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An Empirical Investigation of U.S. Demand for Fresh-Fruit Imports

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With increasing fresh-fruit import dependence, it is important for the United States to analyze trends and future trade scenarios, and develop strategies to achieve economic efficiency in the international market. Import demand elasticities are effective for analyzing trends and predicting possible development scenarios for international trade. This study uses a Source-Differentiated Almost Ideal Demand System to estimate elasticities of demand for mangoes and guavas, bananas, avocadoes, and papayas imported from NAFTA, DR-CAFTA, and MERCOSUR; and subsequently employs these elasticity estimates to measure the expected impact of import tariffs on the U.S. imports of fresh fruits from Mexico.

***Key words**:* AIDS Model, Fruits, Import Demand Elasticities, Seasonality, Serial Correlation, SDAIDS, Trade Agreements

The United States is one of the world's major importers of fresh fruits with a constantly increasing import trend and 50% average share of imports in domestic consumption from 2014 to 2015 (U.S. Department of Agricultue (USDA)-Economic Research Service (ERS), 2016). In the last three decades, U.S. imports of fresh fruits have been increasing at an annual average growth rate of 7%, making up 9% of the total U.S. food imports (in dollar terms) in 2015 (USDA-ERS, 2016). According to the USDA, since the 1990s, U.S. demand for fresh fruits has increased more than the domestic production; consequently, the imports have increased to satisfy the country's increased demand (USDA-ERS, 2016). In 2015, fresh fruits and nuts—bananas, nuts, berries, avocadoes, grapes, melons, and pineapples—accounted for 82% ($10.3 billion) of the total value of all fresh-fruit imports ($12.5 billion).

The main trading partners of the United States are the member countries of the North American Free Trade Agreement (NAFTA),[1] the Southern Common Market (or the

[1] NAFTA will likely be replaced soon with the U.S.-Mexico-Canada Agreement (USMCA). The new USMCA trade agreement was signed on November 30, 2018, by U.S. President Trump, Mexico's President Peña Nieto, and Canada's Prime Minister Trudeau. While NAFTA remained in effect while the new USMCA is revised by Congress, the new USMCA will come into effect if Congress votes to approve, which is expected to be voted on by the end of 2019 (Tausche, 2019) or perhaps later (Pramuk, 2019) or perhaps it may not pass (Pramuk and Tausche, 2019).

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Common Market of Southern Cone—MERCOSUR) and its associate countries, the Dominican Republic-Central America Free Trade Agreement (DR-CAFTA), as well as some countries with bilateral preferential or free trade agreements with the United States. From 2005 to 2015, Mexico (with an average share of 32% in 2005-2015), Chile (16%), Guatemala (8%), Costa Rica (10%), Vietnam (5%), Ecuador (5%), Peru (3%), Honduras (3%), and Canada (2%) together accounted for 84% of the U.S. imports of fresh fruits.

With an increasing dependence on fresh-fruit imports, it is important for the United States to analyze trends and future trade scenarios under increased tariffs, and develop corresponding action plans for achieving economic efficiency in the international market. Estimation of import demand elasticities is an effective approach for building economic models and predicting possible development scenarios for international trade. Elasticities estimated for different sources of origin enable interested parties to evaluate the effects of changes in total expenditure and own price on the quantity of a good imported, as well as the economic relationships among various exporters in a particular import market.

Considerable research has been devoted to the estimation of the U.S. demand for fresh fruits at the retail level (e.g., You, Epperson, and Huang, 1996; Huang, 1993; Brown and Lee, 2002; Durham and Eales, 2010) and import level (e.g., Muhammad, Zahniser, and Fonsah, 2015; Tshikala and Fonsah, 2012; Mekonnen, Fonsah, and Borgotti, 2011; Nzaku, Houston, and Fonsah, 2010). However, to the best of our knowledge, there is no recent empirical analysis aimed at estimating import demand elasticities for fresh fruits at the source level. Elasticity estimates from prior studies are summarized in Table 1. In general, own-price elasticity estimates for fresh fruits ranged from -0.03 for cherries in You, Epperson, and Huang (1996) to -1.68 for pears in Durham and Eales (2010). Expenditure elasticities ranged from being negative (inferior goods) for certain fruits to being positive (normal goods). The expenditure elasticities of fresh fruits suggesting normal goods ranged from 0.09 for bananas in Huang (1993) to 2.64 for apples from New Zealand in Mekonnen, Fonsah, and Borgotti (2011). When comparing the retail-level and import-level elasticity estimates, one must be careful with making inferences about the similarity of these estimates because one category uses domestic, retail-level prices and the other category uses import-level prices (generally per-unit value).

Table 1. Demand Elasticity Estimates in Prior Studies.

