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How trade affects the US produce industry: the case of fresh tomatoes

RESEARCH ARTICLE

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Abstract

The US produce industry faces intensifying competition from imports, particularly those from Mexico, the largest exporter of produce to the United States. Fresh produce imports from Mexico have grown dramatically in recent years. This study examines the impact of increasing fresh tomato imports from Mexico on market price and revenue of US growers. Results show that tomato prices are highly sensitive to supply, suggesting a saturated market. Imports from Mexico have significant negative impacts on the prices of US domestic tomatoes. A scenario of 50% increase in tomato imports from Mexico could result in a $252 million (27%) revenue loss for American growers, thus posing great challenges to the sustainability of the declining US tomato industry.

Keywords: Mexican competition, trade, produce industry, fresh tomatoes, demand analysis
JEL code: Q11, Q13, Q18

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1. Introduction

The US fresh produce industry has been facing various challenges over the last two decades. Foreign competition is among the greatest challenges and has had significant impacts on major fresh produce commodities in the United States such as tomatoes (Guan *et al.*, 2018a), peppers (Biswas *et al.*, 2018), and berries (Suh *et al.*, 2017). The case of the tomato industry provides a perfect example of the intensifying competition from imports in the produce market. Fresh tomatoes are one of the largest agricultural commodities traded between the United States and Mexico. The industry has declined significantly since the North American Free Trade Agreement (NAFTA) took effect in 1994, with Mexico emerging as a major supplier dominating the US tomato market (Wu *et al.*, 2018a). Over a ten-year period from 2009 to 2019, the volume and value of imported tomatoes from Mexico to the United States have increased by 62 and 76%, respectively. Tomato imports from Mexico to the United States reached almost $2 billion in 2019. The surging imports have caused great distresses in the US tomato industry. California and Florida, the major producers of fresh tomatoes in the United States, have seen significant declines in tomato production area over 2009-2019, from 39,500 acres to 25,500 acres and from 34,600 acres to 25,000 acres, respectively (USDA-NASS, 2020). The rapid declines have caused mounting trade tensions between the two countries in recent years (Guan *et al.*, 2018b; Wu *et al.*, 2018a).

Studies of U.S.-Mexico vegetable trade have investigated the effect of U.S. import tariffs on the growth in U.S. imports of fresh vegetables (Gantz, 2019; Málaga *et al.*, 2001; Marchant and Nanga, 1996). NAFTA eliminated U.S. vegetable tariffs and has been credited for the trade performance. Like NAFTA, the United States-Mexico-Canada Agreement (USMCA) will continue to foster market integration between the United States and Mexico and facilitate the free movement of agricultural commodities. In the meanwhile, Mexico's subsidies allotted for modern agricultural technologies (e.g. protected production and drip irrigation) have rapidly expanded its production capacity and pose a great challenge to the US tomato industry (Wu *et al.*, 2018b). Although the suspension of antidumping investigation agreement sets floor prices for imported Mexican tomatoes, studies show that the effect of the floor prices is limited (Wu *et al.*, 2018a). The surge of Mexican tomatoes on the US market has significantly reduced the market share of US domestic tomatoes. This study investigates the effect of tomato imports from Mexico on market prices and the sustainability of the US tomato industry to inform policy making and strategic business planning in the US produce sector.

This study applies the Generalized Inverse Demand System (GIDS) model (Brown *et al.*, 1995; Eales and Unnevehr, 1988) to disaggregated data reflecting both variety and origin. Proper disaggregation could avoid specification errors and generate more insights into consumer purchase behavior due to variety and origin being important differentiating characteristics in consumer decisions. In addition, weekly data as opposed to monthly (Asci *et al.*, 2016) or quarterly (Seale *et al.*, 2013) data are used to estimate potential economic losses attributed to depressed commodity prices as well as unharvested crops that are abandoned when prices are too low, thus providing a more robust analysis.

The rest of the paper presents (1) an overview of Mexican competition in the US fresh tomato market; (2) the demand system model; (3) a description of the data sources; (4) a discussion of the empirical results; and (5) a summary of the major findings and policy implications.

2. Overview of Mexican competition in the US fresh tomato market

In the United States, Florida (winter tomatoes) and California (summer tomatoes) are the two largest producers of fresh tomatoes. Both industries have declined since NAFTA took effect in 1994. Florida tomato production, which totaled 1,716 million pounds in 1993, more than double the imports from Mexico that year, declined to 866 million pounds by 2019 (accounting for only 23% of fresh tomatoes sold in the United States in 2019). California tomato production, averaging 1,083 million pounds annually until 2011, trended downward to 726 million pounds in 2019 (Figure 1). The decline of the US tomato industry coincided with

