Applied Economic Perspectives and Policy (2018) volume 40, number 3, pp. 402–420.
doi:10.1093/aepp/ppx039
Advance Access publication on 26 October 2017.

Submitted Article

Economic Effects of the U.S. Food Safety Modernization Act

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Submitted 12 November 2014; editorial decision 29 December 2016.

Abstract *The Food Safety Modernization Act (FSMA) substantially expands the authority of the U.S. Food and Drug Administration to regulate fresh produce marketed in the United States. This article uses an equilibrium-displacement framework incorporating stochastic food-borne illness outbreaks to simulate long-run market effects of FSMA using the North American fresh-tomato industry as a case study. We demonstrate how, under FSMA, certain categories of suppliers will gain advantage over others. Growers and suppliers within the United States, and their buyers, are likely to gain relative to foreign producers and importers because FSMA imposes specific requirements for importers. Among fully regulated growers, large growers will benefit relative to small growers. Many producers have already adopted food-safety standards that closely resemble the FSMA rules, and the cost of implementing the FSMA requirements for these producers will be much lower than for other producers.*

Key words: food policy, food safety, Food Safety Modernization Act (FSMA), food trade, tomatoes, produce markets, private standards

JEL codes: L51, Q17, Q18.

The U.S. Food Safety Modernization Act (FSMA) is being implemented in stages from 2016 to 2022. Farmers, food processors, manufacturers, distributors, and retailers all have strong private incentives to provide safe food and to require that their suppliers follow standards for food-safety practices, in an effort to ensure good food-safety outcomes. FSMA will impose additional regulatory burden by mandating that nearly all growers and processors of certain foods who are seeking to market their products in the United States comply with standards for food-safety practices that closely resemble existing private and voluntary or collective standards.

For small farms not currently undertaking standardized food-safety practices, the recurring cost of compliance with FSMA will be onerous—$5,872 per year in costs for farms with $86,000 in sales, for example, according to the FDA Regulatory Impact Analysis (FDA 2015c). Larger farms, meanwhile, will be able to achieve some economies of scale by complying with FSMA, a cost advantage accentuated by the greater likelihood that large farms have adopted GAPs or similar standards. In addition, foreign producers will be adversely affected, relative to U.S. competitors, because FSMA imposes special requirements for importers that do not apply to distributors of U.S.-grown or -produced food.

In this article, we simulate the long-run implications of FSMA implementation for U.S. farmers and importers of produce from Canada and Mexico using the fresh-tomato industry as a case study. We employ an equilibrium-displacement framework to demonstrate differential shifts in supply curves for various classes of producers, and model improvements in food-safety outcomes by running simulations of stochastic outbreaks of food-borne illness that lead to negative demand shocks, with and without the implementation of FSMA. Our simulation results highlight the benefits that FSMA implementation will bring to large U.S. growers and the disadvantages it will impose on foreign growers and importers as well as smaller U.S. growers.

This article provides a timely perspective by simulating *ex ante* the distributional effects of a regulation that mandates production practices for a broad range of farms growing fresh produce. Importantly, the article illustrates the gains likely to be made by large U.S. producers that have already adopted standards for food-safety practices at the behest of buyers or in an effort to protect collective industry reputation (Winfree and McCluskey 2005). Our analysis draws on restricted farm-level data from the 2012 Census of Agriculture, which allows us to simulate at a refined level the distributional effects of FSMA implementation.[1] Along with a study by Gray et al. (2005) on the effects of collective action for food-safety standards in the pistachio industry, this article is among the first to incorporate negative demand shocks and a gradual return to the previous level into an EDM.

The next section discusses the relevant background and requirements of FSMA. This is followed by a discussion of the advantages of selecting the fresh-tomato industry as an illustrative case study. Then, we describe the simulation methodology and results. We conclude with a discussion of some caveats of the study. An online supplementary appendix provides additional documentation.

Background

FSMA was hailed as "historic legislation" that would result in "sweeping improvements to the security and safety of [the U.S.] food supply," (Hamburg 2011). The legislation increased regulation of food safety in the United States and countries exporting to the United States by expanding the food-safety oversight authority of the U.S. Food and Drug Administration (FDA). Specifically, the FSMA legislation requires the FDA to develop and issue certain regulations or "rules" that specify required practices and

[1]*The farm-level data used in this analysis are not available to the public. Researchers may request special tabulations for certain USDA National Agricultural Statistics Service (NASS) data sets, to be accessed in a NASS Data Lab.*

standards for farms, processors, and marketers of foods for which FDA has legal oversight with regard to food safety.[2] We focus below on the FSMA rules that will affect costs for the first stages of the fresh-produce marketing chain, that is, before products reach the first buyer beyond the farmer or importer.

