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Assessing the Impact of SPS Regulations on U.S. Fresh Fruit and Vegetable Exports

Jason H. Grant, Everett Peterson, and Radu Ramniceanu

Sanitary and phytosanitary (SPS) measures are not new, but their significance in international agri-food trade continues to grow. Much less is known about the trade-restricting potential of these measures because of the difficulty in identifying when SPS regulations exist and how and to what extent they are applied. We develop a novel database of SPS treatments affecting United States exports of nine fresh fruits and vegetables and a formal econometric model to investigate the trade-restricting nature of these measures. The results suggest that SPS treatments generally reduce trade, but the actual restrictiveness of these measures diminishes as U.S. exporters accumulate treatment experience and vanishes when exporters reach a certain threshold.

Key words: fruit and vegetable trade, gravity equation, non-tariff measures, phytosanitary treatments, zero-inflated Poisson

Introduction

The focus of agricultural trade policy concerns has shifted from tariffs and quantitative restraints, which dominated much of the research and policy agenda in the lead-up to the Uruguay Round Agreement on Agriculture (URAA), to non-tariff barriers and a plethora of other policies that are "behind a nation's border" (World Trade Organization, 2012, p. 6). Among the potential list of non-tariff barriers affecting agricultural trade, sanitary and phytosanitary (SPS) measures occupy a special place. SPS measures are prominent 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. Additionally, the World Trade Organization (WTO) Agreement on the Application of SPS Measures permits countries to adopt their own standards to protect human, animal, or plant health, provided these standards are based on a risk assessment, not discriminatory toward countries with similar conditions, and are minimally trade distorting to prevent the disingenuous use of these measures as instruments of protectionism (Josling, Roberts, and Orden, 2004).

While the ability of countries to adopt their own set of SPS measures was instrumental to securing the SPS Agreement, it has led to contentious trade disputes when countries have adopted measures that severely limit market access to achieve small or speculative health or safety benefits. Since 1995, WTO members have lodged 320 official complaints related to SPS measures. Almost one-third of these complaints are related to fruits and vegetables, a disproportionately high share for a sector that has accounted for roughly 10% of global agri-food trade over the past two decades (World Trade Organization, 2012). In the case of the United States, exports of fresh fruits and vegetables (FFVs) have faced substantial SPS regulations in international markets. The long history

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of the U.S.-Japan apple dispute over fire blight, codling moth, and mitigation procedures such as orchard inspections, buffer zones, and chlorine treatment is just one example of SPS restrictions that have seriously affected U.S. competitiveness and, in some cases, completely shut-off global exports (Calvin and Kirssoff, 1998; Calvin, Krissoff, and Foster, 2008). Further, SPS requirements for a given commodity can vary widely across trading partners. For example, U.S. apples must undergo a chlorine dip if exported to Chile; face regional bans in Canada; and undergo cold treatment and methyl bromide fumigation if exported to Egypt. The United States has registered a number of official complaints at the WTO about measures that have increased costs or limited market access for its fruit and vegetable exports, including Australia's restrictions on U.S. exports of table grapes, Indonesia's policies for recognition of pest-free areas, Japan's restrictions on U.S. citrus exports, and China's varietal restrictions on exports of U.S. apples (World Trade Organization, 2009).

A growing body of research has emerged to quantify the trade effects of non-tariff measures (NTMs). Moenius (2004) examined the trade impact of shared standards in twelve Organisation for Economic Cooperation and Development (OECD) countries and found a negative effect from national standards on trade in food and beverages, crude materials, and mineral fuels. Fontagne, Mimouni, and Pasteels (2005) found similar results for sixty-one product groups. Disdier, Fontagné, and Mimouni (2008) used notifications on NTMs and their ad valorem tariff equivalents to estimate the impact of these regulations in agri-food trade. They found that NTMs generally have a negative influence on exports to OECD members. Jayasinghe, Beghin, and Moschini (2010) departed from the aggregate impact and focused instead on the trade impact of NTMs on a particular product—U.S. seed corn exports. They found that U.S. seed corn exports are a decreasing function of the number of foreign SPS/TBT standards required. Similar evidence of the negative trade impact of NTMs has been found in Peterson et al. (2013), Minten, Randrianarison, and Swinnen (2009), Anders and Caswell (2009), Calvin and Kirssoff (1998), Calvin, Krissoff, and Foster (2008), Otsuki, Wilson, and Sewadeh (2001), Disdier and van Tongeren (2010), Peterson and Orden (2008), Maskus, Wilson, and Otsuki (2001), and Chen, Yang, and Findlay (2008). Evidence of the negative trade flow impact of NTMs was recently corroborated in a meta-analysis by Li and Beghin (2012), who found that (controlling for differences in methodology and data sampling) SPS and TBT studies are more likely to find that NTMs impede rather than promote international trade.

One of the most popular sources of information on non-tariff measures is the Trade Analysis and Information System (TRAINS), which is maintained by the United Nations Conference on Trade and Development (UNCTAD) (see Disdier, Fontagné, and Mimouni, 2008; Disdier and van Tongeren, 2010; Essaji, 2008; Gebrehiwet, Ngqangweni, and Kirsten, 2007).[1] Researchers using TRAINS often count the total number of NTMs per industry and country to construct frequency indices (i.e., the proportion of products subject to an NTM within a sector) or coverage ratios (i.e., the share of imports "covered" by the NTM). However, there are several recognized limitations with this data source as documented by Peterson et al. (2013), the most notable of which are: (i) it is not possible to identify specific SPS regulations in the TRAINS database and (ii) the data do not contain a bilateral dimension. Thus, if the WTO is notified about an SPS regulation and records it in the TRAINS database, researchers do not know the nature of the measure and have to make the assumption that the regulation applies equally to all exporters. As Swann (2010) notes, the use of frequency indices and coverage ratios leads to a "mixed bag" problem (p. 10) because simply adding up measures implicitly assigns an equal weight to all regulations.

This article is part of a growing literature attempting to use time-series information on detailed SPS measures to better understand their trade impacts (Xiong and Beghin, 2012, 2013; Drogué and

[1] The Perinorm database does not suffer from many of the drawbacks of TRAINS (available at http://shop.bsigroup.com/en/Navigate-by/Assessment-Tools/Other-Electronic-Products/Perinorm/). However, Perinorm contains information primarily for European Union (EU) countries and focuses exclusively on international and private standards (i.e., battery voltages, door handles, etc.), which are very different from SPS measures used to protect human, plant, and animal health. The global maximum residue limit (MRL) database maintained by the Foreign Agricultural Service (FAS) of the United States Dept. of Agriculture at www.globalmrldatabase.com contains information on residue limits for plant and animal products.

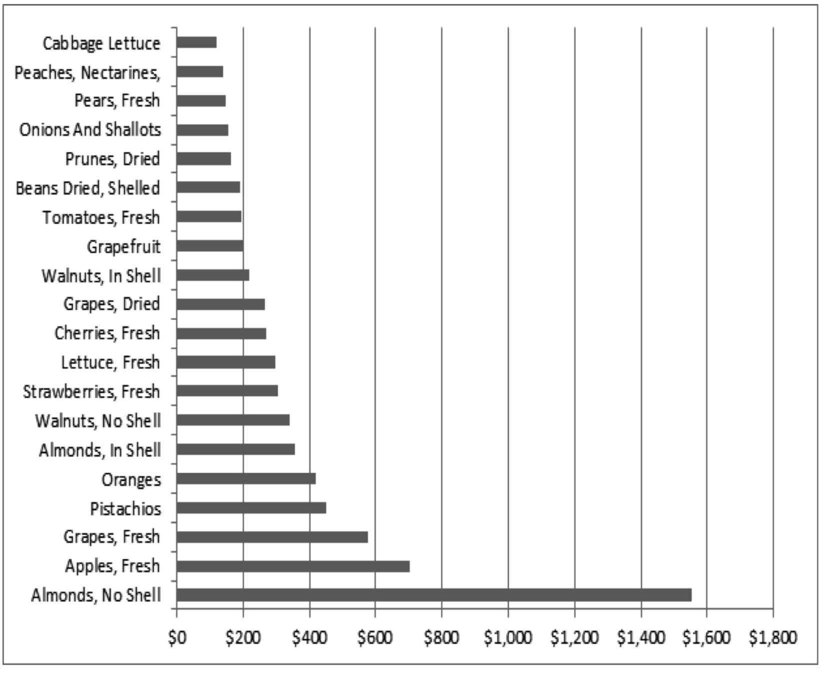

Figure 1. Top Twenty Average U.S. Product Exports by Value, 2006–2010 ($ Mil.)

