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Evaluating the Trade Restrictiveness of Phytosanitary Measures on U.S. Fresh Fruit and Vegetable Imports

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Empirically assessing sanitary and phytosanitary regulations has proven difficult because most data sources indicate whether a regulation exists but provide no information on the type or importance of the respective measure. In this article, we construct a novel database of U.S. phytosanitary measures and match these to 47 fresh fruit and vegetable product imports from 89 exporting countries over the period 1996–2008. A product-line gravity equation that accounts for zero trade flows is developed to investigate the trade impact of different pest-mitigation measures. While the results suggest that phytosanitary treatments generally reduce trade, the actual restrictiveness of these measures diminishes dramatically as exporters accumulate experience, and it vanishes when exporters reach a certain threshold. The results have important policy implications considering the number of empirical studies that find a negative impact of non-tariff measures on trade.

Key words: fruit and vegetable trade, phytosanitary treatments, non-tariff measures, gravity equation, Poisson, Zero-Inflated Poisson.

JEL codes: F13, Q17.

We have witnessed a significant shift in the focus of agricultural trade policy concerns away from border-related costs such as tariffs, which dominated much of the research and policy agenda leading up to the Uruguay Round Agreement on Agriculture (URAA), to non-tariff measures (NTMs) and regulatory policies that are often "behind a nation's border" (Disdier and van Tongeren 2010). While tariffs remain high in a handful of agricultural sectors, as tariffs are reduced (particularly through regional integration) we are learning more about other obstacles to trade that are more obscure and have the potential to distort trade. As Baldwin (2000) noted more than a decade ago, "[t]he 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."

Technical measures such as sanitary and phytosanitary (SPS) regulations are important for many food and agricultural products due to the sensitive nature of issues such as food safety and the protection of plant and animal health. The World Trade Organization (WTO) Agreement on the Application of SPS Measures permits countries to adopt their own set of regulations provided they are based on a risk assessment, are not discriminatory between countries with similar conditions, and are minimally trade-distorting to prevent the disingenuous use of these measures as instruments for protectionism (Josling, Roberts, and Orden 2004). Using phytosanitary measures such as

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methyl bromide fumigation or cold treatment are particularly important to control for pests in fresh fruits and vegetables that could be transmitted through international trade.[1]

There is a growing body of literature investigating the impacts of SPS and other technical measures on international trade patterns (Minten et al. 2009; Anders and Caswell 2009; Jaffee and Henson 2004; World Bank 2005; Calvin and Krisoff 1998; Otsuki et al. 2001; Disdier et al. 2008; Disdier and van Tongeren 2010; Peterson and Orden 2008; Jayasinghe et al. 2009; Maskus et al. 2001; Swann et al. 1996; Moenius 2004; Chen et al. 2008). A major obstacle in this area of research, however, is the difficulty of constructing detailed SPS data suitable for empirical analyses, which involve searching through regulatory agencies' documents to determine the type of measure imposed, when and how it is imposed, and on which country/commodity pairs.

One of the most popular sources of this information is the Trade Analysis and Information System (TRAINS) maintained by the United Nations Conference on Trade and Development (UNCTAD; e.g., Disdier et al. 2008; Disdier and van Tongeren 2010; Essaji 2008; Gebrehiwet et al. 2007).[2] 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 construct coverage ratios (i.e., the share of imports "covered" by the NTM). However, there are several recognized limitations with this approach (see Anderson and van Wincoop 2004). First, TRAINS does not identify specific technical regulations. For example, phytosanitary measures may be included under trade control measures 8153 (Testing, inspection, etc., required to protect plant health), 8163 (Information requirements), 8193 (Technical regulations, not elsewhere specified), 8200 (Pre-shipment inspections), or 8900 (Technical measures, not elsewhere specified).[3] Because these TCM categories may include sanitary, phytosanitary or a host of other technical measures, it is not possible to identify specific SPS regulations in the TRAINS database. Second, there is no bilateral dimension in TRAINS. If an SPS regulation is notified for a particular product, researchers often have to assume it applies to all exporters. Yet as we demonstrate in this article, U.S. phytosanitary measures are not uniform across exporters for a given fresh fruit or vegetable. Rather, they depend on whether there is an identified pest risk in the exporting country, and the degree to which the exporting country can implement approved pest mitigation strategies. Finally, the use of frequency indices and coverage ratios leads to what Swann (2010) calls a "mixed bag" problem. This is because adding up measures assigns equal weight to regulations that may differ in importance and type.[4]

This article investigates the trade restrictiveness of U.S. phytosanitary measures applied to fresh fruit and vegetable imports. First, we develop a unique and comprehensive database on phytosanitary measures using current and archived versions of the Animal and Plant Health Inspection Service (APHIS) *Fresh Fruits and Vegetables Import Manual* (2012), the Code of Federal Regulations, *Federal Register* notices, and APHIS reports over the sample period (1996–2008). Second, we match phytosanitary measures that are country-specific, commodity-specific and year-specific to U.S. bilateral fresh fruit and vegetable (FFV) imports to develop a product line gravity equation to quantify their impact. Finally, we assess the trade restrictiveness of phytosanitary measures, not by reporting percentage changes in trade flows more generally, but by evaluating threshold values in a learning-by-doing framework (Young 1991). The "learning" thresholds are defined as the point at which exporters have accumulated enough experience such that the application

[1] Introductions can occur naturally, through migration, or passively via water or wind dispersion. However, experts believe trade and travel are important vectors, although the lack of data precludes ranking the relative importance of these pathways (National Research Council 2002).

[2] The Perinorm subscription-only database on standards is another popular dataset that does not suffer from many of the drawbacks of TRAINS. http://shop.bsigroup.com/en/Navigate-by/Assessment-Tools/Other-Electronic-Products/Perinorm/. However, Perinorm is based primarily on European Union (EU) countries and focuses exclusively on international and private standards (i.e., battery voltages, door handles, etc.), which are very different from phytosanitary measures used to protect plant health.

[3] As a result of an UNCTAD initiative launched in 2007, recent improvements in the TRAINS database have included new categories that identify specific SPS measures, such as A262, "Quarantine requirement," which includes fumigation. However, to date, the data collected using this more detailed classification are primarily based on notifications of barriers to trade from private firms submitted via a website and are only available for a limited set of countries.

[4] Jayasinghe et al. (2009) also indicate the importance of accurately measuring NTMs in world demand for seed corn because not all SPS regulations to protect plant health are economically important.

of phytosanitary measures is no longer a barrier to trade. We then compute the fraction of exporters that are able meet this threshold level of experience as our metric of the restrictiveness of phytosanitary measures.