One of these rules, the Produce Safety Rule (FDA 2015b), applies to many farms that grow certain fresh-produce commodities.[3] This rule will require inspection of agricultural water, hygiene and sanitary standards, and efforts to prevent contamination of fresh produce with animal feces, with special requirements for growers of sprouts from beans and seeds. Generally speaking, compliance with the FSMA Produce Safety Rule will involve fixed costs and farms will be able to benefit from some economies of scale in complying with the rule. For example, large farms may be able to hire a full-time food-safety supervisor or manager to ensure compliance with FSMA, whereas smaller farms will elect to use existing managerial capacity to ensure compliance, taking valuable human capital away from the main role of running the farm business. At the very least, larger farms can benefit from repeating practices across several dozen fields, and completing a single set of paperwork to document compliance. In addition, large farms are relatively likely to have adopted private or collective standards for food-safety practices at the behest of buyers. Other FSMA rules—the Foreign Supplier Verification Program (FSVP) rule and the Third-Party Accreditation rule—impose special requirements for importers, and in so doing are likely to affect the relative prices of imported food and food produced domestically.

Compliance with the Produce Safety Rule will be required beginning in January 2018 for growers with average annual sales of at least $500,000. Smaller growers will be allowed to begin compliance one or two years later, depending on their value of sales. The FSVP requires that compliance with other FSMA rules be verified beginning six months after the required implementation dates of those rules for a given size category or type of firm.

The North American Fresh-Tomato Industry

To demonstrate the implications of the differences in costs of FSMA compliance among different types of growers, we use as an illustrative case study the North American fresh-tomato industry.[4] This industry has several unique features that make it particularly useful for the case study.

First, although tomatoes are farmed in every U.S. state, imports make up the majority of fresh tomatoes sold in the United States, with over 98% of imports (by value) coming from Mexico or Canada in each year since 2007 (U.S. International Trade Commission 2016). The FSVP rule requires

[2]*Generally speaking, the USDA oversees the safety of meat, poultry, catfish, and processed egg products, while the FDA oversees the safety of other foods. The precise delineation of jurisdiction is somewhat more complicated (see FDA 2016).*

[3]*The FSMA legislation specifies that the Produce Safety Rule applies only to "raw agricultural commodities" (U.S. Congress 2011, 124 Stat. 3900). The Produce Safety Rule lists those commodities that the FDA deems to be frequently consumed raw, including commodities such as apples, strawberries, cucumbers, and fresh-market tomatoes but not asparagus, lima beans, eggplant, or potatoes (FDA 2015b). In addition, growers of produce, such as processing tomatoes, that undergoes a "kill step" that reduces the risk of food-borne illness do not need to comply with the Produce Safety Rule for those commodities.*

[4]*Fresh-market tomatoes are distinct cultivars from processing tomatoes, which are never sold fresh.*

importers to verify that their suppliers are fully compliant with the other FSMA rules, whereas intermediaries involved in distributing U.S.-grown or -processed food need not undertake any such verification. The likely effect will be to increase the cost and price of foreign-produced food, relative to U.S.-produced food, even if foreign growers have already adopted GAPs. The differential effects for foreign producers can be demonstrated readily using an industry where imports account for roughly half of U.S. consumption.

The second advantage of exploring the effects of FSMA on the fresh-tomato industry is that many fresh-tomato growers have already adopted collective or private standards for on-farm food-safety practices that closely resemble the requirements of the FSMA Produce Safety Rule. Since 2008, a Florida state law (Florida Administrative Code, Chapter 5G-6) has required fresh-tomato growers of any significant size in that state to comply with a commodity-specific “Good Agricultural Practices,” or GAPs, standard. California’s leading industry members adopted the same standard in 2007. Industry sources indicate that generic (not commodity-specific) GAPs have more recently superseded the fresh-tomato GAPs as a de facto requirement, demanded by many major buyers such as Walmart, Safeway, and Costco.

FSMA will thus impose costs on all (non-exempt) farms that have not already voluntarily (or in accordance with local law) adopted standards for on-farm food-safety practices. Growers that have already adopted GAPs will still need to incur some costs for training and to document compliance with FSMA, even if the FSMA Produce Safety Rule does not impose requirements for food-safety practices that are more stringent than the existing GAPs standards. By requiring that all firms and farms (except those meeting the exemption criteria) adopt standards and practices that have already been adopted by many firms and farms, FSMA will confer a competitive advantage on the early adopters.[5] We demonstrate the advantages likely to be gained by the growers that have adopted such standards and, as a sensitivity analysis, show how these effects vary in response to assumptions about the rate of adoption of GAPs among growers outside Florida and California.