DeMaria, 2012; Winchester et al., 2012; Ferro, Wilson, and Otsuki, 2013). We overcome many of the limitations of the TRAINs database by focusing on a specific subset of SPS concerns related to plant health product treatments (i.e., fumigation, cold treatment, water, vapor heat, etc.) affecting U.S. exports of fresh fruits and vegetables with a clear bilateral dimension to the data. More specifically, we investigate the trade restrictiveness of SPS regulations on U.S. exports of onions, peas, walnuts, apples, cherries, grapes, peaches/nectarines, oranges and strawberries to 139 countries over an eleven-year period (1999–2009). First, we use the Export Certification Project (EXCERPT) to develop a novel database of detailed SPS regulations affecting U.S. exports (see Jayasinghe, Beghin, and Moschini, 2010, for an application to U.S. corn seed exports). The dataset includes a product, country, and time dimension to permit an econometric analysis. We demonstrate that SPS measures come in different forms and are not uniformly applied across partner countries but depend on the nature of the pest risk in the exporting country. Second, we match these regulations to data on U.S. bilateral exports and develop a product line gravity model to estimate their impacts. Finally, using the estimated coefficients from the model, we compute the trade restrictiveness of SPS regulations, not by reporting percentage changes in trade flows as is typically done but by evaluating threshold values in a "learning-by-doing" framework (Young, 1991; Evenett and Venables, 2002). The "learning" thresholds are defined as the point at which U.S. exporters have accumulated sufficient experience treating products in the global marketplace such that the application of SPS measures is no longer a barrier to trade. We then compute the number of years it takes U.S. exporters to meet this threshold level of experience as our metric of the trade restrictiveness of SPS measures.

U.S. Fresh Fruits and Vegetables and Phytosanitary Regulations

Production of fruit, vegetables, and tree nuts is a $36 billion dollar industry in the United States, with cash receipts that have nearly doubled since 1990.[2] While a significant portion of this growth may be attributed to increases in domestic consumption of fresh fruits and vegetables, exports have played a

[2] See http://www.ers.usda.gov/topics/crops/vegetables-pulses.aspx#.UpYutsSsim4 for vegetable production and http://www.ers.usda.gov/topics/crops/fruit-tree-nuts/background.aspx#.UpYu6cSsim4 for fruit and tree nut production

Table 1. Frequency of SPS Treatments and Origin Restrictions

	Treatment Requirement								
Commodity	**MB**	**Cold**	**MB or Cold**	**Cold or FR**	**MB or PH**	**SD & Cold**	**VH/Cold QF**	**Origin**	**Total**
Onions	0	0	0	0	0	0	0	24	24
Peas	15	33	11	0	33	0	0	24	116
Walnuts	42	0	0	0	11	0	0	3	56
Oranges	63	54	43	0	0	0	276	49	485
Grapes	20	25	11	11	0	11	0	159	237
Apples	19	120	12	0	0	0	0	140	291
Cherries	59	25	13	11	0	0	0	181	289
Peaches	97	64	33	0	0	0	0	39	233
Strawberries	40	25	11	11	0	0	0	136	223
Total	355	346	134	33	44	11	276	755	1,954

Source: EXCERPT
Notes: Each observation consists of a country by commodity by year occurrence.
MB: Methyl bromide fumigation Cold: Cold treatment MB or Cold: Methyl bromide fumigation or cold treatment Cold or FR: Cold treatment or fumigation plus refrigeration MB or PH: Methyl bromide or phosphine fumigation SD & Cold: Fumigation with sulfur dioxide/carbon dioxide mix and cold treatment VH/Cold QF: Vapor heat or cold treatment or quick freeze Origin: Origin restriction

significant role. Between 1991 and 2010, exports of fresh fruits—including tree nuts—tripled from $3.4 billion to almost $11 billion, while fresh vegetable exports increased from $2.0 billion to $5.4 billion. Over the last ten years, the growth rate of all U.S. fruit and tree nut exports has averaged almost 10% per year, while the growth rate of vegetable exports averaged 6%.

Figure 1 reports exports by value for the top twenty fruit and vegetables products for the period from 2006 to 2010. Unshelled almonds have the largest export value, averaging $1.6 billion annually. The leading fresh fruit exports are apples, grapes, and oranges (including tangerines), with combined exports averaging nearly $2.0 billion annually, or about a quarter of the value of total fresh fruit exports. Export sales of fresh berries are led by strawberries at $304 million. Among vegetables, lettuce is the largest fresh export ($298 million annual average) followed by tomatoes, ($196 million), dried beans ($190 million), and onions ($157 million).

A fundamental requirement by foreign countries, however, is that U.S. products be safe and not pose a risk to human, animal, or plant health. To ensure the safety of imported food for consumption and to prevent the spread of pests and diseases in producing regions, many foreign countries require SPS measures on U.S. exports. However, because complying with SPS measures can be costly and could prohibit products from being exported altogether, these measures affect the competitiveness of U.S. exporters.

Table 1 summarizes the frequency of SPS treatment requirements and origin restrictions (ORs) applied to U.S. exports of onions, peas, walnuts, oranges, grapes, apples, cherries, peaches/nectarines, and strawberries from 1999 to 2009. Each column tabulates the number of specific SPS treatments required on U.S. exports to foreign nations. For example, from 1999 to 2009, there are fifteen instances of importers requiring methyl bromide (MB) fumigation on U.S. pea exports. ORs are the most common SPS regulation, accounting for nearly 40% of all occurrences. Fumigation with MB and cold treatment, which account for approximately 35% of all occurrences, are the next most common regulations. Interestingly, while fresh fruits consist of two-thirds of the products in our sample (6 out of 9), they face 90% (1,758/1,954) of all SPS regulations. Oranges have the highest incidence of SPS measures in our sample (485), accounting for nearly one-quarter of all observed regulations.

In table 2, we match the EXCERPT-based SPS regulations with bilateral U.S. export data defined at the six-digit product codes of the Harmonized System (HS) to determine the relationship between

Table 2. Frequency of Phytosanitary Regulations and Trade

Phytosanitary Treatment Definitions	Frequency of Positive Trade	Frequency of Zero Trade
Methyl bromide fumigation	269	86
Cold treatment	252	94
Methyl bromide fumigation or cold treatment	99	35
Cold treatment or fumigation plus refrigeration of fruits	33	0
Fumigation with methyl bromide or phosphine	43	1
Cold treatment & sulfur dioxide/carbon dioxide fumigation	11	0
Vapor heat or cold treatment or quick freeze	61	215
Origin restrictions	522	233
Total	1,290	664

SPS treatments and the incidence of zero trade flow records. Of the 1,954 observations subject to a SPS regulation, approximately one-third are associated with zero trade. While there may be other reasons why no trade occurred, such as transportation costs or prohibitive tariffs on a few product lines, the data suggest that SPS regulations may be a key determinant in whether the United States exports to a given destination. The most restrictive regulation appears to be the combination treatment of vapor heat or cold treatment or quick freeze (VH/Cold/QF) applied to U.S. orange exports (see table 1), with nearly three-quarters of the occurrence of this SPS regulation associated with no trade. Origin restrictions appear to be the next most restrictive regulation. Conversely, fumigation with MB and cold treatment requirements appear to be the least restrictive, with only one-quarter of all occurrences associated with no trade. In addition, while not shown in table 2, products subject to MB fumigation or cold treatment also have the highest export values, \$3.7 billion and \$2.4 billion, respectively, of all treatment options listed in table 2.