U.S. Regulations of Fresh Fruit and Vegetable Imports

U.S. imports of FFVs more than doubled between 1999 and 2008, increasing from $5.2 to $10.8 billion. The growing share of imported FFVs in the American diet, which increased from 28% to 41% for fruits and from 3% to 18% for vegetables on a volume basis over this period, has increased awareness of the way in which imports are regulated to prevent the introduction of pests and diseases via shipments of these products from abroad.[5] While APHIS currently monitors and regulates the entry of most agricultural imports, federal efforts to control the introduction of foreign pests date back to the Plant Quarantine Act of 1912, which addressed concerns over pest outbreaks in nursery stock (Josling, Orden, and Roberts 2004). APHIS has the authority to promulgate import regulations under the Plant Protection Act of 2000 to reduce the risk of plant pests entering and to implement domestic control programs in the event of outbreaks. In the most restrictive cases, APHIS can prohibit imports from countries that have identified pest risks and have not developed approved mitigation practices. For example, APHIS permits the importation of fresh apples and oranges from only a subset of suppliers, with approved countries accounting for 38% and 71% of global exports of these commodities, respectively.[6] However, if mitigation measures that will reduce the risk of pest or disease outbreaks can be identified, APHIS will recommend that the commodity be allowed to enter subject to a set of phytosanitary requirements. In the event that no pest risks are identified, APHIS will allow the product to enter subject to routine inspection requirements.

Phytosanitary Measures

Phytosanitary measures on FFVs eligible for entry fall into five categories as described in 7 CFR 319.56-4 of the U.S. Code of Federal Regulations: treatments, destination restrictions, origin restrictions, pre-clearance procedures, and systems approaches (table 1). We do not analyze the effects of measures in the latter three categories because they are used infrequently and generally apply to sub-national trade flows.[7] This article focuses on two of the five categories of phytosanitary measures: treatments and destination restrictions.

Approved treatment requirements include methyl bromide fumigation, cold treatment, water treatment, heat treatment, irradiation, or a combination of these treatments (table 2). To gain insight on the frequency with which treatments are applied in the data, table 2 tabulates the number of country/commodity/year triplets where at least one treatment is required over the period 1996–2008. For each category of treatments we also document whether trade is positive or zero. Of the 9,073 total trade flow observations, 1,515 (16.7%) are associated with at least one required treatment. Of the 1,515 observations subject to a treatment, 590 (29%) are associated with zero trade flows (table 2). This indicates that treatments may be a key determinant in countries' "decision to export"—an important point we return to when we develop the empirical model. Based on the total number of observed, non-zero import flows (5,084), treatments are required on 18% (925 observations) of those shipments. However, these measures are required more often for fresh fruits, at 28%, or 688 out of 2,478 observations, than for fresh vegetables at 9%, or 237 out of 2,606 observations (table 2).

Considerable variation exists in the frequency with which treatments are applied across countries and commodities. Methyl bromide fumigation, the main treatment requirement for fresh vegetables, and cold treatment jointly account for nearly three-quarters (74%) of all treatments applied. Approximately one-half of all occurrences of methyl bromide fumigation and one-third of all cold treatment occurrences are associated with zero trade flows. Treatments required in combination, such as fumigation and cold (refrigeration) treatments, are also strongly associated with zero trade flows, whereas most occurrences

[5] See http://www.ers.usda.gov/topics/international-markets-trade/us-agricultural-trade/import-share-of-consumption.aspx.

[6] See http://www.ers.usda.gov/Data/FruitVegPhyto/.

[7] Moreover, preclearance procedures are often optional, so their application to individual consignments at the port in the exporting country cannot be ascertained from Federal publications. See, for example, the *Fresh Fruits and Vegetables Import Manual* (2012), which states, "Consignments may or may not be pre-cleared," for fruits and vegetables imported from Argentina.

Table 1. U.S. Phytosanitary Measures for Fresh Fruit and Vegetable Imports

Measure	Description	Example
Phytosanitary treatments	Phytosanitary treatments authorized for use under provisions of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), as amended, for the prevention of the movement of agricultural pests into or within the United States and its territories.	Fresh mangoes from India must be irradiated before being shipped to the United States.
Geographical restrictions on origin	Products must be grown in greenhouses or in areas/regions that are recognized as pest-free by APHIS.	Papayas from Brazil must be grown in the states of Bahla, Espirito Santo, and Rio Grande do Norte.
Geographical restrictions on destination	APHIS distinguishes between 13 different U.S. ports of entry. However, some ports, including Puerto Rico and Alaska, are not considered part of the continental United States.	The United States allows the importation of squash from New Zealand only into Hawaii.
Preclearance procedures in the exporting country	Preclearance procedures involve inspection on the territory of the exporting country by APHIS authorities of a product that is associated with quarantine pests. In addition, the product is accompanied by a phytosanitary certificate stating the product has been inspected and found free of pests.	Mangoes from the Philippines must be pre-cleared prior to export.
Systems approaches to pest risk management	A group of different pest risk-mitigation techniques which cumulatively achieve the desired level of phytosanitary protection, at least two of which act independently.	Fresh Hass avocados grown in approved orchards in the Mexican state of Michoacán are subject to a number of risk-mitigation practices at numerous points in the supply chain that cumulatively achieve the desired level of phytosanitary protection.

Source: Animal and Plant Health Inspection Service (2012).

of water, pest-specific/host variables, and heat treatments are associated with positive trade (table 2).

Table 3 illustrates the share of countries eligible to ship to the United States and the share of U.S. imports (by product value) that are subject to at least one treatment for 25 FFV products. For grapes, mangoes, oranges, and okra, a large share of exporting countries, as well as a large share of total imports are subject to at least one treatment. For apricots, asparagus, peaches and nectarines, and plums and sloes, treatments appear to affect a relatively large share of U.S. imports. Conversely, treatments for apples, garlic, and grapefruit affect 29.2%, 20%, and 36.4% of exporters, respectively, but the respective shares of U.S. imports subject to at least one treatment in each product category are 2%, 0%, and 6.9%. This may suggest that exporters affected by required

Table 2. Frequency of Phytosanitary Treatments

	Zero Trade Flow		Positive Trade Flow		Total	
Phytosanitary Treatment	Fruits	Vegetables	Fruits	Vegetables	Fruits	Vegetables
Methyl bromide fumigation	24	237	96	199	120	436
Water treatment	12	0	103	0	115	0
Heat treatment	1	0	11	4	12	4
Pest-specific/host variable	0	3	12	34	12	37
Cold treatment	209	0	356	0	565	0
Irradiation	0	2	6	0	6	2
Treatments required in combination						
Fumigation plus refrigeration of fruits	11	0	22	0	33	0
Methyl bromide fumigation and cold treatment	59	0	34	0	93	0
Cold treatment or fumigation plus refrigeration of fruits	23	0	43	0	66	0
Water treatment or methyl bromide fumigation	9	0	2	0	11	0
Methyl bromide fumigation or cold treatment	0	0	3	0	3	0
Total	348	242	688	237	1036	479

Source: Authors' calculations.

treatments for apples, garlic, and grapefruit are relatively insignificant in the U.S. import market, or it could suggest that treatment costs to bring a product into compliance with APHIS standards are prohibitive such that exporters do not select into exporting (i.e., garlic). Finally, there are some products (e.g., bananas, melons, papayas, strawberries, carrots, cauliflower, globe artichokes, and others not listed in table 3) for which treatments are not required.

