are dropped from regression estimations because a small number of observations belonging to this category.

stringency measure based he fact that it likely matters more to exporters what the MRL policy is in the destination market as opposed to what tolerance level is advocated by Codex.

Second, we constructed a new database on international fruit and vegetable exports matched to maximum residue limits for each country in 2013 and 2014. The results of the country-level index indicate that Brazil, Iceland, Norway, Switzerland, Turkey, and the EU rank among the most stringent among all US trading partners, Canada and China, two of the top markets for US exports of fruits and vegetables show moderate stringency levels, while Japan is consistently among the least restrictive MRL partners in our database. At product level, brussels sprouts, avocadoes and celery rank among the highest MRL stringent commodities whereas the top US fruit exports consisting of apples, grapes, oranges, cherries and strawberries, have a moderate stringency index. Further, the results clearly indicate that there is a significant gap in regulations regarding maximum residue limits among several major US foreign markets for fruits and vegetables. For instance, the BSI-insecticide for apples is stricter than BSI-herbicide and BSI-fungicide between the US and the EU, while there is virtually no difference among the three classes of chemical indices for apple trade between the US and TPP markets. The stringency index results also provide a snapshot of regulatory heterogeneity between the US and its important export markets in the EU and TPP countries. Overall, the bilateral stringency indices suggest much stricter regulations for the EU compared to TPP markets for both fruits and vegetables and across different classes of chemicals, suggesting that trade negotiators will likely want to emphasize the dissimilarity of MRL tolerances in the T-TIP negotiations. Thus, the results of this study provide important policy implications as the negotiations between the US and TPP and T-TIP countries progress.

References

Achterbosch, T., A. Engler, and M.L. Rau, M. 2009. Measure the measure : the impact of differences in pesticide MRLs on Chilean fruit exports to the EU. Paper presented at the International Association of Agricultural Economists Conference, Beijing, China, 08.

Anderson, J.E., and E. van Wincoop. 2003. Gravity and Gravitas: A Solution to the Border Puzzle. *American Economic Review* 93(1): 170–192.

Baldwin, R. 2000. Regulatory Protectionism, Developing Nations and a Two-Tiered World Trading System. Brookings Trade Forum. Washington, DC: Brookings Institute Press.

Baldwin, R., and D. Taglioni. 2006. Gravity for Dummies and Dummies for Gravity Equations. National Bureau of Economic Research Working Paper 12516.

Beghin, J. C., and J. C. Bureau. 2001. Quantification of sanitary, phytosanitary, and technical barriers to trade for trade policy analysis. Working Paper 01-WP291. Center for Agricultural and Rural Development, Iowa State University.

Beghin, J. 2014. The Protectionism of Food Safety Standards in International Agricultural Trade. Agricultural Policy Review, Center for Agricultural and Rural Developmnet (CARD), Iowa State University.

Beghin, J., M. Maertens, and J. Swinnen, 2015. Nontariff Measures and Standards in Trade and Global Value Chains, Annual Review of Resource Economics, *Annual Reviews* 7(1): 425-450.

Burnquist, H. L., K. Shutes, M.L. Rau, M.J. Pinto de Souza, and R. Nunes de Faria. 2011. Heterogeneity Index of Trade and Actual Heterogeneity Index – the case of maximum residue levels (MRLs) for pesticides. Poster prepared for presentation at the Agricultural & Applied Economics Association’s 2011 AAEA & NAREA Joint Annual Meeting, Pittsburgh, Pennsylvania, 06.

Center for International Development at Harvard University. 2004. Sanitary and Phytosantary Measures and Technical Barriers to Trade Summary. Global Trade Negotitations Home Page. http://www.cid.harvard.edu/cidtrade/issues/spstbt.html

Chen, C, J. Yang, and C. Findlay. 2008. Measuring the Effect of Food Safety Standards on China’sAgricultural Exports. *Review of World Economics* 144(1): 83–106.

De Sousa, J. 2012. The currency union effect on trade is decreasing over time, *Economics Letters* 117(3): 917-920.

Disdier, A., L. Fontaigné, and M. Mimouni. 2008. The Impact of Regulations on Agricultural Trade: Evidence from the SPS and TBT Agreements. *American Journal of Agricultural Economics* 90(2): 336–350.

Drogué, S., and F. DeMaria. 2010. Do different regulations in Maximum Residue Levels of pesticides affect trade competitiveness? The case of apples and pears. Presented at 12. Annual conference ETSG 2010, Lausanne, CHE (2010-09-09 - 2010-09-11). http://prodinra.inra.fr/record/40781

Drogué, S., and F. DeMaria. 2012. Pesticide residues and trade, the apple of discord? *Food Policy* 37(6): 641–649.

Epstein, R. 2013. Codex Alimentarius Committee on Pesticide Residues, Science and technology Program, USDA. ftp://ftp.fao.org/codex/alimentarius/a131_24e.pdf

European Commission website, http://ec.europa.eu/ (accessed May 2014).

Feenstra, R. 2004. Advanced International Trade:Theory and Evidence. Princeton, NJ: Princeton University Press.

Ferro, E., J.S. Wilson, and T. Otsuki. 2013. The effect of product standards on agricultural exports from developing countries. The World Bank, Policy Research Working Paper Series: 6518, 2013. Development Research Group, Trade and International Integration Team, 06.

Foletti, L., and A. Shingal. 2014a. Stricter Regulation Boosts Exports: the case of Maximum Residue Levels in Pesticides. MPRA Paper 59895, University Library of Munich, Germany.

Foletti, L., and A. Shingal. 2014b. Trade Effects of MRL Harmonization in the EU. Working Paper 2014/5, nccr trade regulation, swiss national centre of competence in research.

Fontagne, L., M. Mimouni, and J.-M. Pasteels. 2005. Estimating the Impact of Environmental SPS and TBT on International Trade. *Integration and Trade* 22: 7–37.

Grant, J. H., E. Peterson, and R. Ramniceanu. 2015. Assessing the Impact of SPS Regulations on U.S. Fresh Fruit and Vegetable Exports. Journal of Agricultural and Resource Economics. 40(1): 144-163. Copyright 2015 Western Agricultural Economics Association. ISSN 1068-5502

Grant, J.H. and S. Arita. 2016 *Forthcoming*. Revealed Concerns: A New Look at the Impact of Non-Tariff Measures on Agri-Food Trade, Commissioned Paper, International Agricultural Trade Research Consortium (IATRC), June 2016.

Grant, J.H. 2013. Is the Growth of Regionalism as Significant as the Headlines Suggest? Lessons for Agricultural Trade, *Agricultural Economics* 44(1): 93-109

Gower, J.C. 1971. A General Coefficient of Similarity and Some of Its Properties. *Biometrics* 27(4): 857-871.

Heckman,J. J. 1979. Sample Selection Bias and a Specification Error. *Econometrica* 47(1): 153–161.