In addition to the frequency of SPS regulations being applied to U.S. exports, it is also interesting to consider the share of U.S. exports associated with at least one SPS treatment. As a share of the total value of exports, SPS regulations were imposed on U.S. cherry exports in the year 2000 more than any of the other eight commodities in our sample (excluding onions, which are only affected by ORs). Seventy-five percent of cherry exports were subject to at least one SPS regulation, but only eight out of the seventy destination countries imposed these regulations (Australia, Japan, Korea, New Zealand, French Polynesia, Taiwan, Venezuela, and South Africa). However, by 2009, while the Untied States still exported cherries to the same seventy countries, eleven of which impose SPS regulations (Brazil, India, and Indonesia added to the list), only 45% of total cherry exports were subject to at least one SPS regulation. Thus, U.S. cherry exports grew more rapidly in destination countries that did not impose SPS regulations compared to the destination countries that did impose SPS regulations, with an average annual growth rate of 0.16% in SPS-regulated markets compared to a 14% average annual growth rate in SPS-unregulated markets.[3]

Empirical Model

A product-level gravity model is utilized, based on the frameworks in Anderson and van Wincoop (2003) and Baldwin and Taglioni (2006), that assumes all varieties of commodity k (e.g., apples, oranges) are differentiated by their source, and consumer preferences' in destination region d for

[3] Fresh peas, walnuts, and oranges experienced similar differences in growth rates between SPS-regulated and unregulated destination markets, whereas strawberries, grapes, apples, and peaches experienced higher growth rates in SPS regulated markets.

commodity k are weakly separable and represented by a CES sub-utility:

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

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 initially to ease notation.

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

$$V_{odk} = p_{odk} x_{odk} = \frac{\alpha_{odk} p_{odk}^{1-\sigma_k} E_{dk}}{PI_{dk}^{1-\sigma_k}}, \tag{2}$$

where p_{odk} is the price of commodity k from region o in region d, E_{dk} is expenditure on commodity k in region d, and PI_{dk} is the CES price index. If t_{odk} represents the 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, into equation (2) yields

$$V_{odk} = \frac{\alpha_{odk} (t_{odk} pp_{ok})^{1-\sigma_k} E_{dk}}{PI_{dk}^{1-\sigma_k}}. \tag{3}$$

Assuming all markets for commodity k clear, then the quantity of commodity k produced in region o will equal the quantity demanded across destination regions, including domestic consumers in country o. Thus the 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:

$$Y_{ok} = \sum_{d=1}^{R} V_{odk} = \sum_{d=1}^{R} \frac{\alpha_{odk} (t_{odk} pp_{ok})^{1-\sigma_k} E_{dk}}{PI_{dk}^{1-\sigma_k}}. \tag{4}$$

Solving for $pp_{ok}^{1-\sigma_k}$ in equation (4) and substituting into equation (3) yields an extended version of equation (7) in Baldwin and Taglioni (2006) that incorporates an explicit commodity dimension for fresh fruit and vegetables:

$$V_{odk} = \frac{\alpha_{odk} t_{odk}^{1-\sigma_k} Y_{ok} E_{dk}}{\left[\sum_{d=1}^{R} \frac{\alpha_{odk} t_{odk}^{1-\sigma_k} E_{dk}}{PI_{dk}^{1-\sigma_k}} \right] PI_{dk}^{1-\sigma_k}} = \frac{\alpha_{odk} t_{odk}^{1-\sigma_k} Y_{ok} E_{dk}}{\Omega_{ok} PI_{dk}^{1-\sigma_k}}. \tag{5}$$

Trade costs consist of all factors needed to get commodity k from producers in region o (i.e., the United States in this study) to consumers in region d. In the context of FFVs, we assume that the trade cost function is multiplicative in nature (Anderson and van Wincoop, 2003) and includes the following factors affecting fresh fruit and vegetable trade:

$$DM_k = \exp(origin_{odk}^{\alpha_1}) ZDM_k^{\alpha_0}; \tag{6}$$

$$trans_{odk} = dist_{od}^{\delta_1} \exp(origin_{odk}^{\delta_2}) Ztrans_{odk}^{\delta_0}; \tag{7}$$

$$SPS_{odk} = \exp\left(\prod_{p} treat_{podk}^{\lambda_p} \right) Ztreat_{odk}^{\lambda_0}; \tag{8}$$

where DM_k denotes transport and trade margins in both regions o and d to get commodity k to the border of region o and from the border of region d to consumers, $trans_{odk}$ denotes international transport margins between o and d for commodity k, and SPS_{odk} is the cost of SPS treatments for commodity k required by region d from region o. Note that with the multiplicative specification, all trade cost factors must be measured on a per unit, *ad valorem* basis. For example, DM_k in the origin nation is defined as one plus the per unit trade and transport margin of commodity k divided by pp_{ok}.[4] An additional factor affecting trade costs and not included in equations (6)–(8) are bilateral tariffs, which we discuss below.

The trade cost factors in equations (6)–(8) are difficult to measure, much less observe. However, we do observe whether an origin restriction is in place, the physical distance between countries, and, importantly, the types of SPS treatments applied. The binary variable $origin_{odk}$ is equal to 1 if region d will only accept commodity k from certain (often pest-free) zones in the origin country (o) and 0 otherwise; $dist_{od}$ is the geographical distance between regions o and d; $treat_{podk}$ is a binary variable equal to 1 if SPS treatment type p on commodity k is required before exporting to region d and 0 otherwise; and ZDM_k, $Ztrans_{odk}$, and $Ztreat_{odk}$ are unobserved determinants of trade and transport margins and SPS treatment costs.

To complete our product-line gravity equation, two additional refinements to equation (5) are necessary. Because the CES subutility 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 commodity (partition) and income, the price indices for each commodity are also not observable. Thus, we assume that E_{dk} is a function of total income per capita (GDP) with $E_{dk} = GDP_d^{\beta}$. Because the overall utility function for the representative consumer in region d need not be homothetic, β need not equal 1. Second, because this analysis focuses entirely on the U.S. exports, a larger production of commodity k in importing region d would, all else equal, reduce the propensity to import. Thus, we include Y_{dk} and Y_{ok} in the gravity model but use production quantities (Q_{dk} and Q_{ok}) as opposed to values and assume that $Y_{dk} = Q_{dk}^{\phi}$ and $Y_{ok} = Q_{ok}^{\psi}$ where the parameters ϕ and ψ need not be equal to 1. Production values are largely incomplete for a number of countries due to missing information on producer prices.