Contrary to what is reported in TRAINS, treatments clearly have a bilateral and product-specific dimension. In addition, there are many instances where exporters are not subject to these regulations. This variation in treatment and control groups permits us to identify their trade impacts using a formal model of trade flows.

"Gravity" at the Product Line

A product-level gravity model is utilized, based on the frameworks presented in Anderson and van Wincoop (2003) and Baldwin and Taglioni (2006), that assumes all varieties of commodity k (e.g., apples, broccoli, etc.) are differentiated by their source, and consumer preferences in the destination region d for commodity k are weakly separable and can be represented by a CES sub-utility function as follows:

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

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 initially suppressed 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:

$$(2) \qquad V_{odk} = p_{odk} x_{odk} = \frac{\alpha_{odk} p_{odk}^{1-\sigma_k} E_{dk}}{\sum_{r=1}^{R} \alpha_{rdk} p_{rdk}^{1-\sigma_k}}$$

where p_{odk} is the price of commodity k from region o in region d, and E_{dk} is expenditure on commodity k in region d. Note that the denominator in equation (2) can be expressed

Table 3. Share of Exporting Countries and Total U.S. Import Value Subject to at Least One Phytosanitary Treatment Requirement for Select Commodities, 2008

Commodity	Share of Exporters with at Least One Required Phytosanitary Treatment (%)	Share of Import Value with at Least One Required Phytosanitary Treatment (%)
Fruits		
Apples	29.2	2.0
Apricots	17.6	86.7
Bananas	0.0	0.0
Cherries	8.7	2.3
Grapefruit	36.4	6.9
Grapes	60.0	76.6
Mangoes	41.9	43.0
Melons	0.0	0.0
Oranges	34.5	53.4
Papayas	0.0	0.0
Peaches and nectarines	15.0	96.5
Plums and sloes	16.7	99.5
Strawberries	0.0	0.0
Vegetables		
Asparagus	8.0	50.3
Broccoli	0.0	0.0
Cabbage	4.5	0.0
Carrots	0.0	0.0
Cucumbers	0.0	0.0
Garlic	20.0	0.0
Globe artichoke	0.0	0.0
Head lettuce	5.3	1.9
Okra	36.8	69.1
Peppers	1.9	0.0
Tomatoes	3.8	0.0

Sources: Authors' calculations.

in terms of the price index (PI_{dk}) for the CES sub-utility function:

$$(3) \qquad PI_{dk} = \left\{ \sum_{r=1}^{R} \alpha_{rdk} p_{rdk}^{1-\sigma_k} \right\}^{\frac{1}{1-\sigma_k}}.$$

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 (3) in equation (2) yields:

$$(4) \qquad V_{odk} = \frac{\alpha_{odk} \left(t_{odk} pp_{ok}\right)^{1-\sigma_k} E_{dk}}{PI_{dk}^{1-\sigma_k}}.$$

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. This implies that 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:

$$(5) \qquad Y_{ok} = \sum_{d=1}^{R} V_{odk} = \sum_{d=1}^{R} \frac{\alpha_{odk} (t_{odk} pp_{ok})^{1-\sigma_k} E_{dk}}{PI_{dk}^{1-\sigma_k}}.$$

Solving for $pp_{ok}^{1-\sigma_k}$ in equation (5) and substituting into equation (4) yields an extended version of Baldwin and Taglioni (2006, equation (7)) that incorporates an explicit commodity dimension for FFVs:

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

Trade costs (t_{odk}) consist of all factors needed to get commodity k from producers in region o 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 the fresh fruit and vegetable trade:

$$(7) \qquad DM_k = \exp\left(destin_{odk}^{\alpha_1}\right) ZDM_k^{\alpha_0}$$

$$(8) \qquad trans_{odk} = dist_{od}^{\delta_1} \exp\left(destin_{odk}^{\delta_2}\right) Ztrans_{odk}^{\delta_0}$$

$$(9) \qquad PHT_{odk} = \exp\left(\prod_p treat_{podk}^{\lambda_p} \right) Ztreat_{odk}^{\lambda_0}$$

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 PHT_{odk} is the cost of phytosanitary 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}.[8] An additional factor affecting trade costs that is not included in equations (7) through (9) is bilateral tariffs, which we incorporate below.

The trade cost factors in equations (7) through (9) are difficult to measure, much less observe. However, we can observe whether a destination restriction is in place, the physical distance between countries, and the types of phytosanitary treatments applied, which are related to these unobservable factors. The binary variable $destin_{odk}$ is equal to 1 if region o faces a destination restriction on commodity k shipped to region d, and zero otherwise; $dist_{od}$ is the geographical distance between regions o and d; $treat_{podk}$ is a binary variable equal to one if region o must use phytosanitary treatment p on commodity k exported to region d, and zero otherwise; and ZDM_k, $Ztrans_{odk}$, and $Ztreat_{odk}$ are unobserved determinants of trade and transport margins and phytosanitary treatment costs, respectively.[9]

To complete our product line gravity equation, two additional refinements to equation (6) are necessary. Because the CES sub-utility function is homothetic, an increase in E_{dk} will yield a proportional increase in V_{odk}, all else being constant.[10] However, E_{dk} is not directly observable. While in general, E_{dk} is a function of the price indices for each partition (commodity) in the weakly separable utility function and income, the price indices for each commodity are also not observable. Thus, we assume that E_{dk} is a function of total income (GDP) in region d: $E_{dk} = GDP_d^{\beta}$. Because the overall utility function for the representative consumer in region d need not be homothetic, β need not equal one. Similarly, an increase in the value of production in region o (Y_{ok}) will lead to a proportional increase in V_{odk}, all else being constant. However, because data on Y_{ok} for the 89 countries and 47 commodities in our sample contains a large number of missing values (due to unobserved producer prices), we use production quantities (Q_{ok}) as a proxy for production value and assume that $Y_{ok} = Q_{ok}^{\phi}$, where the parameter ϕ need not be equal to one.[11]

Substituting equations (7) through (9) into equation (6), along with E_{dk} and Y_{ok} yields our baseline gravity model at the product line. Taking the natural logarithm and including time subscripts and one plus the bilateral tariff inclusive of preferential rates ($tariff_{odkt}$) yields:

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

There are a few differences between the gravity model specified in equation (10) and the econometric model used in this article. First, index d refers only to the United States. Because of the time-intensive nature of collecting data on phytosanitary regulations, including additional importing countries would only be feasible through a collective effort. Second, due to a limited number of observations for each specific treatment, we initially use a generic treatment variable ($treat_{odkt}$) that is equal to 1 if any treatment is required. We also estimate a more flexible specification that includes individual treatments.[12]

[8] Two other issues are worth noting. First, we assume that producer prices (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, the presence of a PHT affects t_{odk} directly because of the additional cost of treating products. However, if treatments are required during transit or throughout domestic supply chains (as in the case of systems approaches), then PHTs may also affect domestic and international transport and marketing margins.