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

Jayasinghe, S., J. Beghin, and G. Moschini. 2009. Determinants of World Demand for U.S. corn Seeds: The Role of Trade Costs. *American Journal of Agricultural Economics* 92 (4): 999–1010.

Josling, T., D. Roberts, and D. Orden. 2004. Food Regulation and Trade:Toward a Safe and Open Global System .Washington,DC: Institute for International Economics.

Kee, H. L., A. Nicita, M. Olarreaga. 2008. Import Demand Elasticities and Trade Distortions. *The Review of Economics and Statistics* 90(4): 666–682, by the President and Fellows of Harvard College and the Massachusetts Institute of Technologyta

Lawrence, R.Z. 1996. *Regionalism, Multilateralism, and Deeper Integration.* Washington, D.C.: The bookings Institution, Integrating National Economics Series.

Li, Y., and J.C. Beghin. 2013. Protectionism indices for non-tariff measures: An application to maximum residue levels. *Food Policy* 45(01): 57–68. http://doi.org/10.1016/j.foodpol.2013.12.005

Madden, B. 2014. MRL Meeting. Office of Pesticide Programs, Registration Division, U.S. Environmental Protection Agency.

Mayer, T., and S. Zignago. 2006. Notes on CEPII's Distance Measures. Unpublished manuscript. Paris, France, May. Available at: http://www.cepii.fr/ anglaisgraph/workpap/summaries/wp_resume.asp?annee=2011&ref=25& NoDoc=3877

Moenius, J. 2004. Information versus Product Adaptation: The Role of Standards in Trade. Working Paper, Kellogg School of Management, Northwestern University.

Orden, D., J.C. Beghin, and G. Henry. 2012. Key Findings of the NTM-IMPACT Project. *The World Economy* 35(8): 967-972.

Organization for Economic Co-operation and Development. 2005. Agricultural Policies in OECD Countries: Monitoring and Evaluation in 2005. Paris, September.

Otsuki, T., J.S. Wilson, and M. Sewadeh. 2001. What Price Precaution ? European Harmonisation of Aflatoxin Regulations and African Groundnut Exports. *European Review of Agricultural Economics* 28(2): 263–284.

Peterson, E., J. Grant, D. Roberts, and V. Karov. 2013. Evaluating the Trade Restrictiveness of Phytosanitary Measures on U.S. Fresh Fruit and Vegetable Imports. *American Journal of Agricultural Economics* 95: 842–858. doi: 10.1093/ajae/aat015.

Pham, C., and W. Martin. 2008. Estimating the Gravity Model When Zero Trade Flows are Important (Economic Series 2008-03). Burwood, VIC, Australia: Deakin University, Faculty of Business and Law.

Preeg, E. H. 1998. *From Here to Free Trade*, University of Chicago Press, Chicago, IL.

Rau, M., K. Shutes, and S. Schlueter. 2010. Index of Heterogeneity of Requirements in International Agri-food Trade. Assesment of the Impacts of Non-Tariff Measures NTM on the Competitiveness of the EU and Selested Trade Partners. NTM Impact Working Paper 10/01.

Rau, M.L., K. Shutes, S. Schlueter, M. Poto, and B. van der. Meulen. 2010. Requirements in International Agri-Food Trade: Constructing an Index of Regulatory Heterogeneity. Assesment of the Impacts of Non-Tariff Measures NTM on the Competitiveness of the EU and Selested Trade Partners. NTM Impact Working Paper 10/03.

Santos Silva, J.M.C., and S.Tenreyro. 2006.The Log of Gravity. Review of Economics and

Statistics 88 (4): 641–658. Santos Silva, J.M.C.,and S.Tenreyro. 2011. Further Simulation Evidence on the Performance of the Poisson Pseudo-Maximum Likelihood Estimator. *Economic Letters* 112 (2): 220–222.

Smolka, S. 2006. The new EU-Regulation on Maximum Residue Levels of Pesticides in Food - An Overview. Paper presented at the Seminar of Pesticide Residues in Food – Regulation, Monitoring, Policy, Modra, Slovakia, 06. www.pan-germany.org, www.pesticide-residues.org

Swann,G.P., P. Temple, and M. Shurmer. 1996. Standards and Trade Performance: The UK Experience. *Economic Journal* 106: 1297–1313.

USDA FAS MRL Global database, https://www.globalmrl.com/home (accessed December 2013 and December 2014).

United States Trade Representative. 2014. Report on Sanitary and Phytosanitary Measures

Van Der Meulen, B.M.J., and M. Van Der. Velde. 2004. Food Safety Law in the European Union. European Food Law Institute serires. Published by Wageningen Academic Publishers, 09.

Wheat, D. 2013. Tighter EU Standards Threaten Exports of U.S. Apples, Pears. Capital Press, 09.

World Health Organization (WHO). 2009. Principles and methods for the risk assessment of chemicals in food. Published under the joint sponsorship of the United Nations Environment Programme, the International Labour Organization and the World Health Organization, ISBN 978 92 4 157240 8 (NLM classification: WA 712), ISSN 0250-863X.

Wilson, J.S., and T. Otsuki. 2004. To Spray or Not to Spray: Pesticides, Banana Exports, and Food Safety. *Food Policy* 29(2): 131–146.

Wilson, J.S., T. Otsuki, and B. Majumdsar. 2003. Balancing food safety and risk: do drug residue limits affect international trade in beef? The Journal of International Trade & Economic Development. *Taylor and Francis Journals* 12(4): 377-402.

Winchester, N., M.L. Rau, C. Goetz, B. Larue, T. Otsuki, K. Shutes, C. Wieck, H.L. Burnquist, H. M.J. Pinto de Souza, and R. Nunes de Faria. 2012. The Impact of Regulatory Heterogeneity on Agri-food Trade. *World Economy* 35(8): 973–993.

Wolff, C. 2014. SPS Issues at the WTO. Thematic SPS Workshop on Risk Analysis, WTO, Centre William Rappard, Geneva, 10.

World Trade Organization. 2012. World Trade Report. Trade and public policies: A closer look at non-tariff measures in the 21st century.

WTO Committee on SPS Measures. 2013. Specific Trade Concerns, G/SPS/GEN/204/Rev.13, 02.

Xiong, B., and J.C. Beghin. 2012a. Does European Aflatoxin Regulation Hurt Groundnut Exporters from Africa? *European Review of Agricultural Economics* 39 (4): 589–609

Xiong, B., and J.C. Beghin. 2012b. Stringent Maximum Residue Limits, Protectionism, and Competitiveness. International Trade Research Consortium, Working Paper 142384, Department of Economicss, Iowa State University.

Xiong, B., and J.C. Beghin. 2013. Disentangling Demand-Enhancing and Trade-Cost Effects of Maximum Residue Regulations. Staff General Research Papers 34393, Department of Economicss, Iowa State University.

