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The Food Safety Modernization Act and Differential Revenues to Differently Sized U.S. and Foreign Tomato Producers

Lisha Zhang, James L. Seale Jr., Mechel S. Paggi, and Troy G. Schmitz

The Food Safety Modernization Act (FSMA) provides new U.S. food safety standards to lower the incidence of foodborne diseases. We analyze the FSMA in terms of adoption effects on differently sized domestic and foreign farms producing fresh tomatoes for the U.S. market. Findings indicate that adoption of the FSMA will negatively affect the revenues of very small farms the most as well as small U.S. farms. However, it will positively affect the revenues of foreign farms (especially Canadian) and large U.S. farms. This may lead to the restructuring of tomato production and distribution in the U.S. tomato market.

Key words: farm size, food safety, fresh tomatoes, FSMA, import demand, revenue changes

The Food Safety Modernization Act

Food contamination poses a significant challenge for health and safety regulators. Not only can contaminated food cause food poisoning but, given the interconnected nature of the U.S. food market, a localized contamination at a single food supplier can impact consumers across the country. According to the Centers for Disease Control and Prevention (2017), "On average, each year about 48 million people (one in six Americans) get sick from contaminated foods or beverages, of whom 128,000 are hospitalized, and 3,000 die, as a result of foodborne diseases." While there exists disagreement over the precise findings of these sorts of estimates, there is little doubt that food contamination is an important public issue (Scallan et al., 2011; Byrd-Bredbenner et al., 2015; Popov, Lyon, and Hollcroft, 2016).

The increase in consumption of imported food has also intensified concerns over U.S. food safety (Buzby, 2003; Becker, 2010; Buzby, Unnevehr, and Roberts, 2008; Welburn, Bier, and Hoerning, 2016). According to the U.S. Food and Drug Administration (2018), "approximately 95% of seafood, 51% of fresh fruits and 28% of vegetables are imported". "Imported foods that appear to be adulterated, misbranded, or that fail to comply with U.S. labeling requirements or other laws can be refused entry into the United States by the Food and Drug Administration (FDA)" (Gale and Buzby, 2009, p. 10). From 2014 to 2018, food types most commonly refused entry into the United States because of food safety issues and violations of FDA rules included fishery and

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seafood products (19%), other (19%),[1] vegetables and vegetable products (13%), and fruits and fruit products (11%) (U.S. Food and Drug Administration, 2019).

Over the years, continuing outbreaks of foodborne disease have underscored the importance of updating and improving food safety regulations. According to the Centers for Disease Control and Prevention (2017), "Reducing foodborne illness by 10% would keep five million Americans from getting sick each year." Part of the problem is that the previous law on food safety, which dates to 1938, failed to deal with many current food safety issues in an effective and efficient manner (DeWaal and Plunkett, 2009; Drew and Clydesdale, 2015). In response to present-day food-safety issues, Congress passed the Food Safety Modernization Act (FSMA), which was signed into law by President Obama in 2011.

Under the FSMA, the FDA has the authority to regulate procedures regarding how fresh food should be grown, processed, and transported. In taking a preventative approach, the FSMA places the primary responsibility for food safety on the people and businesses that provide fresh food to the public, whether this includes the farms that produce the food, the businesses that sell the food, and anything in between. The FSMA shifts the burden of responsibility for foodborne illnesses onto food producers and providers, with the hope that this shift will lead to more rapid identification and control of the sources of such outbreaks.

The FSMA contains regulations on both imported and domestically produced fresh foods. Foreign producers exporting fresh food products into the United States must comply with regulations regarding issues such as "soil amendments, hygiene, packaging, temperature controls, animals in the growing area, and water" (U.S. Food and Drug Administration, 2014). Imported products that fail to meet these standards can now be denied entry into the U.S. market.

Not all farms have to comply with the FSMA. In particular, the FSMA exempts compliance by the smallest farms and businesses. In order to qualify for a complete exemption from FSMA requirements, a farmer needs to either not sell produce at all, sell only low-risk or processed produce, or meet the $25,000 revenue cap. It is estimated that such exemptions cover approximately 113,870 farms (U.S. Food and Drug Administration, 2014).

Based on the annual value of production, the U.S. Food and Drug Administration (2014) defines farm sizes as follows: (i) very small farms ($25,000–$250,000), (ii) small farms ($250,000–$500,000), and (iii) large farms (>$500,000). The final rule (U.S. Food and Drug Administration, 2015) specifies different compliance dates for different sizes of farms: January 26, 2018, for large farms; January 26, 2019, for small farms; and January 26, 2020, for very small farms. All farms that must comply with FSMA regulations are allowed two additional years to meet agricultural water requirements.

After excluding the 113,870 farms producing less than $25,000 of fresh food produce, there remain approximately 75,767 farms, of which 40,211 are nonexempt (U.S. Food and Drug Administration, 2014) (Table 1). Among these, 26,947 are very small, 4,693 are small, and 8,571 are large. In total, 149,426 farms are either exempted or not covered by FSMA. Among the uncovered farms, 26,482 are very small, 4,454 are small, and 4,620 are large. Table 2 summarizes additional details about covered farms of different sizes. While large farms comprise only 21% of all farms covered by the FSMA, they own 81% of the total acreage covered. Very small farms, by contrast, make up 67% of FSMA covered farms but account for only 10% of covered acreage. Similarly, the average food sales for large farms is $2,638,384 and only $75,279 for very small farms (U.S. Food and Drug Administration, 2014).

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[1] "Other" includes snack food items, whole-grain/milled-grain products/starch, nuts and edible seeds, dressings and condiments, macaroni and noodle products, coffee and tea, beverage bases, concentrate, nectar, food sweeteners (nutritive), milk/butter/dried milk products, vegetable oils, dietary conventional foods/meal replacements, gelatin/pudding mix/pie filling, soup, cereal preparations/breakfast food, baby food products, ice cream products, meat and meat products (including poultry), filled milk/imitation milk products, vegetable protein products, alcoholic beverages, egg and egg products, prepared salad products.