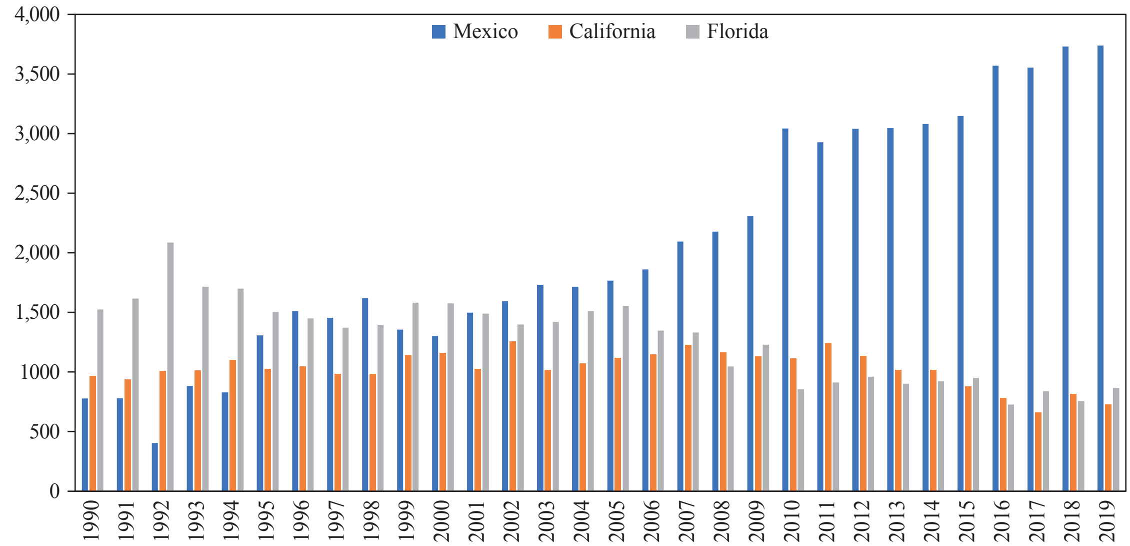

Figure 1. Tomato quantities (million pounds) imported from Mexico and produced in Florida and California (GTIS, 2020; USDA-NASS, 2020).

a rapid growth of imports from Mexico, which increased from 883 million pounds in 1993 to 3,740 million pounds in 2019, growing 424%.

Round and plum tomatoes account for over 95% of the fresh tomato supply in the US market. Other varieties, such as cherry and grape tomatoes, are not considered in the study because (1) they are popular for salads and snacking with less substitution with round and plum tomatoes (Whiting *et al.*, 2003); and (2) they have a smaller import share. Imported cherry and grape tomatoes accounted for only 6% of total tomato imports in 2019.

Over a six-year period, 2014-2019, the annual amount of tomatoes sold in the US market fluctuated at around 5,000 million pounds. In 2014, US round (1,758 million pounds) and plum (273 million pounds) tomatoes accounted for 35 and 5% of the total US market supply, respectively, compared to Mexican round (29%) and plum (24%) tomatoes sold in the US market that year. While the United States imports round tomatoes from other countries (ROW, rest of the world), such as Canada, the Netherlands, and Spain, the ROW market share is much smaller at about 6%. In 2019, US round and plum tomatoes made up 27 and 8% of the total US market supply, respectively, while the share of Mexican round and plum tomatoes made up 28 and 30%, respectively. During 2014-2019, the gap in overall tomato market share between the United States and Mexico widened, from 40 vs 53% to 35 vs 58%. US tomato growers are likely to lose even more market share as Mexico continues to increase its tomato production capacity.

The seasonal pattern of tomato supplies suggests that Mexican tomatoes are a greater threat to US winter tomato growers (Figure 2). During 2014-2019, the market share of Mexican tomatoes in the winter window was 61% (33% for round and 28% for plum) compared to US tomatoes' 34% (29% for round and 5% for plum). In comparison, Mexico accounted for only 44% (23% for round and 21% for plum) of the total summer market supply, which was similar to the market share of US tomatoes. US tomato growers, particularly Florida growers, contend that the dominant status of Mexican tomatoes in the winter season has depressed market prices due to unfair trade practices by Mexico. This study aims to quantify the effect of Mexican tomato imports on the US tomato industry to inform policy making in the US produce sector.