Table 1. List of Countries that report pesticides MRL standards

	List of countries				Notes
Codex	Algeria	Costa Rica	Kenya	Philippines	Some countries may defer to the US or the EU if there is no Codex MRL
	Angola	Dominican Republic	Lebanon	Trinidad and Tobago	
	Bahamas	Ecuador	Morocco	Tunisia	
	Bangladesh	El Salvador	Netherlands Antilles	United Arab Emirates	
	Barbados	Guatemala	Nicaragua	Venezuela	
	Bermuda	Hong Kong	Pakistan	Honduras	
	Cambodia	Jamaica	Panama		
	Colombia	Jordan	Peru		
European Union	Belgium	French Pacific Islands	Ireland	Portugal	
	Denmark	French West Indies	Italy	Spain	
	Finland	Germany	Netherlands	Sweden	
	France	Greece	Poland	United Kingdom	
Exporting countries	Albania	Antigua and Barbuda	Cayman Islands	Haiti	
	Nevis	Sri Lanka	St. Lucia		
Gulf Cooperation Council	Bahrain	Kuwait	Oman	Qatar	
	Saudi Arabia				
Own standards	Argentina	China	Israel	South Africa	Some countries may defer to Codex if there is no own standard
	Australia	Cuba	Japan	South Korea	
	Brazil	Egypt	Malaysia	Switzerland	
	Brunei	Iceland	New Zealand	Taiwan	
	Canada	India	Norway	Thailand	
	Chile	Indonesia	Russia	Turkey	
	Customs Union of Belarus, Kazakhstan, and Russia		Singapore	Vietnam	
United States	Mexico				

Source: MRLdatabase.com, December 2013 and 2014

Table 2. Default MRL in parts per million (ppm)

Default MRL in parts per million (ppm)	Country
0.01 ppm	Japan
0.01 ppm	Norway
0.01 ppm	EU
0.01 ppm	Iceland
0.1 ppm	Canada
A default MRL of 0.01 ppm applies when no GCC, Codex, US or EU MRL is established.	Saudi Arabia
Codex MRL	Brazil
Codex MRL	Chile
Codex MRL	India
Codex MRL	Israel
Codex MRL	Thailand
Codex MRLs	Cuba
Codex MRLs	Singapore
Codex MRLs	Vietnam
Codex MRL + 0.01 ppm	Argentina
Codex MRLs + 0.01 ppm	Malaysia
EU MRL regulations + 0.01 ppm	Turkey
EU MRLs	United Arab Emirates (UAE)
Least restrictive value between MRLs established in their national regulation (0.1 ppm default included) and MRLs established by Codex.	New Zealand
Less restrictive value established in the EU and Codex regulations + 0.01 ppm	South Africa
US MRLs + EU MRLs	Dominican Republic
When there is a conflict between the two regulations, MRLs established by the Customs Union take precedence.	Russia

Source: MRLdatabase.com, December 2013, 2014

Table 3. Comparing MRL patterns across countries with Codex and US MRLs, and their level of protectionism (International science-based Codex)

Region	More stringent than Codex %	More stringent than US %	Level of protectionism (international science base codex)	Level of protectionism (international science base codex) with default value	Number of established MRLs	Number of non-established MRLs
Brazil	61	64	1.52	1.12	2,065	12,246
Turkey	51	64	1.43	1.39	1,454	12,857
Russia	53	68	1.39	1.57	904	13,407
Switzerland	42	62	1.35	1.35	9,167	5,144
Iceland	35	64	1.29	1.44	10,361	3,950
Norway	35	64	1.29	1.44	10,361	3,950
Taiwan	45	55	1.28	1.28	6,271	8,040
European Union	32	63	1.25	1.40	10,513	3,798
Israel	20	54	1.19	1.19	5,247	9,064
United Arab Emirates	0	60	1.13	1.13	10,871	3,440
South Korea	34	45	1.10	1.10	7,852	6,459
Argentina	10	51	1.09	1.31	4,530	9,781
Chile	8	46	1.07	1.07	5,511	8,800
Australia	38	51	1.05	1.05	5,191	9,120
Indonesia	5	47	1.02	1.02	384	13,927
Vietnam	5	46	1.02	1.02	4,242	10,069
Brunei	8	43	1.01	1.01	4,856	9,455
Thailand	1	45	1.00	1.00	3,927	10,384
Malaysia	3	44	0.99	1.21	4,168	10,143
Saudi Arabia	1	43	0.98	0.98	4,033	10,278
Canada	37	19	0.97	1.28	5,242	9,069
India	2	40	0.96	0.96	4,425	9,886
Singapore	5	40	0.94	0.94	4,514	9,797
South Africa	0	57	0.91	1.00	10,956	3,355
China	21	43	0.89	0.89	827	13,484
United States	30	0	0.88	0.88	14,311	0
New Zealand	0	35	0.87	0.94	4,704	9,607
Japan	17	32	0.73	0.93	9,146	5,165
Gulf Cooperation Council[1]	12	26	0.64	0.64	398	13,913

Note: Codex numbers of established MRLs are 3,839 and non-established MRLs are 10,472.

[1] Gulf Cooperation Council consists of Bahrain, Kuwait, Oman, Qatar, and Saudi Arabia

Table 4. Summary Statistics

Variable	Mean	Std. Dev.	Min	Max
Trade flow	$796,281	$11.6 mil.	$0.000	$1660.0 mil.
Log Distance	8.587	1.000	4.394	9.894
RTA	0.372	0.483	0.000	1.000
BSI	1.039	0.317	0.000	2.715
BSI-Fungicides	1.040	0.340	0.000	2.717
BSI-Herbicides	1.051	0.402	0.000	2.711
BSI-Insecticides	1.045	0.367	0.000	2.715

Note: Number of observation equal to 257,647.

Table 5. The BSI indices at Country Level for different class of chemical (assuming the US as origin country)