Table 1. FDA Accounting of Farms Eligible for Qualified Exemptions and Nonexemptions from FSMA

	$25K or Less Monetary Value of Food Produced	Very Small	Small	Large	Total
Total number of farms	113,870	53,429	9,147	13,191	189,637
Total non-exempt farms	–	26,947	4,693	8,571	40,211
Total farms exempt	113,870	26,482	4,454	4,620	149,426

Source: U.S. Food and Drug Administration (2014).

Table 2. FDA Accounting of Farms to Be Nonexempt from FSMA, Other Than Sprouting Operations

	Very Small	Small	Large	Total
Number of farms	26,947	4,693	8,571	40,211
Percentage by size (%)	67	12	21	100
Produce acres	447,342	389,610	3,636,623	4,473,575
Percentage by size (%)	10	9	81	100
Average produce acres per farm	16.6	83	424.3	111.3
Average food sales per farm ($)	75,279	320,696	2,638,384	650,200

Source: U.S. Food and Drug Administration (2014).

This disparity across farm sizes is important because the expected impact of the FSMA on particular farms may depend extensively on farm size. According to Paggi et al. (2013), vegetable and fruit producers, as price takers, will have to comply with whatever rules and standards their buyers in fresh produce markets require, even though the compliance costs of those requirements will differ among producers. These new compliance costs will, in turn, result in substantial structural changes in the market (Hardesty and Kusunose, 2009; Paggi et al., 2013). For instance, adoption and verification of new safety procedures throughout the food supply chain will tend to impose additional costs on farms. As a result, the marginal costs will increase for all farms, regardless of size (Bovay and Sumner, 2018; Bovay, Ferrier, and Zhen, 2018). The average additional cost of adopting these procedures and the negative impact of these new compliance costs will tend to decrease as farm size increases. As a result, the compliance costs of adopting the FSMA will tend to harm very small farms more than large farms.

In this paper, using the fresh tomato industry as an example,[2] we estimate how adoption of the new FSMA regulations will impact the revenues of differently sized farms (both domestic and foreign) that produce fresh tomatoes for sale in the United States in order to determine whether the FSMA will negatively impact fresh produce producers based on the size of their farms or their country of origin. Specifically, we analyze the following questions. How much will quantity demanded for fresh tomatoes, produced either in the United States or abroad, change as a result of the FSMA? How much will the revenues of fresh tomato producers change due to compliance with the FSMA? Will the FSMA have different impacts on producers depending on the size of their operations?

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[2] The harmonized code for “fresh tomatoes” in our study is 0702, which is defined as “tomatoes; fresh and chilled.”

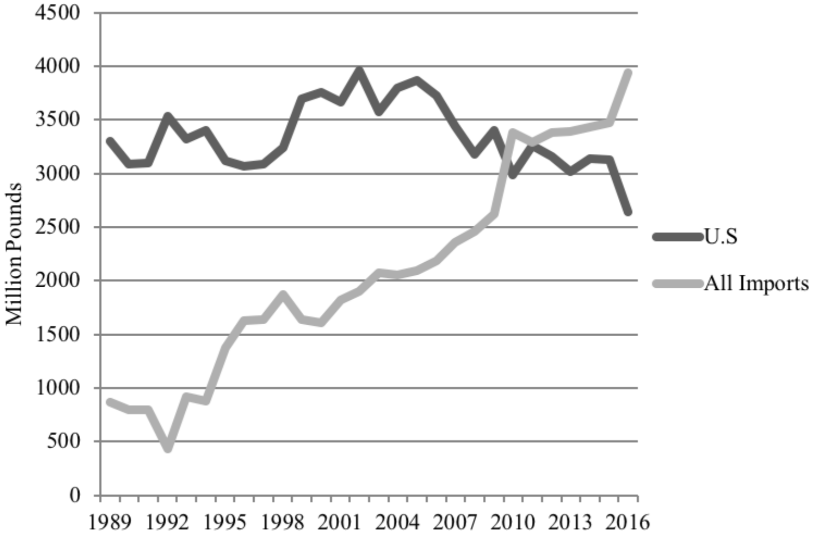

Figure 1. Quantities Demanded for U.S.-Produced and All Imported Fresh Tomatoes, 1989–2017

Data

Since the first group of tomato producers (large farms) was required to comply with the FSMA by January 2018, we used monthly data from January 1989 (the first month with available import data) to December 2017 (the last month before the first group complied with FSMA) for our analysis. Value and quantity data for exports and imports of fresh tomatoes by country of origin were obtained from the USDA Foreign Agricultural Service (FAS) (2019c).[3] Data on domestic production and price were obtained from several sources to reflect the most recent updates. In particular, data on domestic production were collected from the USDA's Economics, Statistics, and Market Information (ESMI) (2019f) (January 1989–December 2009) and Agricultural Marketing Service (AMS) (2019a) (January2010–December 2017).[4] Data on domestic price, measured as the price received by farmers, were obtained from ESMI (2019e) (January 1989–December 2001), the National Agricultural Statistics Service (NASS) (2019d) (January 2002–October 2012, March 2014–December 2017), and AMS (2019b) (November 2012–February 2014). In addition, we transform monthly variables using 12-month lagged differences to adjust for seasonal effects in tomato demand (Kmenta, 1990; Seale, Marchant, and Basso, 2003; Asci et al., 2016; Valdez-Lafarga, Schmitz, and Englin, 2019).

The data indicate two salient facts concerning demand for domestically produced and imported tomatoes. First, while demand for domestically produced tomatoes has stayed relatively stable, demand for imported tomatoes has steadily increased since 1989. In 2010, the quantity demanded of imported fresh tomatoes exceeded that of U.S.-produced tomatoes for the first time (Figure 1). Second, imports of fresh tomatoes originate from only a relatively few countries. As Figure 2 shows, Mexico and Canada are the two primary countries exporting fresh tomatoes to the U.S. market. Tomatoes from Mexico have dominated the U.S. import market since 1989.