The third advantage of using fresh tomatoes as a case study relates to FSMA’s provision of several types of exemptions for farms. All farms that sell less than $25,000 in fresh produce will be fully exempt from the Produce Safety Rule. In addition, farms that have $500,000 or less in annual revenue from sales of food (including produce) may qualify for a partial exemption if at least half of their sales (in terms of value) are direct to consumers, restaurants, or retail food establishments within the same state or within a 275-mile radius. Among U.S. farms that grow fresh tomatoes, we estimate (based on restricted data from the 2012 USDA Census of Agriculture) that 73% have total produce sales less than $25,000, and that another 7% qualify for a partial exemption. We explicitly simulate the market equilibrium effects of the FSMA Produce Safety Rule on both groups of exempt farms.

Simulating the Effects of FSMA: Case Study of the Fresh-Tomato Industry

When FSMA is implemented, the marginal cost of producing fresh tomatoes will increase, except on farms exempt from the Produce

[5]*The principle of regulatory capture may apply to the FSMA rulemaking process, but we leave further discussion and analysis of that possibility to future research.*

Safety Rule.[6] Depending on how their marginal costs of production compare with competitors' and with the increase in the market price of fresh tomatoes, farms will either expand or contract production after implementation of the FSMA regulations.

While it is possible that demand could shift in response to changes in expectations about food safety and the risk of food-borne illness, we anticipate that buyers will be indifferent about the implementation of the on-farm food-safety practices required by FSMA. Our simulation involves randomly-occurring outbreaks of food-borne illness associated with individual farms. In the event of an outbreak, a negative demand shift ensues, and demand subsequently returns slowly to the original level. For our simulation, we assume that the implementation of the FSMA Produce Safety Rule will reduce the frequency of outbreaks of food-borne illness among farms that have not already adopted GAPs. Thus, on average, demand for fresh tomatoes will shift outward after the implementation of FSMA, relative to a baseline in which food-borne illness outbreaks are more common.

Based on this framework, the simulation results presented in this article compare two sets—those with and without the adoption of FSMA—of simulated farmgate and border prices, quantities, market shares, and revenues over streams of many years. Monthly shifts in the supply of fresh tomatoes are simulated for sixty-four different categories of farms, differentiated by size, location, and GAPs adoption status.[7] In addition, food-borne illness outbreaks are introduced as stochastic supply shocks, which induce negative demand responses. The results of the simulation allow the comparison of gains and losses for producers categorized by size, region, and GAPs adoption status, and account for seasonal shifts in production and prices.

This article builds on an extensive body of literature in which researchers have simulated the effects of regulations, collective actions by producer organizations, or outbreaks of food-borne illness or animal disease using equilibrium-displacement type models. Alston et al. (2007) outlined a general framework for analyzing a supply shift that triggers a demand shift, summarizing a dozen studies of mandated commodity promotion ("check-off") programs in California. Most of these studies were *ex post* analyses of commodity promotion programs; one (Gray et al. 2005) involved an *ex ante* simulation of the costs and benefits of a federal marketing order that mandated quality standards and an inspection program for aflatoxin (a toxin linked to cancer) in California pistachios. Like Gray et al. (2005), we simulate outcomes for the industry over streams of many years to capture dynamic responses to supply-curve shifts that lead to improved product safety, and a positive demand shift, relative to the current-policy scenario. In these authors' simulation, demand for pistachios after an outbreak event returned to pre-outbreak levels over time, with the negative shock decaying at a rate of 30% per year.

[6]*According to the Regulatory Impact Analysis for the Produce Safety Rule, farms falling below this threshold must incur administrative costs to earn the requirements of the rule and to document that they are "not covered by" (i.e., exempt from) the rule (FDA 2015c). We assign costs of learning the rule to all farms, exempt and non-exempt, in 2018, the first year of required compliance with the Produce Safety Rule for tomato growers.*

[7]*To be specific, shifts are simulated for each month, plus two separate shifts for October, to distinguish between periods of the year in which two different floor prices face imports from Mexico under a suspension agreement for an antidumping case.*

Richards and Patterson (1999) also used an equilibrium-displacement framework to evaluate the effects of two food-borne illness outbreaks incorrectly attributed to the California strawberry industry. In their analysis, news reports about outbreaks of food-borne illness affected demand for strawberries, rather than the outbreak events, per se. Richards and Patterson (1999) were thus able to estimate demand responses to both good and bad news about the safety of strawberries, and simulated welfare effects of such news events using these demand responses as inputs to an equilibrium displacement model using both short-run (with incomplete buyer response and less elastic supply response) and long-run scenarios.

More recently, Rejesus, Safley, and Strik (2014) simulated the welfare effects of a hypothetical outbreak of food-borne illness, inducing a negative demand shift in the U.S. blackberry industry. Their analysis, like ours, incorporated results from Arnade, Calvin, and Kuchler (2009), who found that consumer expenditures on bagged spinach sharply decreased following a heavily publicized outbreak of *E. coli* associated with the product, and slowly increased again but still had not returned to pre-outbreak levels sixty-eight weeks later.