Region	BSI		BSI-insecticides		BSI-herbicides		BSI-fungicides	
	Equally weighted	Trade weighted	Equally weighted	Trade weighted	Equally weighted	Trade weighted	Equally weighted	Trade weighted
Iceland	1.679	1.587	1.696	1.660	1.652	1.473	1.702	1.573
Norway	1.673	1.680	1.691	1.710	1.648	1.551	1.711	1.793
Switzerland	1.620	1.518	1.627	1.519	1.484	1.620	1.727	1.528
European Union	1.620	1.567	1.630	1.591	1.635	1.547	1.616	1.521
Russia	1.596	1.559	1.677	1.690	1.388	1.196	1.795	1.920
Turkey	1.570	1.403	1.486	1.399	2.207	2.190	2.018	2.125
Brazil	1.551	1.657	1.557	2.006	1.302	1.141	1.867	1.620
United Arab Emirates	1.507	1.377	1.468	1.428	1.624	1.460	1.490	1.206
South Africa	1.459	1.466	1.403	1.453	1.578	1.533	1.512	1.434
Taiwan	1.426	1.456	1.329	1.397	1.522	1.521	1.635	1.523
Israel	1.360	1.288	1.330	1.251	1.279	1.268	1.652	1.188
Chile	1.288	1.460	1.252	1.366	1.379	1.592	1.344	1.784
Australia	1.277	1.181	1.251	1.174	1.258	1.080	1.405	1.393
Argentina	1.263	1.290	1.166	1.227	1.204	1.338	1.293	1.346
Indonesia	1.252	1.087	1.238	1.037	1.646	1.592	0.939	1.189
South Korea	1.251	1.204	1.200	1.126	1.029	1.004	1.576	1.679
Thailand	1.243	1.201	1.147	1.137	1.594	1.491	1.296	1.153
Saudi Arabia	1.232	1.207	1.142	1.147	1.413	1.558	1.309	1.218
Brunei	1.192	1.206	1.139	1.129	1.130	1.162	1.329	1.312
Vietnam	1.168	1.174	1.037	1.119	1.760	1.626	1.144	1.114
Peru	1.165	1.191	1.048	1.163	1.688	1.776	1.182	1.085
India	1.151	1.157	1.106	1.202	1.060	0.834	1.247	1.130
Singapore	1.144	1.112	1.078	1.033	1.166	1.250	1.239	1.186
Malaysia	1.142	1.131	1.044	1.074	1.401	1.444	1.308	1.125
GCC[1]	1.117	1.131	1.122	1.127	1.057	1.225	1.309	1.228
Canada	1.115	1.121	1.080	1.107	1.080	1.165	1.155	1.129
New Zealand	1.084	1.063	0.964	0.989	1.467	1.454	1.090	0.962
China	1.066	1.054	0.892	0.726	1.428	1.437	1.415	1.443
Mexico	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Japan	0.952	0.922	0.872	0.817	1.008	0.999	1.120	1.120

[1] GCC: Gulf Cooperation Council

Figure 1. The BSI indices at country level for different class of chemical- trade weighted (assuming the US as origin country)

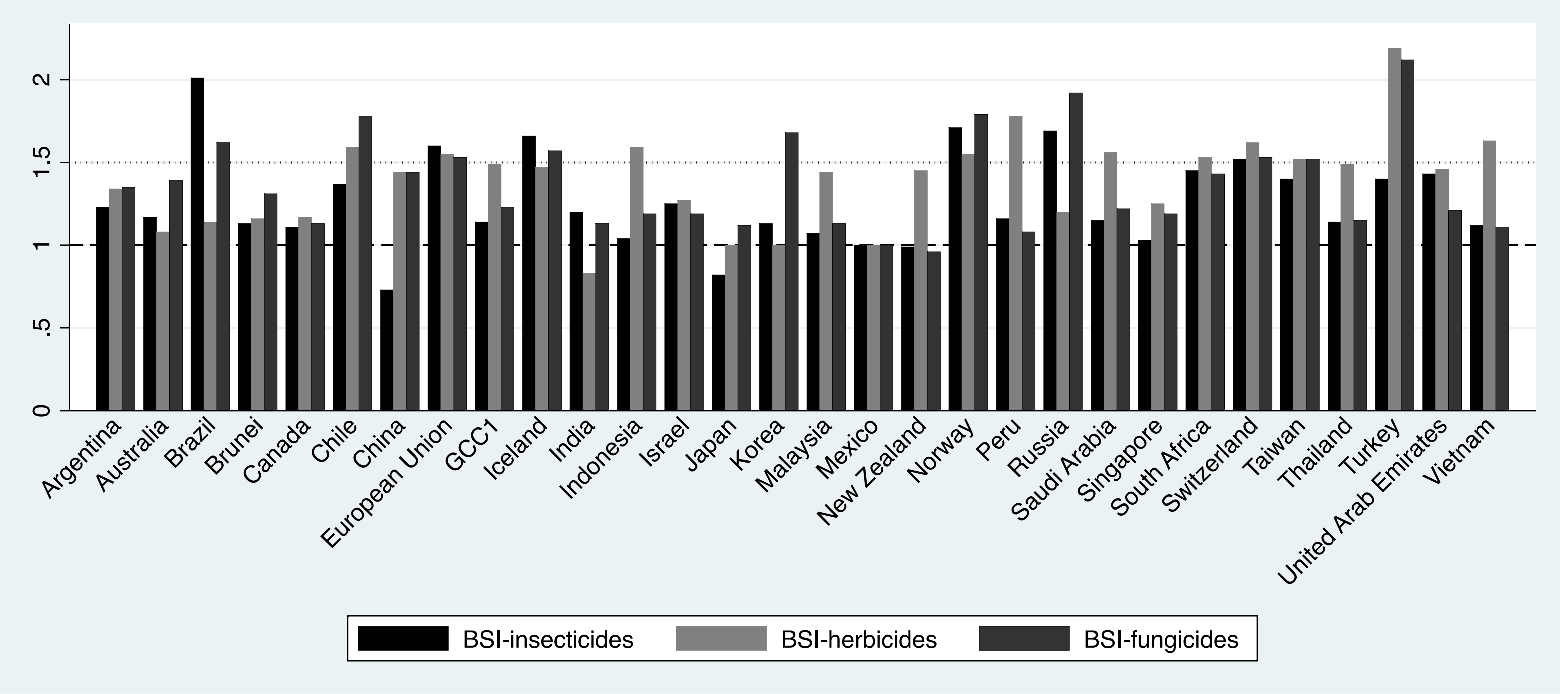

Figure 2. The box plot BSI indices at country level for insecticides, herbicides and fungicides