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[3] More specifically, "U.S. customs districts" was selected from "data sources," "import consumption" (or "export" for export data) was selected from "product type," and "HS-4" was selected from "product group." The data on expenditure and quantity of imported (or exported) tomatoes from different countries came from HS-4 code "0702."

[4] Consumption of domestically produced tomatoes is equal to domestic production minus exports.

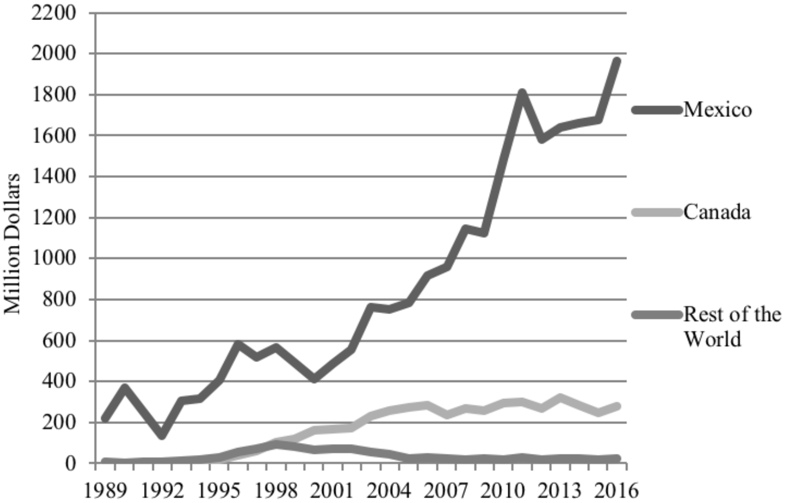

Figure 2. Import Value of Fresh Tomatoes by Country of Origin, 1989–2017

Differential Demand Systems and Choice of Functional Form

The demand elasticities for domestically produced and imported fresh tomatoes estimated or assumed in recent work require revision. For instance, Valdez-Lafarga, Schmitz, and Englin (2019) estimated the Slutsky and Cournot price elasticities for tomatoes produced in the United States, Mexico, Canada, and other countries using monthly data from 1991–2014.[5] They applied the Rotterdam model (Theil, 1965) in their analysis. However, they failed to address why the Rotterdam model best fit the data. Bovay and Sumner (2018) assumed -0.5 as the demand elasticity for their simulations but failed to provide any detail about how that value was obtained.

In contrast, Asci et al. (2016) addressed the question of model selection in a similar fashion to the present study, based on monthly data from 1989–2014. After testing to determine which model best fit that data, they estimated elasticities using the Nesting model (Lee, Brown, and Seale, 1994) and the Central Bureau of Statistics (CBS) model (Keller and van Driel, 1985). However, we cannot use their findings for this study for two reasons: (i) They implicitly assume that the demand for domestically produced tomatoes is equal to domestic production, without addressing the role of exports; and (ii) this study does not include monthly data up to the point at which the first groups of producers adopted the FSMA. In another study, Zhang and Seale (2017) also addressed the question of model selection when estimating elasticities for tomatoes from both domestic and foreign sources, but the analysis failed to address the issue of seasonality in the yearly data from 1989–2014. Thus, given that the approaches taken in recent studies lack certain desirable characteristics, we choose to estimate the demand elasticities of both domestically produced and imported fresh tomatoes ourselves, in order to address the most recent information on demand in the U.S. market for tomatoes. Estimating those elasticities requires both updated data and a test to determine which model best fits that data.

In this paper, we consider five potential differential demand systems: (i) Rotterdam (Theil, 1965); (ii) Almost Ideal Demand System (AIDS) (Deaton and Muellbauer, 1980); (iii) Central Bureau of Statistics (CBS) (Keller and van Driel, 1985); (iv) National Bureau of Research (NBR) (Neves,

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[5] A Slutsky (compensated) price elasticity measures the percentage change in the quantity demanded of good *i* from a 1% change in the price of good *j* holding real expenditure constant while a Cournot (uncompensated) price elasticity measures the percentage change in quantity demanded of good *i* from a 1% change in the price of good *j* holding nominal expenditure constant. A Slutsky price elasticity measures the substitution effect of a price change in good *j* on the quantity demanded of good *i* while a Cournot price elasticity additionally measures the expenditure effect of a price change in good *j* on the quantity demanded of good *i*.

1987); and (v) the Nesting model (Barten, 1993; Lee, Brown, and Seale, 1994). The choice of functional form is based on selecting the model that bests fits the data, based on log-likelihood-ratio tests (LRT). In our analysis, we treat the demands for domestically produced tomatoes and imported tomatoes as weakly separable (Winters, 1984; Seale, Marchant, and Basso, 2003; Asci et al., 2016; Valdez-Lafarga, Schmitz, and Englin, 2019).

The general differential demand equation may be obtained from the results of Barten's (1964) fundamental matrix:

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

where $w_i = p_i q_i / \sum_{i=1}^{n} p_i q_i$ is the budget share of good i; n is the number of goods considered; p_i and q_i are the price and quantity, respectively, of good i; $d(\ln Q) = \sum_{i=1}^{n} w_i d(\ln q_i)$ is the Divisia volume index representing real expenditure; $\theta_i = \frac{\partial(p_i q_i)}{\partial M}$ is the marginal share of good i; M is total expenditure on U.S. tomatoes; and π_{ij} is the i, jth Slutsky (compensated) price parameter.