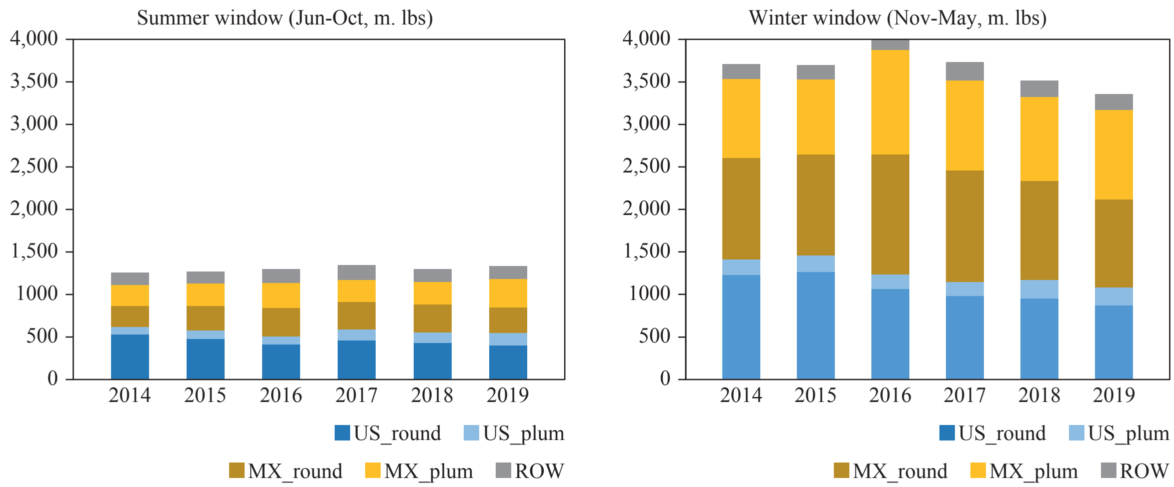

Figure 2. Tomato shipments in (A) summer and (B) winter windows (USDA-AMS, 2020).

3. Methods

Traditional demand system models assume prices are predetermined at the market level, which is unrealistic for perishable goods (Asci *et al.*, 2016; Suh *et al.*, 2017). This study uses the Generalized Inverse Demand System (GIDS) which properly addresses the issue (Brown *et al.*, 1995; Eales and Unnevehr, 1988; Li *et al.*, 2019; Moore and Griffiths, 2018; Wong and Park, 2018). Following Holt and Goodwin (1997), quantities of tomatoes are assumed fixed in the short run because the perishable nature of tomatoes requires products to be cleared in market within a short timeframe, and the relatively long production cycle makes adjustment within season infeasible. Consistent with Fousekis and Revell (2004), we assume multi-stage budgeting and weak separability so that U.S. consumers allocate total expenditure among groups of commodities, tomatoes being one of them. The assumption of weak separability, which implies that tomatoes are weakly separable from other foods in consumer choices, also enables us to focus empirically on interaction among tomato types.

The GIDS nests four differential inverse demand models: Rotterdam Inverse Demand System (RIDS), Almost Ideal Inverse Demand System (AIIDS), Inverse Central Bureau of Statistics (ICBS), and Inverse National Bureau of Research (INBR) models (Brown *et al.*, 1995). RIDS and AIIDS are two flexible specifications introduced by Barten and Bettendorf (1989). The ICBS model was established by combining the AIIDS scale parameterization and the RIDS quantity parameterization, while the INBR model uses the RIDS scale parameterization and the AIIDS quantity parameterization (Eales *et al.*, 1997).

Consider that the total budget of a representative consumer $m = \sum_{i=1}^{n} p_i q_i$, where p_i and q_i are the price and quantity of the ith good, respectively, and n is the number of goods. Denote $\pi_i = p_i/m$ as a normalized price. The consumer is assumed to maximize his utility $u = u(q)$ subject to the budget constraint (m), where q is the vector of quantities ($q_1,\dots, q_n$). The compensated inverse demand function can be derived from a distance function $D = D(u,q)$, which measures the proportional amount by which quantities must be scaled back to reach a new indifference curve (Deaton and Muellbauer, 1980). We assume the distance function is homogeneous, concave, non-decreasing in quantities, and decreasing in utility. Therefore, the normalized price π_i can be derived by differentiating the distance function with respect to q_1.

$$\pi_i(u,q) = \frac{\partial D(u,q)}{\partial q_i} \quad (1)$$

Totally differentiating $\pi_i(u,q)$ yields

$$d\pi_i(u,q) = \frac{\partial \pi_i}{\partial u} du + \sum_{j=1}^{n} \frac{\partial \pi_i}{\partial q_j} dq_j \quad (2)$$

where the first term ($\frac{\partial \pi_i}{\partial u} du$) represents the scale effects, and the second term ($\sum_{j=1}^{n} \frac{\partial \pi_i}{\partial q_j} dq_j$) represents the substitution effects. If we define Q as a reference quantity bundle for all goods, then any q_i can be written as $q_i = k_i Q$, where k_i is a positive scalar for goods i. Equation 2 can then be rewritten as:

$$d\pi_i(u,q) = \frac{\partial ln\pi_i}{\partial lnk_i} \sum_{j=1}^{n} dlnu/(\frac{\partial lnu}{\partial lnk_j}) + \sum_{j=1}^{n} \frac{\partial \pi_i}{\partial q_j} dq_j \tag{2'}$$