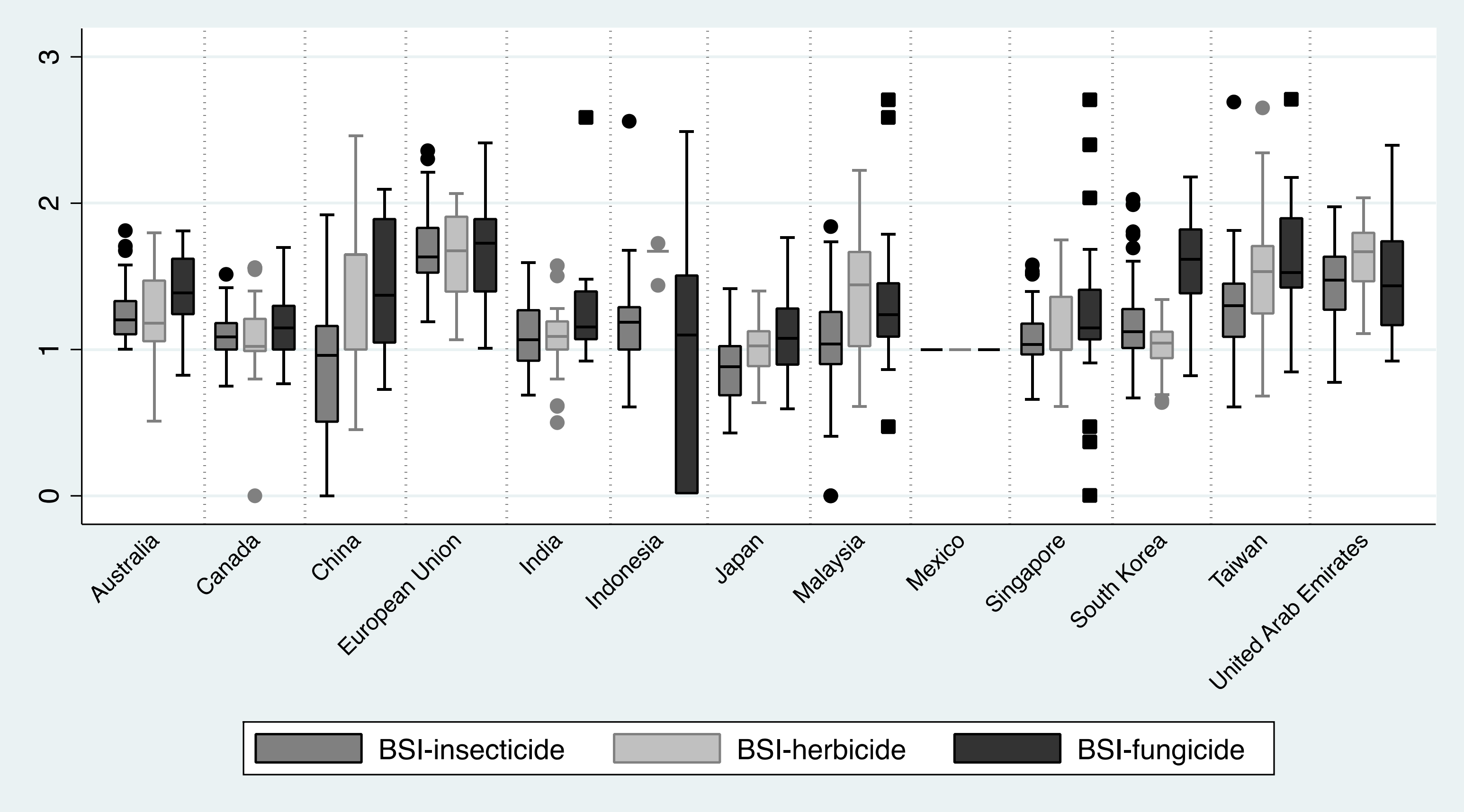

Table 6. The BSI indices at commodity level for different class of chemical (assuming the US as origin country)

	BSI		BSI-insecticides		BSI-herbicides		BSI-fungicides	
Commodity	**Equally weighted**	**Trade weighted**	**Equally weighted**	**Trade weighted**	**Equally weighted**	**Trade weighted**	**Equally weighted**	**Trade weighted**
BRUSSELS SPROUTS	1.618	1.204	1.629	1.215	1.254	1.286	1.682	1.136
BROCCOLI	1.607	1.273	1.655	1.295	1.216	1.330	1.702	1.191
CAULIFLOWER	1.566	1.181	1.642	1.231	1.209	1.257	1.479	1.029
AVOCADOS	1.557	1.300	1.221	1.116	1.723	1.443	2.224	1.706
CELERY	1.557	1.308	1.661	1.333	1.134	1.440	1.400	1.253
MANGOES	1.533	1.750	1.251	1.566	1.769	1.818	2.013	2.253
CARROTS	1.482	1.187	1.590	1.165	1.101	1.221	1.368	1.147
PINEAPPLES	1.478	1.353	1.458	1.341	1.438	0.814	1.994	1.619
ONIONS	1.477	1.306	1.498	1.360	1.323	1.300	1.571	1.301
LEEKS	1.417	1.225	1.512	1.073	1.419	1.098	1.401	1.321
PAPAYAS	1.405	1.088	1.122	0.776	1.762	1.485	1.631	1.597
ASPARAGUS	1.404	1.205	1.338	1.114	1.392	1.318	1.407	1.162
HEAD LETTUCE	1.381	1.196	1.377	1.243	1.177	1.409	1.502	1.122
SPINACH	1.371	1.026	1.363	1.020	1.198	1.010	1.566	1.099
POTATOES	1.344	1.202	1.333	1.231	1.431	1.133	1.324	1.204
EGGPLANTS	1.337	1.023	1.261	1.040	1.196	1.105	1.510	0.961
STRAWBERRIES	1.320	1.187	1.216	1.083	1.558	1.192	1.302	1.300
PEPPERS	1.317	1.225	1.279	1.183	1.228	1.499	1.355	1.108
LEAF LETTUCE	1.296	1.042	1.269	1.060	1.280	1.540	1.415	0.962
FRESH BEANS	1.286	1.169	1.243	1.154	1.595	1.210	1.233	1.164
SQUASH, PUMPKINS ARTICHOKE &	1.279	1.210	1.310	1.178	1.208	1.494	1.286	1.190
BANANAS	1.275	1.309	1.060	0.993	1.551	1.829	1.349	1.332
CUCUMBERS	1.272	1.158	1.335	1.212	1.170	1.140	1.144	1.095
PEAS	1.262	1.182	1.209	1.243	1.677	1.141	1.062	1.111
RASPBERRIES & BLACKBERRIES	1.262	1.205	1.068	1.047	1.624	1.121	1.467	1.406
KIWIFRUIT	1.256	1.223	1.089	1.187	1.748	1.239	1.214	1.416
CHERRIES	1.251	1.161	1.131	1.020	1.354	1.141	1.510	1.461
APPLES	1.248	1.139	1.288	1.161	1.373	1.217	1.191	1.110
MELON	1.231	1.100	1.325	1.126	1.162	1.125	1.027	1.016
PEARS & QUINCES	1.228	1.130	1.209	1.136	1.652	1.201	1.228	1.136
PEACHES & NECTARINES	1.228	1.183	1.192	1.137	1.425	1.174	1.328	1.258
GRAPEFRUIT	1.223	1.103	1.181	1.043	1.593	1.159	1.106	1.238
CRANBERRIES & BLUEBERRIES	1.220	1.140	1.144	1.099	1.520	1.094	1.288	1.240
GARLIC	1.212	1.249	1.058	1.220	1.004	0.995	1.387	1.346
LEMONS & LIMES	1.204	0.953	1.138	0.871	1.661	1.137	1.152	1.126
PLUMS & SLOES	1.199	1.107	1.046	0.935	1.434	1.330	1.566	1.404
ORANGES	1.193	1.052	1.151	0.985	1.561	1.149	1.115	1.292
APRICOTS	1.190	1.137	1.105	0.933	1.340	1.044	1.388	1.389
MANDARINS & CLEMENTINES	1.168	0.959	1.105	0.925	1.497	1.018	1.152	1.023
TOMATOES	1.168	1.049	1.157	1.078	1.123	0.984	1.184	1.037
GRAPES	1.144	1.105	1.121	1.025	1.102	1.116	1.159	1.142
DATES	1.140	1.039	1.140	1.039	-	-	-	-
FIGS	1.079	1.004	1.043	1.003	1.459	0.908	-	-
LEGUMES EXC PEAS BEANS	1.068	1.009	1.080	1.051	1.222	1.086	0.971	0.955
MUSHROOMS & TRUFFLES	0.875	0.868	0.878	0.818			1.002	1.001

