U.S. and Mexican Tomatoes:
Perceptions and Implications of the
Renegotiated Suspension Agreement

Serhat Asci, James L. Seale, Jr., Gulcan Onel, and John J. VanSickle

The 2013 antidumping investigation suspension agreement introduced new categories of tomatoes and raised reference prices of Mexican field-grown and greenhouse tomatoes by 43% and 89%. We analyze the substitution and complementary relationships among different categories of tomatoes grown in the United States, Mexico, and other countries and measure substitution and income effects of reference price increases. Findings indicate that the new agreement may decrease demand for U.S. field-grown tomatoes in favor of Mexican field-grown and Mexican greenhouse tomatoes. Policies to increase overall U.S. tomato expenditures may be more favorable for U.S. tomato producers than the new reference prices.

Key words: differential demand models, fresh tomato industry, greenhouse tomato, suspension agreement

Introduction

Fresh tomatoes are the highest-valued fresh vegetable in the United States, resulting in increased rent-seeking actions among importers and domestic producers. Importers try to increase their market share through low prices, while domestic producers try to keep a high-valued market without investing in costly production practices, such as greenhouse production. U.S. and Mexican fresh tomato producers have engaged in a trade conflict since the early 1970s (Bredahl, Schmitz, and Hillman, 1987; VanSickle, Evans, and Emerson, 2003). Many U.S. producers believe that their industry is vulnerable to excessive imports and low prices from foreign competitors. Specifically, Florida field-grown tomato producers have filed numerous antidumping petitions against Mexico since 1978. To resolve this conflict, policy makers have introduced suspension agreements, which can be renegotiated.

Historically, Florida producers have received higher prices for their tomatoes in the winter tomato market, which runs from the beginning of December to the end of April (figure 1). The winter tomato market in the United States consists predominantly of Florida field-grown (24%), Mexican field-grown (23%), and Mexican greenhouse (39%) tomatoes. Recently, other states, including California and Arizona, have joined the competition by producing greenhouse tomatoes during the winter season, putting downward pressure on winter tomato prices and potentially increasing the conflict between Mexican and U.S. tomato producers. We assess both imported and domestic greenhouse tomato production in order to address potential trade conflicts between the United States and Mexico and their implications. The results of this study are important for international trade participants and for policy makers. Understanding how consumers perceive Mexican greenhouse tomatoes is a helpful tool for designing future trade policies to deal with potential trade conflicts.

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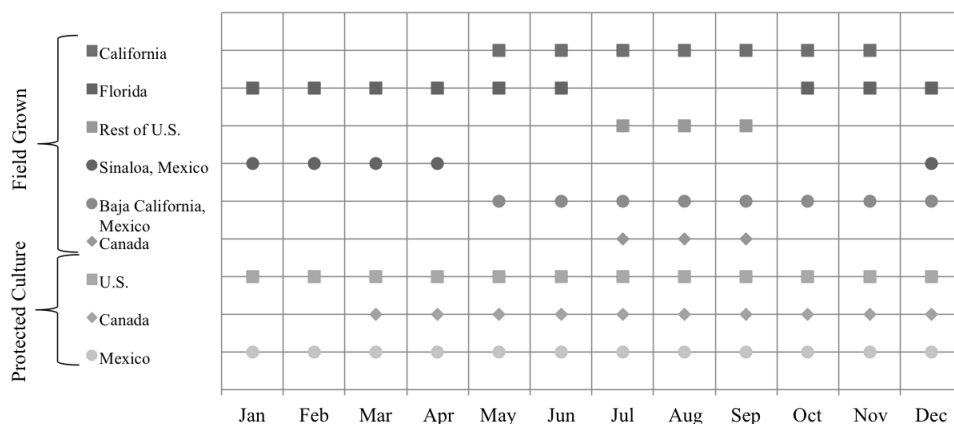
Figure 1. Field-Grown and Protected-Culture Fresh Market Tomato Shipments by Month

Notes: Adopted from Cook and Calvin (2005).

This paper examines tomato demand in the United States and evaluates consumer preferences for domestic and imported field-grown (FG) and greenhouse (GH) tomatoes. We examine the substitution and complementary relationships between imported and domestically produced tomatoes and how consumers perceive these relationships. If domestic and imported tomatoes are substitutes, then consumers will perceive them as similar products, and if they are complements, then consumers will perceive them as noncompetitive products. Based on this economic notion, we analyze consumer preferences for GH and FG tomatoes grown in the United States relative to tomatoes imported from Mexico by evaluating cross-price effects of demand for these products.

The demand analysis is conducted in two parts. The first part provides a general and aggregated perspective of U.S. tomato markets. The second part analyzes disaggregated categories of U.S. and Mexican FG and GH tomatoes. Domestic demand includes U.S. produced and imported fresh tomatoes, which are treated as weakly separable (Winters, 1984; Seale, Marchant, and Basso, 2003). Using monthly data on aggregate and disaggregated categories of tomatoes, we estimate and compare four differential demand systems: Rotterdam model, Almost Ideal Demand System (AIDS), Central Bureau of Statistics (CBS) model, and the National Bureau of Research (NBR) model. We also estimate a General model that nests all four differential demand systems (Barten, 1993; Lee, Brown, and Seale, 1994).

Our model selection tests reveal that none of the four differential demand systems fits the aggregate data as well as the General model. However, the CBS model fits the disaggregated data best among all the demand systems considered in the analysis. Our empirical results signify that U.S. domestic tomatoes are substitutes with imported tomatoes at the aggregate level; therefore, they are perceived as similar products. Disaggregated analysis further reveals that U.S. FG tomatoes compete with U.S. GH tomatoes, with both Mexican FG and GH tomatoes, and with tomatoes in the rest-of-tomatoes (ROT) category. U.S. GH tomatoes are substitutes with U.S. FG and Mexican FG tomatoes but not with Mexican GH tomatoes.

Background on the U.S. and Mexican Fresh Tomato Industries

The U.S. fresh tomato industry is one of the highest-valued fresh vegetable industries in the nation, with a production value of $1.1 billion in 2013 (Food and Agriculture Organization of the United Nations, 2013; U.S. Department of Agriculture, Economic Research Service, 2014). The United States is also one of the world's largest tomato producers, producing 24.6 million hundred weight (cwt) in 2013 (Food and Agriculture Organization of the United Nations, 2013; U.S. Department of Agriculture, Economic Research Service, 2014). The two largest tomato producing states are Florida
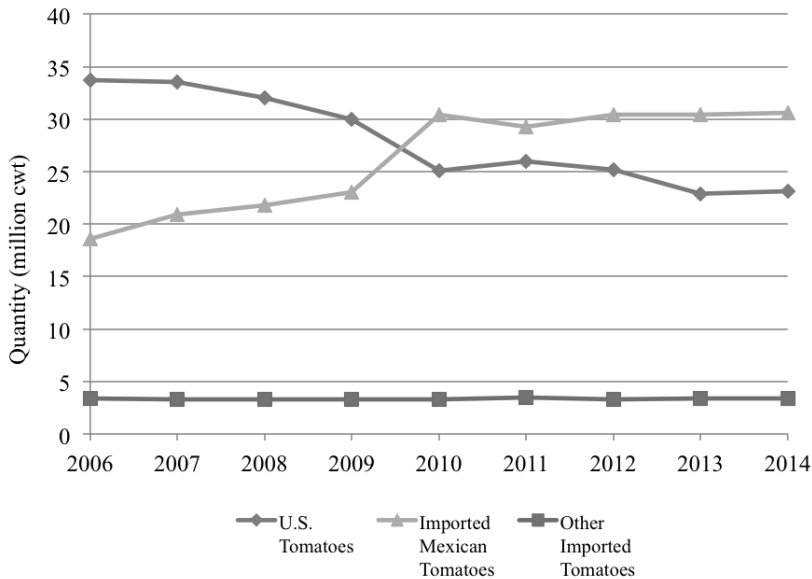
Figure 2. Fresh Tomato Shipments in the U.S. Market (Million cwt), 2006–2014

Notes: Calculated by authors from fresh tomato shipments (U.S. Department of Agriculture, Agricultural Marketing Service, 2015; U.S. Department of Agriculture, Foreign Agricultural Service, 2014).

(9.0 million cwt) and California (8.4 million cwt) (U.S. Department of Agriculture, Economic Research Service, 2014). Fresh FG tomatoes are harvested in California during all seasons except for winter. In Florida, fresh FG tomatoes are harvested from October to June, with peak production from November to January. Over time, both California and Arizona have become key states in GH tomato production and have also entered the U.S. winter tomato market.