The Rotterdam model introduced by Theil (1965) is obtained by assuming that θ_i and π_{ij} are constant parameters to be estimated by replacing w_i with $\bar{w}_{it} = (w_{it} + w_{i,t-1})/2$, where t represents time, by letting $d(\ln x_{it}) = \ln x_{it} - \ln x_{i,t-1}$ where x represents p or q, and by adding an error term in equation (1). The functional form of the Rotterdam model is specified as

$$\bar{w}_{it} d(\ln q_{it}) = \theta_i d(\ln Q_t) + \sum_{j=1}^{n} \pi_{ij} d(\ln p_{jt}) + \varepsilon_{it}. \tag{2}$$

By replacing θ_i in the Rotterdam model with $\bar{w}_i + \beta_i$ and rearranging terms, Keller and van Driel (1985) derived the CBS model:

$$\bar{w}_{it}(d(\ln q_{it}) - d(\ln Q_t)) = \beta_i d(\ln Q_t) + \sum_{j=1}^{n} \pi_{ij} d(\ln p_{jt}) + \varepsilon_{it}. \tag{3}$$

The time-series AIDS equation may be obtained from the CBS model by substituting into equation (3) for π_{ij} by $\gamma_{ij} = \pi_{ij} + \bar{w}_i \, \delta_{ij} - \bar{w}_i \bar{w}_j$ (Deaton and Muellbauer, 1980):

$$d(\bar{w}_{it}) = \beta_i d(\ln Q_t) + \sum_j \gamma_{ij} d(\ln p_{jt}) + \varepsilon_{it}. \tag{4}$$

The NBR model (Neves, 1987) is generated by replacing β_i with $\theta_i - \bar{w}_i$ in equation (4), to yield

$$d(\bar{w}_{it}) + \bar{w}_{it} d(Qt) = \theta_i d(\ln Q_t) + \sum_j \gamma_{ij} d(\ln p_{jt}) + \varepsilon_{it}. \tag{5}$$

Note that all four of the above models have the same right-side variables and structure but different dependent variables. The four models are not nested, but Barten (1993) derived a model nesting all four models at the cost of two additional parameters. His approach used different dependent variables for each original model but the same variables and structure on the right side of the equations. Lee, Brown, and Seale (1994) extended Barten's model and specified the functional form of the Nesting model as

$$\bar{w}_{it} d(\ln q_{it}) = (\delta_1 \bar{w}_{it} + d_i) d(\ln Q_t) + \sum_j [e_{ij} - \delta_2 \bar{w}_{it}(\delta_{ij} - \bar{w}_{jt})] d\ln p_{jt} + \varepsilon_{it}, \tag{6}$$

where δ_{ij} is the Kronecker delta ($\delta_{ij} = 1$ if $i = j$; $\delta_{ij} = 0$ if $i \neq j$); $d_i = \delta_1 \beta_i + (1 - \delta_1)\theta_i$; $e_{ij} = \delta_2 \gamma_{ij} + (1 - \delta_2)\pi_{ij}$; and δ_1 and δ_2 are the two additional nesting parameters to be estimated.

The demand restrictions associated with equation (6) are

$$\text{Adding-up:}\quad \sum_i d_i = 1 - \delta_1 \text{ and } \sum_i e_{ij} = 0;$$

$$\text{Homogeneity:}\quad \sum_j e_{ij} = 0; \text{ and}$$

$$\text{Symmetry:}\quad e_{ij} = e_{ji}.$$

By restricting δ_1 and δ_2, as shown below, we arrive at the four competing demand systems:

$$\text{Rotterdam:}\quad \delta_1 = 0,\ \delta_2 = 0,$$

$$\text{CBS:}\quad \delta_1 = 1,\ \delta_2 = 0,$$

$$\text{AIDS:}\quad \delta_1 = 1,\ \delta_2 = 1, \text{ and}$$

$$\text{NBR:}\quad \delta_1 = 0,\ \delta_2 = 1.$$

With these restrictions, the four models may be written as follows Lee, Brown, and Seale (1994):

$$\text{Rotterdam: } \bar{w}_{it} d(\ln q_{it}) = \theta_i d(\ln Q_t) + \sum_j \pi_{ij} d(\ln p_{jt}) + \varepsilon_{it}; \tag{7}$$

$$\text{CBS: } \bar{w}_{it} d(\ln q_{it}) = (\beta_i + \bar{w}_{it}) d(\ln Q_t) + \sum_j \pi_{ij} d(\ln p_{jt}) + \varepsilon_{it}; \tag{8}$$

$$\text{AIDS: } \bar{w}_{it} d(\ln q_{it}) = (\beta_i + \bar{w}_{it}) d(\ln Q_t) + \sum_j (\gamma_{ij} - \bar{w}_{it}(\delta_{ij} - \bar{w}_{jt}) d(\ln p_{jt}) + \varepsilon_{it}; \text{ and} \tag{9}$$

$$\text{NBR: } \bar{w}_{it} d(\ln q_{it}) = \theta_i d(\ln Q_t) + \sum_j (\gamma_{ij} - \bar{w}_{it}(\delta_{ij} - \bar{w}_{jt}) d(\ln p_{jt}) + \varepsilon_{it}. \tag{10}$$

We test which model best fits the data by using the LRT, which is specified as

$$LRT = -2(\ln L_R - \ln L_U), \tag{11}$$

where L_R represents the likelihood value of the restricted model (i.e., Rotterdam, CBS, AIDS, or NBR) and L_U represents the likelihood value of the unrestricted model (i.e., Nesting model). The test is approximately $\chi^2(q)$ in distribution, where q is the number of imposed restrictions. In this case, there are two restrictions for each test (i.e., δ_1 and δ_2). The LRT results, reported in Table 3, indicate that none of the four models fits the data as well as the Nesting model. Barten (1993), Lee. Brown, and Seale (1994), and Asci et al. (2016) argue that the Nesting model is a demand system in its own right. Accordingly, we choose the Nesting model for the following analysis.

The LRT is also used to test the restrictions of homogeneity and symmetry for each model, with q equal to the difference between the number of parameters in the restricted and unrestricted models. We find that homogeneity, reported in Table 3, is not rejected by the Nesting model (6.64) or the CBS model (5.99) at the 5% significance level. When the homogeneity- and symmetry-restricted model is tested against the homogeneity-restricted model, symmetry is rejected by all five models at the 5% significance level but not rejected by the Nesting model (14.41), Rotterdam (15.47) or the CBS model (12.77) at the 1% significance level. As shown by Meisner (1979) and discussed by Asci et al. (2016), the asymptotic LRT is biased toward rejecting symmetry as the number of commodities in the demand system increases.