Fruit	Study	Own-price elasticity	Expenditure elasticity
Apples	Huang (1993)	-0.19	-0.36
	You, Epperson, and Huang (1996)	-0.16	-0.19
	Brown and Lee (2002)	-0.52*	1.03*
	Durham and Eales (2010)	-1.13*	0.70
	Durham and Eales (2010)	-1.19*	0.82
	Mekonnen, Fonsah, and Borgotti (2011)[a] – Canada	-1.18*	0.28
	Mekonnen, Fonsah, and Borgotti (2011)[a] – Chile	0.03	2.63*
	Mekonnen, Fonsah, and Borgotti (2011)[a] – New Zealand	-0.14	2.64*
	Mekonnen, Fonsah, and Borgotti (2011)[a] – ROW	1.08	1.95*
Avocadoes	Nzaku, Houston, and Fonsah (2010)[a]	-0.88*	1.14*
Bananas	Huang (1993)	-0.50*	0.09
	You, Epperson, and Huang (1996)	-0.42*	0.63
	Brown and Lee (2002)	-0.54*	0.40
	Durham and Eales (2010)	-0.98*	0.74
	Durham and Eales (2010)	-0.90*	0.68
	Muhammand, Zahniser, and Fonsah (2015)[a] – Colombia	-0.41*	1.00*
	Muhammand, Zahniser, and Fonsah (2015)[a] – Costa Rica	-0.67*	1.27*
	Muhammand, Zahniser, and Fonsah (2015)[a] – Ecuador	-0.29*	0.71*
	Muhammand, Zahniser, and Fonsah (2015)[a] – Guatemala	-0.36*	1.20*
	Muhammand, Zahniser, and Fonsah (2015)[a] – Honduras	-0.76*	0.92*
	Muhammand, Zahniser, and Fonsah (2015)[a] – ROW	-0.49*	0.61*
	Nzaku, Houston, and Fonsah (2010)[a]	-0.54*	1.11*
Cantaloupe	Tshikala and Fonsah (2012)[a]	-1.14	1.22
Cherries	You, Epperson, and Huang (1996)	-0.03	-1.80
Grapefruits	Huang (1993)	-0.45*	-0.49
	You, Epperson, and Huang (1996)	-1.02*	0.60
	Brown and Lee (2002)	-1.11*	0.42
Grapes	Huang (1993)	-1.18*	0.56
	You, Epperson, and Huang (1996)	-0.91*	0.66
	Brown and Lee (2002)	-0.56*	1.14*
	Durham and Eales (2010)	-1.62*	1.12
	Durham and Eales (2010)	-1.67*	1.28
	Nzaku, Houston, and Fonsah (2010)[a]	-0.38	0.95*
Lemons	You, Epperson, and Huang (1996)	-0.30	0.44
Mangoes/Guavas	Nzaku, Houston, and Fonsah (2010)[a]	-0.61*	0.55*
Melons	Tshikala and Fonsah (2012)[a] – Fresh	-1.18*	0.96
	Tshikala and Fonsah (2012)[a] – Frozen	-1.36*	-0.34
Oranges	Huang (1993)	-0.85*	-0.16*
	You, Epperson, and Huang (1996)	-1.14*	0.89
	Brown and Lee (2002)	-0.67*	1.75
	Durham and Eales (2010)	-1.37*	1.40
	Durham and Eales (2010)	-1.30*	1.05
Papayas	Nzaku, Houston, and Fonsah (2010)[a]	-0.12	0.84*
Peaches	You, Epperson, and Huang (1996)	-0.96*	-0.08
Pears	You, Epperson, and Huang (1996)	0.29	0.93
	Brown and Lee (2002)	-0.52*	1.03*
	Durham and Eales (2010)	-1.44*	0.77
	Durham and Eales (2010)	-1.68*	0.93
Pineapples	Nzaku, Houston, and Fonsah (2010)[a]	-0.20	0.71*
Strawberries	You, Epperson, and Huang (1996)	-0.28	-0.47
Watermelons	You, Epperson, and Huang (1996)	-0.60*	0.41
	Tshikala and Fonsah (2012)[a]	-0.36*	1.03

Note: An asterisk (*) indicates statistical significance at $p = 0.05$. Superscript ([a]) indicates studies at the import level.

This study employs a Source-Differentiated Almost Ideal Demand System (SDAIDS) to estimate recent elasticities of demand for four major fresh fruits (mangoes and guavas, bananas, avocadoes, and papayas) imported from three important trade agreement blocs (NAFTA, DR-CAFTA, and MERCOSUR). The study incorporates the main exporters of fresh fruits to the United States, and, therefore, contributes to a better understanding of the economic and trade relationships among these countries. In addition, this study fills the information gap in analyzing recent substitution and complementarity patterns for fresh fruits by sources of origin. The study is unique in that it attempts a relatively high level of disaggregation and, in doing so, is the first to conduct an analysis with source differentiation at the trade-agreement-bloc level.

Data

This study uses data on monthly imports in U.S. dollars and quantities (in metric tons) for 11 years from January 2005 to December 2015 for a total of 132 observations, reported by the U.S. International Trade Commission (USITC). Prices were adjusted for inflation, using the consumer price index reported by the U.S. Department of Labor (2016). The study also uses the U.S. Gross Domestic Product data reported by the U.S. Department of Commerce (2016). All data used are publicly available. The estimated system of demand equations analyzes the monthly imports of:

1. Mangoes and guavas imported through NAFTA (100% imported from Mexico) with an average import market share of 60%, MERCOSUR (40% imported from Peru, 30% from Brazil, and 30% from Ecuador) with an average import market share of 20%, and the rest of the world (ROW) (30% imported from Guatemala, 10% from Thailand, 7% from Nicaragua, 3% from Costa Rica, and 50% from other countries) with an average import share of 20%;
2. Bananas imported through DR-CAFTA (50% imported from Guatemala, 31% from Costa Rica, 15% from Honduras, and 1% from other countries) with an average import market share of 63%, and ROW (56% imported from Ecuador, 11% from Mexico, 3% from Peru, and 30% from other countries) with an average import market share of 37%;
3. Avocadoes imported through NAFTA (100% imported from Mexico) with an average import market share of 84% and ROW (59% imported from Chile, 13% from Dominican Republic, and 28% from other countries) with an average import market share of 16%;

4. Papayas imported through NAFTA (100% imported from Mexico) with an average share of 74%, DR-CAFTA (82% imported from Guatemala and 18% from Dominican Republic) with an average import share of 6%, and ROW (64% imported from Belize, 24% from Brazil, 11% from Jamaica, and 1% from other countries) with an average import share of 20%.

Table 2. Average Real Prices, Average Monthly Import Quantities and Average Import Values, for the Selected Fresh Fruits, 2005-2015.

Category-Source	Average Price $/kg	Average Quantity (1000 kg)	Average Import value ($1000)
Bananas – DR-CAFTA	0.40	221,400	89,577
Avocadoes – NAFTA	2.17	29,797	64,763
Bananas – ROW	0.43	123,740	52,694
Mangoes and guavas – NAFTA	1.60	18,102	28,976
Avocadoes – ROW	1.45	7,958	11,548
Papayas – NAFTA	0.65	8,950	5,791
Mangoes and guavas – MERCOSUR	1.13	4,899	5,532
Mangoes and guavas – ROW	1.51	5,311	8,001
Papayas – ROW	0.67	2,417	1,617
Papayas – DR-CAFTA	0.59	777	460

Note: Data are real and include products as reflected in the U.S. Harmonized Tariff Schedule. *Source:* U.S. International Trade Commission (2016).

Table 2 exhibits the average real import values, average quantities, and weighted average real prices for the selected fresh fruits. From 2005 to 2015, the average real value of imports was the highest for bananas imported through DR-CAFTA ($89.6 million), followed by avocadoes imported through NAFTA ($64.8 million), and bananas imported through ROW ($52.7 million). Bananas through DR-CAFTA were the most imported (221.4 thousand tons), followed by bananas imported from ROW (123.7 thousand tons), and avocadoes imported through NAFTA (29.8 thousand tons). Because of their high price, avocadoes imported through NAFTA rank third in terms of volume but second in terms of real dollars. According to Figure 1, on average, bananas imported through DR-CAFTA maintained a 36% share of the total import value of the selected fruit-source combinations, which is approximately $90 million per month. Avocadoes imported through NAFTA and bananas from ROW had 23% (approximately $61 million) and 22% (approximately $52 million) shares, respectively.