Substituting equations (6)–(8) into equation (5) along with E_{dk}, Y_{ok}, and Y_{dk} yields our baseline gravity model at the product line. Taking the natural logarithm and including time subscripts yields

$$
\begin{aligned}
\ln V_{odkt} \quad = \quad & \ln \alpha_{odk} + (1-\sigma_k)\Bigg(\sum_p \lambda_p treat_{podkt} + (\alpha_1+\delta_2) origin_{odkt} + \delta_1 \ln dist_{od} + \\
& \lambda_0 \ln Ztreat_{odkt} + \alpha_0 \ln ZDM_{okt} + \delta_0 \ln Ztrans_{odkt} + \theta_0 \ln ZDM_{dkt}\Bigg) + \\
& \beta \ln GDP_{dt} + \varphi \ln Q_{dkt} + \psi \ln Q_{okt} - \ln \Omega_{okt} - (1-\sigma_k) \ln PI_{dkt}.
\end{aligned} \tag{9}
$$

There are a few differences between the gravity model specified in equation (9) and the econometric model used in this article. First, index o refers only to the United States. Because of the time intensive nature of collecting data on SPS regulations, including additional exporting countries would only be feasible through a collective effort. Second, we exclude Import Permits (IP) and SPS Work Plans (WP) from the analysis even though these two additional measures were identified in the EXCERPT database. WPs are rarely used and are very heterogeneous in their requirements and application. Because most WPs do not require SPS treatments, they are unlikely to be correlated with $treat_{podkt}$ or $origin_{odkt}$.[5] Conversely, import permits are required on all shipments

[4] Two other issues are worth noting. First, we assume that producer (pp_{ok}) and destination prices (pp_{odk}) are measured in the same currency (i.e., U.S. dollars) and therefore abstract from price differences due to exchange-rate misalignments. Second, while SPS treatments will affect t_{odk} directly, any treatments required during transit or throughout domestic supply chains (as in the case of systems approaches) will also affect domestic and international transport and marketing margins.

[5] There are a total of 211 out of 8,052 (2.6%) observations requiring a WP with the correlation between WPs and origin restrictions and SPS treatments equaling 0.07 and 0.18, respectively.

of products requiring an SPS or origin restriction measure and thus are subsumed into the variables $treat_{odkt}$ and $origin_{odkt}$. Third, because of the limited number of observations for each individual SPS treatment, we use an "aggregate" treatment variable ($treat_{odkt}$) that is equal to 1 if any SPS treatment is required.[6] However, we do have a significant commodity-by-destination dimension in the database. Thus, we also estimate a more flexible specification where the SPS treatment variable in equation (9) is expanded to include a commodity-specific SPS treatment. This is facilitated by the interaction of treatodkt and commodity-specific dummy variables (excluding onions, which face no specific SPS treatments).

Fourth, an important innovation in Peterson et al. (2013) was the identification of "learning-by-doing" effects in complying with foreign SPS measures. To investigate this possibility for U.S. exporters, we include a U.S. "experience" variable ($exper_{ot}$) that records the cumulative number of destination countries that require an SPS treatment for a given commodity and year. This variable accumulates year-over-year such that the learning effect is relatively large early on but increases at a decreasing rate as SPS treatment experience grows. To avoid losing observations for which the cumulative experience is zero, we use the natural logarithm of 1 plus the cumulative experience.

One limitation with the cumulative experience variable is that the United States starts with no treatment experience in the first year of our sample period. While it is likely that the United States has some treatment experience prior to 1999, we do not observe treatment information prior to this time period (i.e., before the creation of the EXCERPT Database described in the next section). To examine the robustness of the potential learning effect, we also construct two alternative measures of SPS treatment experience. First, we assume that existing SPS regulations affecting U.S. exports of product k in the first year of our sample (1999) also apply to the same products and destination markets in the three preceding years (1996–1998).[7] Second, we repeat this exercise but assume that the 1999 product-destination SPS treatments were applicable to corresponding observations during the 1990–1998 period. This latter scenario is intended to create a much larger stock of SPS treatment experience before our sample period begins in 1999.

Interaction of the binary treatment variable ($treat_{odkt}$) and the cumulative experience variable ($exper_{kt}$) allows us to measure possible learning effects. If the interaction between treatments and experience is positive and statistically significant, we compute a threshold experience level equal to the point at which the learning effect offsets the negative impact of SPS treatments. We then calculate the average number of years it takes U.S. exporters in our sample to actually achieve this threshold as our measure of the trade restrictiveness of SPS treatments. It should be noted that our framework does not consider the possible demand-enhancing effects of SPS treatments (for example, if SPS measures ensure higher quality products) and thus we are unable to evaluate potential welfare implications (Xiong and Beghin, 2012).

Fifth, equation (9) includes two price indices, Ω_{okt} and PI_{dkt}, which are not directly observable. If nothing is done, Ω_{okt} and PI_{dkt} (which are correlated with t_{odk} and E_{dk}) would be subsumed in the error term. Baldwin and Taglioni (2006), Anderson and van Wincoop (2003), Feenstra (2004), and others suggest the use of time-varying, country-specific fixed effects (ot, dt) as a consistent alternative to control for a country's overall resistance to trade with their partners in the rest of the world. Yet equation (9) contains an explicit commodity dimension so the use of time-varying country-by-commodity fixed effects (okt, dkt) is required for consistent estimation. However, with only one exporting country ($o = United\ States$), the time-varying country-by-commodity fixed effects (dkt) would soak up all of the degrees of freedom in our sample. Thus, we adopt an alternative approach that involves dummy variables for destinations (139), commodities (9), and years (11), but not the interaction among them. Because the sample period of our data is relatively short, the country-by-commodity price indices may not change much. However, there may be substantial

6 The coefficients on MB and cold treatment were the only two individual SPS treatments that we are able to estimate with precision.

7 Although we do not observe actual SPS regulations in place in the 1996–1998 periods we do observe product line U.S. bilateral exports so that a three-year stock of SPS treatment experience for 1996–1998 can be created.

destination specific shocks (i.e., recessions, conflicts, etc.), changes in world commodity prices and general inflationary pressures that can be absorbed by destination, commodity, and yearly dummy variables.

The final challenge in estimating equation (10) is the prevalence of zero trade flows.[8] Recent papers by Santos Silva and Tenreyro (2006), Helpman, Melitz, and Rubinstein (2008), Grant and Boys (2012), and Jayasinghe, Beghin, and Moschini (2010) show that omitting zero trade flows—due to the logarithmic transformation of the dependent variable in equation (10)—leads to biased estimates due to sample selection issues. The sample-selection problem can be particularly problematic if the reason for the existence of zero trade is correlated with SPS trade costs. Thus, we consider several estimation methods to assess the overall robustness of our estimates. First we use an Ordinary Least Squares (OLS) specification where the dependent variable is scaled by the log of one plus the value of U.S. bilateral exports. Because of the *ad hoc* nature of adding a small constant to the dependent variable, we also consider the family of nonlinear count-data models including the Poisson (pseudo) maximum likelihood model (PPML), the Negative Binomial, and the Zero-Inflated Poisson (ZIP) (Burger, van Oort, and Linders, 2009).[9] Santos Silva and Tenreyro (2006, 2011) show the use of count models, such as the PPML, yields unbiased and consistent estimates of the model's parameters when the dependent variable is not necessarily an integer and there is a high frequency of zero trade flows.

Given these modifications, the product-level gravity model we estimate is

$$\begin{aligned} V_{dkt} = {} & \exp[\pi_d + \pi_t + \pi_k + \beta_1 \ln Q_{dkt} + \beta_2 \ln Q_{kt,US} + \\ & \beta_3 \ln GDP_{dt} + \beta_4 FTA_{dt} + \lambda_1 \ln(1 + exper)_{kt} + \lambda_2 treat_{dkt} + \\ & \lambda_3 treat_{dkt} \times \ln(1 + exper)_{dkt} + \lambda_4 origin_{dkt}]\varepsilon_{dkt}, \end{aligned} \tag{10}$$

where subscript o, which represents the United States, has been suppressed, and π_d, π_k, and π_t, are importer, commodity, and year fixed effects, respectively. FTA_{dt} is a dummy variable equal to 1 for destination countries that share a free trade agreement (FTA) with the U.S. in time period t. The coefficients of interest are λ_2 through λ_4, which estimate the trade effects of SPS treatments, the interaction of treatments and experience, and origin restrictions on imports, respectively. Finally, ε_{dkt} is the multiplicative error term.