Multiplying Equation 2′ by q and reorganizing it to obtain RIDS:

$$w_i dln\pi_i = \theta_i d\ lnQ + \sum_{j=1}^{n} \theta_{ij}\ dlnq_j \tag{3}$$

where $\theta_i = w_i \frac{\partial ln\pi_i}{\partial lnk_i}$ and $\theta_{ij} = w_i \frac{\partial ln\pi_i}{\partial lnq_j}$ are the scale elasticity and compensated quantity elasticity (flexibility), respectively, multiplied by the budget share $w_i = p_i q_i / m$, and $d\ lnQ = \sum_{j=1}^{n} w_i dlnq_j$ is the Divisia volume index. The ICBS model can be obtained by adding $w_i \theta_i d\ lnQ$ to both sides of Equation 3.

$$w_i dln\frac{p_i}{P} = \gamma_i d\ lnQ + \sum_{j=1}^{n} \theta_{ij}\ dlnq_j \tag{4}$$

where $P = \sum_{j=1}^{n} w_i dlnp_j$ is the Divisia price index and $\gamma_i = w_i + \theta_i$. Moreover, adding $w_i(d\ lnq_i - d\ lnQ)$ to both sides of Equation 4, we can derive the AIIDS model as:

$$dlnw_i = \gamma_i d\ lnQ + \sum_{j=1}^{n} \gamma_{ij}\ dlnq_j \tag{5}$$

Where $\gamma_{ij} = \theta_{ij} + w_i(\delta_{ij} - w_j)$ and δ_{ij} denotes the Kronecker delta, which is equal to unity if $i=j$ and zero otherwise. Adding $-w_i\ dlnQ$ to both sides of Equation 5 yields the INBR

$$dlnw_i - w_i\ dlnQ = \theta_i d\ lnQ + \sum_{j=1}^{n} \gamma_{ij}\ dlnq_j \tag{6}$$

The GIDS model that nests all four differential demand systems (Equations 3–6) can be written as:

$$w_i dln\pi_i = (\beta_i - d_1 w_i) d\ lnQ + \sum_{j=1}^{n} (\beta_{ij} - d_2 w_i(\delta_{ij} - w_i))\ dlnq_j \tag{7}$$

Where $\beta_i = (1 - d_1)\theta_i + d_1\gamma_i$ and $\beta_{ij} = (1 - d_2)\theta_{ij} + d_2\gamma_{ij}$. d_1 and d_2 are the nesting parameters that can yield four types of inverse demand models. The RIDS, AIIDS, ICBS, and INBR models can be obtained by setting (d_1,d_2) equal to different values: RIDS when $(d_1,d_2) = (1,1)$; AIIDS when $(d_1,d_2) = (0, 0)$; ICBS when $(d_1,d_2) = (0, 1)$; and INBR when $(d_1,d_2) = (1, 0)$. The typical demand restrictions for GIDS are $\sum_i \theta_i = -1$ and $\sum_i \theta_{ij} = 0$ for adding up, $\sum_j \theta_{ij} = 0$ for homogeneity, and $\theta_{ji} = \theta_{ij}$ for symmetry. The flexibilities, including price flexibilities (f_{ij}) and scale flexibilities (f_i), can be calculated (Anderson, 1980; Eales *et al.*, 1997) as

$$f_{ij} = \frac{\theta_{ij}}{w_i} + (d_2 - 1)(\delta_{ij} - w_i) \tag{8}$$

and

$$f_i = \frac{\theta_i}{w_i} + d_1 - 1. \tag{9}$$

4. Data

Weekly data covering the period January 2014 through December 2019 on prices and quantities of fresh tomatoes from the United States, Mexico, and ROW are used. The Quandt-Andrews unknown breakpoint test indicates that there are no structural breaks for both the quantities and prices during this period. Besides the aggregated estimation, we also disaggregate the market into winter and summer windows. The winter window covers approximately 36 weeks from October 23 through June 30, and the summer window has about 16 weeks from July 1 through October 22. Given that only round tomatoes are imported from ROW, the market is divided into US round tomatoes, US plum tomatoes, Mexican round tomatoes, Mexican plum tomatoes, and ROW round tomatoes.

Weekly prices at shipping points and shipment volumes for US and Mexican tomatoes are obtained using USDA-AMS data.[1] Because the price of ROW tomatoes is unavailable at the shipping points and the ROW shipping volumes are only available on a monthly basis, we convert terminal-point prices into shipping-point prices by multiplying the terminal-point prices by the average ratio of Mexican tomato prices at the shipping point to those at the terminal points (Asci *et al.*, 2016), and we convert monthly volumes to weekly volumes using the cubic spline interpolation method. Table 1 presents weekly tomato quantities and shipping-point prices. Some features are worth noting. First, the prices of Mexican tomatoes are comparable to those of US tomatoes in recent years. Second, the overall round tomato prices are higher than the plum tomato prices. Third, ROW round tomatoes have the highest prices because the majority are greenhouse tomatoes imported from Canada.

Dropping the equation for ROW to avoid singularity, we use an Iterative Linear Least Squares Estimator (IL) as proposed by Blundell and Robin (1999) to estimate the remaining four equations. We test the GIDS model first to determine which specification in the nested models is compatible with the data. Next, we test theoretical restrictions of adding-up, homogeneity, and symmetry on the selected model. Then, based on the tests, parameter estimates from the optimal specification are used to calculate flexibilities.