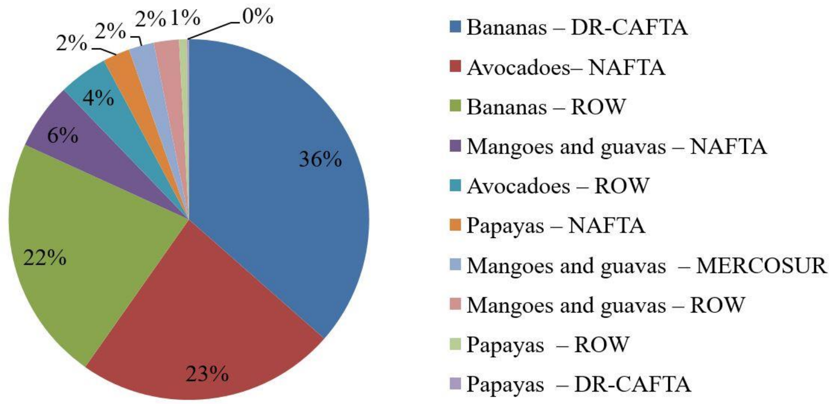

Figure 1. Average Real Expenditure Shares of the Selected Fruits and Sources, 2005-2015.
Note: Figure displays expenditure shares computed from real data and included products as reflected in the U.S. Harmonized Tariff Schedule.

Fresh-fruit imports normally exhibit seasonal patterns, which are mostly due to diversity in climate conditions of the import sources. In addition, most of the selected fresh-fruit imports exhibit increasing or decreasing trends. On average, mangoes and guavas imported through NAFTA reach their minimum when the imports through MERCOSUR and ROW are at their highest. For some months, those minimums are zero, which means that, in these months, no mangoes and guavas are imported from the corresponding source. With the United States being the closest to the other two NAFTA countries, growing seasons in NAFTA countries tend to be more similar relative to MERCOSUR countries (such as Brazil and Peru) and countries from ROW, which explains the seasonality. Therefore, NAFTA and the other sources usually substitute each other in the U.S. market. Seasonal patterns are different in the case of imports of fresh bananas, where increasing trends are more notable. For some periods, seasonal substitution of the sources of origin can be observed; there are also some periods when the fresh fruits from these sources enter the U.S. market together. The seasonal trends between bananas through DR-CAFTA and bananas from ROW may be similar because climate conditions in Guatemala, Costa Rica, and Honduras (DR-CAFTA) for growing bananas are similar to those in Ecuador, which accounts for 56% of bananas imported from ROW.

U.S. imports of avocadoes were increasing during the period of 2005-2015. From 1914-2007, the United States banned imports of avocadoes to avoid agricultural diseases and pests. Upon its removal in 2007, the United States became the world’s largest avocado importer (U.S. Agency for International Development, 2014). The main source of avocadoes for the United States is Mexico, with average monthly imports of $61 million. Imports through NAFTA are substantially higher than imports from ROW (60% of which are imported from Chile and 27% from Peru). From August through October, imports from Mexico reach their minimum while imports from ROW reach their maximum, suggesting strong evidence of seasonal patterns. Imports of papayas from ROW, which are mostly from Belize and Brazil, have been decreasing over the past decade, while imports through DR-CAFTA have increased and imports through NAFTA have remained fairly stable. This is due mainly to increased imports of papayas from Guatemala and almost a twofold reduction of imports from Belize. Strong evidence of seasonal patterns can also be observed in fresh papaya imports.

Empirical Model

The Almost Ideal Demand System (AIDS) was first introduced by Deaton and Muellbauer in 1980. Since then, the model has gained wide popularity, and many variations have been introduced, making it more flexible and applicable. Derived from the price-independent generalized logarithmic (PIGLOG) model, the AIDS model ideally satisfies the axioms of choice and the conditions for exact aggregation over consumers. At each level of utility, the AIDS model assumes that consumers minimize expenditure to realize the given utility (Deaton and Muellbauer, 1980). In this study, a Source-Differentiated AIDS (SDAIDS) model was used to estimate the expenditure share equations. The SDAIDS model differentiates the fruits by their sources of origin.

In the AIDS model, the expenditure function, denoted by c, has the following form:

(1) $$\log c(p,u) = (1-u)\log(\mathrm{a(p)}) + u\log\big(\mathrm{b(p)}\big),$$

where

(2) $$\log a(p) = \alpha_0 + \sum_k \alpha_k \log(p_k) + 0.5 * \sum_k \sum_j \gamma_{kj}^* \log(p_k)\log(p_j)$$

and

(3) $$\log b(p) = \log a(p) + \beta_0 \prod_k p_k^{\beta_k}.$$

where α, β, and γ are parameters; and u is the utility index taking on values of 0 for the subsistence and 1 for the bliss, so that *a(p)* can be considered as the cost of subsistence and *b(p)* as the cost of bliss. Then, the AIDS cost function can be written as

$$(4) \qquad \log c(p,u) = \alpha_0 + \sum_k \alpha_k \log(p_k) + 0.5 * \sum_k \sum_j \gamma_{kj}^* \log(p_k) \log(p_j) + u * \beta_0 \prod_k p_k^{\beta_k}.$$

Shepard's Lemma (a special case of envelope theorem) can be used to get the quantity demanded q_i by taking the derivative of the expenditure function ($\log c(p,u)$) with respect to the p_i. That is,

$$(5) \qquad \frac{\partial c(p,u)}{\partial p_i} = q_i.$$

Thus, taking the derivative of log $c(p,u)$ with respect to log (p_i) will yield the expenditure share of the good *i* through the following relation

$$(6) \qquad \frac{\partial \log c(p,u)}{\partial \log(p_i)} = \frac{p_i q_i}{c(p,u)} = w_i.$$

Therefore, the logarithmic differentiation of (4) with respect to the log (p_i) results in budget shares

$$(7) \qquad w_i = \alpha_i + \sum_j \left(0.5 * (\gamma_{ij}^* + \gamma_{ji}^*)\right) \log(p_j) + \beta_i \left(\log\left(\sum_{i=1}^{n} p_i q_i \right) - \log P \right),$$

where *P* is a nonlinear price index defined as

$$(8) \qquad \log(P) = \alpha_0 + \sum_k \alpha_k \log(p_k) + 0.5 * \sum_j \sum_k \gamma_{ij} \log(p_k) \log(p_j) \ .$$

Equation (7) is the AIDS demand function in expenditure share form. The price index shown in equation (8) is applied to deflate the logarithm of expenditure. The following are the restrictions for the parameters of the AIDS model:

(9) Adding up: $\sum_{i=1}^{n} \alpha_i = 1, \quad \sum_{i=1}^{n} \gamma_{ij} = 0, \quad \sum_{i=1}^{n} \beta_i = 0,$

(10) Homogeneity: $\sum_{j} \gamma_{ij} = 0$, and

(11) Symmetry: $\gamma_{ij} = \gamma_{ji}$.