In addition to the various works summarized by Alston et al. (2007), other papers that have used an equilibrium-displacement framework to study similar issues include the following: Paarlberg et al. (2003), who simulated the effects of hypothetical outbreaks of foot-and-mouth disease; Pendell et al. (2010), who simulated the welfare effects of the adoption of an identification and tracing system for U.S. livestock; Muth et al. (2002), who simulated the welfare effects of mandating post-harvest treatment of oysters, incorporating positive demand effects; and Mottaleb et al. (2012), who simulated equilibrium effects of the adoption of a new variety of drought-resistant rice under varying climate-change scenarios.

Simulation Methodology

The simulation model is developed as follows. Let equation (1) represent the supply function of producer i:

$$Q_i^s = f(P; \mathbf{x}_i) \tag{1}$$

where Q_i^s is the quantity supplied, P is the price received per unit, and $\mathbf{x}_i$ is a vector of exogenous variables that determine the cost of production. In the long run, over a forty-year horizon, all costs are variable costs. We let the relationship between Q_i^s and P be linear.

Under FSMA, in addition to facing a price increase, ΔP, producer i will also face an increase in marginal costs, ΔC_i. Hence, the net change in per-unit revenue received is $\Delta P - \Delta C_i$. To represent the response of producer i to changes in prices and costs, a simple rearrangement of the familiar elasticity of supply formula, with the change in per-unit revenue replacing ΔP, yields

$$\Delta Q_i^s = \varepsilon_i \frac{\Delta P - \Delta C_i}{P} Q_i^s \tag{2}$$

where ε_i is the elasticity of supply.

In this simplified, illustrative model, let a representative consumer's demand for fresh tomatoes be characterized by

$$Q^d = g(P; \mathbf{y}) \tag{3}$$

where Q^d is the quantity demanded, P is the price per unit, and $\mathbf{y}$ is a vector of exogenous variables that shift demand and which may include information about food safety. (In this simulation, information about outbreaks of food-borne illness is the only component of $\mathbf{y}$.) If the relationship between Q^d and P is linear, the market-clearing condition can be written as in equation (4), with ΔQ_i^s from equation (2), where $Q^d = \sum_i Q_i^s$:

$$Q^d + \Delta Q^d = Q^d\left(1 + \eta\frac{\Delta P}{P}\right) = \sum_i Q_i^s + \Delta Q_i^s \Longleftrightarrow \eta\frac{\Delta P}{P}Q^d = \sum_i \varepsilon_i \frac{\Delta P - \Delta C_i}{P} Q_i^s \tag{4}$$

where η is the own-price elasticity of demand. In the simulation analysis, the market-clearing condition given in equation (4) reflects both the negative supply shocks in the event of occasional outbreaks of food-borne illness in fresh tomatoes (in the form of product recalls) and the negative demand responses to such outbreaks. The characterization of the negative demand responses is derived from the empirical literature and is atheoretical (see the online supplemental appendix for more details). As mentioned, sixty-four categories of producers are used to characterize the industry, with sixty-four supply curves.

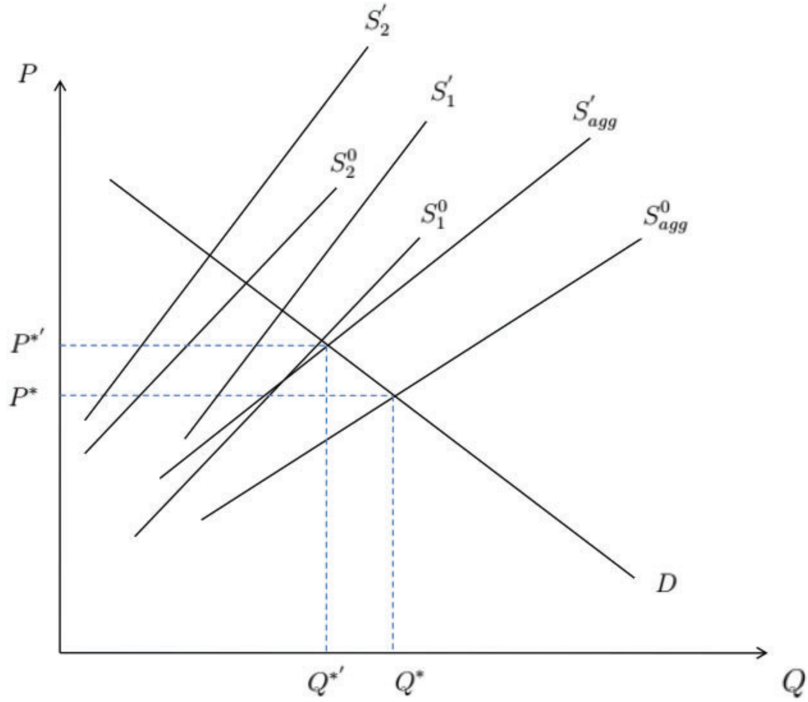
Figure 1 portrays a simplified version of the simulation model, in the case where demand for fresh tomatoes is constant before and after FSMA implementation. In figure 1, only two producer categories characterize the entire market, rather than sixty-four. The implementation of FSMA increases marginal costs for both groups, rotating the individual supply curves and shifting the aggregate supply curve. In this diagram, the cost of implementing FSMA imposes a smaller increase in marginal costs on supplier category 1, and demand does not shift after the implementation of FSMA (which would be the case in this simulation only if food-safety outcomes did not improve after the implementation of FSMA).