Since 2000, fresh tomato imports from Mexico have almost doubled; Mexico now exports more than 50% of its domestic fresh tomatoes (House of Produce, 2013). Figure 2 illustrates how fresh tomato imports from Mexico have surpassed U.S fresh tomato production over time. Most of Florida's winter production of fresh tomatoes is shipped to the eastern United States, while most of Mexico's production is shipped to the western United States (VanSickle, Evans, and Emerson, 2003). More than half of the fresh tomatoes consumed in the United States are imported from Mexico and Canada, and half of these imported tomatoes are produced in greenhouses (figure 3). Historical data show that the increase in fresh tomato imports corresponds with the increase in GH tomato imports from Mexico (Asci, VanSickle, and Cantliffe, 2014). The United States imported nearly 34 million cwt of fresh tomatoes in 2013, of which Mexico accounted for 14.8 million cwt FG (including plum), 13.9 million cwt GH, and 1.8 million cwt specialty (including grape and cherry) tomatoes and Canada accounted for 3.1 million cwt (U.S. Department of Agriculture, Foreign Agricultural Service, 2014). Other countries, such as the Netherlands and Spain, export fresh GH tomatoes to the United States in much smaller quantities. Yield per acre of GH tomatoes can be up to twenty times that of FG tomatoes, which leads to increased market share of imported GH tomatoes in the United States through lower prices and consistent quality products (Cantliffe and VanSickle, 2009). U.S. GH tomato production was 1.7 million cwt in 2013, constituting 6.9% of domestic fresh tomato production (U.S. Department of Agriculture, Agricultural Marketing Service, 2015).

The dynamics of the tomato market became contentious in the United States when Mexico entered the U.S. tomato market as a major player after the United States placed an embargo on products from Cuba in 1962 (VanSickle, 1997). Florida producers filed their first antidumping petition against Mexico in 1978 as Florida's market share eroded. That petition was withdrawn and minimum quality standards were imposed on Mexican imported tomatoes, which resulted in reduced shipments of Mexican tomatoes to U.S. markets in the 1980s (VanSickle, 1997). This situation

(a) Winter tomatoes expenditure

(b) Total expenditure
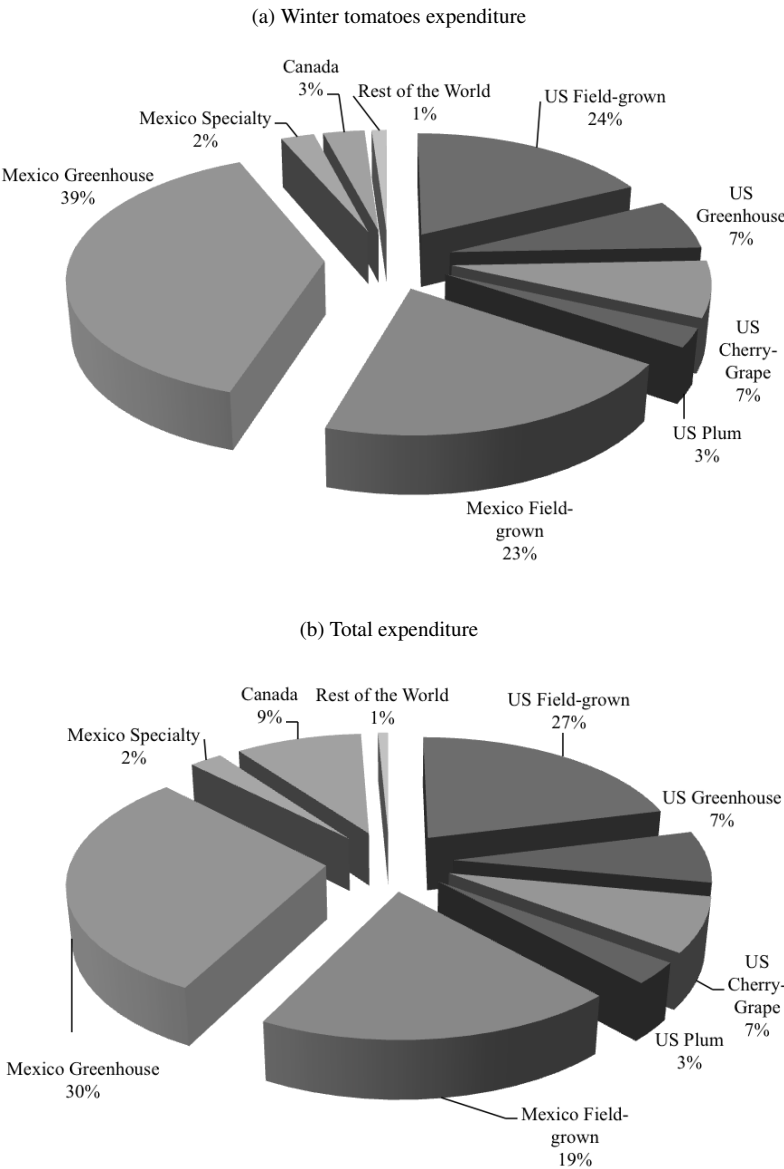
Figure 3. Average U.S. Share of Winter (December–April) and Total Tomato Expenditure in the Last Five Years, 2010–2014

Notes: Calculated by authors from fresh-tomato shipments (U.S. Department of Agriculture, Agricultural Marketing Service, 2015).

changed after the North American Free Trade Agreement (NAFTA) was enacted in 1994 due in part to the large peso devaluation (Krueger, 1999). In response, the United States filed another petition in 1995 (VanSickle, 1997). After a long debate, this case ended with a suspension agreement in 1996 (VanSickle, Evans, and Emerson, 2003). Part of the agreement established separate floor prices for summer (17.20 cents/pound) and winter (21.69 cents/pound) tomatoes. The suspension agreement has been renegotiated several times since then, most recently in 2013. This last negotiation further differentiated floor prices with new and diversified product definitions, such as open field/adapted environment and controlled environment tomatoes and specialty loose and packed tomatoes (U.S. Deparment of Commerce, 2013). While this agreement sharply increased floor prices of summer

and winter FG tomatoes, Mexican tomato imports are still predicted to rise in the near future due to recent investments in Mexican greenhouses (House of Produce, 2013). Because of the dynamics in the U.S. tomato markets, a comprehensive study analyzing the competitiveness of U.S. fresh tomato markets is essential for stakeholders and policy makers. Assessing linkages between U.S. and Mexican tomatoes will help policy makers better understand the market and the impacts of trade policies.

Differential Demand Systems

In our analyses, we consider four different differential demand systems (Rotterdam, AIDS, CBS, and NBR) and choose the most appropriate model among them. To do so, we consider the General model introduced by Barten (1993), which nests all four demand systems. The Rotterdam model was developed by Barten (1964) and Theil (1965). Deaton and Muellbauer (1980) introduced the AIDS model, including its time-series version. Keller and Van Driel (1985) established the CBS model by combining the Rotterdam price parameterization and the AIDS income parameterization. The CBS model differs from the Rotterdam model in that its marginal shares are not constant as they are in the Rotterdam model. Finally, Neves (1987) developed the NBR model, which uses the Rotterdam income parameterization and the AIDS price parameterization.

Consider a utility function that takes the general form, $\boldsymbol{U} = U(q_1, \ldots, q_n)$, where q_i is the quantity of the ith good and n is the number of goods. We assume differentiability and nonsaturation so that $\partial \boldsymbol{U}/\partial q_i > 0$. Generalized diminishing marginal utility requires that the Hessian matrix of the utility function, $\boldsymbol{U} = [\partial^2 \boldsymbol{U}/\partial q_i \partial q_j]$, is a negative definite and symmetric $n \times n$ matrix. Demand equations are derived by maximizing the utility function subject to the consumer's budget constraint, $\sum_i p_i q_i = M$, where p_i is the price of good i $(=1, \ldots, n)$ and M is the total budget so that $\sum_i p_i \frac{\partial q_i}{\partial p_j} = -q_j$ and $\sum_i p_i \frac{\partial q_i}{\partial M} = 1$; that is,

$$(1) \qquad \qquad Max\, U(q_i, \ldots, q_n) - \mu \left(\sum_i p_i q_i - M \right).$$

Differentiating equation (1) with respect to q_i, p_j, and M and using Barten's (1964) fundamental matrix yields the general differential demand equation

$$(2) \qquad \qquad w_i d(\ln q_i) = \theta_i d(\ln Q) + \sum_{j=1}^{n} \pi_{ij} d(\ln p_j),$$

where $w_i = p_i q_i / \sum_i (p_i q_i)$ represents the budget share of good i while parameter θ_i is the marginal budget share of good i, π_{ij} is a compensated (Slutsky) price parameter for commodity i with respect to the price of commodity j, and $d(\ln Q) = \sum_j w_j d(\ln q_j)$ is the Divisia volume index that represents real income. Constraints on equation (2) from demand theory are as follows: adding-up, $\sum_i \theta_i = 1$, $\sum_i \pi_{ij} = 0$; homogeneity, $\sum_j \pi_{ij} = 0$; and Slutsky symmetry, $\pi_{ij} = \pi_{ji}$.