The AIDS model estimates a set of parameters that are used in the calculation of demand elasticities. Following Green and Alston (1990), the uncompensated (Marshallian) price elasticities were calculated as

$$(12) \quad \varepsilon_{ij} = -\delta_{ij} + \frac{\gamma_{ij} - \beta_i(\alpha_j + \sum_{k=1}^{n} \gamma_{jk} \log(p_k))}{w_i},$$

where δ_{ij} is the Kronecker delta with $\delta_{ij} = 1$ if $i = j$ (own-price elasticity) and $\delta_{ij} = 0$ if $i \neq j$ (cross-price elasticity).

Expenditure elasticities are calculated as

$$(13) \quad \varepsilon_{ix} = 1 + \frac{\beta_i}{w_i}.$$

Using the Slutsky equation, compensated (Hicksian) price elasticities are calculated as

$$(14) \quad e_{ij} = \varepsilon_{ij} + w_i * \varepsilon_{ix}.$$

Per the law of demand, uncompensated own-price elasticities of demand are expected to have a negative sign. The expenditure elasticities are expected to have a positive sign. The estimated compensated cross-price elasticities are expected to have either positive or negative signs, depending on the fruit and the source of origin, pointing to corresponding substitutability (for a positive sign) or a complementarity (for a negative sign).

Procedures

Equation (7) was adjusted to account for seasonal and trend patterns present in the data, and for the potential issues related to serial correlation and endogeneity. Similar to Tshikala and Fonsah (2012); Nzaku, Houston, and Fonsah (2010); and Arnade, Pick, and

Gehlhar (2005); this study used the harmonic regression method to account for seasonality by adding trigonometric variables

$$(15) \quad sin_i = f(trend, SL) = \sin\left(2\pi \frac{t_i}{12}\right)$$

and

$$(16) \quad cos_i = f(trend, SL) = \cos\left(2\pi \frac{t_i}{12}\right),$$

where t_i is the corresponding trend variable taking up 1 for the first observation and *n* for the n^{th} observation, π is a mathematical constant approximately equal to 3.1416, and SL is the seasonal length which is equal to 12 for the monthly data. The statistical significance of the parameter estimates associated with the trigonometric variables indicated the original share equation exhibited seasonality.

In addition to the restrictions of the AIDS model given by equations (9), (10), and (11), the sums of coefficients of trigonometric variables are also restricted to zero (see also Tshikala and Fonsah, 2012; Nzaku, Houston, and Fonsah, 2010; and Arnade, Pick, and Gehlhar, 2005):

$$(17) \quad \sum_i s_i = 0 \text{, and}$$

$$(18) \quad \sum_i c_i = 0 \text{,}$$

where *i* is the index of each fruit-source combination; and c_i and s_i are the coefficients for the sine and cosine functions, measuring their contributions to the model (Arnade, Pick, and Gehlhar, 2005).

Given that the share equations have fairly linear trends, the study introduced an additional variable for each of the budget share equations. The trend variable took the value of 1 for the first observation and increased chronologically thereafter. The estimated coefficient of the trend variable was also restricted to a sum of zero:

$$(19) \quad \sum_i z_i = 0,$$

where *i* is the index of each fruit-source combination and z_i is the coefficient of the trend variable for each of the share equations.

Systems of demand equations often encounter the issue of endogeneity of the expenditure (Attfield, 1985). In this study, the total expenditure was defined as the sum of expenditures on all selected fruit-source combinations, whereas the expenditure share w_i was defined as the ratio of the i^{th} expenditure to the total expenditure, leading to the endogeneity of the total expenditure. Therefore, following Attfield (1985), this study used a log-log model for the estimation of total expenditure as a function of the real prices used in its calculation and real GDP. That is,

$$(20) \quad \log(X_t) = a_0 + \sum_i v_i \log(p_{i_t}) + g * \log(GDP_t) + \rho_1 \left\{ \log(X_{t-1}) - (a_0 + \sum_i v_i \log(p_{i_{t-1}}) + g * \log(GDP_{t-1})) \right\} + \varepsilon_i,$$

where log(*X*) is the logarithm of total expenditure; p_i is the price of i^{th} fruit-source combination; GDP is the real monthly GDP; the subscript *t* as in time refers to the monthly observation; a_0, g, and v_i, are the parameters to be estimated; and ε_i is the error term.

Following Berndt and Savin (1975), a first-order autoregressive procedure [AR(1)] was used to address serial correlation. One common coefficient, ρ, was obtained for each system of equations. For consistency, the estimation of the total expenditure was done once serial correlation was addressed. The final expenditure share equations had the following form:

$$(21) \quad w_{i_t} = \alpha_i + \sum_j \gamma_{ij} \, log(p_{j_t}) + \beta_i log\left(\frac{X}{P}\right)_t + s_i sin_t + c_i cos_t + z_i trend_t + \rho \left\{ w_{i_{t-1}} - (\alpha_i + \sum_j \gamma_{ij} \, log(p_{i_{t-1}}) + \beta_i log\left(\frac{X}{P}\right)_{t-1} + s_i sin_{t-1} + c_i cos_{t-1} + z_i trend_{t-1}) \right\} + \varepsilon_i$$

where *t* represents time; *i* and *j* represent fruit-source combination indices; w_i is the import expenditure share for each fruit-source combination; p_j is the import price of j^{th} fruit-source combination; *X* is the expenditure on all goods included in the model; *trend* represents the linear trend variable; $\alpha_i, \gamma_{ij}, \beta_i, c_i, s_i$ and z_i are the parameters; *P* is the nonlinear price index, given by equation (8); $Sin_i=f(t_i,SL)$ and $cos_i=g(t_i,SL)$ are trigonometric functions capturing seasonality; ρ is the first-order autoregressive coefficient; and ε_i is the error term. The iterated, seemingly unrelated regression procedure (ITSUR) was used to estimate the share equations. The analysis was conducted using Statistical Analysis System (SAS) software version 9.3. The last equation (w_{10}, which corresponds to papayas imported from ROW) was omitted to avoid the singularity of the variance-covariance matrix of error terms, which occurs due to the budget shares adding up to 1. The parameter estimates of the last equation were recovered utilizing the adding up, homogeneity, and symmetry restrictions given by (9), (10), (11), (17), (18), and (19). The coefficient of determination (R^2) for the omitted equation was estimated by squaring the coefficient of correlation between the predicted and actual expenditure shares.