[9] As one reviewer noted, using dummy variables to estimate the impact of policy measures in the gravity equation has its drawbacks because they may also pick up contemporaneous factors unrelated to the SPS measures.

[10] Because the CES utility function is homothetic, the budget share for each good remains constant as income changes, holding prices constant. In this paper, the budget share is equal to V_{odk} divided by E_{dk}.

[11] The correlation coefficient between production quantities and values is 0.78.

[12] Missing data for exporter production reduces the number of observations with at least one treatment from 1,515 in the SPS database to 1,231 in our sample. However, the relative frequency of specific treatments and their application is virtually identical to the complete SPS database. In these specifications, irradiation treatment is excluded because it occurs too infrequently. Pest specific/host variable treatment requires methyl bromide fumigation, so it is combined with the methyl bromide fumigation treatment

The third difference is that equation (11) excludes systems approaches, origin restrictions, and preclearance procedures, which raises the potential for omitted variable bias (table 1). However, we believe that the potential bias is small. Systems approaches are infrequently used (48 country/commodity pairs), and are very heterogeneous in their requirements and application.[13] Because most systems approaches do not require phytosanitary treatments, it is unlikely to be correlated with $treat_{odkt}$ or $destin_{odkt}$.[14] There are even fewer origin restrictions in our sample (25 country/commodity pairs). While the potential correlation between origin restrictions and treatments and destination restrictions is less obvious, it is small in our sample (less than 0.05 in both cases). Two other factors limit an investigation into origin restrictions. First, the Animal and Plant Health Inspection Service *Fresh Fruits and Vegetables Import Manual* (2012) lacks information on the year that country-specific and commodity-specific origin restrictions entered into force, and picking a year such as 1996 would be completely arbitrary. Second, in most cases origin restrictions limit the export of fresh fruit and vegetable products from specific regions within a country that have an identified pest risk. Because we do not observe the origin of production in the trade flow data, nor do we know how important each region is in the total production of a given fresh fruit and vegetable product, a precise investigation of the trade restrictiveness of origin restrictions is not feasible. Finally, because preclearance procedures are often optional, the choice of whether to have a consignment pre-cleared is not likely correlated with either the presence of a treatment or a destination restriction.

An important innovation of this article is that it estimates possible "learning-by-doing" effects from complying with U.S. phytosanitary measures such that the trade-restricting nature of these regulations decreases as exporting countries become more proficient at performing the required treatments (e.g., Young 1991). To investigate this possibility, we include an "experience" variable ($exper_{odt}$) that records the cumulative number of commodities subject to a treatment for each exporter and year.[15] Interaction of the binary treatment variable ($treat_{odkt}$) and the cumulative experience variable allows us to measure this "learning" effect. Because we would expect that the marginal effect of experience diminishes as exporters gain experience, we use the natural logarithm of one plus the cumulative experience of our empirical model. We add one to cumulative experience to avoid losing observations when cumulative experience is zero. If the interaction between treatments and experience is positive and statistically significant, then we can compute a threshold experience level where the "learning" effects that offset the negative impacts of a treatment can be determined. We then calculate the fraction of exporters in our sample that actually achieve this threshold as our measure of the trade restrictiveness of phytosanitary treatments.

The price indices, Ω_{okt} and PI_{dkt}, are not directly observable. If nothing else was done, Ω_{okt} and PI_{dkt} (which are correlated to t_{odk} and E_{dk}) would be subsumed into the error term. Baldwin and Taglioni (2006), Anderson and van Wincoop (2003), Feenstra (2004), and many others suggest the use of time-varying country-specific fixed effects (ot, dt) as a consistent alternative to control a country's overall resistance to trade with their partners in the rest of the world. However, the gravity equation derived in (10) contains an explicit commodity dimension, which means that using time-varying country-by-commodity fixed effects (okt, dkt) are required for consistent estimation. With only one importing country ($d =$ United States), the use of time-varying exporter-by-commodity fixed effects (okt) would absorb all the degrees of freedom

category. Finally, treatments required in combination (table 2) are aggregated into one individual treatment category. In summary, the individual treatments included in the estimations are: methyl bromide fumigation (MB); cold (COLD); water (WTR) treatment; and MB and/or cold/refrigeration/water treatments required in combination (collectively referred to as MB/COLD; table 2).

[13] Systems approaches were initiated in 1994 as an alternative to chemical treatments such as ethylene dibromide, which had their registration cancelled by the Environmental Protection Agency in the 1980s. The term was first used to describe an insect management system developed for the importation of avocados from Mexico (National Plant Board 2002).

[14] The correlation between systems approaches and $treat_{odkt}$ and $destin_{odkt}$ is 0.015 and 0.024, respectively. As explained in the results section, the coefficients on $treat_{odkt}$ and $destin_{odkt}$ are unaffected by the inclusion or exclusion of a dummy variable denoting systems approaches.

[15] One limitation with the cumulative experience variable is that all exporters start with no treatment experience in the first year of our sample period. This is not likely to be the case since a number of exporters have been required to treat FFV products well before 1996. However, it was not possible to characterize the cumulative experience variable at the beginning of our sample because we do not observe treatment information prior to this time period. Another possible measure would be the quantity of all commodities subject to a given treatment. However, this measure would likely be jointly determined with V_{odk} (through x_{odk}), creating the potential for endogeneity bias.

in our sample. Thus, we adopt two alternative approaches. First, because the sample period of our data is relatively short (13 years), we specify time-invariant exporter-by-commodity group fixed effects using five composite fruit and five composite vegetable categories to control for Ω_{okt}.[16] Second, because the United States is the only importing country in the sample, we cannot use importer-by-commodity fixed effects to control for PI_{dkt}. To overcome this limitation, we construct a relative price ratio ($PRATIO_{kt}$) equal to the U.S. producer price divided by the average *fob* price across all exporters of commodity k at time t to control for the U.S. multilateral price index (PI_{dkt}). This provides a time-varying, commodity-specific measure of U.S. prices relative to the rest of the world.