Following Theil (1965), one can obtain the well-known Rotterdam model by adding an error term in equation (2) and by assuming that θ_i and π_{ij}s are constant parameters to be estimated, $w_i = (w_{i,t} + w_{i,t-1})/2$, and $d(\ln X) = \ln X_t - \ln X_{t-1}$, where X represents p and q. The Rotterdam model's expenditure elasticity (η_i) of good i is

$$(3) \qquad \qquad \eta_i = \frac{\theta_i}{w_i};$$

its Slutsky (compensated) price elasticity (η_{ij}) is

$$(4) \qquad \qquad \eta_{ij} = \frac{\pi_{ij}}{w_i};$$

and its Cournot[1] (uncompensated) price elasticity (c_{ij}) is

$$(5) \qquad\qquad c_{ij} = \frac{\pi_{ij} - \theta_i w_j}{w_i}.$$

Replacing θ_i with $w_i + \beta_i$ in equation (2) and rearranging the terms lead us to the CBS model (Keller and Van Driel, 1985),

$$(6) \qquad\qquad w_i(d(\ln q_i) - d(\ln Q)) = \beta_i d(\ln Q) + \sum_{j=1}^{n} \pi_{ij} d(\ln p_j) + \varepsilon_i.$$

Substituting π_{ij} by $\gamma_{ij} = \pi_{ij} + w_i \delta_{ij} - w_i w_j$ into equation (6) gives us the (differential) AIDS equation (Barten, 1993),

$$(7) \qquad\qquad d(w_i) = \beta_i d(\ln Q) + \sum_{j=1}^{n} \gamma_{ij} d(\ln p_j) + \varepsilon_i.$$

The NBR model is generated by replacing β_i with $\theta_i - w_i$ in equation (7),

$$(8) \qquad\qquad d(w_i) + w_i d(Q) = \theta_i d(\ln Q) + \sum_{j=1}^{n} \gamma_{ij} d(\ln p_j) + \varepsilon_i.$$

To provide direct comparisons between these four demand systems, Barten (1993) developed a General model that nests all four differential demand systems. The General model nests these four differential demand systems by introducing two more parameters, δ_1 and δ_2. The General model can be written as

$$(9) \qquad w_i d(\ln q_i) = (d_i + \delta_1 w_i) d(\ln Q) + \sum_{j=1}^{n} e_{ij} d(\ln p_j) - \delta_2 w_1 (d(\ln p_i) - d(\ln P)) + \varepsilon_i,$$

where $d_i = \delta_1 \beta_i + (1 - \delta_1)\theta_i$, $e_{ij} = \delta_2 \gamma_{ij} + (1 - \delta_2)\pi_{ij}$, and $d(\ln P) = \sum_j w_j d(\ln p_j)$ is the Divisia price index. The constraints on the model are: adding-up, $\sum_i d_i = 1 - \delta_1$, $\sum_i e_{ij} = 0$; homogeneity, $\sum_j e_{ij} = 0$; and Slutsky symmetry, $e_{ij} = e_{ji}$. The expenditure elasticity, Slutsky price elasticity, and Cournot price elasticity are $\eta_i = (d_i + \delta_1 w_i)/w_i$; $\eta_{ij} = (e_{ij} - \delta_2 w_i(\delta_{ij} - w_j))/w_i$; and $c_{ij} = [(e_{ij} - \delta_2 w_i(\delta_{ij} - w_j)) - (d_i + \delta_1 w_i)w_j]/w_i$, respectively, where δ_{ij} represents the Kronecker delta equal to unity if $i = j$ and 0 otherwise. The parameters, δ_1 and δ_2, are treated as constant parameters and provide information about which of the four differential demand systems best fits the data. Equation (9)) becomes a Rotterdam model when $\delta_1 = 0$ and $\delta_2 = 0$; a CBS model when $\delta_1 = 1$ and $\delta_2 = 0$; an AIDS model when $\delta_1 = 1$ and $\delta_2 = 1$; and an NBR model when $\delta_1 = 0$ and $\delta_2 = 1$.

One of the first applications of these differential demand systems to import demand for an agricultural commodity was by Seale, Sparks, and Buxton (1992), who used the Rotterdam demand model to estimate fresh apple imports. More recently, Schmitz and Seale (2002) estimated demand for Japanese fresh fruit imports, and Seale, Marchant, and Basso (2003) estimated U.S. demand for domestically produced and imported red wine using differential demand models. We use a comprehensive estimation methodology that considers all four nested models and chooses the best model that explains the demand for imported fresh FG and GH tomatoes in the United States.

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[1] Cournot price elasticities reflect both price and income effects with respect to a change in the price of a good. In theory, Cournot own-price elasticies are lower (more negative) than the Slutsky own-price elasticies.

Data

We use monthly data on fresh tomato imports and domestic fresh tomato shipments. The data on fresh tomato imports are collected from the Global Agricultural Trade Systems (GATS) of the U.S. Department of Agriculture, Foreign Agricultural Service (2014). The import data comprise various fresh tomato products classified under the Harmonized Commodity Description and Coding System (HS) at the ten-digit level.

In addition to data on U.S. fresh tomatoes, we also use data on dollar import values and quantities of all Mexican tomatoes (field-grown, greenhouse, and specialty), Canadian tomatoes (mainly greenhouse), Dutch tomatoes (greenhouse), and Rest-of-World (ROW) tomatoes (mainly greenhouse) in the aggregate models. Data used for the aggregate demand analysis cover January 1989 to December 2014, yielding 312 observations. We obtain data on shipping-point prices of U.S. tomatoes from the U.S. Department of Agriculture, Economic Research Service (2014). The import values are recorded as CIF-type values (cost, insurance, and freight), which are compatible with the domestic shipping-point prices. These monthly data are available only up to June 2010 (U.S. Department of Agriculture, Economic Research Service, 2014), but we extend the data to December 2014 by using daily shipping-point reports by the U.S. Department of Agriculture, Agricultural Marketing Service (2015).

The disaggregated data allow us to compare U.S. and Mexican FG and GH tomatoes. For the disaggregated analysis, we use 123 monthly observations on import values and quantities of Mexican FG and GH tomatoes and the shipping-point expenditures and quantities of U.S. FG and GH tomatoes. The last category in the disaggregated analysis is called Rest of Tomatoes (ROT), and it consists of U.S. and Mexican specialty tomatoes and all other tomato imports into the United States. Obtaining disaggregated import data from GATS on Mexican FG, GH, and specialty tomatoes is straightforward. However, properly disaggregating U.S. tomato data is relatively tedious because monthly prices for all categories of fresh U.S. tomatoes (field-grown, greenhouse, plum, cherry, and grape tomatoes) are only available at the terminal points. To convert terminal-point prices into shipping-point prices, we multiply the terminal-point prices by the ratio of total expenditures at the shipping point to total expenditures at the terminal point. Daily quantities at the shipping points for all categories of fresh U.S. tomatoes between October 2004 and December 2014 are available from the U.S. Department of Agriculture, Agricultural Marketing Service; we aggregate daily observations into monthly observations.

Results

Prior to estimating the demand for imported and domestic tomatoes, we check for stationarity of the variables in equation (9) using Augmented Dickey-Fuller (ADF) unit root tests. Differential demand models use the differences of the natural logarithms variables; this transformation generally wipes out any unit roots that may be present at the levels of the variables. Results of unit root tests, reported in appendix table A1, confirm that all variables used in the demand system estimation are stationary. Since we use monthly time-series data, we transform all variables by taking their twelve-month differences to account for seasonal effects (Kmenta, 1990; Seale, Marchant, and Basso, 2003).

Once the parameters of the demand models are estimated, it is important to ensure that the parameters do not suffer from a bias caused by a structural break or parameter instability in the system. A traditional approach to testing for a break would be to pick an arbitrary sample breakpoint thought to be associated with a major event relevant to the time series at hand and use a Chow (1960) test for structural change. This approach is not recommended here as it suffers from the arbitrary nature of the selected breakpoint. Instead, recent literature suggests procedures allowing the break point to be determined endogenously by the data. Accordingly, to test for parameter stability in our estimated aggregate and disaggregated demand systems, we use a system extension of the well-known Andrews (2003) *supremum*-F test (*sup*-F) for detecting and testing structural change

of unknown timing. The system *sup*-F test consists of computing Chow breakpoint tests at every observation except for those too near the end points of the sample. The sup-F test is applied to data in this study with 20% trimming. Results for both aggregate and disaggregated models are presented in the lower section of appendix table A1. The null hypothesis of parameter equality between two regimes is tested against the alternative that some parameters in the system are statistically different before and after an unknown break point to be determined endogenously with the test. The highest value of the sequential F statistic is 2.05 in the aggregate model and 0.59 in the disaggregated model. One problem with endogenous break tests is that the distribution of the test statistic for testing the null of linearity is unknown due to nuisance parameters. We therefore create the exact distribution of the test statistic for each of the two selected models based on 1,000 bootstrap replications. Critical values reported in appendix table A1 indicate that the null hypothesis of no structural change cannot be rejected in either the aggregate or the disaggregated models.