Figure 2 extends the basic simulation model to reflect reductions in periodic outbreaks and resulting demand shocks. In figure 2, demand shifts from D to D', increasing price while also increasing quantity, relative to a situation in which demand does not shift. If a positive shift in demand is large, quantity sold may even increase after the implementation of FSMA.

As discussed earlier, all simulations of market conditions after the implementation of FSMA are compared with simulations of market conditions in the absence of the implementation of FSMA. Baseline market conditions are simulated because stochastic variation in food-safety outcomes and corresponding demand shocks are an integral characteristic of fresh-produce markets. By comparing simulated and stochastic post-FSMA market conditions with simulated and stochastic non-FSMA market conditions, a better sense of the distribution of outcomes emerges. The increase in demand for fresh tomatoes illustrated in figure 2, corresponding to the reduced

Figure 1 Schematic of shifts in supply and demand as in simulation model, two groups of producers, no demand shift

Note: This figure represents a simplified version of the simulation framework with only two groups of producers, and with no shift in demand after the implementation of FSMA. Supply curves for producer categories 1 and 2 shift from S_1^0 to $S_1^{'}$ and S_2^0 to $S_2^{'}$, respectively, and the aggregate supply curve shifts from S_{agg}^0 to $S_{agg}^{'}$. Correspondingly, equilibrium price and quantity shift from P^* and Q^* to $P^{*'}$ and $Q^{*'}$, respectively.



probability of an outbreak under FSMA, relative to the baseline, contributes to an increase in the simulated post-FSMA market price of fresh tomatoes.

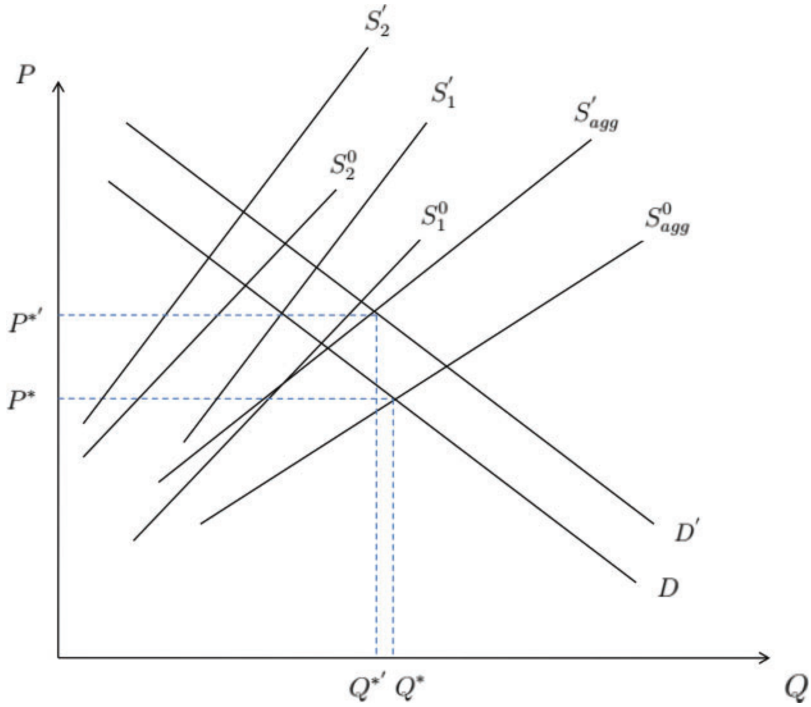
Major Assumptions for Simulation Analysis

To make our analysis tractable, we employ several assumptions that simplify the structure of our simulation model, as follows. First, we assume that the fresh tomato market is perfectly competitive, such that price equals marginal cost and a single market price, $p_i = p_j = P, \forall i, j$, prevails. In addition, we abstract away from considering differences in qualities of tomatoes (such as size, color, ripeness, firmness, and whether they are sold on the vine), and characterize fresh tomatoes as a homogeneous product. Although perfect competition does not characterize all agricultural markets (Sexton 2013), we abstract from buyer or seller market power, given that there are thousands of buyers and sellers in the North American fresh tomato market and that, while some buyers may have market power at certain times in certain regions, no market power exists at the national level.