A final challenge in estimating equation (10) 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 trade costs. In the context of FFVs, if phytosanitary treatments are prohibitive, then firms may not select into exporting, which explains why zeros exist but not for random reasons. With this in mind, we adopt the Poisson estimation framework as discussed in Santos-Silva and Tenreyro (2006):[17]

$$
\begin{aligned}
(11)\quad V_{okt} = \exp[&\pi_{ok} + \pi_t + \beta_1 \ln Q_{okt} \\
&+ \beta_2 \ln(1 + tariff_{okt}) \\
&+ \beta_3 \ln PRATIO_{okt} + \beta_4 destin_{okt} \\
&+ \lambda_1 \ln(1 + exper_{ot}) + \lambda_2 treat_{okt} \\
&+ \lambda_3 treat_{okt} * \ln(1 + exper_{ot})]\varepsilon_{okt}
\end{aligned}
$$

where subscript d, which represents the United States, has been suppressed; π_{ok} and π_t are exporter-by-commodity (group) and year fixed effects, respectively; and ε_{okt} is the error term.

While the Poisson model provides a natural way to address the "zeros" issue, it has been criticized on two grounds, first because it assumes equal dispersion between the conditional mean and variance (Cameron and Trivedi 1990), and second, because it cannot deal with excessive zeros that may be the result of a different data-generating process (Burger, van Oort, and Linders 2009). As suggested by one reviewer, when analyzing a dataset with excessive zeros, the zero-inflated class of models should be considered.

In the context of FFVs, there are several reasons why excessive zeros may result.[18] First, perishability may limit FFV trade between distant countries in certain years (i.e., mangoes from India are often shipped by air). Second, FFV production or harvest shortfalls can occur due to weather and/or pests and disease, which limit a country's ability to export. Finally, explicit policy measures such as tariffs and phytosanitary measures may inflate the number of zeros in the data. In each case, zero trade flow records for each exporter will look identical in the database, but the reasons for the existence of zero trade are different. For these reasons, we also estimate the Zero-Inflated Poisson (ZIP) model and test the ZIP estimator against the standard Poisson method using Vuong's (1989) Likelihood Ratio test for model selection.

The ZIP method generates two separate models and then combines them by adjusting the probabilities of export flows in the Poisson regression for observations that are "certain" zeros. First, a logit model is specified to predict exporter/commodity observations that are certain zeros. Then, a Poisson model is generated to predict bilateral trade for exporter-commodity pairs that are not certain zeros. As described in the next section, we have eliminated a number of "excess" zeros in cases where production is null or climatic conditions prevent exporters from producing (and therefore exporting) certain FFV products (i.e., tropical products cannot be grown in temperate climates). Thus, our logistic inflation equation used to predict any remaining

[16] Using 4,183 unique exporter-commodity fixed effects (89 countries by 47 commodities) would not allow sufficient degrees of freedom for estimation. The vegetable and fruit categories are: (Veg1) Asparagus, Broccoli, Brussels Sprouts, Cabbage, Cauliflower, Globe Artichokes; (Veg2) Carrots, Garlic, Leeks, Onions, Potatoes, Mushrooms & Truffles; (Veg3) Head Lettuce, Leaf Lettuce, Spinach; (Veg4) Cucumbers, Eggplants, Squash, Jicamas, Pumpkins, Breadfruit; (Veg5) Okra, Peppers, Tomatoes, Fresh Beans; (Fruit1) Grapefruit, Lemons, Limes, Mandarins & Clementines, Oranges; (Fruit2) Avocados, Bananas, Mangoes, Papayas, Pineapples; (Fruit3) Cherries, Cranberries & Blueberries, Currants, Raspberries & Blackberries, Strawberries; (Fruit4) Apples, Apricots, Grapes, Kiwifruit, Peaches & Nectarines, Pears & Quinces, Plums & Sloes.

[17] While Poisson regressions are typically associated with studies involving count data, Santos-Silva and Tenreyro (2006) show succinctly that the PPML estimation strategy 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 flow records (see also Santos Silva and Tenreyro 2011).

[18] See Burger, van Oort, and Linders (2009) for a more general explanation.

excess zeros focuses on two policy variables: phytosanitary treatments and bilateral tariffs.

Data

Information on U.S. treatments during the period 1996–2008 was obtained from the *Fresh Fruits and Vegetables Import Manual* (Animal and Plant Health Inspection Service 2012).[19] The APHIS manuals contain information (organized by exporting country) on the regulatory regime and the conditions under which an exporter can ship FFVs to the United States. The manuals are released several times a year to reflect the implementation of any new regulations or amendments. Because trade data used in this article are compiled annually, the last edition for a given year is used to match treatments and lists of approved products. Because regulatory requirements do not change frequently within a year, drawing information from the last APHIS manual published in a given year ensures that all changes in phytosanitary requirements are accounted for without having to track intra-year changes across each edition. Changes in phytosanitary requirements are identified by comparing the treatment requirements and list of approved products across two consecutive years.

A concordance is developed between the 47 APHIS fresh fruit and vegetable identifiers and the Harmonized Trade Classification (HTS) codes reflected in U.S. bilateral import data. Most APHIS commodities are associated with a single HS6-digit category. However, further disaggregation was needed to eliminate dried, frozen or preserved products for bananas, cabbage, fresh beans, carrots, mangoes, lemons, and limes, which are defined at the HTS8-digit level, whereas broccoli is defined at the HTS10-digit level.[20] Bilateral annual imports of FFVs are obtained from the U.S. International Trade Commission.[21] Because the United States imports FFVs from over 150 countries, a filter was applied. To be included in the sample, a country must have shipped at least $100,000 of at least one FFV product for at least three years (out of the 13 years in our sample).[22] Applying this filter yields 89 exporting countries in our sample.

Production quantities and values are obtained from the Food and Agriculture Organization (FAO).[23] Some FAO commodity definitions did not always match the HTS product definitions contained in the trade data. For example, the FAO product category green onion (including shallots) is used for both onions and leeks. Other FAO product categories are combinations of the individual product categories in our sample. For example, lemons and limes are one product category in the FAO data, whereas they are two separate commodities in the trade data. In this case, we apply the same production data to both lemons and limes as a proxy for exporter production.

Bilateral applied tariffs, including preferential rates, are derived from the USITC trade data. In addition to reporting the free on board (*fob*) and cost, insurance and freight (*cif*) U.S. import values, the USITC also reports the (landed) duty paid import value, which includes tariffs and other surcharges assessed at the port of entry. Bilateral applied tariffs are computed by dividing the landed duty paid import value by the *cif* import value for each observation (see also Debaere and Mostashari 2010). United States producer prices from the FAO and world unit value prices from the UN Commodity Trade Statistics Database (COMTRADE) were used to construct the relative price ratio ($PRATIO_{kt}$).[24]

A fully-balanced panel yields 54,379 observations (89 exporters $*$ 47 FFV product categories $*$ 13 years). However, a number of zero trade flow observations are excluded from the sample. First, some country/commodity pairs are ineligible for entry into the United States under APHIS rules due to pest concerns or the inability of exporters to implement approved pest mitigation strategies. Second, many zero

[19] The current edition of the manual is available online. To construct the 1996–2008 database, previous editions of the manual in hard copy (1996–1999) and various electronic formats (2000–08) were obtained from the archives of APHIS's Plant Protection and Quarantine (PPQ) Manuals Unit in Frederick, MD, on November 12–13, 2008.