Data Description

Phytosanitary measures faced by U.S. exporters of cherries, grapes, strawberries, apples, peaches and nectarines, oranges, peas, walnuts, and onions for a period of eleven years starting May 1999 and ending December 2009 were retrieved from the subscription-based Export Certification Project (EXCERPT) database maintained by the Center for Environmental and Regulatory Information Systems (CERIS) at Purdue University, and by the Plant Protection and Quarantine (PPQ) branch of APHIS. The EXCERPT database contains monthly summaries of SPS import requirements for more than 250 countries which are used by U.S. exporting firms and authorized certification officials in the preparation and issuance of export certificates (USDA Animal and Plant Health Inspection Service, 2009). Import requirements of each country may consist of all or a combination of the following

[8] In the context of FFVs, there are several possible explanations for the presence of zero trade flows. First, perishability may limit FFV trade between distant countries in certain years (i.e., some fruit and vegetable products are shipped by air). Second, FFV production shortfalls can occur in the United States due to weather and/or pests and disease, which limit its ability to export. Finally, explicit policy measures such as tariffs and SPS measures may lead to zeros in the data. Thus, zero trade flows define an equilibrium in the model, whether they are the result of climatic conditions or prohibitive trade cost measures.

[9] Roy (2011), Liu (2009), and Grant and Boys (2012) have similarly used the log of 1 plus the value of bilateral trade and produced very similar estimates compared with nonlinear models treating the dependent variable in levels such as the Poisson and Negative Binomial. Further, it should be noted that the estimated coefficients for the Negative Binomial and ZIP models are scale dependent.

six SPS measures identified: import permits (IP), geographic restrictions on origin of production, work plans to pest risk management, seasonal restrictions, SPS product treatments, and additional declarations (ADs).[10]

Ten SPS treatment types affecting U.S. FFV exports to control plant pests of "quarantine significance" were identified in the EXCERPT database. Chemical treatments include fumigation with MB, fumigation plus refrigeration of fruits, and cold treatment plus fumigation of fruits. Nonchemical treatments include water treatment, high-temperature forced air, irradiation, vapor heat, cold treatment, and quick freeze. Additionally, Australia and New Zealand require fumigation with a mixture of Sulfur Dioxide and Carbon Dioxide (SO_2 and CO_2), while Australia, Mexico, Malaysia, and Chile require fumigation with Phosphine on certain products.

It should be noted that EXCERPT does not contain information on differences between the United States and destination countries' pesticide residue limits (often referred to as maximum residue limits or MRLs). As one reviewer noted, the SPS treatment dummy variable in the current model may be picking up an MRL effect. However, we believe this bias is unlikely for at least two reasons. First, SPS treatments are applied in response to an identified pest risk that could affect plant health, whereas MRL tolerances address human health concerns and reflect a country's perceived risk from exposure to pesticide residues. Thus, the potential correlation between plant health treatments investigated in this study and human health MRLs is likely small. Second, the SPS treatments investigated in this study are cold- or gas-based treatments (see table 1) as opposed to application of a liquid chemical on products. Thus, it is unlikely that SPS treatments explain the implementation of MRLs standards.

Origin restrictions, the final SPS regulation identified in our sample, stipulates the conditions under which a state, county, or region can ship products to foreign destinations. As their name suggests, these measures limit the regions from which exports may originate and typically require that a product be free of certain pests known to inhabit that region. For example, fresh strawberries exported to Taiwan and originating in California must be certified as free of stem nematode, western flower thrips, and plum curculio while strawberries originating in Hawaii must be certified as free of Mediterranean fruit fly in addition to being free of stem nematode and western flower thrips.[11]

U.S. annual export values for the nine products are obtained from the U.S. International Trade Commission.[12] U.S. annual production data are obtained from the USDA's National Agricultural Statistics Service and annual production data for importing countries are obtained from the Food and Agriculture Organization's Production Statistics (PRODSTAT) database.[13] GDP per capita are obtained from the United Nations Statistical Division with the exception of Taiwan, which is obtained from the International Macroeconomic Database of the Economic Research Service.[14] Coding for U.S. free trade agreements is based on those agreements notified to the WTO and contained in the Regional Trade Agreements Information System (RTA-IS).[15]

The 139 countries in our sample (Appendix table 1) are chosen based on the criteria that each country imported at least one of the nine commodities of interest for at least one year over the

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[10] Because of the large number of country/year/month/commodity observations (approximately $140 \times 11 \times 12 \times 9 = 155{,}320$), data on importers' SPS requirements were extracted from EXCERPT using a custom application programmed in Java and compiled and executed in the Netbeans Integrated Development Environment (IDE). The application accepts the EXCERPT data in HTML format after which it extracts and stores the year, month, and ISO-3 alpha country code from the Universal Resource Locator (URL) file path.

[11] Other examples include fresh cherries exported to Chile and originating in the California counties of Calaveras, Contra Costa, Fresno, Kern, Kings, Madera, Merced, Sacramento, San Benito, San Joaquin, Santa Clara, Stanislaus, and Tulare must have an additional declaration stating that products are free of various pests and have been subjected to a post-harvest fungicide treatment while fresh cherries originating in all other counties of California are prohibited from being exported to Chile.

[12] Available at http://dataweb.usitc.gov/

[13] NASS data are available at http://www.nass.usda.gov/Statistics_by_Subject/index.php?sector=CROPS, while FAO production values are available at http://www.nass.usda.gov/Statistics_by_Subject/index.php?sector=CROPS

[14] UN Statistics are available at http://unstats.un.org/unsd/snaama/selbasicFast.asp.

[15] Available at http://rtais.wto.org/UI/PublicMaintainRTAHome.aspx

Table 3. Variable Acronyms and Summary Statistics (n=8,052)

Variable	Mean	Std. Dev.	Min	Max
Bilateral Exports$_{dkt}$	$2,863	$13,524	$0	$270,235
Importer Production$_{dkt}$	212	1,316	0	31,204
US Production$_{kt}$	3,119	3,113	158	11,790
GDP per capita$_{dt}$	$11,365	$12,403	$107	$72,575
FTA$_{dt}$	0.04	0.20	0	1
Treat$_{dkt}$	0.10	0.31	0	1
Origin Restriction$_{dkt}$	0.09	0.29	0	1
SPS Experience$_{dkt}$	6.17	10.02	0	78

Notes: Bilateral exports are expressed as Free on Board (FOB) values in $1,000 USD. GDP per capita is expressed in $1,000 constant 2000 dollars.

eleven-year period. In some cases, the EXCERPT database combines countries with identical SPS requirements such as the various European Union (EU) expansions. Similarly, the Inter-African Group has a harmonized set of regulations, as do the former Soviet Union countries of Armenia, Azerbaijan, Belarus, Estonia, Georgia, Kazakhstan, Kyrgyz, Latvia, Lithuania, Moldova, Russian Federation, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan.[16]

A balanced panel for 139 countries, 9 commodities, and 11 years would contain 13,761 observations. However, many of these countries do not import one or more of the nine commodities for the entire sample period, and some countries do not have production or GDP information for all years. Thus, the final sample is an unbalanced panel of 8,052 observations. A total of 3,106 observations, or 39% of the sample, are associated with zero U.S. exports. Table 3 presents summary statistics for the variables in our econometric model.