Table 3. Log-Likelihood-Ratio Test Statistics for Different Restrictions in the Nesting, Rotterdam, CBS, AIDS, and NBR Models

	$-2\left[L(\theta^R) - L(\theta^U)\right]$							
	Nesting	**Rotterdam**	**CBS**	**AIDS**	**NBR**	$\chi^2(0.05)$	$\chi^2(0.01)$	**DF**[a]
Homogeneity	6.64	10.02	5.99	14.72	10.63	7.82	11.35	3
Symmetry	14.41	15.47	12.77	28.79	26.31	12.59	16.81	6
Model selection	–	47.41	150.33	269.43	251.81	5.99	9.21	2

Notes: [a]DF indicates degrees of freedom.

Having determined that the Nesting model is the best model with which to conduct our analysis, we use its parameter estimates to calculate Slutsky and Cournot price elasticities. The Slutsky and Cournot elasticities calculated using the Nesting model are specified respectively as

$$S_{ij} = \frac{e_{ij}}{w_i} - \delta_2\left(\delta_{ij} - w_j\right) \text{ and} \tag{12}$$

$$C_{ij} = \frac{e_{ij}}{w_i} - \delta_2\left(\delta_{ij} - w_j\right) - \frac{\left(\delta_1 w_i + d_i\right) w_j}{w_i}. \tag{13}$$

Our study focuses on U.S.-produced fresh tomatoes and imported fresh tomatoes from Mexico, Canada, and the rest of the world (ROW),[6] resulting in a four-equation demand system. The estimation of elasticities is conditional on U.S consumers' total expenditure on fresh tomatoes. Table 4 reports the conditional Slutsky (compensated) and Cournot (uncompensated) price elasticities calculated using the Nesting model.

First turning to own-price elasticities (column 6 of Table 4), all conditional Slutsky (compensated) and Cournot (uncompensated) own-price elasticities are negative and statistically different from 0 at the 5% significance level. Additionally, their absolute values are all less than 1, indicating that these goods are conditionally inelastic: The percentage change in quantity demanded is smaller than the percentage change in own price. Note the Slutsky own-price elasticities, which measure the substitution effect of an own-price change on quantity demanded, are smaller absolutely than the corresponding Cournot ones because, in the case of normal goods, the Cournot own-price elasticity is simply equal to the Slutsky own-price elasticity minus a positive expenditure term, which measure the expenditure effect of an own-price change on quantity demanded. The substitution effect of an own-price change on quantity demanded is smallest for U.S.-grown tomatoes and largest for ROW tomatoes. The story changes when we consider the conditional Cournot own-price elasticities (column 6, Table 4), which subtract the (positive) expenditure effect from the substitution effect. When considering both effects of an own-price change, the quantity demanded of U.S.-grown tomatoes is most sensitive to an own-price change followed by—in order of decreasing sensitivity—ROW-, Mexican-, and Canadian-grown tomatoes, with a range from -0.91 (United States) to -0.29 (Canada).

The Slutsky cross-price elasticities may be used to indicate whether two goods are substitutes or complements. Positive Slutsky cross-price elasticities indicate substitution while negative ones indicate complementarity. In our case of fresh tomatoes consumed in the United States, all the conditional Slutsky cross-price elasticities are positive and statistically different from 0 at the 5% significance level indicating that U.S.-, Mexican-, Canadian-, and ROW–grown fresh tomatoes are substitutes for each other (columns 1–5 of Table 4).

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[6] The label "ROW" includes 42 countries: Argentina; the Bahamas; Belgium-Luxembourg; Botswana; Brazil; Bulgaria; Chile; China; Colombia; Costa Rica; Denmark; the Dominican Republic; Ecuador; El Salvador; France; Germany; Guatemala; Honduras; India; Israel; Italy; Japan; Leeward-Windward Islands; Mauritius; Morocco; Mozambique; the Netherlands; New Zealand; Nicaragua; Niger; Norway; Philippines; Poland; Somalia; Spain; Sweden; Switzerland; Thailand; Trinidad and Tobago; Ukraine; United Kingdom; and Venezuela.

Table 4. Slutsky (compensated) and Cournot (uncompensated) Price Elasticities Conditional on Total Expenditure on Domestically Produced and Imported Fresh Tomatoes Using the Nesting Model, 1989–2017

	Conditional Slutsky Cross-Price Elasticities				Conditional Slutsky Own-Price Elasticities
Countries	**United States**	**Mexico**	**Canada**	**ROW[a]**	
1	**2**	**3**	**4**	**5**	**6**
United States	–	0.14***	0.02***	0.01***	−0.17***
		(0.02)	(0.00)	(0.00)	(0.02)
Mexico	0.16***	–	0.02***	0.02***	−0.20***
	(0.03)		(0.01)	0.00	(0.03)
Canada	0.14***	0.10***	–	0.03***	−0.27***
	(0.02)	(0.03)		(0.01)	(0.04)
ROW	0.16***	0.33***	0.11***	–	−0.60***
	(0.06)	(0.08)	(0.04)		(0.07)

	Conditional Cournot Cross-Price Elasticities				Conditional Cournot Own-Price Elasticities
Countries	**United States**	**Mexico**	**Canada**	**ROW[a]**	
1	**2**	**3**	**4**	**5**	**6**
United States	–	−0.48***	−0.11***	−0.03***	−0.91***
		(0.05)	(0.01)	(0.00)	(0.04)
Mexico	−0.11**	–	−0.03**	0.01	−0.43***
	(0.05)		(0.01)	(0.00)	(0.05)
Canada	0.00	−0.01	–	0.02**	−0.29***
	(0.04)	(0.05)		(0.01)	(0.04)
ROW	0.00	0.19*	0.09*	–	−0.85***
	(0.10)	(0.11)	(0.05)		(0.11)

Notes: Single, double, and triple asterisks (*,**, and ***) indicate significance at the 10%, 5%, and 1% level, respectively. Numbers in parentheses are asymptotic standard errors.