Second, we consider only the effects of FSMA on farms, farm buyers, importers, and importers' buyers; that is, on farmgate and border prices and quantities. Fully addressing the transmission of farm costs through the

Figure 2 Schematic of shifts in supply and demand as in simulation model, two groups of producers, with demand shift

Note: This figure adds a positive shift in demand after the implementation of FSMA to the situation presented in figure 1. The supply curves shift in the same way as in figure 1.



supply chain to the retail consumer would require data on farmgate and retail prices for tomatoes differentiated by production region, which are unavailable. Instead of making strong assumptions about this relationship or borrowing estimates of the price transmission elasticity from outdated studies or studies of other markets, we avoid discussion of the effects of FSMA on retail prices.

Third, we use the cost estimates from the FDA's Regulatory Impact Analyses (FDA 2015a, 2015c) as the basis for the shifts in marginal cost. The details of the cost-shift calculations are discussed in the online supplementary a ppendix. Finally, farms will not consolidate or exit the fresh-tomato market in direct response to the regulations.

Simulation Results

We now turn to the results of the simulation model developed above, under three sets of parameters, scenarios A, B, and C, as described in table 1.[8] We highlight the simulated effects of FSMA implementation on import share and farm size distribution. We also discuss the relative impact on farms that have already adopted standard food-safety practices.

Table 2 shows that the simulated effect of the implementation of FSMA is to increase the wholesale market price of fresh tomatoes by about 0.6% to

[8] *The online supplementary appendix discusses the background, context, and justifications for the parameters chosen in these three scenarios.*

Table 1 Assumptions Used in Scenarios A, B, and C

Parameter	Scenario A	Scenario B	Scenario C
Short-run supply elasticity (response to outbreaks and demand shocks)	1.5	1.0	0.5
Long-run supply elasticity (response to FSMA implementation costs)	15	10	5
Distribution of farm sizes in Mexico and Canada	Same as U.S. States except Florida and California	Same as U.S.	Same as Florida and California
Baseline rate of GAPs adoption:			
Florida	100% (except for qualified and exempt farms)		
California medium and larger farms	90%	95%	100%
All regions except Florida and California:			
Medium and larger farms	60%	80%	100%
Small farms	40%	60%	80%
Very small farms	20%	40%	60%

Note: Medium and larger farms defined as those with produce sales of at least $500,000 annually; small farms with produce sales of $250,000 to $499,999; very small farms with produce sales of $249,999 or less.

Table 2 Simulated Changes in Market Prices and Quantities of Tomatoes Shipped, after Implementation of FSMA, Percent

	Mean change (95% confidence bounds)		
	Scenario A	**Scenario B**	**Scenario C**
Price	2.44 (1.50, 5.42)	1.07 (0.729, 3.30)	0.595 (0.158, 5.13)
Quantity	0.104 (−2.86, 10.4)	0.259 (−1.47, 9.87)	−0.0375 (−0.332, 0.0155)

Source: Authors' simulations.

2.4%, depending on the scenario.[9] The magnitudes of the price increases reflect an average increase in demand due to a reduction in the frequency of outbreaks, so that the price increase exceeds the increase in marginal costs of production, which range from 0.2% to 1.5%, depending on the

[9]*As with all simulations, there is uncertainty inherent in the magnitude of the effects cited here. In tables, we present 95% confidence bounds to accompany the simulated mean effects, which capture the asymmetric effects of outbreaks on supply and demand better than do standard deviations. These bounds are defined as the range of values in which 95% of simulated outcomes occur, but are distinct from statistical 95% confidence bounds. In the simulation, most parameters that enter the model are chosen as point estimates from data with a variance. The 95% confidence bounds reported here are determined by the stochastic variation in outbreaks of food-borne illness and the effects on supply and demand triggered by those outbreaks.*

scenario.[10,11] Because of this increase in marginal costs, the predominant effect of FSMA implementation is to shift the supply curve in, and the quantity of tomatoes sold in the United States remains about the same as in the non-FSMA (baseline) simulation.[12]

In two of the three scenarios for our sensitivity analysis, we find that the share of imports is likely to decrease. Table 3 summarizes results across all producers in each of the three countries considered, as well as results for three regions within the United States. In scenarios A and B, U.S. growers increase revenues by 16% and 5%, respectively, after the implementation of FSMA. Part of this advantage stems from Florida growers having been required by state law to have adopted GAPs since 2008. Growers in Mexico and Canada will be penalized further by the cost of the Foreign Supplier Verification Program. In scenario A, growers in Mexico and Canada lose 5% and 23% of revenues, respectively, compared with the simulations in which FSMA is not implemented. Losses are less substantial in scenario B than in scenario A, in large part because scenario B assumes larger farm sizes in Mexico and Canada.