Results

The regression results are organized in two scenarios (tables 4 and 5). Table 4 presents the aggregate treatment results. Columns (1) and (2) report the results using an OLS specification in which the dependent variable is the log of 1 plus the value of U.S. bilateral exports so that zero trade flows are retained. Columns (3)–(5) report the results for the nonlinear count data models, with results for the PPML estimation reported in column (3), the negative binomial in column (4), and the ZIP results in column (5). Finally, columns (6) and (7) incorporate the 1996–1998 and 1990–1998 stock of SPS treatments, respectively, to reflect the fact that U.S. exporters likely had treatment experience in fruits and vegetables before our sample period began in 1999. Column (6) assumes that treatments required in 1999 were also required in the 1996–1998 periods, which corresponds to the first three years of implementation of the WTO's Agreement on the Application of SPS measures. Column (7) repeats this exercise but assumes that SPS treatments existed over a much longer time period, 1990–1998, and thus U.S. exporters begin with a much larger stock of treatment experience in 1999. Finally, table 5 presents results using a more flexible specification where the SPS treatment and origin restriction coefficients are allowed to vary by commodity. In all scenarios (tables 4 and 5), we estimate possible learning effects associated with SPS treatments in the global marketplace defined as the point at which the negative SPS treatment effect turns positive. A comparison of these experience thresholds across products and time allows us to determine the restrictiveness of foreign SPS measures facing U.S. exports.

The ZIP estimator generates two separate models and then combines them by adjusting the probabilities of export flows in the second-stage Poisson regression for observations that are "certain" zeros. First, a logit model is specified to predict destination-by-commodity

[16] In 2004 Latvia, Lithuania, and Estonia become formal members of the EU and modified their SPS regulations to those of the other EU member states.

Table 4. SPS Treatment Effects on U.S. Fruit & Vegetable Exports, 1999–2009

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Estimation Method	**OLS**	**OLS**	**Poisson**	**Negative Binomial**	**ZIP**	**ZIP with 1996–1998 stock of experience**	**ZIP with 1990–1998 stock of experience**
Fixed Effects Included	**Year & Country**	**Year, Country & Commodity**	**Year, Country & Commodity**	**Year, Country & Commodity**	**Year, Country & Commodity**	**Year, Country & Commodity**	**Year, Country & Commodity**
Log Importer Production	−0.15***	−0.22***	−0.13***	−0.19***	−0.05***	−0.12***	−0.11***
	(0.02)	(0.02)	(0.02)	(0.02)	(0.01)	(0.01)	(0.01)
Log U.S. Production	0.36***	0.40***	0.80***	0.62***	0.35***	0.35***	0.45***
	(0.02)	(0.12)	(0.20)	(0.12)	(0.03)	(0.07)	(0.06)
Log Importer GDP/capita	1.48***	1.47***	1.12**	1.91***	0.71	1.41***	1.82***
	(0.39)	(0.37)	(0.47)	(0.39)	(0.50)	(0.45)	(0.44)
Free Trade Agreement	0.12	0.12	0.28*	0.25**	0.21*	0.54***	0.64***
	(0.18)	(0.17)	(0.15)	(0.12)	(0.15)	(0.13)	(0.14)
SPS	−1.81***	−1.66***	−0.43	−1.68***	−0.58*	−1.16**	−2.91***
	(0.33)	(0.30)	(0.34)	(0.25)	(0.32)	(0.55)	(0.68)
Log (1 + experience)	−0.33***	−0.32***	−0.06	−0.34***	−0.08	0.98***	3.11***
	(0.10)	(0.09)	(0.12)	(0.08)	(0.13)	(0.21)	(0.29)
SPS × log (1+experience)	0.75***	0.72***	0.20*	0.57***	0.21*	0.39**	0.75***
	(0.13)	(0.12)	(0.12)	(0.09)	(0.12)	(0.16)	(0.17)
Origin Restriction	0.16	0.23**	0.11	−0.04	0.45***	0.01	−0.02***
	(0.11)	(0.11)	(0.12)	(0.10)	(0.12)	(0.11)	(0.11)
Experience Threshold (product-destination pairs)	11.0***	10.0***	9.0	19.0***	16.0***	20.0***	48.0***
Pr > F	0.00	0.00	0.12	0.00	0.03	0.00	0.00
No. of years to reach threshold	2	2	2	3	3	3	6
						Inflation Equation	
SPS					−0.43***	−0.44***	−0.56***
					(0.08)	(0.08)	(0.09)
Origin Restriction					−0.26***	−0.25***	−0.22***
					(0.08)	(0.08)	(0.08)
Vuong Statistic of ZIP vs. Standard Poisson					27.92***	29.6***	28.9***
Pr > Z					0.00	0.00	0.00
(pseudo) R^2	0.43	0.52	0.77	0.27	0.54	0.65	0.68

Notes: Number of zero observations = 3,106. Number of nonzero observations = 4,946. The dependent variable is the log of one plus the value of U.S. bilateral exports in columns (1) and (2) and the levels value of exports in columns (3)–(5). Robust standard errors are in parentheses. Single, double, and triple asterisks (*, **, ***) indicate statistical significance at the 10%, 5%, and 1% levels. Column (5) includes a first-stage inflation equation (logit model) to predict excessive zero trade flows using SPS treatments and origin restrictions as dependent variables.

Table 5. Product-Specific SPS Treatment Effects on U.S. Fruit & Vegetable Exports, 1999–2009

ZIP Model	Peas	Walnuts	Oranges	Grapes	Apples	Cherries	Peaches	Strawberries
Interaction with SPS	−0.78	4.54***	−5.44***	−1.64	−2.52***	4.45*	1.15	−8.11**
Std. Err.	(1.02)	(0.89)	(1.27)	(1.79)	(0.65)	(1.22)	(0.82)	(2.38)
Interaction with SPS & Log (1 + Experience)	−0.18	−1.70***	1.75***	0.60	0.66***	−0.78**	−0.31	1.35**
Std. Err.	(0.31)	(0.28)	(0.38)	(0.48)	(0.18)	(0.32)	(0.25)	(0.62)
Interaction with origin restriction	−1.79***	1.21***	−0.66**	−0.67***	0.43**	−0.15	0.83**	−0.07
Std. Err.	(0.42)	(0.33)	(0.33)	(0.20)	(0.20)	(0.32)	(0.39)	(0.22)
Threshold Experience Value (product-destination pairs)	–	–	22***	15	47***	–	–	415
Pr > F			0.00	0.25	0.00	–	–	0.33
No. of years to reach threshold	–	–	2 years	–	5 years	–	–	–
Model Statistics	$R^2 = 0.69$; No. of zero obs. = 3,106; No. of nonzero obs. = 4,946							

Notes: The dependent variable is the value of U.S. bilateral exports. Robust standard errors are in parentheses. Single, double, and triple asterisks (*, **, ***) indicate statistical significance at the 10%, 5%, and 1% levels. All results are estimated using the ZIP model with three vectors of commodity interactions: (i) commodities interacted with the SPS treatment dummy, (ii) commodities interacted with SPS treatment and logarithmic treatment experience, and (iii) commodities interacted with the origin restriction dummy. Onions are not included because they do not face SPS regulations. Coefficient estimates in the first-stage inflation equation of the ZIP model are not shown to save space but include all product-specific SPS and origin restriction variables.

observations that are “certain” zeros, thus leading to “zero inflation” in the database. Then a Poisson model is estimated to predict bilateral trade for exporter-commodity pairs that are not “certain” zeros. The variables used to predict excessive zeros are SPS treatments and origin restrictions (along with country, commodity, and year fixed effects). We also report Vuong’s 1989 likelihood ratio (LR) test for model selection of the ZIP estimator against the standard Poisson.