Figure 3. The box plot BSI indices at commodity level for different class of chemical insecticides, herbicides and fungicides

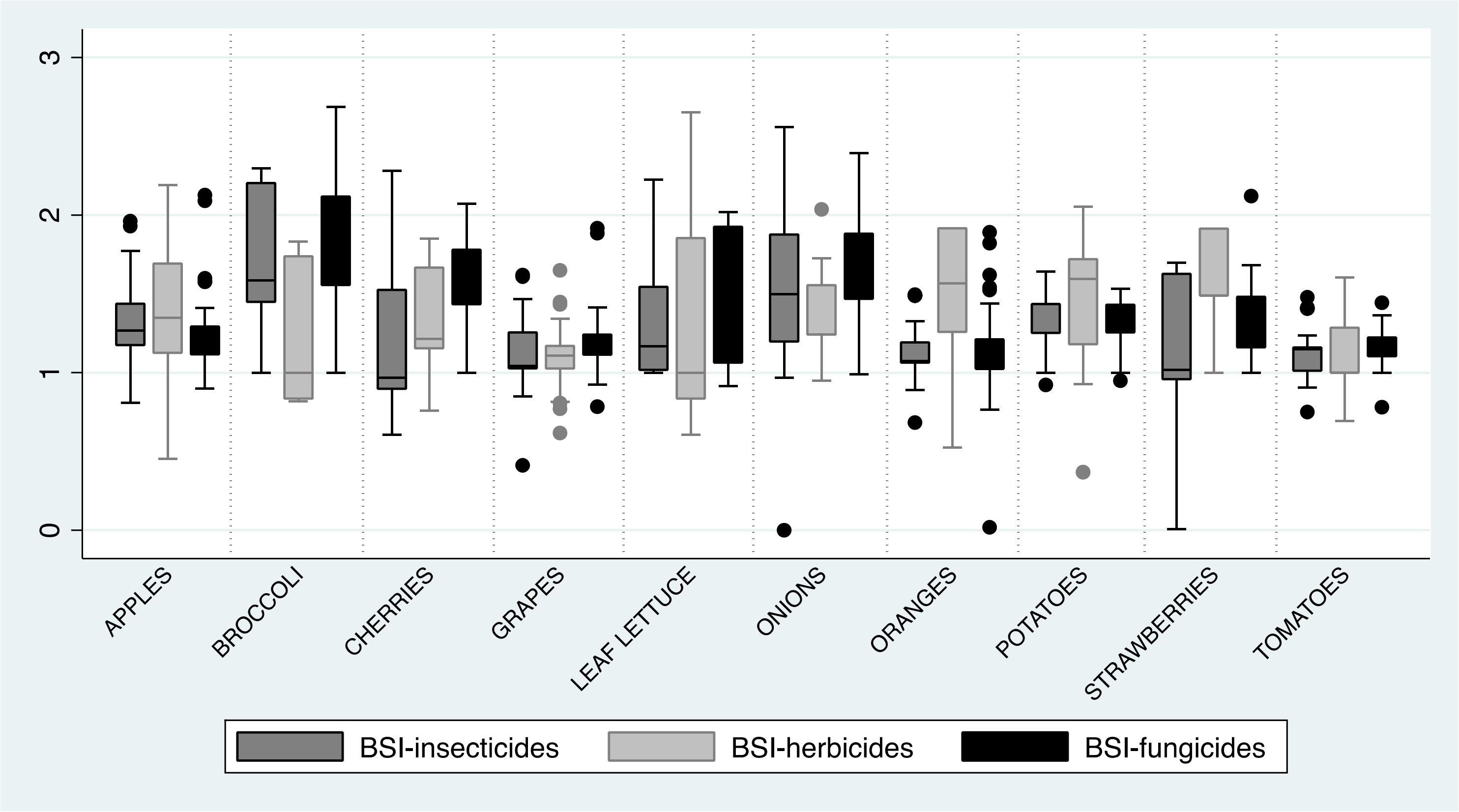

Figure 4. TPP Stringency Indices for Top US Exports – Trade Weighted

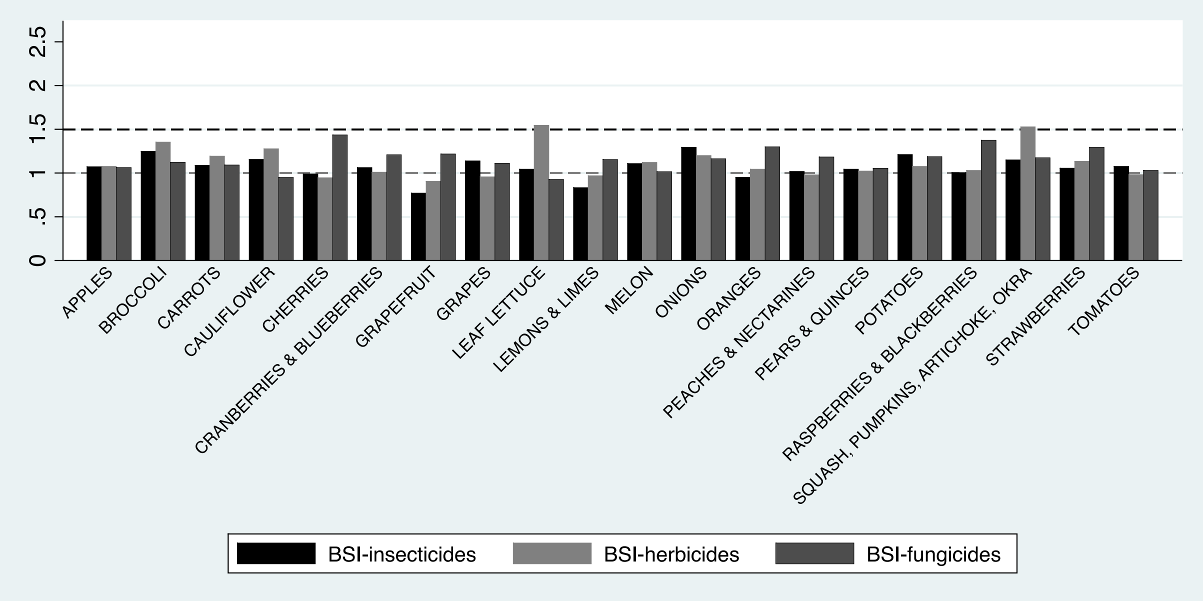

Figure 5. EU Stringency Indices for Top US Exports – Trade Weighted

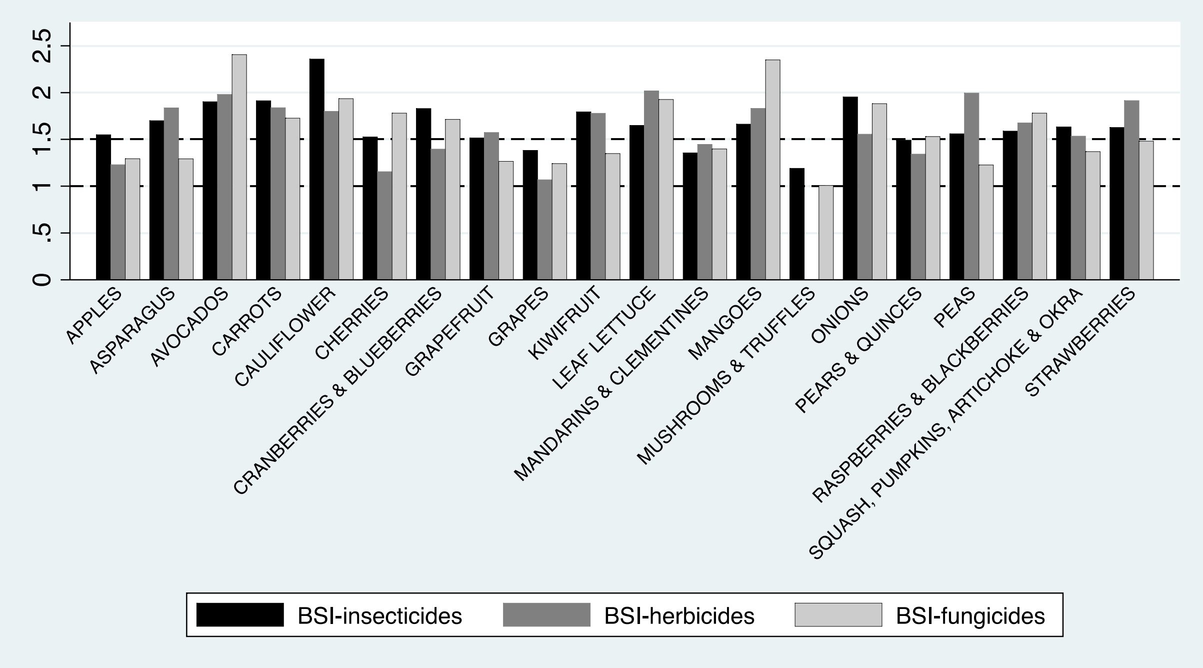

Figure 6. The box plot BSI indices for different classes of chemicals across the EU and TPP markets – Trade Weighted

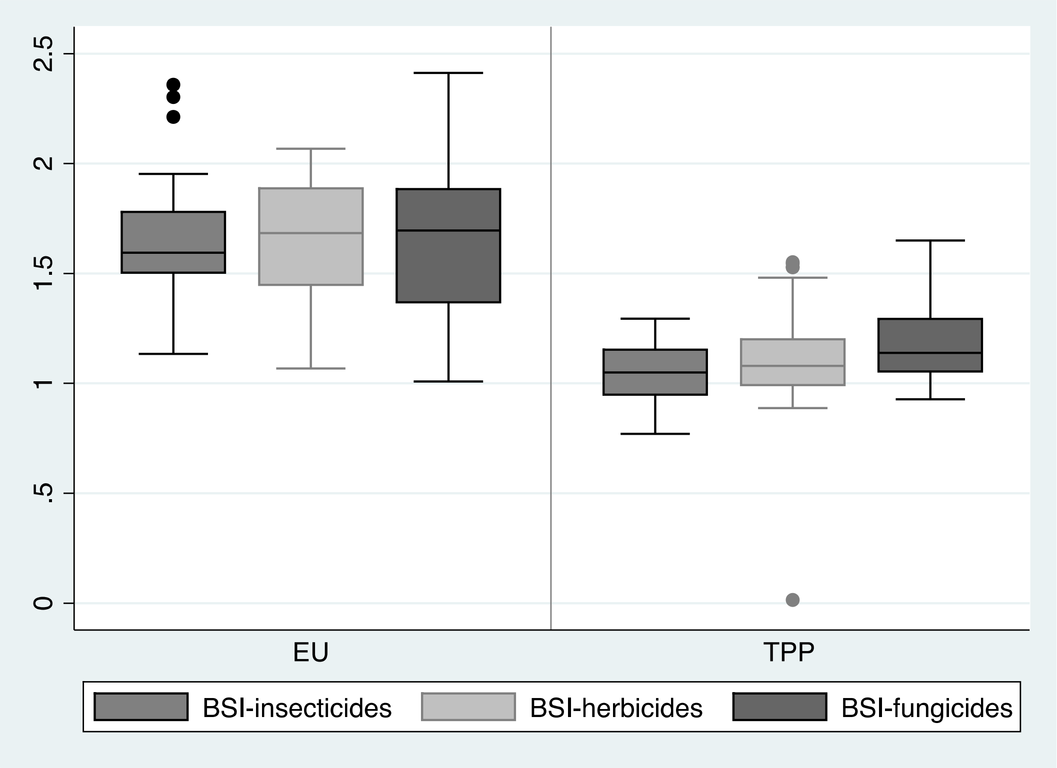

Table 7. The stringency level across products for TPP markets and the European Union

		BSI<1	1<BSI<1.5	1.5<BSI
TPP	BSI-insecticides	15	33	0
	BSI-herbicides	11	31	4
	BSI-fungicides	5	38	3
EU	BSI-insecticides	-	12	36
	BSI-herbicides	-	13	33
	BSI-fungicides	-	18	28

Table 8. Bilateral Stringency Indices Impacts on Exports of Fruits and Vegetables, 2013-2014

	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Estimation Method	**OLS**	**Poisson**	**Negative Binomial**	**OLS**	**Poisson**	**Negative Binomial**