[a] ROW indicates rest of world.

When a corresponding Slutsky cross-price elasticity is positive, a negative (positive) Cournot cross-price elasticity implies that the expenditure effect is greater (smaller) absolutely than the substitution effect. In our case, eight of the 12 conditional Cournot cross-price elasticities are statistically different from 0 at the 10% significance level. Of these eight, five are negative and three are positive. The quantity demanded for U.S.-grown tomatoes responds to changes in the price of tomatoes imported from all sources; among these, it is most sensitive to a price change for Mexican-grown tomatoes (−0.48). By contrast, of all the imported tomatoes considered, only the quantity demanded for Mexican-grown tomatoes responds to changes in the price of U.S.-grown tomatoes (−0.11). Also, the quantity demanded for Mexican tomatoes responds to a price change for Canadian tomatoes (−0.03). Of the three positive and significant conditional Cournot cross-price elasticities, the quantity demanded of ROW-grown tomatoes is sensitive to price changes for Mexican- and Canadian-grown fresh tomatoes, and the quantity demanded of Canadian-grown tomatoes is sensitive to a price change in ROW-grown tomatoes. Finally, the absolute values of all

Table 5. Average Cost of Full Compliance with the Produce Rule, by Farm Sales Category

Category (value of annual produce sales)	Average Cost of Compliance per Farm ($)	Increase in Cost (%)
Very small farms ($25,000–$250,000)	5,560	6.77
Small farms ($250,000–$500,000)	21,136	6.04
Large farms (>$500,000)	29,228	0.92

Source: Bovay, Ferrier, and Zhen (2018).

conditional Cournot cross-price elasticities are less than 1, implying that they are all inelastic. This indicates that percentage changes in quantity demanded are less than percentage changes in price for tomatoes from all sources.

Simulation Analysis and Results

Major Assumptions of Simulation Analysis

For the simulation analysis reported below, we make four major assumptions. First, we assume that the fresh tomato market is perfectly competitive for farms in the same size category. Therefore, we can divide the fresh tomato market into three submarkets: markets for very small, small, and large farms. Price is assumed to equal the marginal cost with a single market price for each submarket because "there are thousands of buyers and sellers in the North American fresh tomato market, while some buyers may have market power at certain times in certain regions, no market power exists at the national level" (Bovay and Sumner, 2018, p. 406).

The marginal costs, however, vary among farms of different sizes. Thus, we relax the assumption made by Bovay and Sumner (2018), who assumed the marginal cost was the same across all farms. Here, we allow that marginal cost (price) to differ among size categories of farms, which better reflects actual market conditions. Farms of different sizes face different produce buyers. For example, large farms may sell their products to other food suppliers, at lower prices, as those products pass through the supply chain into the retail markets. Small farms, in contrast, may sell their products directly to consumers at higher prices (e.g., as local farmers might do at farmers' markets).

Second, following Bovay and Sumner (2018), our simulation analysis focuses on farms, farm buyers, importers, and import buyers. Without data on the efficiency of the transmission of farms' costs through the supply chain to consumers, we do not address the effects of the FSMA on retail markets in this paper in order to avoid making unnecessarily strong or unrealistic assumptions. Third, since producers of other fresh produce commodities must also abide by the FSMA, the substitution effects between tomatoes and other fresh fruits and vegetables may be considered negligible for the purposes of the present study. Therefore, we focus our simulations on fresh tomatoes without considering the cross-effects of FSMA adoption for other fruits and vegetables on quantities demanded for fresh tomatoes and revenues from producing and selling fresh tomatoes. We leave this interesting question for future research.

Fourth, because compliance costs data for U.S. fresh tomato producers are not available, we follow Bovay, Ferrier, and Zhen (2018) and instead use average compliance costs across all food commodities affected by FSMA for our simulation analysis, as summarized in Table 5. The average costs of implementing the FSMA for the three size categories of farms are $5,560 (very small), $21,136 (small), and $29,228 (large). The cost increases of compliance for the three categories are 6.77%, 6.04%, and 0.92% for very small, small, and large farms, respectively. For foreign tomato producers, average compliance costs for fresh tomatoes across all food commodities are not available. Instead, we assume that, for different sizes of foreign tomato producers, compliance costs will increase by 1%–10%. This range allows foreign costs of compliance to increase by less than the percentage cost increase of very small farms but no more than 1.5 times that category's cost increase of 6.77% (i.e., $6.77\% \times 1.5 = 10\%$).

The simulation analysis is performed in three steps. In step one, based on the conditional Cournot price elasticities reported in Table 4 and the estimated price (cost) increases for U.S. farms, we run 10 scenarios based on possible increases in import price (from 1% to 10%). In step two, for each import price scenario, we estimate the cumulative changes in quantity demanded of fresh tomatoes by country of origin. In step three, using the results from step two, we calculate the changes in revenue for domestic and foreign producers with differently sized farms under each import price scenario.

Percentage Changes in Quantities Demanded

The cumulative changes in quantities demanded are calculated using 10 scenarios based on potential increases in import price (ranging from 1% to 10%), resulting from the possible scenarios of increased compliance costs for foreign producers. For the three categories of U.S. domestic producers, price changes are equal to cost changes of compliance. Table 6 illustrates how the cumulative effects of the FSMA on tomato prices are calculated given a 1% increase in import price for very small U.S. and foreign farms. In column 2, conditional Cournot price elasticities are used for calculation if they are significantly different from 0 at or below the 10% level. The changes in quantities demanded, as reported in column 3, are equal to the conditional Cournot price elasticities multiplied by 6.77% (the price increase for very small U.S. farms) for U.S. producers and by 1% for producers from Mexico, Canada, or ROW. For example, when the price of domestic tomatoes increases by 6.77% and the price of imported tomatoes increases by 1%, the cumulative percentage change in quantity demanded for Mexican tomatoes is −1.18%, while the cumulative change in quantity demanded for tomatoes from the United States, Canada, and ROW is −6.78%, −0.27%, and −0.57%, respectively.