The Durbin-Watson statistic was estimated by calculating the ratio of the sum of the squared differences of the residuals ($\hat{e}_t$) and their first lags to the sum of the squared residuals (Durbin and Watson, 1951). The uncompensated elasticities of demand were calculated using equations (12) and (13); the compensated elasticities of demand were calculated using equation (14).

Results

An SDAIDS was estimated for mangoes and guavas imported through NAFTA (i = 1), mangoes and guavas imported from MERCOSUR countries and associates (i = 2), mangoes and guavas imported from ROW (i = 3), bananas imported through DR-CAFTA (i = 4), bananas imported from ROW (i = 5), avocadoes imported through NAFTA (i = 6), avocadoes imported from ROW (i = 7), papayas imported through DR-CAFTA (i = 8), papayas imported through NAFTA (i = 9), and papayas imported from ROW (i = 10).

Table 3 reports the SDAIDS parameters that were estimated (equations (20) and (21)). Slightly more than a third of 119 parameters estimated were significant at the 0.01 level. In fact, 43, 56, and 70 parameters estimated were significant at the 0.01, 0.05, and 0.10 levels, respectively. Several of the trigonometric variables—refer to the s_i and c_i parameter estimates—successfully captured seasonality, except for a couple of the coefficients that were statistically significant but perhaps not practically significant. On the contrary, several coefficients associated with the trend variable—refer to the z_i

parameter estimates—were statistically significant but not practically significant. Since the study uses monthly data and the share equations had fairly linear trends, the trend variable was not excluded from the model.

Table 4 reports the coefficients of determinations, Durbin-Watson statistics associated with the estimated share equations, and the first-order autoregressive coefficient. The statistical significance of the ρ coefficient along with the Durbin-Watson statistics being close to 2 indicated that the problem of serial correlation was successfully addressed in the model. The highest coefficient of determination was 86%, while the lowest was 32%, suggesting an overall reasonable fit for the system of equations.

Table 3. SDAIDS Parameter Estimates.

Parameter Estimates from Equation (21):

			γ_{i1}	γ_{i2}	γ_{i3}	γ_{i4}	γ_{i5}	γ_{i6}	γ_{i7}	γ_{i8}	γ_{i9}	γ_{i10}
α_1	-1.080*	γ_{1j}	-0.096*	0.015	-0.012	-0.071†	0.118*	0.086†	-0.053‡	-0.003*	0.022*	-0.007*
α_2	0.273	γ_{2j}		-0.008	0.007	0.017	-0.035‡	0.000	0.006	0.001	-0.004	0.003‡
α_3	-0.171	γ_{3j}			-0.007	-0.007	0.024	-0.006	-0.002	-0.000	0.004	-0.000
α_4	-0.261	γ_{4j}				0.090‡	0.008	-0.023	-0.024	-0.003†	0.017†	-0.005
α_5	1.735*	γ_{5j}					0.016	-0.158*	0.052	0.004†	-0.039*	0.010†
α_6	0.878†	γ_{6j}						0.081	0.042	0.001	-0.027*	0.005‡
α_7	-0.549‡	γ_{7j}							-0.026	-0.002‡	0.010	-0.003
α_8	-0.030*	γ_{8j}								0.001*	0.001†	-0.000
α_9	0.277*	γ_{9j}									0.013*	0.004*
α_{10}	-0.071*	γ_{10j}										-0.005*

		i	s_i	c_i	z_i	ρ
β_1	0.089*	1	0.008‡	-0.072*	-0.000*	0.514*
β_2	-0.021	2	0.002	0.029*	0.000	
β_3	0.017	3	0.006‡	-0.003	-0.000‡	
β_4	0.061†	4	-0.027*	-0.007	-0.001*	
β_5	-0.105*	5	0.015*	-0.012†	-0.001*	
β_6	-0.079*	6	0.016†	0.049*	0.002*	
β_7	0.047‡	7	-0.022*	0.023*	-0.000†	
β_8	0.003*	8	0.000	-0.000	0.000*	
β_9	-0.019*	9	0.002†	-0.006*	0.000	
β_{10}	0.007*	10	0.000	-0.001‡	-0.000*	

Additional Parameter Estimates from Equation (20):

α_0	ρ_1	v_1	v_2	v_3	v_4	v_5	v_6	v_7	v_8	v_9	v_{10}	g
15.342*	0.460*	-0.043†	0.011	-0.097*	0.434*	0.027	0.098	0.042	0.022	-0.123‡	-0.087	3.873*

Note: Double daggers (‡), daggers (†) and asterisks (*) denote statistical significant at $p = 0.10$, $p = 0.05$, and $p = 0.01$ respectively.

Table 4. R^2's, Durbin-Watson Statistics, and First-Order Autoregressive Coefficient (ρ).

i	R^2	DW
Mangoes and guavas – NAFTA	0.85	1.82
Mangoes and guavas – MERCOSUR	0.39	2.04
Mangoes and guavas – ROW	0.32	1.72
Bananas – DR-CAFTA	0.49	1.92
Bananas – ROW	0.78	2.26
Avocadoes – NAFTA	0.79	1.98
Avocadoes – ROW	0.58	1.35
Papayas – NAFTA	0.67	2.16
Papayas – ROW	0.86	1.60
Papayas – DR-CAFTA	0.82	2.05
Parameter	Estimate	p-value
ρ	0.514	0.000

Demand Elasticities

The uncompensated and compensated price elasticities of demand are reported in Table 5. Their signs were the same in 78 instances and different in 22 instances. In all instances where the sign was different, at least one elasticity was not statistically different from zero; except for the cross-price elasticity between mangoes and guavas through NAFTA and bananas through DR-CAFTA ($\hat{\varepsilon}_{14}$ was negative and statistically significant, while $\hat{e}_{14}$ was positive and statistically significant). In addition, most of the elasticity coefficients were inelastic; only 7 elastic coefficients among the uncompensated price elasticities and 4 among the compensated elasticities were elastic. These elastic coefficients were the same for both uncompensated and compensated price elasticities, except for 3 instances, but only the cross-price elasticity between mangoes and guavas from ROW and avocadoes through NAFTA was statistically significant at the 0.01 level in both cases ($\hat{\varepsilon}_{36}$ was elastic and significant, while $\hat{e}_{36}$ was inelastic and significant).