In scenario C, the size distribution of farms in Mexico and Canada is assumed to be the same as the size distribution of farms in Florida and California, which are substantially larger than farms in other U.S. states. As a result, the share of imports in U.S. fresh tomato consumption increases by about 0.06 percentage points after the implementation of FSMA, in scenario C. In scenario C, the only region that is projected to lose market share is "other U.S. states", which loses revenues and shares in all three scenarios; California and Florida see gains from FSMA in scenario C.

Table 4 shows the simulated effects of FSMA on U.S. fresh-tomato farms by size of farm and exemption status, according to baseline (pre-FSMA) sales categories. The largest U.S. farms—those with at least $1 million in produce sales annually—stand to benefit most from the implementation of FSMA. For example, in scenario B, the revenue of these larger farms increases by 7% to 9%, while the smallest fully-covered farms could expect to see revenues decrease by 29%. In two scenarios, domestic farms with produce sales above $500,000 per year and farms not covered by the rule are expected to gain revenues and market shares. Meanwhile, qualified farms, which must incur some cost of compliance, are likely to fare somewhat better than the other small and very small farms, but still lose 8% to 22% of revenues, depending on the scenario. The relative advantage gained by firms that qualify for exemptions may give strong incentives for certain small farms to change their business practices, including crop mix or marketing practices. While the simulation does not account for these changes in

[10]Competition implies that the increase in marginal costs of production equals the costs of compliance as a share of revenue.

[11]Note that the estimated increase in costs of production as a share of revenue differs from the FDA's estimate because we assume that many farms have already adopted GAPs standards. Scenarios B and C include assumptions that the rate of GAPs adoption is relatively high and that farms in Mexico and Canada are substantially larger than in scenario A; the effects of these assumptions are to decrease the simulated marginal cost of FSMA compliance.

[12]The simulation uses an elasticity of demand for fresh tomatoes of –0.50. If demand did not shift after the implementation of FSMA and price increased by 2.4% — as in scenario A — the quantity sold would decrease by about $2.4\% * 0.50 = 1.2\%$, in contrast to the 0.1% increase seen in the simulation in scenario A.

Table 3 Simulated Changes in Revenue and Market Shares, by Region and Country, after Implementation of FSMA

Producer category	**Mean change in revenue (percent) (95% confidence bounds)**			**Mean change in market share (percentage points) (95% confidence bounds)**		
	Scenario A	**Scenario B**	**Scenario C**	**Scenario A**	**Scenario B**	**Scenario C**
Florida	26.4	7.91	0.607	5.75	1.72	0.145
	(10.1, 44.2)	(0.554, 17.8)	(0.239, 1.09)	(3.12, 7.27)	(0.530, 2.15)	(0.0522, 0.207)
California	20.3	7.25	0.754	1.93	0.661	0.0628
	(10.4, 47.0)	(2.76, 21.8)	(0.240, 1.25)	(0.773, 3.43)	(−0.543, 1.79)	(0.0204, 0.124)
Other U.S. states	−19.0	−4.17	−2.79	−1.67	−0.446	−0.264
	(−49.7, −1.18)	(−7.93, 8.88)	(−4.78, −0.948)	(−2.54, −0.00174)	(−1.19, 0.110)	(−0.434, −0.0890)
United States total	15.5	5.21	−0.0595	6.01	1.94	−0.0563
	(6.84, 26.0)	(0.327, 14.2)	(−0.230, 0.323)	(2.94, 7.40)	(0.270, 2.71)	(−0.103, 0.0170)
Mexico	−4.62	−1.67	0.145	−3.85	−1.54	0.0314
	(−12.1, 11.1)	(−5.04, 9.10)	(−0.298, 0.444)	(−6.00, -1.39)	(−2.78, 0.834)	(−0.0318, 0.0447)
Canada	−22.6	−3.44	0.413	−2.16	−0.403	0.0250
	(−34.4, −7.13)	(−5.54, 6.07)	(0.0602, 0.703)	(−2.97, −0.750)	(−1.07, 0.248)	(0.00832, 0.0584)

Source: Authors' simulations.

Table 4 Simulated Changes in Revenue and Market Shares, by Producer Category, after Implementation of FSMA—U.S. Farms only