5. Model estimation and results

Wald statistics are used to test whether the GIDS model is rejected in favor of one of the nested models. Test results show that the computed Wald statistics for the RIDS, INBR, and ICBS models are larger than their critical values, which implies those models are too restrictive. The AIIDS model is not rejected at the conventional significance levels (Supplementary Table S1). Therefore, we apply the AIIDS model in the final estimation. Under the AIIDS specification, three theoretical restrictions – adding-up, homogeneity, and symmetry – are applied to the estimation. The estimation results for the final model are provided in Supplementary Table S2.

[1] The prices of US round and plum tomatoes and Mexican plum tomatoes are based on tomatoes packed in single 25-pound cartons, while the price of Mexican round tomatoes is based on tomatoes packed in two-layer cartons.

Table 1. Weekly tomato quantities and prices in the US market, 2014-2019.[1]

Variable	Mean	Std. Dev.[2]	Min	Max
	Quantity (million pounds)			
Quantity of US Round	29	4	24	42
Quantity of US Plum	6	1	2	9
Quantity of MX Round	29	11	14	47
Quantity of MX Plum	25	7	15	37
Quantity of ROW Round	7	4	1	12
	Price ($/pound)			
Price of US Round	0.52	0.22	0.17	1.42
Price of US Plum	0.50	0.18	0.26	1.19
Price of MX Round	0.54	0.25	0.27	1.75
Price of MX Plum	0.47	0.18	0.27	1.16
Price of ROW Round	0.66	0.26	0.27	1.74

[1] MX = Mexico; ROW = rest of the world; US = United States.

[2] Std. Dev. = standard deviation.

5.1 Scale elasticities

Scale elasticities are the price response to the change in the aggregate shipment of tomatoes from all origins. The results in Table 2 indicate that all estimates are negative and statistically significant at the 1% significance level. The estimates represent that a 1% increase in the aggregate shipments of tomatoes will result in a decrease in the prices of US round (1.23%), US plum (0.86%), Mexican round (1.04%), Mexican plum (0.71%), and ROW round (0.94%) tomatoes. The results indicate that the prices of round tomatoes are elastic (scale elasticity less than -1) and those of plum tomatoes are inelastic (scale elasticity greater than -1). The US round tomato prices are the most sensitive to market supply. The estimates in Table 2 also imply that with an increase in aggregate shipments, the market values of US and Mexican round tomato shipments will shrink while those of US and Mexican plum tomatoes will increase, suggesting a saturated US market for round tomatoes. This finding justifies the observation that the US and Mexican plum tomato supplies increased while the round tomato supplies decreased during the study period. Scale elasticities calculated for the two market windows reveal that the difference of the elasticity estimates between the two windows is insignificant (Table 2). The breakdown components of each scale elasticity estimate are presented in Table 3.

5.2 Price flexibilities

Table 3 shows price flexibility estimates. Price flexibilities represent the percentage of changes in tomato prices (rows in Table 3) with respect to a 1% change in tomato shipments from different sources (columns in Table 3). The own-price flexibilities are presented in diagonal elements of Table 3, and the off-diagonal elements are the cross-price flexibilities. Most of the flexibilities are negative and statistically significant at the 1% significance level. All absolute values of flexibilities are less than 1 at the sample mean of the data, implying the price responses are inflexible. The own-price flexibility of US round tomatoes is -0.62, more than triple that of US plum tomatoes (-0.19). Grant *et al.* (2010) find that the own-price flexibility of US tomatoes is less sensitive (-0.37) for the period 1994-2006. The more elastic response found in our study suggests increasing market saturation during 2014-2019. Prices of Mexican tomatoes are relatively less sensitive to their own shipments, at -0.47 and -0.37 for round and plum tomatoes, respectively. Prices of US tomatoes are more sensitive to their own shipments in summer while prices of Mexican tomatoes are more sensitive in winter.

The estimated cross-price flexibilities are mostly negative and statistically significant at the 1% significance level, suggesting substitutable, competing relationships. Price flexibilities of US round tomatoes with respect to shipments of Mexican round and plum tomatoes are -0.30 and -0.22, respectively, for the period 2014-2019, compared to -0.12 for the period 1994-2006 in the study by Jung (2009). The higher flexibilities estimated in our study suggest an increasingly competitive market where Mexico has become a dominant power and its market share has dramatically increased. The prices of US round tomatoes are more sensitive to shipments from Mexico in winter as Mexican tomatoes play a larger role in the winter market (Valdez-Lafarga *et al.*, 2019). For example, an increase of Mexican round tomato shipments reduces the prices of

Table 2. Scale elasticities in the summer and winter windows, 2014-2019.[1,2]

	All		Summer		Winter	
	Scale elasticities	S.E.	Scale elasticities	S.E.	Scale elasticities	S.E.
US round	-1.227***	(0.037)	-1.204***	(0.034)	-1.242***	(0.040)
US plum	-0.855***	(0.048)	-0.884***	(0.038)	-0.835***	(0.055)
MX round	-1.038***	(0.027)	-1.048***	(0.034)	-1.034***	(0.024)
MX plum	-0.712***	(0.047)	-0.682***	(0.051)	-0.727***	(0.045)
ROW round	-0.944***	(0.088)	-0.961***	(0.061)	-0.928***	(0.113)

[1] MX = Mexico; ROW = rest of the world; S.E. = standard error; US = United States.