Consistent with the law of demand, all uncompensated and compensated own-price elasticities had the expected negative sign. Particularly, for uncompensated price-elasticities, if the corresponding own-prices increase by 1%, holding all other factors fixed, the quantity demanded is expected to decrease, on average, by 0.95% for mangoes and guavas imported through NAFTA; by 1.09% for mangoes and guavas imported through MERCOSUR; by 1.15 % for mangoes and guavas imported from ROW; by

0.68% for bananas imported through DR-CAFTA; by 0.96% for avocadoes imported from ROW; by 0.25% for papayas imported through NAFTA; and by 1.60% for papayas imported from ROW. In addition, all own-price elasticities were inelastic, except for the own-price elasticities of mangoes and guavas through both MERCOSUR and ROW, and for papayas from ROW where the coefficients were elastic. The obtained elasticity estimates range from -1.59 to -0.25. In general, most of the results of this study are consistent with those obtained by Nzaku, Houston, and Fonsah (2010); as well as by You, Epperson, and Huang (1996); Huang (1993); and Brown and Lee (2002). For example, the own-price elasticity of bananas ranged from -0.98 to -0.42 in previous studies, and the uncompensated own-price elasticity of bananas imported through DR-CAFTA was found to be -0.67 in this study. However, the latter three studies are at retail level while this study is at country level. As the estimation results suggest, the U.S. retail-level demand for fresh fruits tends to be more price-elastic than the import-level demand.

Table 5. Uncompensated (ε_{ij}) and Compensated (e_{ij}) Cross-Price Elasticities of Demand.

ε_{ij}	1	2	3	4	5	6	7	8	9	10
1	-0.945*	-0.190*	0.112†	-0.513*	-0.420*	-0.467*	-0.026	-0.003	-0.036†	0.006
2	-0.359†	-1.088*	0.111	0.313	-0.064	1.196*	-0.279	-0.002	0.058	0.035‡
3	0.341*	0.074	-1.147*	0.055	-0.190	-1.257*	0.357‡	0.010‡	-0.057	0.047*
4	-0.005	-0.005	0.017	-0.677*	-0.249*	-0.277*	0.033	-0.003	0.000	0.000
5	-0.854*	-0.017	0.009	-0.177	-0.155	-0.107	-0.043	0.004	-0.044‡	0.005
6	-0.011	0.103*	-0.097*	-0.250†	-0.132	-0.223	-0.017	-0.006†	-0.025‡	-0.006
7	-0.011	-0.189	0.176‡	-0.060	-0.557†	-0.419	-0.958*	-0.006	-0.064	0.013
8	-0.087	-0.085	0.121	-1.096	0.072	-1.200*	-0.170	-0.241	0.231	0.006
9	0.047	0.051	-0.018	0.352	-0.337	-0.135	-0.035	0.020	-0.246†	0.081‡
10	0.080	0.069	0.145*	-0.292	-0.157	-0.487†	0.086	0.002	0.235	-1.598*
e_{ij}	1	2	3	4	5	6	7	8	9	10
1	-0.797*	-0.134†	0.168*	0.393*	0.126	0.111	0.083	0.002	0.024	0.023*
2	-0.354†	-1.086*	0.113	0.342	-0.047	1.214*	-0.276	-0.002	0.059	0.035‡
3	0.447*	0.114	-1.107*	0.699*	0.199	-0.846*	0.435†	0.013†	-0.014	0.060*
4	0.064*	0.021	0.043*	-0.251†	0.008	-0.006†	0.084	-0.001‡	0.029	0.008
5	-0.823	-0.005	0.020	0.013	-0.040	0.015	-0.020	0.005	-0.032	0.009
6	0.029	0.118*	-0.082*	-0.009	0.014	-0.068	0.012	-0.005‡	-0.009	-0.001
7	0.113	-0.142	0.223†	0.697†	-0.100	0.064	-0.866*	-0.002	-0.014	0.028
8	0.060	-0.029	0.176†	-0.203	0.611	-0.630‡	-0.062	-0.236	0.290	0.024
9	0.060	0.056	-0.013	0.433‡	-0.289	-0.084	-0.025	0.021	-0.241†	0.083‡
10	0.195*	0.113‡	0.189*	0.407	0.265	-0.041	0.170	0.006	0.281‡	-1.584*

Note: Double daggers (‡), daggers (†) and asterisks (*) denote statistical significant at $p = 0.10$, $p = 0.05$, and $p = 0.01$ respectively. The subscript i = 1, 2, …, 10; where 1 = mangoes and guavas from NAFTA countries, 2 = mangoes and guavas from MERCOSUR countries or associates, 3 = mangoes and guavas from the rest of the world, 4 = bananas from DR-CAFTA, 5 = bananas from the rest of the world, 6 = avocadoes from NAFTA, 7 = avocadoes from the rest of the world, 8 = papayas from DR-CAFTA, 9 = papayas from NAFTA, and 10 = papayas from the rest of the world.

The estimated own-price elasticities can be useful in evaluating the impact of various market factors (such as import quotas, tariffs, and other import duties) on the U.S. imports of fresh fruits. For example, the own-price elasticity of mangoes and guavas imported through NAFTA was estimated to be 0.95 meaning that a 20% specific import tariff would reduce the quantity demanded of mangoes and guavas through NAFTA by 19%. This information, if combined with the estimation of the supply function of domestic producers, could be used to assess this trade policy implication on economic welfare, including the redistribution of wealth among consumers and producers that results from the imposition of the tariff.