Fixed Effects Included						
BSI	-0.70***	-0.88***	-0.44***	-0.68***	-0.86***	-0.41***
	(0.03)	(0.15)	(0.08)	(0.03)	(0.15)	(0.08)
BSI $_{\textbf{US-EU}}$				-2.36***	-1.38***	-1.58***
				(0.08)	(0.14)	(0.09)
BSI $_{\textbf{US-TPP}}$				0.70***	-0.15	0.39***
				(0.11)	(0.2)	(0.11)
Log Distance	-1.69***	-0.99***	-1.34***	-1.70***	-1.00***	-1.36***
	(0.01)	(0.03)	(0.02)	(0.01)	(0.03)	(0.02)
RTA	0.99***	1.07***	0.80***	0.93***	0.98***	0.73***
	(0.02)	(0.1)	(0.05)	(0.02)	(0.1)	(0.05)
Observations	257,647	257,647	257,647	257,647	257,647	257,647
(pseudo) R^2	0.527	0.572	0.308	0.529	0.598	0.309

Note: The dependent variable is the log of one plus the value of exports in column (1) and (3) and the level of exports in column (2) and (5). The dependent variable in column (3) and (6) are scaled by million. Robust standard errors are in parentheses. One, two and three asterisks denote significance at the 10%, 5% and 1% levels, respectively. Fixed effects included importer, exporter & commodity.