[2] *** $P<0.01$.

Table 3. Price flexibilities for both windows (summer and winter), 2014-2019.[1,2]

Price change % \ 1% increase in supply	US round	US plum	MX round	MX plum	ROW
	All samples				
US round price	-0.616***	-0.073*	-0.302***	-0.219***	-0.018
	(0.035)	(0.029)	(0.036)	(0.045)	(0.014)
US plum price	-0.228***	-0.194***	-0.191***	-0.214***	-0.028
	(0.043)	(0.037)	(0.046)	(0.055)	(0.017)
MX round price	-0.240***	-0.052*	-0.466***	-0.175***	-0.104***
	(0.025)	(0.020)	(0.027)	(0.032)	(0.010)
MX plum price	-0.132**	-0.051	-0.134**	-0.366***	-0.029
	(0.042)	(0.035)	(0.045)	(0.056)	(0.017)
ROW round price	0.025	-0.025	-0.325***	-0.127	-0.492***
	(0.081)	(0.068)	(0.083)	(0.106)	(0.033)
Expenditure share	0.30	0.07	0.31	0.23	0.09
	Summer window				
US round price	-0.662***	-0.068**	-0.257***	-0.192***	-0.025*
	(0.031)	(0.026)	(0.032)	(0.040)	(0.012)
US plum price	-0.179***	-0.352***	-0.161***	-0.174***	-0.018
	(0.035)	(0.030)	(0.036)	(0.044)	(0.014)
MX round price	-0.310***	-0.067*	-0.311***	-0.224***	-0.136***
	(0.032)	(0.026)	(0.034)	(0.041)	(0.013)
MX plum price	-0.136**	-0.051	-0.170***	-0.305***	-0.020
	(0.046)	(0.038)	(0.048)	(0.061)	(0.019)
ROW round price	0.019	-0.017	-0.229***	-0.089	-0.644***
	(0.056)	(0.048)	(0.058)	(0.074)	(0.025)
Expenditure share	0.34	0.08	0.24	0.21	0.13
	Winter window				
US round price	-0.586***	-0.075*	-0.330***	-0.235***	-0.015
	(0.037)	(0.031)	(0.039)	(0.048)	(0.015)
US plum price	-0.262***	-0.085*	-0.212***	-0.242***	-0.035
	(0.049)	(0.043)	(0.053)	(0.063)	(0.020)
MX round price	-0.216***	-0.046*	-0.520***	-0.158***	-0.093***
	(0.022)	(0.018)	(0.025)	(0.029)	(0.009)
MX plum price	-0.130**	-0.051	-0.117**	-0.396***	-0.033*
	(0.040)	(0.033)	(0.044)	(0.053)	(0.016)
ROW round price	0.031	-0.033	-0.411***	-0.162	-0.353***
	(0.103)	(0.087)	(0.106)	(0.135)	(0.041)
Expenditure share	0.28	0.06	0.34	0.25	0.07

[1] Numbers in parentheses are standard errors. *** $P<0.01$, ** $P<0.05$, * $P<0.1$.

[2] MX = Mexico; ROW = rest of the world; US = United States.

US round tomato price by 0.33% in winter and by only 0.26% in summer, respectively. Since Florida is the major producer in winter, the higher cross-price flexibility in winter implies a heavier competition between Florida and Mexico, which partly explains why the tomato trade dispute has been led by Florida growers (Guan *et al.*, 2018b; Wu *et al.*, 2018a).

The estimated price flexibilities of Mexican round and plum tomatoes with respect to shipments of US round tomatoes are -0.24 and -0.13, respectively, lower (in absolute value) than those of US round tomatoes with respect to shipments of Mexican round and plum tomatoes. Mexican round, Mexican plum, and US round tomatoes are the three major tomato varieties in the US market. The lower price flexibilities of Mexican tomatoes in response to the US tomato supply suggest a more dominant position of Mexican tomatoes in the market. The price responses of Mexican round and plum tomatoes to the shipments of US plum tomatoes were -0.05. These lower price flexibilities are consistent with the fact that US plum tomatoes make up only a very small market share and therefore have little impact on the market.