[20] The HS code for Globe artichokes changed in 2007. Consequently, this commodity is defined as a combination of HS 070910 (globe artichokes, fresh or chilled) and HS 07099065 (globe artichokes, fresh or chilled). Trade data involving "not elsewhere specified" categories and minor or specialty products were excluded from the analysis.

[21] Available at www.usitc.gov.

[22] Note that this filter does not mean that *every* product a country exports must total $100,000 or more. Rather, it simply dictates that an exporter must ship at least one product totaling $100,000 or more for at least three out of the 13 years. If that condition is met, the exporter and all of the products it ships, some of which may total considerably less than $100,000, are included in the sample.

[23] FAO production data are available at http://faostat.fao.org/site/339/default.aspx.

[24] Comtrade data can be accessed by subscription at http://comtrade.un.org/db/.

Table 4. Summary Statistics and Treatment Correlations

Variable	Mean	Std. Dev.	Min.	Max.
U.S. import value (V_{odk})	\$11.1 mil.	\$5.19 mil.	\$0	\$1.14 bil.
Log exporter production ($\ln Prod_{odk}$)	10.917	2.330	1.099	16.447
Log U.S./World relative price ratio ($\ln PRATIO_{kt}$)	−0.396	0.701	−2.332	2.334
Log bilateral tariff ($\ln(1 + tariff_{odk})$)	0.018	0.043	0	0.240
Destination restriction ($destin_{okt}$)	0.970	0.171	0	1
Cumulative treat experience ($exper_{ot}$)	18.9	22.5	0	116
Generic SPS treatment ($Treat_{okt}$)	0.173	0.378	0	1
MB	0.061	0.240	0	1
WATER	0.013	0.112	0	1
COLD	0.062	0.242	0	1
HEAT	0.002	0.042	0	1
MB/Cold Combinations	0.023	0.149	0	1

Correlation Coefficients of Phytosanitary Treatments

Variable	MB	Water	Cold	Heat	MB/Cold Combinations
MB	1				
WATER	−0.029	1			
COLD	−0.066	−0.029	1		
HEAT	−0.011	−0.005	−0.011	1	
MB/Cold Combinations	−0.033	−0.017	−0.039	−0.006	1

Note: The acronyms MB, WATER, HEAT, and MB/Cold Combinations denote methyl bromide fumigation, water, cold, heat treatments, and methyl bromide and refrigeration or cold treatments required in combination, respectively. Pest-specific/host variable treatment requires MB fumigation so it is combined with the MB treatment category. The MB/Cold Combinations is a composite of all treatments listed in table 2 under *Treatments Required in Combination*.

trade flows are associated with countries that are not able to produce a given commodity due to climatic or biological factors (i.e., bananas cannot be grown in Canada); FAO production data are used to identify these occurrences. Third, even if production is possible, if a country does not export a given commodity to any country during the sample period, and there is no evidence of U.S. phytosanitary measures in place, that country/commodity pair is also excluded from the sample. In other words, we assume there is no "potential" for trade for countries that have never exported a particular product. Finally, for some observations data are missing for some independent variables (namely exporter production). The final sample includes 7,405 observations, of which 2,933 observations (40%) are zero trade flows. Table 4 presents the summary statistics.

Econometric Results

The results, along with robust standard errors, are presented in table 5 and are organized as follows. Column (A) employs the standard Poisson regression model presented in equation (11). Columns (B) through (G) report the results using the ZIP estimator along with the Vuong (1989) test for model selection. Column (B) is identical to (A) except the former uses the ZIP estimator. Columns (C) and (D) consider learning-by-doing effects for fresh fruit and fresh vegetable commodities, respectively. Column (E) provides a robustness check on our choice of coding the treatment variable when it was conditional on the product originating from a pest-free zone in the origin country, while Column (F) provides a robustness check using production values as opposed to quantities. The final column examines specific phytosanitary treatments.

The estimated coefficients for exporter production, the relative price ratio, and destination restrictions have the correct sign and are statistically significant across all specifications. Exporters that produce more export more to the United States. A higher U.S. producer price relative to the average export price in the rest of the world reduces the competitiveness of domestic fruit or vegetable production, resulting in higher U.S. imports. Not surprisingly, exporters subject to a destination restriction have lower bilateral trade with the United States, all else being equal, compared with exporters who do not face a destination restriction. While the estimated coefficient for bilateral tariffs has the expected negative sign for

Table 5. Estimation Results of Phytosanitary Measures Applied to U.S. Fresh Fruit and Vegetable Imports, 1996–2008

	Model						
	(A)	(B)	(C)	(D)	(E)	(F)	(G)
Estimation Method:	Poisson	ZIP	ZIP	ZIP	ZIP	ZIP	ZIP
Vuong Test Zero Inflated vs. Poisson:		38.20***	24.13***	27.76***	37.39***	24.17***	37.83***
Prob > z		(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Variable							
Log (Exporter production)	0.79***	0.77***	0.98***	0.56***	0.75***	0.49***	0.77***
	(0.03)	(0.03)	(0.04)	(0.04)	(0.03)	(0.07)	(0.03)
Log (1 + bilateral tariff)	−1.26	−1.24	1.25	0.12	−1.41	−2.47*	−1.77
	(1.30)	(1.33)	(1.56)	(1.79)	(1.33)	(1.46)	(1.33)
Log (relative price ratio)	0.29***	0.32***	0.04	0.61***	0.29***	0.19***	0.24***
	(0.06)	(0.06)	(0.07)	(0.10)	(0.06)	(0.06)	(0.06)
Destination restriction	−1.19***	−0.98**	−0.80**	−2.09***	−1.22***	−1.12**	−0.84**
	(0.30)	(0.38)	(0.37)	(0.44)	(0.35)	(0.42)	(0.37)
Phytosanitary treatment	−0.62***	−0.62*	−0.46**	−5.27***	−1.37***	−1.54***	
	(0.35)	(0.36)	(0.29)	(1.28)	(0.37)	(0.59)	
Log (1 + cum. experience)	−0.14	−0.13	−0.21**	−0.19	−0.14	−0.14	
	(0.17)	(0.16)	(0.10)	(0.13)	(0.17)	(0.16)	
Treatment* Log (1 + cum. experience)	0.39***	0.37***	0.37***	1.91***	0.51***	0.56***	
	(0.10)	(0.10)	(0.08)	(0.48)	(0.10)	(0.15)	
MB							−0.02
							(0.47)
Water							−0.75
							(0.61)
Heat							0.21
							(0.30)
Cold							0.26
							(0.44)
MB/Cold Combination							−2.78***
							(1.04)
MB*Log(1 + cum. experience)							0.28**
							(0.13)
Water*Log(1 + cum. experience)							0.28
							(0.39)
Heat*Log(1 + cum. experience)							0.22*
							(0.11)
Cold*Log(1 + cum. experience)							0.13
							(0.13)
MB/Cold*Log(1 + cum. experience)							0.72
							(0.66)
Inflation Equation Results							
Phytosanitary treatment		−0.14**	−0.10	0.13	−0.14**	0.10	
		(0.07)	(0.08)	(0.13)	(0.07)	(0.07)	
Log (1 + bilateral tariff)		4.37***	2.61*	3.85***	4.37***	5.59***	4.35***
		(0.56)	(1.37)	(0.63)	(0.56)	(0.66)	(0.56)
MB							−0.10
							(0.11)
Water							−1.54***
							(0.31)
Heat							−2.23**
							(1.03)
Cold							−0.18*
							(0.10)
MB/Cold Combinations							1.01***
							(0.22)
Observations	7,405	7,405	3,532	3,873	7,405	5,639	7,405
Pseudo-R^2	0.86	0.82	0.78	0.89	0.83	0.73	0.82