Aggregate Demand Analysis

The aggregate model of tomatoes is a system of five demand equations that consists of demand for tomatoes from the United States, Mexico, Canada, the Netherlands, and the Rest of the World (ROW). We estimate all four differential demand systems (i.e., Rotterdam, CBS, AIDS, and NBR) plus the General model using iterative seemingly unrelated regressions.[2] Since the complete demand system is singular, one equation is dropped before estimation. The parameters of the deleted equation are recovered post-estimation using the adding-up conditions (Barten, 1969).

The Hildreth-Lu procedure is used to test for autocorrelation. The autocorrelation parameter, ρ, is chosen by searching over a range of ρ values in the following manner. All variable are first transformed, such that $X_{12} = X_{12} \cdot \sqrt{1 - \rho^2}$ for the first observation and $X_t = X_t - \rho \cdot X_{t-12}$ for $t = 13, \ldots, T$ (Prais and Winsten, 1954). The demand systems are estimated using these transformed variables recursively for a range of autocorrelation parameters between -1 and 1; ρ is chosen with maximum likelihood (ML) based upon the largest log-likelihood value of the multivariate regressions (Hildreth and Lu, 1960). Autocorrelation is tested in each demand system by a log-likelihood ratio (LR) test in which the restricted model constrains $\rho = 0$ and the unrestricted model transforms the data as described above with the ML ρ. In all models, autocorrelation is rejected at the 5% significance level, thus making the Prais-Winston transformation unnecessary.

Theoretical restrictions of homogeneity and symmetry of the parameters of the demand systems are tested using LR tests. Appendix table A2 illustrates the results. The homogeneity hypothesis cannot be rejected in any of the estimated demand systems. Symmetry is tested conditional on homogeneity, and the symmetry restrictions are rejected in all demand systems at the 5% significance level, except for the Rotterdam Model.[3] However, symmetry is not rejected in any of the demand systems at the 10% significance level.

We use model selection tests to compare the four demand systems against the General model that nests all of them to find the best model for estimating the demand for aggregate categories of tomatoes. LR tests are conducted to compare the four demand systems to the General model after imposing homogeneity and symmetry restrictions. The LR test results, reported in appendix table A3, indicate that none of the four demand models fits the data as well as the more flexible General model. Accordingly, we deem the General model to be the best model for estimating the demand for aggregate categories of tomatoes.[4]

Parameter estimates of the General model with homogeneity and symmetry restrictions imposed on price coefficients are provided in table 1. The additional parameters of the General model, δ_1 and δ_2, are both positive and significantly different from both 0 and 1, confirming the significance

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[2] The software used for the parameter estimation is the Time Series Processor v. 5.0 (Hall and Cummins, 2005).

[3] Meisner (1979) argues that this may be due to the fact that the LR tests are biased toward rejecting symmetry, especially when the number of commodities included in the demand system is fairly large.

[4] Barten (1993) and Lee, Brown, and Seale (1994) argue that the General model is a demand system in its own right.

Table 1. Parameter Estimates of Aggregate U.S. Tomato Demand, General Model, 1989–2014

	U.S.	**Mexico**	**Canada**	**Netherlands**	**ROW**	**δ_1**	**δ_2**
Constant	−0.015**	0.009	0.005***	0.000	0.000	0.342***	0.367***
	(0.006)	(0.006)	(0.001)	(0.000)	(0.000)	(0.091)	(0.049)
Expenditure Coeff.	0.378***	0.273***	0.000	0.003	0.005*		
(d_i)	(0.070)	(0.061)	(0.008)	(0.004)	(0.003)		
Slutsky Price Coeff. (e_{ij})							
United States	**−0.031***	0.029*	−0.001	0.001	0.002***		
	(0.017)	(0.016)	(0.002)	(0.001)	(0.001)		
Mexico		**−0.032***	0.000	0.005*	−0.001		
		(0.017)	(0.004)	(0.002)	(0.002)		
Canada			**−0.006**	0.004**	0.002		
			(0.004)	(0.002)	(0.001)		
Netherlands				**−0.009***	0.000		
				(0.002)	(0.001)		
ROW					**−0.002***		
					(0.001)		

Notes: Single, double, and triple asterisks (*, **, ***) represent statistical significance at the 10%, 5%, and 1% level. Only diagonal and upper triangular elements of price coefficients are reported because the price matrix is symmetric. Asymptotic standard errors appear in parentheses.

of the General model compared to the other differential demand models considered. Three of the five expenditure coefficients are significantly greater than 0; we can expect the three expenditure elasticities based on the significant coefficients to be significantly greater than δ_1, 0.342. All own-price coefficients are negative, as expected, suggesting that the corresponding Slutsky (compensated) own-price elasticities must be negative; three of them are significantly different from 0. On the other hand, the signs of the cross-price parameters of the General model do not necessarily indicate substitution or complementary effects between goods. If $\delta_2 > 0$ and $e_{ij} > 0$, then goods i and j must be substitutes. However, if $\delta_2 > 0$ and $e_{ij} < 0$, it is still possible for the two goods to be substitutes. In our case, $\delta_2 > 0$, and the e_{ij}s for U.S.-Mexico, U.S.-ROW, Mexico-Netherlands, and Canada-Netherlands are statistically greater than 0; therefore, we expect tomatoes from these countries to be substitutes.

The conditional expenditure, Slutsky price elasticities, and Cournot price elasticities for U.S. tomatoes and imported tomatoes by country of origin are presented in table 2. All elasticities are computed at the sample means using the parameter estimates in table 1. All of the conditional expenditure elasticities are statistically significant at the 10% level or higher. The expenditure elasticities of demand for U.S., Mexican, and ROW tomatoes are greater than unity; a 1% increase in total expenditure for tomatoes leads to a slightly larger percentage increase in the quantity demanded of tomatoes produced in these countries. The expenditure elasticities for Canadian and Dutch tomatoes are inelastic (less than unity).

All Slutsky and Cournot own-price elasticities are negative and significant at the 1% level. Except for Dutch tomatoes, the demand for tomatoes is own-price inelastic. For instance, a 1% increase in the price of U.S. tomatoes, *ceteris paribus*, decreases the quantity demanded for U.S. tomatoes by 0.8%, while the same percentage increase in prices of Mexican and Canadian tomatoes decreases their quantity demanded by only 0.7% and 0.5%, respectively. The differences in the own-price Cournot elasticities suggest that U.S. tomatoes may have a price advantage in the market if market prices fall but not if prices rise.

Slutsky (compensated) cross-price elasticities are computed holding real income constant after a price change and indicate substitution and complementary relationships between goods. A positive and statistically significant Slutsky cross-price elasticity indicates that two goods are substitutes, while a negative and significant Slutsky cross-price elasticity indicates that the two goods are

Table 2. Conditional Expenditure, Slutsky and Cournot Price Elasticities of Aggregate U.S. Tomato Demand, General Model, 1989–2014

	U.S.	Mexico	Canada	Netherlands	ROW	Expenditure Elasticity
			Slutsky Price Elasticities			
United States	**−0.23*****	0.19***	0.03***	0.01***	0.01***	1.05***
	(0.02)	(0.02)	(0.00)	(0.00)	(0.00)	(0.09)
Mexico	0.27***	**−0.32*****	0.03**	0.02***	−0.00	1.07***
	(0.04)	**(0.04)**	(0.01)	(0.01)	(0.00)	(0.13)
Canada	0.19***	0.14**	**−0.42*****	0.07***	0.03	0.34***
	(0.03)	(0.06)	**(0.06)**	(0.02)	(0.02)	(0.10)
Netherlands	0.25***	0.48***	0.36***	**−1.05*****	−0.03	0.53**
	(0.08)	(0.19)	(0.13)	**(0.13)**	(0.07)	(0.27)
ROW	0.50***	−0.08	0.29	−0.07	**−0.64*****	1.06***
	(0.11)	(0.25)	(0.19)	(0.13)	**(0.13)**	(0.38)
			Cournot Price Elasticities			
United States	**−0.79*****	−0.20***	−0.05***	−0.01***	0.00	
	(0.04)	(0.05)	(0.01)	(0.00)	(0.00)	
Mexico	−0.30***	**−0.72*****	−0.05***	0.00	−0.01*	
	(0.06)	**(0.07)**	(0.02)	(0.01)	(0.00)	
Canada	0.00	0.01	**−0.45*****	0.06**	0.02	
	(0.05)	(0.08)	**(0.06)**	(0.02)	(0.02)	
Netherlands	−0.03	0.28	0.32**	**−1.06*****	−0.04	
	(0.13)	(0.23)	(0.13)	**(0.13)**	(0.07)	
ROW	−0.06	−0.48*	0.22	−0.08	**−0.65*****	
	(0.19)	(0.31)	(0.19)	(0.13)	**(0.13)**	

Notes: Single, double, and triple asterisks (*, **, ***) represent statistical significance at the 10%, 5%, and 1% level. Elasticities are calculated at sample means. Asymptotic standard errors appear in parentheses.

complements. Table 2 shows that, overall, fourteen out of twenty Slutsky cross-price elasticities are positive and statistically significant at the 1% level. All Slutsky cross-price elasticities involving U.S. tomatoes are positive and statistically significant at the 1% level, indicating that U.S. tomatoes are substitutes with all the imported tomatoes.