The estimated coefficients for importer and U.S. production, GDP per capita in the destination market, and U.S. participation in free trade agreements have the correct sign and are statistically significant (with the exception of FTAs in the OLS models). Importers that produce more import less U.S. fresh fruit and vegetable products, all else equal, while increased U.S. production encourages more U.S. exports. Higher incomes on a per capita basis in destination countries generate a more than proportionate increase in FFV imports, suggesting that U.S. FFV exports may be luxury goods in foreign markets.[17] Membership in U.S.-based FTAs appears to increase trade. For example, in the Poisson model in column (3), FTA membership increases U.S. FFV exports by $(\exp(0.28) - 1) \times 100)$ 32%, on average.[18] Vuong’s 1989 LR test of the ZIP model (column 5) against the standard Poisson model (column 3) is positive and statistically significant, which suggests there is evidence of excessive zeros in the trade matrix and the two-step ZIP procedure is the preferred specification. Thus, in columns (5)–(7) we report the first-stage inflation equation results in which SPS treatments and origin restrictions are used to predict the probability of zero trade flows. Interestingly, both coefficeints are negative and statistically significant, suggesting that SPS and origin restrictions reduce the likelihood of zero inflation.

We now turn to a discussion of the trade effects of SPS measures impacting U.S. exports. Because SPS treatments can increase exporters’ cost of accessing destination markets, these measures may reduce U.S. exports if the cost of treating products is greater than the premium that might be obtained from being able to sell treated products in the destination market. Our results support the notion that SPS regulations generally reduce trade. Ignoring for the moment the interaction of SPS and treatment experience, the coefficient on the SPS dummy variable is negative and statistically significant across all specifications in table 4 (the exception being column 3, where the negative coefficient is marginally insignificant with a p-value of 0.20). The economic interpretation is that SPS measures are trade restrictive for U.S. exporters with no treatment experience. For example, an SPS treatment reduces the trade of inexperienced exporters by 81% in the OLS model (column 2) and 44% in the ZIP specification (column 5).[19]

While the above result is typical in the empirical literature, the positive and statistically significant coefficient for the SPS treatment-experience interaction term in all specifications indicates that while treatments have a negative effect on U.S. exporters on average, this effect diminishes as U.S. exporters accumulate treatment experience. This result is consistent with a “learning-by-doing” framework whereby U.S. exporters are able to treat shipments more efficiently as their cumulative experience grows. Thus, a more policy-relevant question is not the extent to which treatments increase or decrease trade but the level of experience at which treatments no longer restrict U.S. exports.

Differentiating equation (10) with respect to $treat_{dkt}$ and setting it equal to 0 permits us to solve for this threshold level, which is equal to the exponential of the absolute value of the ratio between the coefficient on the SPS treatment and the treatment-experience interaction term. This calculation reveals the number of product-destination markets with an SPS treatment requirement that the U.S. must serve before the SPS treatment is no longer a barrier to trade. Whether this threshold experience level is trade distorting or not is unclear unless we know something about the distribution of U.S. exporters’ cumulative experience treating products in the global market for fresh

[17] The only exception to this is column (5), in which the per capita income coefficient is not significant.

[18] Note that the FTA effect is much larger when we drop the country fixed effects and include a NAFTA variable. Because NAFTA entered into force in 1994 and our sample does not start until 1999, the NAFTA dummy is dropped because it is perfectly collinear with the Canadian and Mexican country fixed effects.

[19] The percentage change in exports from a change in a dummy variable is computed as $[\exp(\hat{\beta}) - 1] \times 100$.

fruit and vegetables. Thus, we compute how many years on average it takes the United States to meet the SPS experience threshold.

For the OLS model specification in column (2), the threshold cumulative experience level is equal to 10 ($\exp(1.66/0.72)$, implying that U.S. exporters must treat ten times before the learning effect of treating products is enough to overcome the negative influence of SPS treatments on trade.[20] In our sample, U.S. exports reach a threshold level of ten treatments after an average of two years (table 4). This suggests that SPS treatments applied to U.S. exports of the nine FFVs in our sample appear to be minimally trade distorting, on average, relative to exporters not facing a treatment requirement. In our preferred nonlinear negative binomial and ZIP specifications in columns (4) and (5), the threshold experience level is nineteen and sixteen product-destination treatments, respectively, which U.S. exporters achieve in an average of three years.

Another way to interpret this result is in the context of overcoming fixed costs of exporting. Treating products may require investments in fumigation chambers, treatment facilities, or refrigeration or cold treatment units during transit, all of which require a fixed investment to bring a product into compliance in the destination market. If the fixed costs can be recovered by subsequent export sales, then the cumulative experience thresholds can be thought of as spreading the fixed costs over a growing number of export shipments (i.e., treatment experience) such that the costs of establishing treatment facilities are no longer a barrier to trade after a certain threshold is reached.

On average, the imposition of an origin restriction seems to have a positive influence on U.S. exports, although the coefficient is not statistically significant in three out of five specifications (columns 1, 3, and 4). This could suggest that origin restrictions are applied to regions within the United States that account for a large share of U.S. exports. For example, the coefficient of 0.45 in column (5) implies that the presence of an origin restriction increases U.S. exports of FFVs by 57% ($(\exp(0.45) - 1) \times 100$). In 2009, the final year of our sample, oranges, grapes, apples, and cherries faced origin restrictions from nineteen, eighteen, twenty, and nineteen destination countries, respectively, and, on average, the U.S. shipped more of these commodities to countries that imposed origin restrictions than to countries with no origin restriction. Conversely, onions, peas, walnuts, peaches, and strawberries faced considerably fewer origin restrictions, from six, four, one, thirteen, and fourteen countries, respectively. On average, the U.S. exported significantly less to countries with origin restrictions for these commodities. Thus, it is hard to predict a priori the sign on the origin restriction variable because it depends on the number of destination countries imposing the restriction and whether the identified regions in the U.S. account for a large or small share of U.S. production and exports.

While informative, the above results say little about which commodities are most affected by SPS measures in foreign markets. In table 5, we present of a more flexible specification where each commodity dummy variable (peas, walnuts, oranges, grapes, apples, cherries, peaches, and strawberries) is interacted with the SPS treatment dummy, the experience variable, and the origin restriction dummy. This specification is important because it allows us to evaluate the trade restrictiveness of SPS measures for each commodity by computing commodity-specific threshold levels and the number of years necessary to reach this threshold. However, one disadvantage of this specification is that the degrees of freedom within each commodity are lower, and it is therefore more difficult to identify the impacts of SPS regulations with precision.

The results in table 5 suggest that there is considerable variation in the SPS treatment effect across commodities. The estimated coefficient for the commodity-treatment interaction term is negative in five out of eight commodities but is only statistically significant in three of these instances. SPS treatments have a significant positive effect on U.S. cherry exports reflecting the fact that the United States exports more cherries to countries that require a SPS treatment than to countries that did not. For example, in 2008, cherry exports averaged \$13.7 million to countries that

[20] We round to the nearest whole number since the experience variable is an integer.

required a SPS treatment and $2.1 million to countries with no treatment requirement. U.S. walnut exports followed a similar trend.

For apples, oranges, and strawberries, the treatment-experience interaction coefficient is positive and statistically significant, which allows us to compute a threshold experience level for those commodities. Since these estimated threshold levels are statistically significant only for apples and oranges, we limit our discussion to these commodities. SPS treatments on apples appear to be more trade restricting than for oranges since the experience threshold of forty-seven treatments for the latter is greater than twenty-two product-destination treatments in the former. In terms of the number of years it takes U.S. exporters to achieve these thresholds, the comparison between apples and oranges is similar, with a five-year threshold for apples compared to a two-year threshold for oranges. The underlying data generally support these differences. Treatment requirements for apples ranged from ten to twelve destination markets in each year of the sample period with cold treatment being the most common SPS requirement. Treatment requirements for oranges ranged from eighteen to twenty destination markets with vapor heat, cold treatment, or quick freeze being the most commonly required SPS regulations. These results suggest two implications. First, both the number of treatments and the type of treatments required by destination countries play a role in determining the trade restrictiveness of SPS treatments for apples and oranges. Second, because U.S. exporters accumulate treatment experience at a faster rate for oranges than for apples, the experience threshold and the number of years to reach this threshold are smaller.