Our results show that price flexibilities are heterogeneous across varieties. For US tomatoes, own-price flexibilities are significantly different between round and plum. Cross-price flexibilities between US round and plum tomatoes are strikingly distinct (-0.23 vs -0.07), while those between Mexican round and plum tomatoes are only slightly different (-0.13 vs -0.18). Therefore, our results suggest that the aggregation of round and plum tomatoes in demand analysis might result in biased estimates, so great care should be exercised when using aggregated data.

5.3 Economic impact of increasing imports from Mexico

To analyze the economic impacts of increasing imports of Mexican tomatoes on the future of the US tomato industry, we assess two scenarios for both windows. Specifically, we simulate the prices and shipment values of US tomatoes if Mexican shipments (both round and plum tomatoes) grow by 25 and 50%, respectively. The assumption of these two scenarios is based on the historical growth in US imports of Mexican tomatoes over the past decade. The baseline scenario is the average shipment values for plum and round tomatoes during 2014-2019. The possible revenue losses are estimated accounting for both decreased market prices and unharvested crops when prices are too low. Based on the harvest cost and the lowest price observed in shipping points, the threshold price at which growers stop harvesting is assumed to be \$0.22 per pound. We also consider another scenario for the harvest threshold price at \$0.25 per pound given the upward trend of the farm labor wage rate. This trend is expected to continue given various campaigns to raise minimum wages and enforcement of strict immigration policies. Therefore, we will simulate a total of four scenarios with two harvest threshold prices (\$0.22/lb and \$0.25/lb) when Mexican shipments increase by 25 and 50%.

The baseline of weekly prices, the values of round and plum tomatoes, and the changes in prices and shipment values of US tomatoes due to increased Mexican shipments are presented in Supplementary Table S3. In the baseline scenarios for US tomatoes, the summer window shows higher prices for both round and plum tomatoes, while the winter window shows several waves of shipment volumes resulting from staggered planting dates to avoid simultaneous harvesting. In the 25% import growth scenario, both round and plum tomato prices across the weeks would be higher than \$0.22/lb, implying that US growers would continue to harvest and ship tomatoes with no abandonments if the threshold harvest price is at \$0.22/lb. Compared to the baseline case, if the threshold value increases to \$0.25/lb, round tomatoes would be abandoned at the 17th week in April (a loss of \$10.1 million in shipment value compared with the baseline case), while plum tomatoes would be abandoned at the 25th week in June (a loss of \$0.6 million in shipment value). In the scenario of a 50% import growth, more round tomatoes would be abandoned – growers would stop harvesting round tomatoes for two weeks (17th and 18th weeks) with the lower harvest threshold, while they would abandon tomatoes for four weeks (16th to 19th weeks from April to May) with the higher threshold.

The estimated changes of revenue (shipment value) for the US tomato industry due to competition from Mexico under different scenarios are summarized in Table 4. The average annual revenue of US tomatoes during 2014-2019 is approximately \$940 million (\$790 million for round tomatoes and \$150 million for plum tomatoes). Under the scenario of a 25% import growth and the \$0.22/lb harvest threshold price, the total loss of the US tomato industry is \$122 million, accounting for 13% of the average revenue (all of the reduction comes from depressed prices). Under the scenario of a 50% import growth and the \$0.22/lb harvest threshold price, the total loss is \$252 million, accounting for 27% of the average revenue of the baseline scenario (\$241 million from a price reduction and \$11 million from crop abandonment). When the threshold price increases to \$0.25/lb, the total losses will increase to \$131 million and \$282 million, accounting for 14

Table 4. Changes in US tomato shipment values under two import scenarios.