The Cournot (uncompensated) cross-price elasticity measures the effect of a price change of tomatoes from country j on quantity demanded of tomatoes from country i, holding nominal income constant. As such, Cournot price elasticity includes both the substitution and the income effects of a price change and, therefore, measures market effects of a price change better than Slutsky price elasticities. For example, the Slutsky cross-price elasticity between U.S. and Mexico is positive (0.2), while the corresponding Cournot elasticity is negative (−0.2), which indicates that the income effect of a change in price of Mexican tomatoes on U.S. tomato demand outweighs the pure substitution effect. The results are the same for the quantity demanded of the U.S. tomatoes when the prices of Canadian and Dutch tomatoes change. Among all Cournot cross-price elasticities, that of Mexican tomatoes when the price of U.S. tomatoes changes is the most negative (−0.3). Taken together, our results suggest that the upward renegotiated reference prices for Mexican tomatoes will likely decrease the quantity demanded of U.S. and Mexican tomatoes.

Disaggregated Demand Analysis

Next, we evaluate U.S. demand for disaggregated categories of tomatoes. We disaggregate the tomatoes according to production techniques/types of tomatoes as well as their origins. The aim with such disaggregation is to compare the consumption preferences of U.S. consumers for FG

Table 3. Parameter Estimates of Disaggregated U.S. Tomato Demand, CBS Model, 2004–2014

	U.S. Field-Grown	U.S. Greenhouse	Mexico Field-Grown	Mexico Greenhouse	ROT
Constant	−0.023***	−0.011***	−0.004	0.040***	−0.001
	(0.006)	(0.002)	(0.005)	(0.003)	(0.002)
Expenditure Coefficient (β_i)	0.011	0.041	−0.043	0.065*	−0.074***
	(0.075)	(0.029)	(0.062)	(0.037)	(0.029)
Slutsky Price Coefficients (π_{ij})					
U.S. field-grown	**−0.130*****	0.026***	0.023**	0.044***	0.036***
	(0.016)	(0.010)	(0.012)	(0.009)	(0.010)
U.S. greenhouse		**−0.027****	0.020***	−0.012	−0.007
		(0.013)	(0.007)	(0.009)	(0.011)
Mexico field-grown			**−0.045*****	−0.024***	0.026***
			(0.012)	(0.009)	(0.008)
Mexico greenhouse				**−0.027****	0.019
				(0.013)	(0.012)
ROT					**−0.073*****
					(0.018)

Notes: Single, double, and triple asterisks (*, **, ***) represent significant at the 10%, 5%, and 1% level. Only diagonal and upper triangular elements of price coefficients are reported because the price matrix is symmetric. Asymptotic standard errors appear in parentheses.

versus GH tomatoes and to analyze the recent suspension agreement between U.S. and Mexico. To analyze this policy change, we focus on comparing U.S. and Mexican FG tomatoes to U.S. and Mexican GH tomatoes. Accordingly, in the disaggregated analysis, we keep these four categories separate while aggregating other tomatoes (U.S. specialty tomatoes and all other tomatoes imported into the United States) into one category, called Rest of Tomatoes (ROT). Total tomato expenditures are the same in the disaggregated analysis as in the aggregate analysis.

All the diagnostics tests applied in the aggregate analysis are applied in this section. Appendix table A1 shows that the variables used in the disaggregated model are all stationary. LR tests based on the Prais-Winsten (1954) transformation and the Hildreth-Lu (1960) procedure suggest significant and negative autocorrelation coefficients in all demand models, with ρ values approximately equal to −0.3.

Tests on homogeneity and symmetry restrictions are reported in appendix table A4. In this case, neither homogeneity nor symmetry restriction are rejected. Appendix table A5 provides results of model selection tests; LR tests comparing the four differential demand models to the General model indicate that the CBS model is preferred to the others at the 5% significance level. Therefore, we only present estimation results of the CBS demand system below.

Table 3 presents the parameter estimates of the autocorrelation-corrected CBS model. An expenditure parameter in a single equation of the CBS model can be greater than, less than, or equal to 0, indicating a corresponding expenditure elasticity greater than, less than, or equal to unity, respectively. The positive and significant expenditure coefficient in the demand equation for Mexican GH tomatoes implies that the expenditure elasticity of demand for Mexican GH tomatoes is greater than unity. In contrast, the expenditure elasticity of demand for the ROT category is less than unity.

The price coefficients reported in table 3 are Slutsky price coefficients; therefore, they are symmetrical. The CBS own-price coefficients in all disaggregated tomato categories are negative, as expected, and statistically different from 0 at the 5% significance level. In addition, six out of ten cross-price coefficients are statistically significant, and five of these six are positive. These results signify that U.S. FG tomatoes are substitutes with U.S. GH, Mexican GH, and ROT tomatoes. U.S. GH-Mexican field-grown and Mexican FG-ROT tomatoes are also substitutes. Only Mexican FG and Mexican GH tomatoes are complements.

Table 4. Conditional Expenditure, Slutsky and Cournot Price Elasticities of Disaggregated U.S. Tomato Demand, CBS Model, 2004–2014

	U.S. Field-Grown	U.S. Greenhouse	Mexican Field-Grown	Mexican Greenhouse	ROT	Expenditure Elasticity
			Slutsky Price Elasticities			
U.S. field-grown	−**0.43*****	0.09***	0.08**	0.15***	0.12***	1.03***
	(0.05)	(0.03)	(0.04)	(0.03)	(0.03)	(0.25)
U.S. greenhouse	0.34***	−**0.35****	0.26***	−0.16	−0.10	1.53***
	(0.13)	**(0.17)**	(0.10)	(0.12)	(0.14)	(0.38)
Mexican field-grown	0.12**	0.11***	−**0.24*****	-0.13***	0.14***	0.77**
	(0.06)	(0.04)	**(0.06)**	(0.05)	(0.04)	(0.33)
Mexican greenhouse	0.20***	−0.06	−0.11***	−**0.12****	0.09	1.30***
	(0.04)	(0.04)	(0.04)	**(0.06)**	(0.05)	(0.17)
ROT	0.17***	−0.03	0.12***	0.09	−**0.35*****	0.65***
	(0.05)	(0.05)	(0.04)	(0.05)	**(0.09)**	(0.14)
			Cournot Price Elasticities			
U.S. field-grown	−**0.74*****	0.01	−0.12*	−0.08	−0.10*	
	(0.07)	(0.04)	(0.07)	(0.07)	(0.06)	
U.S. greenhouse	−0.12	−**0.46*****	−0.03	−0.49***	−0.42***	
	(0.15)	**(0.18)**	(0.13)	(0.15)	(0.15)	
Mexican field-grown	−0.11	0.05	−**0.39*****	−0.30***	−0.03	
	(0.10)	(0.05)	**(0.10)**	(0.09)	(0.08)	
Mexican greenhouse	−0.19***	−0.16***	−0.35***	−**0.41*****	−0.19***	
	(0.06)	(0.05)	(0.06)	**(0.07)**	(0.06)	
ROT	−0.03	−0.09	−0.00	−0.05	−**0.48*****	
	(0.06)	(0.05)	(0.05)	(0.06)	**(0.09)**	

Notes: Single, double, and triple asterisks (*, **, ***) represent significant at the 10%, 5%, and 1% level. Elasticities are calculated at sample means. Standard errors appear in parentheses.

    Conditional expenditure, Slutsky price, and Cournot price elasticities of disaggregated tomato demand are provided in table 4. The conditional expenditure elasticities of demand for U.S. GH and Mexican GH tomatoes are greater than unity and statistically significant at the 1% level, while that of U.S. FG tomatoes is essentially unitary. Accordingly, U.S. GH and Mexican GH tomatoes would benefit more than the other tomato categories from growth of total expenditures for tomatoes in the U.S. markets. The quantity demanded of U.S. FG tomatoes would grow at the same rate as total expenditures for tomatoes.

    All conditional Slutsky and Cournot own-price elasticities are significantly negative, as expected, and less than unity in absolute terms. The own-price elasticities indicate that demand for U.S. FG tomatoes is more sensitive to its own-price change than demand for both GH and FG Mexican tomatoes.