The compensated cross-price elasticities reveal the economic relationships among the fresh fruits by source. A negative (positive) cross-price elasticity implies that, when the price of a fruit from a given source increases by 1%, the quantity demanded of a different fruit from the same or different source decreases (increases), which, in its turn, implies that the categories are complements (substitutes). For example, for compensated cross-price elasticities (holding all other factors constant) when the price of mangoes and guavas through NAFTA increases by 1% the quantity demanded is expected to decrease by 0.13%.for the quantity of mangoes and guavas demanded through MERCOSUR, while it is expected to increase by 0.17% for mangoes and guavas imported from ROW, by 0.39% for bananas imported through DR-CAFTA, and by 0.02% for papayas imported from ROW. The negative and statistically significant cross-price elasticities revealed complementary relationships between mangoes and guavas imported through NAFTA and mangoes and guavas imported through MERCOSUR, and between avocadoes imported through NAFTA and mangoes and guavas imported from ROW. The positive and statistically significant cross-price elasticities indicated substitutability between mangoes and guavas imported through NAFTA and mangoes and guavas imported from ROW, and bananas imported through DR-CAFTA and papayas imported from ROW. Substitute import patterns were also found between mangoes and guavas from ROW and bananas imported through DR-CAFTA, avocadoes imported from ROW, papayas imported through DR-CAFTA, and papayas imported from ROW, between avocadoes imported through NAFTA and mangoes and guavas imported through MERCOSUR, and between mangoes and guavas imported from ROW and papayas imported from ROW.

The expenditure elasticities of demand calculated at the sample means are reported in Table 6. The expenditure elasticities indicate the relationships between the overall change in expenditure on the selected group of fruit categories and the quantities of those categories demanded. All the estimated, statistically significant expenditure elasticities had the expected positive sign, implying that—holding all other factors constant—the quantity demanded of all fruit types is expected to increase when the total expenditure increases. Particularly, as the total expenditure increases by 1%, on average, the quantity demanded is expected to increase by 2.48% for mangoes and guavas imported through NAFTA; by 1.77% for mangoes and guavas imported from ROW; by 1.17% for bananas imported through DR-CAFTA; by 0.52% for bananas imported from ROW; by 0.66% for avocadoes imported through NAFTA; by 2.07% for avocadoes imported from ROW; by 2.45% for papayas imported through DR-CAFTA; and by 1.92% for papayas imported from ROW. Interestingly, the estimated expenditure elasticities revealed that, on average, the selected fresh-fruit categories were responsive to the changes in total expenditures. The estimated expenditure elasticities suggested that mangoes and guavas imported through NAFTA and from ROW, bananas imported through DR-CAFTA, avocadoes imported from ROW, papayas imported through DR-CAFTA, and papayas imported from ROW were considered as luxury goods, and the U.S. demand for these fruits was rather sensitive to changes in total expenditures.

Table 6. Expenditure Elasticities of Demand.

	Expenditure Elasticity	Standard Error
Mangoes and guavas – NAFTA	2.482**	0.214
Mangoes and guavas – MERCOSUR	0.079	0.641
Mangoes and guavas – ROW	1.767**	0.534
Bananas – DR-CAFTA	1.168**	0.075
Bananas – ROW	0.523**	0.099
Avocadoes – NAFTA	0.663**	0.130
Avocadoes – ROW	2.075**	0.547
Papayas – NAFTA	2.449**	0.350
Papayas – ROW	0.221	0.139
Papayas – DR-CAFTA	1.915**	0.195

Note: One asterisk (*) and two asterisks (**) denote statistical significant at $p = 0.05$ and $p = 0.01$, respectively.

Policy Implications

Since the 2016 presidential debates, President Trump announced his dislike of NAFTA (Gandel, 2016) and urged its replacement. Soon after President Trump took office on January 20, 2017, discussions on imposing tariffs on imports from Mexico have periodically appeared in media, including as an option to pay for a border wall to stifle undocumented immigration through Mexico into the United States (Abdullah and Gamboa, 2017) and, most recently, as a warning to Mexico to stop the flow of illegal drugs entering the United States (Egan, 2019). After months of negotiations, on August 27, 2019, President Trump announced the United States and Mexico had agreed on revisions to key parts of NAFTA (Zaru, Faulders, and McGraw, 2018).

Since this study estimated import-source responses to changes in prices of fresh fruits through NAFTA, where more than 95% of the selected fresh-fruit imports come from Mexico, it is possible to assess expected U.S. import changes in the wake of a tariff on fresh-fruit imports. We evaluate the impact of a 20% tariff on fresh fruits imports from Mexico using our demand elasticity estimates assuming constant fresh-fruit prices.

Table 7. Direct Impacts of 20% Tariff on Imports from Mexico.

	Mangoes and Guavas from Mexico	Papayas from Mexico
Pre-Tariff Total Value of Average Monthly Imports (million $)	28.98	5.79
Pre-Tariff Total Quantity of Average Monthly Imports (1000 tons)	18.10	8.95
Pre-Tariff Average Price	1.60	0.65
Own-Price Elasticity	-0.95	-0.25
Change in Total Quantity of Average Monthly Imports (%)	-19.00%	-5.00%
Change in Total Quantity of Average Monthly Imports (1000 tons)	-3.42	-0.44
Post-Tariff Total Quantity of Average Monthly Imports (1000 tons)	14.68	8.51
Post-Tariff Average Price	1.92	0.78
Post-Tariff Total Value of Average Monthly Imports (million $)	28.2	6.61
Change in Total Value of Average Monthly imports (million $)	-0.78	0.82
Change in Total Value of Average Monthly imports (%)	-3.00%	14.00%
Expected Tariff Revenue (million $)	5.64	1.32

The direct impact of the tariff on U.S. imports of mangoes, guavas, and papayas from Mexico was evaluated by using our estimated own-price elasticities of demand. First, the own-price elasticities were used to estimate the percentage change in the corresponding quantities from the imposition of the tariff and then multiplied the results by the average monthly quantities to obtain the expected monthly after-tariff quantity imported in tons. Second, average monthly prices were assumed to increase by the magnitude of the tariff to obtain after-tariff prices. Third, the after-tariff quantities and prices were multiplied to obtain the after-tariff monthly imports in dollars. Finally, 20% of the total value of the new average monthly imports in dollars were assumed to be the tariff revenues (Dharmasena and Capps, 2012). Table 7 reports the estimated direct impact that a 20% tariff can have on U.S. imports of fresh fruits. As the calculations show, holding other factors unchanged, it is expected that the average monthly revenue generated by the tariff on mangoes, guavas, and papayas imported from Mexico will be approximately $7 million. In other words, $7 million is an estimate of at least the first-month revenues under no retaliatory action from Mexico. However, the resulting market surplus may force Mexican producers to reduce their prices if Mexico cannot find an alternative foreign market to export its fresh fruits; and, if so, the tariff burden will be shared between the United States and Mexico. Even if Mexico had several ready-to-export alternative foreign markets for its fresh fruits, it is likely that a 20% import tariff will trigger immediate retaliation from Mexico, which may as well lead to a trade war between the United States and Mexico. This illustrates the complexity and uncertainty of estimating even the immediate effect of a trade policy scenario.