Finally, while the average effect reported in table 4 was positive across all commodities and most specifications, the effect of an origin restriction is negative and statistically significant for fresh peas, oranges, and grapes in table 5. For walnuts, apples, and peaches, the estimated coefficients are positive and statistically significant, again underscoring the difficulty in sorting out the effects of this variable.

Conclusions

SPS requirements in foreign nations are important examples of non-tariff measures facing U.S. exporters. This article assembled a unique and comprehensive database of SPS regulations affecting nine fresh fruit and vegetable products to evaluate their trade impacts by developing a product-line gravity equation in a learning-by-doing framework. The empirical results largely support the existing literature—SPS measures appear to be more of a barrier than a catalyst to trade. However, further investigation illustrated that SPS measures are barriers to trade only in the early years when exporters' treatment experience is lower. Our results suggest that the negative effect of SPS measures diminishes as U.S. exporters accumulate SPS treatment experience in the global marketplace and vanishes when they reach a threshold level of two to three years of exporting. We evaluated the restrictiveness of these measures not by comparing the percentage reductions in trade flows predicted by the model but by computing how long it takes the U.S. to reach the estimated threshold levels where the negative trade-flow effect of SPS measures disappears.

Using our preferred specification that includes a 1996–1998 stock of previous SPS treatment experience coinciding with the first three years of implementation of the SPS Agreement, we find an average threshold level of twenty treatments using the zero-inflated Poisson estimator. This implies that U.S. exporters need to supply products to twenty destination markets that require an SPS treatment before these measures are no longer a barrier to trade. In our sample, U.S. exporters achieve this threshold after three years of exporting. Across individual commodities, the treatment-experience threshold is statistically significant only in the case of U.S. apple and orange exports. Although the experience threshold (forty-seven compared to twenty-two treatments) and the number of years to reach this threshold (five years compared to two years) is greater for apples compared to oranges, it is difficult to reach a definitive conclusion on which commodity is impacted more by SPS measures because U.S. exporters accumulate treatment experience faster in the case of oranges and the type of individual treatments required differs between the two commodities.

While the results shed new light on the trade-distorting nature of SPS treatments, they should be prefaced with three important policy considerations. First, due to the difficult nature of collecting detailed non-tariff SPS measures and matching these to bilateral trade flows, our results are only applicable to nine fresh fruits and vegetables. We hope future research can extend this important data collection effort to include more products. As one reviewer noted, it would be interesting to explore whether destination-market SPS requirements are reciprocal as a potential response to stricter U.S. import regulations. Second, we focused only on the plant health (i.e., phytosanitary) dimension of SPS measures. However, there are growing concerns in Europe and Asia over issues such as pesticide residues and aflatoxins in the fruit and vegetable trade. If these omitted factors are correlated with the SPS treatment dummy, then the coefficients may be picking up a food safety rather than a plant health effect. However, as noted earlier, we believe this bias to be small because of the independent nature to which plant health and human health SPS regulations are applied in the United States.

Third, we have to be cautious when referring to SPS treatments as "barriers" to trade because U.S. exporters may not be permitted to access some foreign markets at all without approved SPS measures in place. In this paper we compare the product-destination countries that do not require an SPS treatment relative to those product-destination country pairs that do. A more precise comparison would be to identify product-country pairs that have an identified pest-risk in the United States and compare U.S. exports before and after the SPS policy was implemented. However, it is difficult to make this comparison because it is not clear how long products with identified pest risks have been required to be treated. On the other hand, because we observe U.S. exporters shipping fresh fruit and vegetable products to partner countries in the presence of these measures, it is likely that there are important welfare gains that outweigh the costs of complying with these regulations.

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Table A1. Sample Countries (n=139)

ISO	Country	ISO	Country	ISO	Country	ISO	Country
hline ANT	Netherlands Antilles	DNK	Denmark	KOR	Korea	PLW	Palau
ARE	United Arab Emirates	DOM	Dominican Rep.	KWT	Kuwait	POL	Poland
ARG	Argentina	DZA	Algeria	LBN	Lebanon	PRT	Portugal
ATG	Antigua and Barbuda	ECU	Ecuador	LBR	Liberia	PYF	French Polynesia
AUS	Australia	EGY	Egypt	LCA	St. Lucia	QAT	Qatar
AUT	Austria	ESP	Spain	LKA	Sri Lanka	ROU	Romania
BDI	Burundi	EST	Estonia	LSO	Lesotho	RUS	Russian Federation
BEL	Belgium	FIN	Finland	LTU	Lithuania	RWA	Rwanda
BFA	Burkina Faso	FJI	Fiji	LVA	Latvia	SAU	Saudi Arabia
BGD	Bangladesh	FRA	France	MAC	Macao	SEN	Senegal
BGR	Bulgaria	GBR	United Kingdom	MAR	Morocco	SGP	Singapore
BHR	Bahrain	GHA	Ghana	MDG	Madagascar	SLE	Sierra Leone
BHS	Bahamas	GIN	Guinea	MEX	Mexico	SLV	El Salvador
BIH	Bosnia Herzegovina	GNQ	Equatorial Guinea	MKD	Yug. Rep. of Macedonia	SMR	San Marino
BLZ	Belize	GRC	Greece	MLI	Mali	SUR	Suriname
BMU	Bermuda	GRD	Grenada	MLT	Malta	SVN	Slovenia
BOL	Bolivia	GTM	Guatemala	MMR	Myanmar	SWE	Sweden
BRA	Brazil	GUY	Guyana	MNG	Mongolia	SYC	Seychelles
BRB	Barbados	HKG	Hong Kong	MOZ	Mozambique	TCD	Chad
BRN	Brunei	HND	Honduras	MRT	Mauritania	TGO	Togo
CAF	Central African Rep.	HTI	Haiti	MUS	Mauritius	THA	Thailand
CAN	Canada	HUN	Hungary	MYS	Malaysia	TTO	Trinidad & Tobago
CHE	Switzerland	IDN	Indonesia	NCL	New Caledonia	TUN	Tunisia
CHL	Chile	IND	India	NER	Niger	TUR	Turkey
CHN	China	IRL	Ireland	NGA	Nigeria	TWN	Taiwan
CIV	Cote d'Ivoire	ISL	Iceland	NIC	Nicaragua	UKR	Ukraine
CMR	Cameroon	ISR	Israel	NLD	Netherlands	URY	Uruguay
COG	Congo, Rep. of	ITA	Italy	NOR	Norway	VCT	St. Vincent & Grenadines
COL	Columbia	JAM	Jamaica	NPL	Nepal	VEN	Venezuela
CRI	Costa Rica	JOR	Jordan	NZL	New Zealand	VNM	Vietnam
CUB	Cuba	JPN	Japan	OMN	Oman	WSM	Western Samoa
CYP	Cyprus	KAZ	Kazakhstan	PAK	Pakistan	YEM	Yemen
CZE	Czech Republic	KEN	Kenya	PAN	Panama	ZAF	South Africa
DEU	Germany	KHM	Cambodia	PER	Peru	ZWE	Zimbabwe
DMA	Dominica	KNA	St. Kitts and Nevis	PHL	Philippines		