Note: Model definitions are: (A) Poisson estimator; (B) Zero-inflated Poisson estimator; (C) Model B using only observations for fruits; (D) Model B using only observations for vegetables; (E) Robustness check on origin specific treatment requirements in Mexico using Model B; (F) Model B using production values instead of quantities; and (G) Specific phytosanitary treatments. All models include country-by-commodity fixed effects. Robust standard errors are in parentheses. One, two and three asterisks denote significance at the 10%, 5%, and 1% levels, respectively.

Table 6. Treatment/Experience Thresholds from Regression Results in Table 5

	(A)	(B)	(C)	(D)	(E)	(F)	(G)
Threshold experience	5.00*	5.00*	4.00*	16.0***	15.0***	15.0**	
Std. err.	(2.64)	(2.91)	(1.89)	(2.13)	(3.63)	(5.92)	
No. of exporters that obtain	33	33	30	15	23	22	
No. of exporters that treat	36	36	32	19	36	34	
MB Experience Threshold							1.00
Std. err.							(1.74)
No. of exporters that obtain							19
No. of exporters that treat using MB							19
Water Experience Threshold							15.0
Std. err.							(15.7)
No. of exporters that obtain							8
No. of exporters that treat using Water							10
MB/cold GE threshold							48.0
Std. err.							(115.6)
No. of exporters that obtain							7
No. of exporters that treat							15

Note: The threshold level of experience is the cumulative number of phytosanitary treatments required such that the marginal effect of phytosanitary treatments is zero. Denoting β^{P} as the phytosanitary treatment effect on trade, and $\beta^{P/CE}$ as the interaction of phytosanitary treatments (P) with cumulative experience (CE), this threshold is calculated as $\exp(\beta^{P}/\beta^{P/CE})$. Experience thresholds are rounded to the nearest whole number. Standard errors of the non-linear threshold predictions are in parentheses and are estimated using the Delta Method.

five of the seven model specifications, it is only statistically different from zero in one case. This occurs because U.S. tariff rates on FFV imports are low and remain low throughout the sample period, with a rate of 1% and a maximum value of 27%; 90% of observations face a tariff of less than 5%.[25]

We now turn to a discussion of the effects of phytosanitary treatments on U.S. imports.[26] We begin by considering the average effect of phytosanitary treatments (columns (A) through (F)). Across all specifications, exporters that are required to use a phytosanitary treatment have lower bilateral trade with the United States compared with exporters that do not have a treatment requirement. However, the coefficient for the treatment–experience interaction is positive and statistically significant across all specifications, indicating that while treatments have a negative effect on trade for exporters with limited experience, this effect diminishes as exporters accumulate treatment experience. This important result is consistent with a "learning-by-doing" framework, whereby exporters are able to treat shipments more efficiently as their cumulative experience grows.

An important policy question then, is not the extent to which treatments increase or decrease trade, but *at what level of experience do treatments no longer restrict trade?* Differentiating equation (11) with respect to $treat_{okt}$ and setting it equal to zero 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 phytosanitary treatment and the treatment-cumulative experience interaction term. The threshold values and their respective standard errors, along with the number of exporters that attain this level are reported in table 6. For the results in column (A), the threshold cumulative experience level is equal to five (exp(0.62/0.39), implying that exporters must treat five times before the trade-restrictive nature of phytosanitary treatments vanishes.[27] Whether this threshold experience level is trade-distorting or not is unclear

[25] Furthermore, the between variation in the panel data is three times the size of the within variation. Because of the country-by-commodity fixed effects, the tariff coefficients in table 5 reflect within variation of exporter-and-commodity pairs over time. Because U.S. tariffs do not vary greatly over time for a given exporter-and-commodity, this explains the insignificance of the tariff coefficient. Moreover, removing the exporter-by-commodity fixed effects from the specification results in negative and highly significant bilateral tariff coefficients in all scenarios.

[26] One reviewer questioned our exclusion of systems approaches (table 1) from the econometric estimation. Systems approaches are very heterogeneous in their application and almost never require a phytosanitary treatment. Furthermore, we note that the treatment-experience interaction effects reported in table 5 and the experience thresholds reported in table 6 are unchanged when a systems approach dummy variable is included.

[27] We round to the nearest whole number for the threshold level of experience because the cumulative experience variable is an integer.

unless we know something about the distribution of exporters' cumulative experience. In our sample, 36 exporters are required to treat at least one commodity in the sample period. Of these exporters, 33 (92%) attain a cumulative treatment experience of five. This suggests that U.S. phytosanitary treatments appear to be minimally trade-distorting relative to exporters not facing a treatment requirement.

In column (B) of table 5, we employ the ZIP estimator, which introduces a logistic inflation equation to differentiate U.S. imports according to the probability of an observation being a "certain" zero from those observations that are at risk of having a zero flow. Using Vuong's (1989) Likelihood Ratio test, we can easily reject the null hypothesis of no excess zeros in favor of the ZIP estimator (table 5). This result also holds across all other specifications in columns (C) through (G). Interestingly, the results from the logistic-based zero inflation equation reported in table 5 suggest that while phytosanitary treatments reduce the likelihood of "certain" zeroes, tariff rates increase this likelihood. Thus, while tariffs had an insignificant effect on the level of trade in column (A), they are a significant determinant of excess zeros. The use of the ZIP estimator has only a small effect on the estimated coefficients for phytosanitary treatments and the treatment-experience interaction term. The only difference between the results in columns (A) and (B) is that the positive treatment-experience interaction coefficient decreases from 0.39 to 0.37. This small change has no effect on the threshold experience level, which remains at five.