    Slutsky (compensated) cross-price elasticities measure the change in quantity demanded of good *i* with a change in price of good *j*, holding real income constant. Positive (negative) Slutsky cross-price elasticities indicate that goods *i* and *j* are substitutes (complements). Out of twenty Slutsky cross-price elasticities, fourteen are positive and ten are statistically different from 0. Only two of the six negative Slutsky cross-price elasticities are statistically significant. The results indicate that U.S. FG tomatoes are substitutes with U.S. GH tomatoes, Mexican GH tomatoes, and ROT. U.S. GH-Mexican FG and Mexican FG-ROT tomatoes are substitutes, while Mexican FG tomatoes-Mexican GH tomatoes are complements.

    The bottom portion of table 4 reports conditional Cournot cross-price elasticities, which measure the response of quantity demanded of one group of tomatoes to a price change in another group of tomatoes, holding nominal income constant. Seven of the twenty Cournot cross-price elasticities

are negative and statistically significant. A 1% increase in the price of Mexican FG tomatoes decreases the quantity demanded of Mexican GH tomatoes by 0.4% and of U.S. FG tomatoes by 0.1%. Moreover, a 1% increase in the price of Mexican GH tomatoes significantly decreases the quantity demanded of U.S. GH tomatoes by 0.5% and of Mexican FG tomatoes by 0.3%. Taken together, these results suggest that the increase in the prices of Mexican FG and GH tomatoes as a result of the new suspension agreement is likely to have a downward impact on quantities demanded of these tomatoes as well as U.S. FG and GH tomatoes. Also, if the new suspension agreement price changes of Mexican tomatoes also cause the prices of domestic fresh tomatoes to increase, the quantity demanded of U.S. FG tomatoes would be most affected among the tomato categories, given the relatively high Cournot own-price elasticity (−0.7).

An Assessment of the Renegotiated Suspension Agreement

The new suspension agreement sets reference prices at $0.2458 per pound for Mexican FG and at $0.3251 per pound for Mexican GH tomatoes from July 1 through October 22, and at $0.31 per pound and $0.41 per pound from October 23 through June 30 (U.S. Deparment of Commerce, 2013). With the previous floor prices set at $0.1720 per pound during summer and $0.2169 per pound during winter, the new reference prices for Mexican FG tomatoes increase by 43% in both summer and winter while those of Mexican GH tomatoes increase by 89% in both summer and winter (U.S. Deparment of Commerce, 2013).

To measure possible effects of the changes in Mexican tomato reference prices, we develop demand simulations based on Slutsky and Cournot price elasticities and three scenarios. In all three scenarios, prices of Mexican FG tomatoes and Mexican GH tomatoes are allowed to increase by the agreed-upon changes in reference prices, 43% and 89%. In the first scenario, prices of U.S. FG and U.S. GH tomatoes do not change (0% increases). In the second scenario, prices of U.S. FG and GH increase by 20% and 40%, while in the third scenario prices of U.S. FG and GH increase by 43% and 89%.

When expenditure is compensated to keep real income constant, the simulated cumulative results (table 5) based on Slutsky elasticities and the three scenarios indicate that, under these assumptions, the quantities demanded of Mexican tomatoes decrease in all three scenarios, while quantities demanded of U.S. tomatoes increase in the first two scenarios but decrease in the third. Expenditures for all tomato types increase in all three scenarios but by differing amounts. Expenditures for Mexican FG increase about 12% in all three scenarios, the least percent change in expenditures among all tomato types, while the percentage increase of expenditures for Mexican GH is the largest for the first two scenarios and is just below that of U.S. GH in the third scenario. Expenditures increase by a greater percentage for U.S. GH than for U.S. FG except for the first scenario, in which U.S. price increases are 0%.

Cumulative simulation results based on the Cournot elasticities for the three scenarios are reported in table 6. Of the two types of elasticities, Cournot price elasticities measure market responses to changes in price better than Slutsky ones, and, accordingly, the simulation results based on Cournot elasticities better capture cumulative market effects of the price changes. Now, quantities demanded decrease for all tomato types for all three scenarios, and the percentage decreases are greater absolutely than those from the Slutsky simulations. The most striking result is that expenditures decrease for all tomato types for all three scenarios. In all scenarios, the percentage decrease in expenditures of U.S. FG is smallest and largest for U.S. GH. When comparing Mexican FG to Mexican GH, the percentage decrease in expenditures of Mexican GH is larger absolutely than that of Mexican FG except for scenario one.

Further simulations are performed to measure the effects of plausible Mexican tomato price changes due to the new Suspension Act and allowing prices of U.S. tomatoes to change by increments ranging from 0% to 43% for U.S. FG and 0% to 89% for U.S. GH. The three price

Table 5. Cumulative Simulated Effects of the New Suspension Agreement on Tomato Quantities and Expenditures Based on CBS Slutsky Price Elasticities and Three Price Scenarios

Tomato Category	2014 Quantity (Million cwt)	2014 Expenditure ($US Million)	2014 Prices ($/cwt)	New price ($/cwt)	Change in Quantity (Million cwt)	% Change in Quantity	New Expenditure ($US Million)	Change in Expenditure ($US Million)	% Change in Expenditure
					Cumulative Demand Effects of All Price Increases				
					43% increase-Mexican FG; 89% increase-Mexican GH; 0% increase-U.S. FG; 0% increase-U.S. GH				
U.S. FG	18.20	784.24	43.09	43.09	3.06	16.8%	915.91	131.67	16.8%
U.S. GH	2.10	152.82	72.77	72.77	0.23	11.2%	169.90	17.08	11.2%
Mexican FG	12.60	505.89	40.15	57.41	−2.76	−21.9%	565.07	59.18	11.7%
Mexican GH	16.90	1,077.54	63.76	120.51	−2.60	−15.4%	1722.72	645.18	59.9%
					43% increase-Mexican FG; 89% increase-Mexican GH; 20% increase-U.S. FG; 40% increase-U.S. GH				
U.S. FG	18.2	784.24	43.09	51.71	0.47	2.6%	965.46	181.22	23.1%
U.S. GH	2.1	152.82	72.77	101.88	0.08	4.0%	222.46	69.64	45.6%
Mexican FG	12.6	505.89	40.15	57.41	−2.73	−21.7%	566.66	60.77	12.0%
Mexican GH	16.9	1,077.54	63.76	120.51	−1.93	−11.4%	1804.19	726.64	67.4%
					43% increase-Mexican FG; 89% increase-Mexican GH; 43% increase-U.S. FG; 89% increase-U.S. GH				
U.S. FG	18.2	784.24	43.09	61.62	−3.88	−21.3%	882.59	98.35	12.5%
U.S. GH	2.1	152.82	72.77	137.54	−0.11	−5.4%	273.37	120.56	78.9%
Mexican FG	12.6	505.89	40.15	57.41	−2.73	−21.7%	566.66	60.77	12.0%
Mexican GH	16.9	1,077.54	63.76	120.51	−1.15	−6.8%	1897.87	820.32	76.1%

Notes: FG is used as an abbreviation for field-grown tomatoes. GH is used as an abbreviation for greenhouse tomatoes.

Table 6. Cumulative Simulated Effects of the New Suspension Agreement on Tomato Quantities and Expenditures Based on CBS Cournot Price Elasticities and Three Price Scenarios

Tomato Category	2014 Quantity (Million cwt)	2014 Expenditure ($US Million)	2014 Prices ($/cwt)	New price ($/cwt)	Change in Quantity (Million cwt)	% Change in Quantity	New Expenditure ($US Million)	Change in Expenditure ($US Million)	% Change in Expenditure
Cumulative Demand Effects of All Price Increases									
43% increase-Mexican FG; 89% increase-Mexican GH; 0% increase-U.S. FG; 0% increase-U.S. GH									
U.S. FG	18.2	784.24	43.09	43.09	−0.94	−5.2%	743.77	−40.47	−5.2%
U.S. GH	2.1	152.82	72.77	72.77	−0.92	−43.6%	86.17	−66.64	−43.6%
Mexican FG	12.6	505.89	40.15	57.41	−5.48	−43.5%	408.95	−96.94	−19.2%
Mexican GH	16.9	1,077.54	63.76	120.51	−8.71	−51.5%	986.92	−90.63	−8%
43% increase-Mexican FG; 89% increase-Mexican GH; 20% increase-U.S. FG; 40% increase-U.S. GH									
U.S. FG	18.2	784.24	43.09	51.71	−4.18	−23.0%	725.01	−59.23	−7.6%
U.S. GH	2.1	152.82	72.77	101.88	−1.30	−62.0%	81.28	−71.54	−46.8%
Mexican FG	12.6	505.89	40.15	57.41	−5.48	−43.5%	408.95	−96.94	−19.2%
Mexican GH	16.9	1,077.54	63.76	120.51	−10.43	−61.7%	779.19	−298.36	−27.7%
43% increase-Mexican FG; 89% increase-Mexican GH; 43% increase-U.S. FG; 89% increase-U.S. GH									
U.S. FG	18.2	784.24	43.09	61.62	−7.90	−43.4%	634.41	−149.83	−19.1%
U.S. GH	2.1	152.82	72.77	137.54	−1.78	−84.6%	44.62	−108.19	−70.8%
Mexican FG	12.6	505.89	40.15	57.41	−5.48	−43.5%	408.95	−96.94	−19.2%
Mexican GH	16.9	1,077.54	63.76	120.51	−12.50	−74.0%	530.52	−547.02	−50.8%

Notes: FG is used as an abbreviation for field-grown tomatoes. GH is used as an abbreviation for greenhouse tomatoes.

scenarios for Mexican tomato prices are as follows: reference prices are entirely reflected (43% increase in Mexican FG and 89% increase in Mexican GH); reference prices are partially reflected (20% increase in Mexican FG and 40% increase in Mexican GH); and reference prices are not reflected. The simulated cumulative results for expenditures for the four types of tomatoes are shown in figure 4.