	Scenario 1: 25% import growth		**Scenario 2: 50% import growth**	
Harvested threshold price ($/lb)	0.22	0.25	0.22	0.25
Baselines (mean shipment value in million USD)	940.6	940.6	940.6	940.6
Round tomatoes	790.2	790.2	790.2	790.2
Plum tomatoes	150.4	150.4	150.4	150.4
Price change (%)				
US round tomatoes	-13.5%	-13.5%	-27.1%	-27.1%
US plum tomatoes	-10.9%	-10.9%	-21.8%	-21.8%
Total losses due to depressed prices (million USD)	-121.5	-119.9	-241.3	-236.6
Round tomatoes	-106.1	-104.7	-210.7	-206.0
Plum tomatoes	-15.4	-15.3	-30.6	-30.6
Losses of unharvested crops (million USD)	0.0	-10.7	-10.7	-45.6
Round tomatoes	0.0	-10.1	-10.1	-45.0
Plum tomatoes	0.0	-0.6	-0.6	-0.6
Total losses (million USD)	-121.5	-130.6	-252.0	-282.2
Total losses (%)	-12.9%	-13.9%	-26.8%	-30.0%
Summer window				
Baselines (mean shipment value in million USD)	288.8	288.8	288.8	288.8
Round tomatoes	236.8	236.8	236.8	236.8
Plum tomatoes	52.0	52.0	52.0	52.0
Price change (%)				
US round tomatoes	-11.1%	-11.1%	-20.1%	-20.1%
US plum tomatoes	-8.4%	-8.4%	-21.4%	-21.4%
Total losses due to depressed prices (million USD)	-31.5	-31.5	-63.0	-63.0
Round tomatoes	-27.1	-27.1	-54.1	-54.1
Plum tomatoes	-4.4	-4.4	-8.8	-8.8
Losses of unharvested crops (million USD)	0.0	0.0	0.0	0.0
Round tomatoes	0.0	0.0	0.0	0.0
Plum tomatoes	0.0	0.0	0.0	0.0
Total losses (million USD)	-31.5	-31.5	-63.0	-63.0
Total losses (%)	-10.9%	-10.9%	-21.8%	-21.8%
Winter window				
Baselines (mean shipment value in million USD)	651.8	651.8	651.8	651.8
Round tomatoes	553.4	553.4	553.4	553.4
Plum tomatoes	98.5	98.5	98.5	98.5
Price change (%)				
US round tomatoes	-13.7%	-13.7%	-27.5%	-27.5%
US plum tomatoes	-11.2%	-11.2%	-22.5%	-22.5%
Total losses due to depressed prices (million USD)	-90.0	-88.5	-176.9	-167.5
Round tomatoes	-79.0	-77.6	-155.2	-145.7
Plum tomatoes	-11.0	-10.9	-21.7	-21.7
Losses of unharvested crops (million USD)	0.0	-10.7	-10.7	-45.6
Round tomatoes	0.0	-10.1	-10.1	-45.0
Plum tomatoes	0.0	-0.6	-0.6	-0.6
Total losses (million USD)	-90.0	-99.1	-187.6	-213.1
Total losses (%)	-13.8%	-15.2%	-28.8%	-32.7%

and 30% of the revenue, respectively, if Mexican shipments increase by 25% and 50% (Table 4). It should be noted that if harvesting costs further increase, there would be more losses due to abandonments.

Table 4 also shows the losses for summer and winter windows. In the summer window, depressed prices would reduce the total shipment values of US tomatoes by $32 million (11% of the total value) and $63 million (22% of the total value) in the two import growth scenarios, respectively. There are no unharvested crops. In the winter window, the total losses are $90 million (14% of the total value) and $188 million (29% of the total value) under the 25 and 50% scenarios with a $0.22/lb threshold price. The loss will increase to $99 million (15% of the total value) and $213 million (33% of the total value), respectively, when the threshold price is $0.25/lb. Although the average tomato price is higher over the winter window, Florida growers would abandon more tomatoes. In the 50% scenario with a $0.25/lb threshold price, the financial loss of growers in Florida (winter window) would be more than three times that of California growers (summer window). In sum, Mexican shipments would cause much more negative effects on the tomato industry of Florida than that of California.

6. Discussion and conclusions

The remarkable growth of imports from Mexico under NAFTA/USMCA and its impact on the US tomato industry have led to multiple disputes and negotiations over the years. Investigating the impact of tomato imports under different scenarios, this study finds sensitive and statistically significant price responses to imports. The findings suggest a substitutable relationship and strong competition between US and Mexican tomatoes. Round tomato prices are particularly sensitive to market supply, suggesting a saturated market. The simulation results show that further increase in imports would cause significant losses to the US tomato industry. It would be particularly damaging to the Florida tomato industry.[2]

As foreign competition and domestic challenges such as labor shortages (Bampasidou and Salassi, 2019; Beal Cohen *et al.*, 2020; Guan *et al.*, 2015; Roka and Guan, 2018) and the phase-out of methyl bromide (Cao *et al.*, 2019; Wu *et al.*, 2020) increasingly erode the profitability of US growers, solutions must be found to make the industry viable and competitive. This applies not only to the fresh tomato industry but also to other major fresh produce commodities such as peppers (Biswas *et al.*, 2018) and berries (Suh *et al.*, 2017). Under the USMCA framework, trade between the United States and Mexico will continue to grow. A successful policy should consider not only the overall trade benefit, it should also take into consideration the distribution of the benefit among interest groups to avoid tension and divide in society. The current US agricultural policy needs to be reformed to address the tectonic shift in market shares and trade patterns observed in the last two decades. One area where the government could play an important role is redirecting resources to promote research and innovation and accelerate the development and deployment of new technologies (e.g. mechanization or automation) to make the US produce industry more sustainable. In addition, the United States and Mexico should work together to address market-distorting practices in the Mexican fruit and vegetable industry (Wu *et al.*, 2018b) which could benefit both the US and Mexican tomato industry in an increasingly saturated market (USDA-FAS, 2018).

Supplementary material

Supplementary material can be found online at https://doi.org/10.22434/IFAMR2021.0005

Table S1. Wald test statistics for nested systems.
Table S2. Estimates of parameters for the AIIDS model.
Table S3. Effects of Mexican shipments on weekly prices and shipment values of US tomatoes.

[2] Note that, to disentangle trade impact, the simulation in this study is a static analysis holding non-trade factors (such as technology) constant.

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