When we vary import price between 1% and 10% by increments of 1%—while maintaining the assumption that domestic prices will increase by 6.77%, 6.04%, and 0.92% for very small, small, and large domestic farms, respectively—then our estimates of the cumulative effect of those price changes on the demand for tomatoes will change according to variations in the import price. Table 7 reports the simulation results given the simulated range of potential import price increases. There are four major results that can be gleaned from Table 7. First, all producers will see a quantity decrease after adoption of the FSMA. Second, the decrease in quantity demanded is most pronounced for very small farms, followed by small and then large farms, for producers in the same source country. For example, the changes in quantity demanded for Mexican tomato producers range from −1.18% (with a 1% increase in import price) to −5.25% (with a 10% increase in import price) for very small farms, from −1.10% to −5.17% for small farms, and from −0.55% to −4.62% for large farms. Third, U.S. farms are expected to see bigger losses in quantity demanded (in terms of percentage) relative to foreign producers of the same size. For example, a very small U.S. farm may see up to a 12.28% loss in quantity demanded, which is larger than the losses for very small farms from other import countries (i.e., 5.25% for Mexico, 2.68% for Canada, and 5.66% for ROW).

Finally, changes in quantity demanded for tomatoes imported from Canada and ROW are the same for all three farm size categories, given the same change in import price. For instance, given that import price increases by 2%, then very small, small, and large Canadian farms will all see a −0.54% change in quantity demanded, while ROW farms of the three sizes will see a 1.13% loss in quantity demanded. This is because the quantities demanded for imported tomatoes from Canada and ROW do not respond to changes in U.S. tomato price based on the statistical significance of the conditional Cournot cross-price elasticities (10% significance level), but they do respond to changes in import prices from other import sources.

Table 6. Cumulative Percentage Changes in Quantities Demanded for Tomatoes for Very Small Farms if Import Price Increases by 1%

Countries 1	Cournot Elasticities 2	Change in Quantity Demanded (%) 3
6.77% price increase in U.S. tomatoes		
United States	−0.91	−6.16
Mexico	−0.11	−0.73
Canada	0.00	0.00
ROW	0.00	0.00
1% price increase in Mexican tomatoes		
United States	−0.48	−0.48
Mexico	−0.43	−0.43
Canada	0.00	0.00
ROW	0.19	0.19
1% price increase in Canadian tomatoes		
United States	−0.11	−0.11
Mexico	−0.03	−0.03
Canada	−0.29	−0.29
ROW	0.09	0.09
1% price increase in ROW tomatoes		
United States	−0.03	−0.03
Mexico	0.00	0.00
Canada	0.02	0.02
ROW	−0.85	−0.85
Cumulative effect of all prices increase		
United States		−6.78
Mexico		−1.18
Canada		−0.27
ROW		−0.57

Notes: [a] ROW indicates rest of world.

Percentage Changes in Revenues after FSMA

Having simulated the changes in quantity demanded brought about by the FSMA for both foreign and domestic tomato producers, we then simulate the changes in revenue for domestic and foreign tomato producers of different size after adoption of the FSMA.[7] These results are reported in Table 8. For U.S. producers, small and very small farms experience revenue losses under all scenarios, although these losses are mitigated as import price increases from 1% to 10%. The range of revenue loss is between 3.51% and 5.84% for very small U.S. farms and between 2.78% and 5.17% for small U.S. farms. Large U.S. farms have an increase in revenue as long as the import price increases by 2%–3%. More precisely, a small revenue loss of 0.10% is expected when the import price increases by 2%, but revenue is expected to increase by 0.25% when the import price increases by 3%. The highest revenue increase for large U.S. farms is 2.35%, when the import price increases by 10%.

For Mexican producers, small and very small farms will see an increase in revenue if the import price increases by 1%–2%. Large Mexican farms will realize a bigger revenue increase than small

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[7] Percentage change in revenue = (1+ percentage change in price) × (1+percentage change in quantity) −1.

Table 7. Cumulative Percentage Changes in Quantities Demanded Using the Nesting Model

	Import Price Increases by									
Countries	**1%**	**2%**	**3%**	**4%**	**5%**	**6%**	**7%**	**8%**	**9%**	**10%**
Very small farms (U.S. price increases by 6.77%)										
U.S.	−6.78%	−7.39%	−8.00%	−8.61%	−9.22%	−9.84%	−10.45%	−11.06%	−11.67%	−12.28%
Mexico	−1.17%	−1.61%	−2.06%	−2.50%	−2.94%	−3.38%	−3.82%	−4.26%	−4.71%	−5.15%
Canada	−0.28%	−0.56%	−0.83%	−1.11%	−1.39%	−1.67%	−1.95%	−2.22%	−2.50%	−2.78%
ROW	−0.57%	−1.13%	−1.70%	−2.26%	−2.83%	−3.40%	−3.96%	−4.53%	−5.10%	−5.66%
Small farms (U.S. price increases by 6.04%)										
U.S.	−6.11%	−6.72%	−7.34%	−7.95%	−8.56%	−9.17%	−9.78%	−10.40%	−11.01%	−11.62%
Mexico	−1.09%	−1.54%	−1.98%	−2.42%	−2.86%	−3.30%	−3.74%	−4.19%	−4.63%	−5.07%
Canada	−0.28%	−0.56%	−0.83%	−1.11%	−1.39%	−1.67%	−1.95%	−2.22%	−2.50%	−2.78%
ROW	−0.57%	−1.13%	−1.70%	−2.26%	−2.83%	−3.40%	−3.96%	−4.53%	−5.10%	−5.66%
Large farms (U.S. price increases by 0.92%)										
U.S.	−1.45%	−2.06%	−2.67%	−3.29%	−3.90%	−4.51%	−5.12%	−5.73%	−6.35%	−6.96%
Mexico	−0.54%	−0.98%	−1.42%	−1.87%	−2.31%	−2.75%	−3.19%	−3.63%	−4.08%	−4.52%
Canada	−0.28%	−0.56%	−0.83%	−1.11%	−1.39%	−1.67%	−1.95%	−2.22%	−2.50%	−2.78%
ROW	−0.57%	−1.13%	−1.70%	−2.26%	−2.83%	−3.40%	−3.96%	−4.53%	−5.10%	−5.66%