When reference prices are fully reflected in Mexican tomato price increases, percentage changes in expenditures for all four types of tomatoes are negative for all simulated prices of U.S. tomatoes. When reference prices are partially reflected, the percentage changes in expenditure are negative in all U.S. price ranges for U.S. FG, U.S. GH, and Mexican FG. However, it is positive for Mexican GH until the prices of U.S. FG and U.S. GH increase beyond 15% and 30%, when it becomes negative. When reference prices are not reflected in Mexican tomato prices, the percentage changes in expenditures of Mexican GH are negative for all U.S. simulated price changes, those of U.S. GH are positive throughout, those of Mexican FG are unchanged throughout, and those of U.S. FG are positive until the prices of U.S. FG and U.S. GH increase by 43% and 89%, when it becomes negative.

Conclusions

The trade conflict between U.S. and Mexico fresh tomato producers has been a repetitive issue over the past few decades. In 1996, the United States established a fixed minimum entrance price for Mexican tomatoes as part of a complex trade agreement. Nevertheless, as the executive vice president of the Florida Tomato Exchange pointed out, "tomato sales have dropped as low as $250 million annually, from as much as $500 million. . . which has led to a push to rescind the agreement" (Strom and Malkin, 2012).

The 2013 renegotiated antidumping investigation suspension agreement between the United States Department of Commerce and the exporters and growers of Mexican fresh tomatoes raised the reference prices of Mexican tomatoes relative to reference prices under the previous agreement (depending upon their category) (U.S. Deparment of Commerce, 2013).[5] While this study agrees with the importance of categorizing tomatoes, it goes further by analyzing the effects of income, substitution, and complementary linkages among the categories of tomatoes. In the aggregate analysis, Slustky cross-price elasticities indicate that U.S. consumers perceive U.S. tomatoes to be competitive or substitute products with Mexican tomatoes. However, the more detailed, disaggregated analysis reveals that U.S. FG tomatoes are perceived as competitive with Mexican FG and Mexican GH tomatoes, while U.S. GH tomatoes are perceived as competitive with Mexican FG tomatoes but not Mexican GH tomatoes. Additionally, Mexican FG and Mexican GH tomatoes are perceived as complements.

When we assess the impact of the renegotiated suspension agreement on the fresh tomato market in the United States, taking into account both the substitution and income effects of reference price changes, we find that the cumulative effects of fully reflected increases in reference prices for Mexican FG and Mexican GH tomatoes decrease the quantities demanded for domestically produced and Mexican FG and GH tomatoes. Interestingly, in the likely case of U.S. tomato prices increasing as a result of higher Mexican tomato prices, the quantity decreases of U.S. tomatoes increase absolutely.

When reference prices are fully reflected in Mexican tomato prices and nominal income remains constant, we find that expenditures for both U.S. and Mexican tomatoes, including FG and GH, decrease. Further, if U.S. tomato prices also increase, the decreases in expenditures for U.S. tomatoes and Mexican GH tomatoes increase absolutely. However, we also find that changes in expenditures

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[5] The suspension agreement increased reference prices for Mexican field-grown tomatoes by 43% and for Mexican greenhouse tomatoes by 89%. Reference prices for Mexican specialty tomatoes were increased by between 107% and 172%.
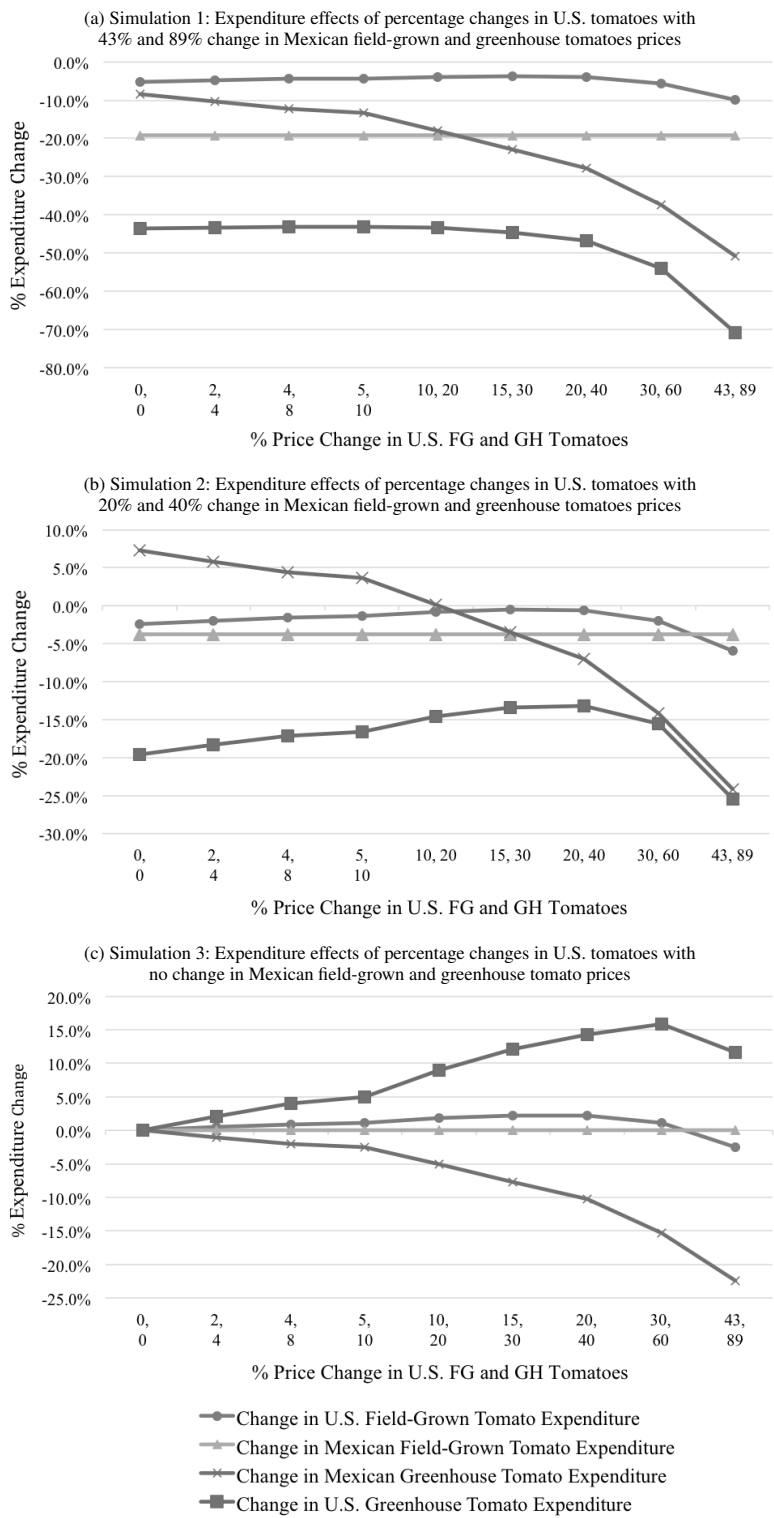
(a) Simulation 1: Expenditure effects of percentage changes in U.S. tomatoes with
43% and 89% change in Mexican field-grown and greenhouse tomatoes prices

(b) Simulation 2: Expenditure effects of percentage changes in U.S. tomatoes with
20% and 40% change in Mexican field-grown and greenhouse tomatoes prices

(c) Simulation 3: Expenditure effects of percentage changes in U.S. tomatoes with
no change in Mexican field-grown and greenhouse tomato prices

**Figure 4. The Simulated Effects of Reference Price Changes on Tomato Expenditures, 2012
Prices and Quantities**

Notes: Simulated by authors from estimated elasticities.

are sensitive to how much Mexican tomato prices and U.S. prices change. For example, if the new reference price increases are partially reflected in Mexican tomato prices, percentage changes in expenditures for Mexican GH tomatoes are positive when price changes are smaller than 15% for U.S. FG and 30% for U.S. GH tomatoes. When Mexican tomato prices do not increase at all, the percentage change of expenditures for U.S. GH tomatoes is positive throughout the entire range of U.S. price changes. It is also positive but small for U.S. FG tomatoes unless prices increase by 43% for U.S. FG and 89% for U.S. GH tomatoes.