Table 9. Bilateral Stringency Indices Impacts on Exports of Fruits and Vegetables, 2013-2014

	(1)	(2)	(3)	(4)	(5)	(6)
Estimation Method	**OLS**	**Poisson**	**Negative Binomial**	**OLS**	**Poisson**	**Negative Binomial**
Fixed Effects Included						
BSI-Fungicides	-0.27***	0.002	-0.34***	-0.25***	-0.04	-0.32***
	(0.04)	(0.14)	(0.08)	(0.04)	(0.14)	(0.08)
BSI-Herbicides	-0.39***	-0.47***	-0.34***	-0.38***	-0.51***	-0.31***
	(0.03)	(0.09)	(0.06)	(0.03)	(0.1)	(0.06)
BSI-Insecticides	-0.51***	-1.05***	-0.68***	-0.49***	-0.95***	-0.65***
	(0.04)	(0.18)	(0.08)	(0.04)	(0.18)	(0.08)
BSI-Fungicides $_{\text{US-EU}}$				-0.54	-0.33	-0.87**
				(0.44)	(0.91)	(0.38)
BSI-Herbicides $_{\text{US-EU}}$				-0.26	0.55	0.84*
				(0.48)	(0.73)	(0.5)
BSI-Insecticides $_{\text{US-EU}}$				-1.70***	-1.51	-1.46***
				(0.62)	(0.93)	(0.53)
BSI-Fungicides $_{\text{US-TPP}}$				-0.07	0.54	0.5
				(0.39)	(0.33)	(0.33)
BSI-Herbicides $_{\text{US-TPP}}$				0.75***	1.14***	-0.32
				(0.28)	(0.3)	(0.26)
BSI-Insecticides $_{\text{US-TPP}}$				-0.11	-1.61***	0.29
				(0.43)	(0.38)	(0.4)
Log Distance	-1.71***	-1.00***	-1.37***	-1.71***	-1.02***	-1.39***
	(0.01)	(0.04)	(0.02)	(0.01)	(0.04)	(0.03)
RTA	0.93***	1.08***	0.84***	0.86***	0.97***	0.75***
	(0.03)	(0.1)	(0.05)	(0.03)	(0.11)	(0.05)
Observations	207,258	207,258	207,258	207,258	207,258	207,258
(pseudo) R^2	0.542	0.614	0.312	0.544	0.592	0.313

Note: The dependent variable is the log of one plus the value of exports in column (1) and (3) and the level of exports in column (2) and (5). The dependent variable in column (3) and (6) are scaled by million. Robust standard errors are in parentheses. One, two and three asterisks denote significance at the 10%, 5% and 1% levels, respectively. Fixed effects included importer, exporter & commodity.

Table 10. Bilateral Stringency Indices Impacts on Exports of Fruits and Vegetables, 2013-2014

Estimation Method	**(1) Selection Equation**	**(2) Outcome Equation**	**(3) Selection Equation**	**(4) Outcome Equation**	**(5) Selection Equation**	**(6) Outcome Equation**	**(7) Selection Equation**	**(8) Outcome Equation**
BSI	-0.16***	-0.51***	-0.16***	-0.49***				
	(0.02)	(0.05)	(0.02)	(0.05)				
BSI $_{\text{US-EU}}$			-0.78***	-1.15***				
			(0.04)	(0.07)				
BSI $_{\text{US-TPP}}$			-0.19***	1.06***				
			(0.05)	(0.11)				
BSI-Fungicides					-0.09***	-0.32***	-0.09***	-0.28***
					(0.02)	(0.06)	(0.02)	(0.06)
BSI-Herbicides					-0.12***	-0.24***	-0.11***	-0.21***
					(0.01)	(0.04)	(0.01)	(0.04)
BSI-Insecticides					-0.09***	-0.50***	-0.09***	-0.46***
					(0.02)	(0.07)	(0.02)	(0.07)
BSI-Fungicides $_{\text{US-EU}}$							-0.27	-0.05
							(0.23)	(0.37)
BSI-Herbicides $_{\text{US-EU}}$							-0.03	0.16
							(0.2)	(0.39)
BSI-Insecticides $_{\text{US-EU}}$							-0.49**	-1.31***
							(0.23)	(0.5)
BSI-Fungicides $_{\text{US-TPP}}$							-0.28***	-0.22
							(0.09)	(0.34)
BSI-Herbicides $_{\text{US-TPP}}$							0.12**	0.58**
							(0.06)	(0.25)
BSI-Insecticides $_{\text{US-TPP}}$							-0.05	0.67*
							(0.1)	(0.37)
Log Distance	-0.74***	-1.23***	-0.74***	-1.26***	-0.76***	-1.27***	-0.76***	-1.30***
	(0.01)	(0.02)	(0.01)	(0.02)	(0.01)	(0.02)	(0.01)	(0.02)
RTA	0.30***	0.62***	0.30***	0.52***	0.26***	0.70***	0.26***	0.58***
	(0.01)	(0.04)	(0.01)	(0.04)	(0.01)	(0.04)	(0.01)	(0.04)
Observations	257,647		257,647		207,258		207,258	
Estimated rho	0.341***		0.295***		0.315***		0.277***	
	(0.02)		(0.02)		(0.02)		(0.02)	
Estimated lambda	1.188***		1.019***		1.108***		0.968***	
	(0.06)		(0.06)		(0.06)		(0.06)	

Note: One, two and three asterisks denote significance at the 10%, 5% and 1% levels, respectively. Fixed effects included importer, exporter & commodity.

Appendix Table A. List of commodities

Fruits	Vegetables
APPLES	ASPARAGUS
APRICOTS	BROCCOLI
AVOCADOS	BRUSSELS SPROUTS
BANANAS	CARROTS
CHERRIES	CAULIFLOWER
CITRUS NES	CELERY
CRANBERRIES & BLUEBERRIES	CUCUMBERS
CURRANTS	EGGPLANTS
DATES	FRESH BEANS
FIGS	GARLIC
GRAPEFRUIT	GLOBE ARTICHOKES
GRAPES	HEAD LETTUCE
KIWIFRUIT	LEAF LETTUCE
LEMONS & LIMES	LEEKS
MANDARINS & CLEMENTINES	LEGUMES EXC PEAS BEANS
MANGOES	MUSHROOMS & TRUFFLES
MELON	ONIONS
ORANGES	PEAS
PAPAYAS	PEPPERS
PEACHES & NECTARINES	POTATOES
PEARS & QUINCES	RADISHES ETC
PINEAPPLES	SPINACH
PLUMS & SLOES	SQUASH, PUMPKINS, ARTICHOKES & OKRA
RASPBERRIES & BLACKBERRIES	TOMATOES
STRAWBERRIES	WITLOOF CHICORY
WATERMELONS	