Table 8. Cumulative Percentage Changes in Revenues Using the Nesting Model

	Import Price Increases by									
Countries	**1%**	**2%**	**3%**	**4%**	**5%**	**6%**	**7%**	**8%**	**9%**	**10%**
Very small farms (U.S. price increases by 6.77%)										
U.S.	−5.84%	−5.54%	−5.24%	−4.96%	−4.69%	−4.43%	−4.18%	−3.95%	−3.72%	−3.51%
Mexico	−0.18%	0.35%	0.88%	1.40%	1.91%	2.42%	2.91%	3.39%	3.87%	4.34%
Canada	0.72%	1.43%	2.14%	2.84%	3.54%	4.23%	4.92%	5.60%	6.27%	6.94%
ROW	0.43%	0.84%	1.25%	1.64%	2.03%	2.40%	2.76%	3.11%	3.45%	3.77%
Small farms (U.S. price increases by 6.04%)										
U.S.	−5.17%	−4.86%	−4.56%	−4.27%	−3.99%	−3.72%	−3.47%	−3.23%	−3.00%	−2.78%
Mexico	−0.10%	0.43%	0.96%	1.48%	2.00%	2.50%	2.99%	3.48%	3.96%	4.42%
Canada	0.72%	1.43%	2.14%	2.84%	3.54%	4.23%	4.92%	5.60%	6.27%	6.94%
ROW	0.43%	0.84%	1.25%	1.64%	2.03%	2.40%	2.76%	3.11%	3.45%	3.77%
Large farms (U.S. price increases by 0.92%)										
U.S.	−0.46%	−0.10%	0.25%	0.58%	0.91%	1.22%	1.52%	1.81%	2.08%	2.35%
Mexico	0.45%	1.00%	1.53%	2.06%	2.58%	3.08%	3.58%	4.08%	4.56%	5.03%
Canada	0.72%	1.43%	2.14%	2.84%	3.54%	4.23%	4.92%	5.60%	6.27%	6.94%
ROW	0.43%	0.84%	1.25%	1.64%	2.03%	2.40%	2.76%	3.11%	3.45%	3.77%

and very small Mexican producers. Predicted revenue gains range up to 4.23%, 4.31%, and 4.92% for very small, small, and large Mexican producers, respectively.

Canadian and ROW producers, regardless of their size, are expected to experience revenue gains after adoption of the FSMA. For example, even when the import price increases by only 1%, very small, small, and large Canadian farms can all expect a 0.73% gain in revenue. This is because the demand for tomatoes produced in Canada and ROW is not affected by the price changes of tomatoes produced in the United States (column 2 of Table 6). For a 10% increase in import price, the revenue change for Canadian and ROW tomato producers is calculated to increase by 7.05% and 3.77%, respectively.

Overall, these results indicate that complying with the FSMA imposes different compliance costs on farms of different sizes and on farms in different countries. For U.S. farms, the smaller a farm is, the larger (in terms of percentages) and more likely revenue losses are expected to be. In contrast, although Mexican farms are unlikely to experience revenue losses, the size of those farms will affect their revenue gains. Put simply, the larger a Mexican farm is, the bigger the revenue gains are expected to be. We expect that U.S. producers with small and very small farms are the only producers who stand to be worse off from the adoption of the FSMA because their revenue decreases under all simulations in our analysis. Among foreign producers, Canadian farms, regardless of size, benefit most from the adoption of the FSMA because they experience the largest percentage gains in revenue.

Conclusion

The FSMA creates new food safety regulations that shift the burden of responsibility for foodborne illnesses onto food producers and providers in hopes of lowering the incidence of foodborne diseases and of leading to more rapid identification and control of the sources of such outbreaks. However, whether compliance costs will have differential effects on producers of differently sized operations is an important policy question. Using both domestic and foreign farms that produce fresh tomatoes for the U.S. market, this paper analyzes how the adoption of the FSMA will affect farms of different sizes. Our results indicate that the effects of the FSMA on total revenue vary according to both farm size and country of origin.

Small and very small U.S. farms are expected to accrue revenue losses, while large farms will most likely realize revenue gains. Foreign producers, by contrast, will likely experience revenue gains regardless of size, although the magnitude of these gains will vary by country of origin. We expect that Canadian producers will gain the most from FSMA and resulting price increases, while very small U.S. farms will accrue the most significant losses.

The lack of data on compliance costs for different sizes of farms in the fresh tomato industry, both in the United States and in other countries, forced us to use data on compliance costs from across all food industries for our analysis of the U.S. tomato market. With more detailed information about compliance costs, future studies could extend our analysis to estimate changes in profit and economic welfare. The techniques used in the present study can be adapted to any fresh produce industry, whether it involves domestic production, imports, or both.

The implications of our paper are not limited to the fresh tomato industry. Understanding more generally whether and how adoption of the FSMA will differentially affect various sizes of farms is important. Small and very small farms play an important competitive role, ensuring variation in what would otherwise be a highly concentrated market. According to our findings, the FSMA adversely impacts the economic viability of smaller U.S. farms and food producers, raising concerns that such policies will have a negative impact on the number of producers in the U.S. market and resulting in a reduction in the diversity of foods available and in an increase in food prices. This poses a dilemma. U.S. consumers certainly stand to benefit from improved and modernized food safety regulations, but too much regulation may harm consumers due to higher prices and fewer available choices. Future studies could contribute to this debate by exploring whether the overall cost of implementing the FSMA is lower than the reduced cost of associated foodborne diseases as a result of its implementation.

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