In columns (C) and (D) we evaluate whether the experience threshold differs between fresh fruits and fresh vegetables. Two results stand out: first, the threshold experience level for fresh fruits is considerably less, at just four treatments, compared to the threshold experience level for fresh vegetables, at 16. While this may suggest that phytosanitary treatments are more trade-restricting for fresh vegetables, we cannot say definitively until we calculate the proportion of exporters that are able to attain the respective levels. Thirty out of 32 fresh fruit exporters (93%) attain a cumulative experience threshold of four, while 15 out of the 19 (79%) fresh vegetable exporters attain a cumulative threshold of 16 in our sample. Thus, while phytosanitary treatments on fresh vegetables are slightly more trade-restricting, almost 80% of exporters are able to overcome the trade-restricting nature of these measures.

There were several instances where the use of a phytosanitary treatment was conditional on the product originating from a pest-free zone in the country of origin: Chilean grapes and Mexican apples, cherries, grapefruit, mangoes, oranges, peaches and nectarines, and plums and sloes. Because we do not have consignment-level data and cannot directly observe where the product originated, we initially assumed that an exporter would choose to export a product that originated in a pest-free zone because it would reduce trade costs. To examine the robustness of this choice, column (E) reverses the coding of the $treat_{okt}$ variable from no treatment to treatment for these cases in Chile and Mexico. By comparing columns (B) and (E), we can see that this choice turns out to be quite important. The threshold experience level increases from 5 in column (B) to 15 in column (E), and only 64% of all exporters attain this higher level in column (E) compared with 92% in column (B). Note that the threshold level in column (E) likely represents an upper bound since it is conceivable that not all of these products were produced in a region with an identified pest problem. Clearly, however, this choice has important implications for the results, and without detailed intra-national shipment data we are unable to say anything definitive on the origin and pest-free status of production.

As noted earlier, we use production quantities rather than production values in our base gravity model because of the large number of missing observations for the latter (due to missing producer prices). To examine the robustness of this choice, we re-estimate our base model using production values rather than quantities (column F). Because of a much smaller sample (5,639 vs. 7,405), this choice leads to larger standard errors and larger absolute coefficient values for $treat_{okt}$ and the treatment-experience interaction. Thus, the experience threshold is three times higher when production values are used compared with using production quantities (column B). The trade restrictiveness of phytosanitary treatments is also higher, with 22 out of 34 exporters achieving the threshold level compared with 33 out of 36 in column B.

As mentioned in the introduction to this article, empirical assessments of non-tariff measures are often based on countries' notifications to the WTO and compiled in the TRAINS database. One of the novel features of our dataset is that not only do we observe whether a treatment exists, but also we observe the type of treatment required. The final column in table 5 (G) estimates a more flexible specification that includes specific treatment types. There are two concerns in the estimation of this scenario, however. First, the number of observations associated with each treatment is considerably less than the aggregate treatment variable used previously (see tables 2 and 4), making identification more difficult. Second, the limited variation in individual treatments, coupled with the fact that the cumulative experience variable does not have a commodity dimension, will also affect the amount of variation in the treatment-experience interaction term, thereby making identification of the learning-by-doing effect more difficult.

Given these concerns, it is not surprising that the only coefficients that are statistically significant are methyl bromide fumigation and cold treatments required in combination (MB/Cold Combination). Further, only the coefficients on the interaction terms between methyl bromide (MB) and experience, and heat treatment and experience were individually statistically significant. However, the hypothesis that the coefficient for the individual treatment variable and the treatment–experience interaction term are jointly equal to zero is rejected for all five treatments considered. Thus, a longer sample period with more observations for each individual treatment and/or data on individual shipments where we could obtain a better estimate of cumulative experience are needed to more precisely identify the effect of individual treatments on U.S. imports of fresh fruits and vegetables.

Given this caveat, we can compute the threshold experience levels for MB, water, and MB/Cold treatments to provide at least a preliminary estimate of the restrictiveness of each treatment.[28] As shown in column (G) in table 6, MB has the lowest experience threshold level at one, and all exporters attain this level, followed by 15 for water treatment and 48 for MB/Cold combinations. The small threshold level for MB is likely related to the fact that it is the least costly pest mitigation technique, with an average cost of $0.01 per pound of treated product (Ferrier 2010). While the threshold experience level for water treatment is relatively higher than MB fumigation, eight of the ten exporters (80%) that are required to use water treatment achieve this threshold level. Not surprisingly, the most trade-restrictive treatment requires both MB fumigation and cold treatment in combination. With the high threshold experience level of 48, only 47% (7/15) of the exporters in our sample achieve this threshold level. The individual treatment results underscore the important fact that not all phytosanitary treatments are "barriers" to trade, particularly when there are significant "learning" effects in the treatment of fresh fruit and vegetable commodities.

Concluding Remarks

Phytosanitary measures that are required for imports of FFVs in the U.S. market are important examples of non-tariff measures in international trade. Drawing on a unique and comprehensive database of U.S. phytosanitary regulations affecting eligible FFV imports, this article demonstrates a striking result: the negative effect of phytosanitary measures on international trade diminishes as exporters' accumulate treatment experience, and it vanishes when exporters reach a certain threshold. The fraction of exporters that attain the threshold experience level ranges from a low of 64% to a high of 92%, depending on the model specification. Thus, our results suggest that at least two-thirds of exporting partners are able to overcome the trade-restricting impact of all phytosanitary treatments.

When evaluating the impacts of specific types of phytosanitary treatments, we find that measures required in combination, such as methyl bromide fumigation and cold treatment, are the most trade-restrictive measures. Fewer than half of all exporters that are subject to these treatment combinations achieve the experience threshold. Conversely, methyl bromide fumigation individually appears to be the least trade restrictive, with all 19 exporters able to achieve the experience threshold level.

While the results shed new light on the trade-distorting nature of phytosanitary treatments, they should be prefaced with two important policy considerations. First, due to the challenging nature of collecting detailed non-tariff phytosanitary measures and matching these to bilateral trade flows, our analysis focused on U.S. imports of 47 fresh fruits and vegetables, where collecting such data was feasible through consultations with the Animal and Plant Health Inspection Service. However, we

[28] Note that because the coefficients for heat and cold treatments and their interaction terms are positive, the threshold experience level would be negative.

are hopeful that future research will extend this important data collection effort to include more countries and products.

Second, we have to be cautious when referring to treatments as "barriers" to trade because without phytosanitary measures, countries with an identified pest problem would not be allowed to access the U.S. market at all. In other words, the benchmark-counterfactual comparison in this article is the group of exporters that do not have an identified pest risk and are not subject to phytosanitary regulations relative to those exporters that are. A more precise comparison would be to identify countries with an identified pest risk and compare their exports to the United States both with and without the requirement of phytosanitary measures. The problem with this scenario is that we would not observe the counterfactual—countries with an identified pest risk have always been subject to a phytosanitary measure in our sample period. On the other hand, because we observe countries shipping fresh fruit and vegetable products to the U.S. market in the presence of these measures, it is likely that there are important welfare gains that outweigh the cost of regulating these products.

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