Table 8. Indirect Impact of 20% Tariff on U.S. Fresh-Fruit Imports from Other Sources.

	Mangoes and Guavas from MERCOSUR	Mangoes and Guavas from ROW	Bananas from DR-CAFTA	Papayas from ROW
Pre-Tariff Total Value of Average Monthly Imports (million $)	5.53	8	89.58	1.62
Pre-Tariff Total Quantity of Average Monthly Imports (1000 tons)	4.9	5.31	221.4	2.42
Average Price	1.13	1.51	0.4	0.67
Coefficient of Net Cross-Price Effect	-0.02	0.09	0.39	0.02
Change in Total Quantity of Average Monthly Imports (1000 tons)	-0.02	0.09	17.4	0.01
Change in Total Quantity of Average Monthly Imports (%)	-0.30%	1.70%	7.90%	0.50%
Post-Tariff Total Quantity of Average Monthly Imports (1000 tons)	4.88	5.4	238.8	2.43
Post-Tariff Total Value of Average Monthly Imports (million $)	5.51	8.14	96.62	1.62
Change in Total Value of Average Monthly imports (million $)	-0.02	0.14	7.04	0.01
Change in Total Value of Average Monthly imports (%)	-0.30%	1.70%	7.90%	0.50%

The indirect impact of a 20% tariff was estimated using the statistically significant cross-price elasticities of fresh fruits imported from Mexico and all other trade bloc sources. First, the relevant cross-price elasticities were combined to obtain the net impact of a 1% change in the prices of fresh fruits from Mexico on the corresponding fresh-fruit quantities demanded. Next, the results were multiplied by both the magnitude of the tariff and the average monthly quantities to obtain the after-tariff quantities demanded. Finally, the latter quantities were multiplied by the average prices to calculate the after-tariff average monthly imports. Table 8 reports the expected indirect impact of a 20% tariff imposed on fresh-fruit imports from Mexico.

Conclusion

An SDAIDS with preferential trade blocs (NAFTA, DR-CAFTA, MERCOSUR, and ROW) as import sources was used to estimate uncompensated and compensated demand elasticities. Monthly imports, quantities, and values, from January 1, 2005, to December 31, 2015, were obtained from USITC.

The estimated statistically significant elasticities of demand revealed that the demands for all fresh fruits were price-inelastic except for the demand for mangoes and guavas imported through MERCOSUR, mangoes and guavas imported from ROW, and papayas imported from ROW. Most of the statistically significant cross-price elasticities had positive signs, indicating that the fruits imported from various sources were substitutes. Some of the estimated cross-price elasticities of demand had negative signs, indicating that the corresponding fruits were complements for each other. All the estimated expenditure elasticities were positive, implying that the quantity demanded of all fruits increased as real expenditures for those fruits rose (holding all other factors constant).

In addition, this study, in the context of fresh-fruit imports, attempts to quantify and assess the implications of imposing tariffs on imports from Mexico as repeatedly propagated by political leaders as an option to pay for a border wall (Abdullah and Gamboa, 2017), perhaps as a way to negotiate the new U.S.-Mexico-Canada agreement (USMCA) or, most recently, as a warning to Mexico to stop the flow of illegal drugs entering the United States (Egan, 2019). Our estimates indicate that a 20% tariff on mangoes, guavas, and papayas imported from Mexico will generate an average monthly revenue of about $7 million under no retaliatory action.

The new USMCA, also referred to by politicians as NAFTA 1.5 or NAFTA 2.0, was signed on November 30, 2018, was sent to Congress for revision around September 1, 2019 (Tausche, 2019), and is expected to be voted on by Congress by the end of 2019 (Tausche, 2019). The new USMCA is expected to have major impacts on the U.S. dairy, pork, and poultry industries (Burfisher Lambert, and Matheson, 2019; Chepeliev, Tyner, and Mensbrugghe, 2019), but minor changes to current trade trends of fruits and vegetables. Chepeliev, Tyner, and Mensbrugghe (2019) simulated the USMCA in a context of retaliatory agricultural tariffs by Canada and Mexico and found exports of fruits and vegetables experience only a minor drop. Similarly, Burfisher Lambert, and

Matheson (2019) report mostly zero-base-tariff rates under the current USMCA for crops, which included vegetables, fruits, and nuts.

The findings of this study may also be useful in formulating trade policies, assessing the implications of retaliatory trade actions, and in conducting scenario analysis for policy decision-making. Particularly, the estimated elasticities of demand can be used to evaluate the impact of various economic factors (such as tariffs, phytosanitary, or new regulations such as the Food Safety and Modernization Act) that can influence the price of fresh fruits imported to the United States. These elasticities are useful in terms of measuring the degree of responsiveness of U.S. consumers to the changes in prices of imported fresh fruits. For instance, the demand for fresh fruits that were found to be price-inelastic is expected to be less impacted by price changes than those with a higher magnitude for own-price elasticity of demand in absolute value.

A few recommendations for future research need to be noted. First, additional data, including other sources, can be added to make the findings more representative. Second, the selected preferential trade agreements can be analyzed one by one, with a specific variable representing the start of the agreement, to see if the agreement has statistically significant impact on trade. The findings of such studies can be useful in considering formation of a new free trade agreement (for example, an agreement with MERCOSUR countries). Particularly, the approach taken to estimate the impact of tariffs on U.S. imports of fresh fruits can also be used to estimate possible changes if trade barriers were relaxed or removed. Third, further analysis can focus on estimating the supply function of U.S. fresh fruit production, which, if combined with the findings of this study, can be used to estimate optimal tariff levels for each of the sources analyzed in this study. Finally, future research can focus on estimating the supply flexibilities of Mexican fresh fruit production, which will allow for an estimation of an expected response to the imposition of a tariff on goods and services imported from Mexico.

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