Overall, U.S. consumers perceive U.S. FG tomatoes, U.S. GH tomatoes, and Mexican FG tomatoes to be similar or substitute products to imported tomatoes, indicating strong competition between domestically produced FG tomatoes and imported tomatoes. However, when taking into account the income effect of the reference price increases in Mexican tomatoes, the income effect of these price changes is larger than the substitution effect, causing the quantities demanded of U.S. tomatoes to decrease in response to increases in Mexican tomato prices. In contrast, the quantities demanded of U.S. FG and U.S. GH tomatoes would increase if total U.S. tomato expenditure on all tomatoes increased. Accordingly, a policy that increases total U.S. tomato expenditures would be better for U.S. tomato producers than the newly agreed upon reference price policy because the quantity demanded of U.S. FG tomatoes responds positively to a tomato expenditure increase.

In conclusion, simulation results show that—because of the newly renegotiated suspension agreement—price increases of Mexican FG and Mexican GH tomatoes would lead to a loss in expenditures for U.S. FG tomatoes. Only when Mexican tomato prices do not increase are expenditure changes positive for U.S. FG tomatoes. However, in the more probable case of increases in Mexican tomato prices, expenditues for both U.S. FG and GH tomato expenditures decrease, with those for U.S. GH tomatoes decreasing by the largest percentage. Taken together, our results suggest that the upward renegotiated reference prices for Mexican tomatoes will likely decrease the quantity demanded of U.S. and Mexican tomatoes as well as expenditures for all U.S. tomatoes and Mexican FG tomatoes. Under the conditions of partially reflected reference price increases in Mexican tomato prices, changes in the expenditures for Mexican GH tomatoes would be positive for relatively small increases in U.S. tomato prices.

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Appendix

Table A1. Tests on Time Series Properties of the Data

	Unit Root Tests			
	Aggregate Model		**Disaggregated Model**	
Variable	**Test Statistic**	**Critical Value (0.05)**	**Test Statistic**	**Critical Value (0.05)**
$w_1 d(\ln q_1)$	-5.72 (12)	-2.87	-5.29 (0)	-2.89
$w_2 d(\ln q_2)$	-4.78 (12)	-2.87	-3.22 (3)	-2.89
$w_3 d(\ln q_3)$	-6.20 (1)	-2.87	-4.58 (0)	-2.89
$w_4 d(\ln q_4)$	-7.94 (0)	-2.87	-6.81 (1)	-2.89
$w_5 d(\ln q_5)$	-9.77 (0)	-2.87	-5.89 (0)	-2.89
$d(\ln p_1)$	-6.55 (12)	-2.87	-5.60 (0)	-2.89
$d(\ln p_2)$	-7.99 (12)	-2.87	-5.43 (0)	-2.89
$d(\ln p_3)$	-9.52 (11)	-2.87	-3.89 (0)	-2.89
$d(\ln p_4)$	-5.64 (12)	-2.87	-5.06 (1)	-2.89
$d(\ln p_5)$	-8.57 (0)	-2.87	-5.18 (0)	-2.89
$d(\ln Q)$	-11.96 (0)	-2.87	-7.03 (0)	-2.89
$d(\ln P)$	-6.68 (12)	-2.87	-5.77 (0)	-2.89

	Parameter Stability (Structural Break) Tests			
	Aggregate Model		**Disaggregated Model**	
	Test Statistic	**Critical Value (0.05)**	**Test Statistic**	**Critical Value (0.05)**
System *Sup*-F	2.05 (01/92)	2.31	0.59 (02/11)	0.86

Notes: Optimal number of augmented terms in the Augmented Dickey Fuller (ADF) test regressions are selected via Schwarz Information Criterion (SIC) and given in parentheses. The test considered is a system extension of Andrews (2003) supremum-F test for an unknown break point. The exact distribution of the test statistic is not known under the null; critical values are obtained from 1,000 bootstrap replications. The numbers in parentheses are the chosen break dates by the test; they are insignificant at the 5% level.

Table A2. Log-Likelihood Ratio Tests for Homogeneity and Symmetry, Aggregate Analysis

	Log-Likelihood Values	$-2[L(\theta^R) - L(\theta^U)]$	$\chi^2(0.05)$
General Model			
Unrestricted Model (26)	3,290.87		
Homogeneity (22)	3,289.10	3.54	9.49
Homogeneity and Symmetry (16)	3,281.97	14.26	12.59
Rotterdam Model			
Unrestricted Model (24)	3,261.56		
Homogeneity (20)	3,259.51	4.10	9.49
Homogeneity and Symmetry (14)	3,253.22	12.58	12.59
CBS Model			
Unrestricted Model (24)	3,224.13		
Homogeneity (20)	3,221.96	4.34	9.49
Homogeneity and Symmetry (14)	3,213.53	16.86	12.59
AIDS Model			
Unrestricted Model (24)	3,219.25		
Homogeneity (20)	3,217.98	2.54	9.49
Homogeneity and Symmetry (14)	3,208.59	18.78	12.59
NBR Model			
Unrestricted Model (24)	3,206.16		
Homogeneity (20)	3,204.92	2.48	9.49
Homogeneity and Symmetry (14)	3,198.03	13.78	12.59

Notes: Number of parameters estimated is given in parenthesis. $L(\theta^R)$ and $L(\theta^U)$ are the log-likelihood values of the restricted and the unrestricted models, and θ is the vector of parameter estimates.

Table A3. Model Choice Based on Log-Likelihood Ratio Tests, Aggregate Analysis

	Log-Likelihood Values	$-2[L(\theta^R) - L(\theta^U)]$	$\chi^2(0.05)$
General Model (16)	3,281.97		
Rotterdam Model (14)	3,253.22	57.50	5.99
CBS Model (14)	3,213.53	136.88	5.99
AIDS Model (14)	3,208.59	146.76	5.99
NBR Model (14)	3,198.03	167.88	5.99

Notes: Number of parameters estimated is given in parenthesis. $L(\theta^R)$ and $L(\theta^U)$ are the log-likelihood values of the restricted and the unrestricted models, and θ is the vector of parameter estimates. LR values of tested model against the General model, homogeneity and symmetry imposed on both.

Table A4. Log-Likelihood Ratio Tests for Homogeneity and Symmetry, Disaggregated Analysis

	Log-Likelihood Values	$-2[L(\theta^R) - L(\theta^U)]$	$\chi^2(0.05)$
General Model			
Unrestricted Model (26)	908.43		
Homogeneity (22)	907.21	2.44	9.49
Homogeneity and Symmetry (16)	904.13	6.15	12.59
Rotterdam Model			
Unrestricted Model (24)	905.83		
Homogeneity (20)	904.33	3.00	9.49
Homogeneity and Symmetry (14)	901.05	6.56	12.59
CBS Model			
Unrestricted Model (24)	907.16		
Homogeneity (20)	906.10	2.13	9.49
Homogeneity and Symmetry (14)	903.23	5.73	12.59
AIDS Model			
Unrestricted Model (24)	875.00		
Homogeneity (20)	872.77	4.47	9.49
Homogeneity and Symmetry (14)	870.56	4.42	12.59
NBR Model			
Unrestricted Model (24)	871.60		
Homogeneity (20)	868.92	5.37	9.49
Homogeneity and Symmetry (14)	866.38	5.07	12.59

Notes: Number of parameters estimated is given in parenthesis. $L(\theta^R)$ and $L(\theta^U)$ are the log-likelihood values of the restricted and the unrestricted models, and θ is the vector of parameter estimates.

Table A5. Model Choice Based on Log-Likelihood Ratio Tests, Disaggregated Analysis

	Log-Likelihood Values	$-2[L(\theta^R) - L(\theta^U)]$	$\chi^2(0.05)$
General Model (16)	904.13		
Rotterdam Model (14)	901.05	6.16	5.99
CBS Model (14)	903.23	1.80	5.99
AIDS Model (14)	870.56	67.15	5.99
NBR Model (14)	866.38	75.50	5.99

Notes: Number of parameters estimated is given in parenthesis. $L(\theta^R)$ and $L(\theta^U)$ are the LR values of the restricted and the unrestricted models, and θ is the vector of parameter estimates. LR values of tested model against the General model, homogeneity, and symmetry imposed on both.