Producer category	**Mean change in revenue (percent) (95% confidence bounds)**			**Mean change in market share (percentage points) (95% confidence bounds)**		
	Scenario A	**Scenario B**	**Scenario C**	**Scenario A**	**Scenario B**	**Scenario C**
Not covered	−5.41	8.63	1.45	−0.0710	0.0677	0.0104
	(−27.1, 21.8)	(−4.41, 28.1)	(−4.80, 7.82)	(−0.145, 0.0696)	(−0.0836, 0.132)	(−0.0702, 0.0328)
Qualified	−22.3	−10.4	−7.74	−0.232	−0.116	−0.0823
	(−48.8, −4.70)	(−14.6, 1.82)	(−9.30, −7.35)	(−0.324, −0.0615)	(−0.201, −0.0387)	(−0.0902, −0.0730)
Very small	−68.0	−29.3	−12.2	−1.39	−0.631	−0.262
	(−102, −16.8)	(−33.5, −0.298)	(−17.4, 0.492)	(−1.63, −0.411)	(−0.775, −0.181)	(−0.390, 0.00882)
Small	−69.9	−17.2	−5.03	−0.545	−0.144	−0.0432
	(−132, −20.3)	(−27.5, −0.0800)	(−7.07, −4.08)	(−0.662, −0.168)	(−0.188, −0.0688)	(−0.0595, −0.0363)
Medium	−23.0	1.69	0.646	−0.336	0.00782	0.00617
	(−52.2, −4.88)	(−4.88, 14.1)	(−2.96, 2.94)	(−0.453, −0.0662)	(−0.0858, 0.101)	(−0.0451, 0.0163)
Medium large	14.5	6.96	0.887	0.732	0.345	0.0447
	(3.15, 27.4)	(1.99, 16.0)	(0.217, 1.19)	(0.303, 0.982)	(0.0927, 0.542)	(0.00998, 0.0545)
Large	21.0	7.97	0.874	1.29	0.487	0.0559
	(9.23, 32.6)	(2.22, 16.6)	(0.318, 1.52)	(0.669, 1.56)	(0.201, 0.599)	(0.0192, 0.102)
Very large	29.1	8.51	0.899	6.56	1.92	0.214
	(13.9, 42.1)	(2.76, 16.9)	(0.359, 1.80)	(3.42, 7.07)	(0.799, 2.38)	(0.0808, 0.446)

Source: Authors' simulations.
Note: Farms must have at least $25,000 in annual produce sales to be covered by the FSMA Produce Safety Rule. Qualified farms have less than $500,000 in food sales and meet other criteria outlined in the text. Definitions of other farm sizes, for the purposes of this article, are as follows: Very small: $25,000 to $249,999 in produce sales; Small: $250,000 to $499,999; Medium: $500,000 to $999,999; Medium large: $1 million to $4,999,999; Large: $5 million to $9,999,999; Very large = $10 million or more.

Table 5 Simulated Changes in Revenues and Market Shares, Selected Producer Categories, after Implementation of FSMA

Producer category	**Mean change in revenue (percent) (95% confidence bounds)**			**Mean change in market share (percentage points) (95% confidence bounds)**		
	Scenario A	**Scenario B**	**Scenario C**	**Scenario A**	**Scenario B**	**Scenario C**
Florida very large	31.4 (11.2, 51.0)	8.31 (0.448, 17.8)	0.698 (0.280, 1.46)	4.75 (2.61, 5.83)	1.27 (0.420, 1.63)	0.118 (0.0455, 0.252)
California very large	28.9 (17.7, 57.4)	9.22 (3.54, 24.0)	1.32 (1.67, 2.49)	1.70 (0.648, 2.62)	0.530 (−0.197, 1.22)	0.0761 (0.0279, 0.155)
Other U.S. very large	7.44 (−27.1, 26.1)	8.52 (2.91, 23.6)	1.32 (−0.738, 2.58)	−0.102 (−0.0349, 0.416)	0.125 (−0.00786, 0.229)	0.0198 (0.00739, 0.0397)
Mexico very large	30.4 (18.2, 48.2)	9.69 (3.17, 21.6)	0.972 (0.0807, 1.63)	2.23 (1.65, 2.72)	1.55 (0.575, 2.39)	0.265 (0.0934, 0.495)
Florida very small	−39.3 (−82.3, 4.68)	0.576 (−14.4, 27.7)	−2.26 (−0.108, 0.814)	−0.127 (−0.0735, 0.0298)	−0.00617 (−0.0693, 0.0159)	−0.00894 (−0.0374, 0.00157)
California very small	−91.6 (−184, −2.00)	−34.8 (−45.9, 0.780)	−13.4 (−16.9, 0.495)	−0.212 (−0.258, -0.0348)	−0.0853 (−0.114, −0.0215)	−0.0332 (−0.0414, 0.00106)
Other U.S. very small	−70.4 (−106, −16.2)	−34.6 (−39.7, −2.65)	−14.1 (−19.7, 0.528)	−1.05 (−1.26, -0.287)	−0.539 (−0.686, −0.103)	−0.220 (−0.305, 0.00725)
Mexico very small	−76.8 (−82.3, −14.7)	−59.2 (−62.9, −12.2)	−24.1 (−29.1, 0.372)	−6.35 (−6.75, -2.05)	−2.72 (−2.92, −0.926)	−0.232 (−0.276, −0.0205)
Mexico qualified	4.35 (−7.51, 21.7)	−8.32 (−14.4, 1.68)	−7.71 (−8.51, −7.62)	0.0230 (−0.367, 0.292)	−0.250 (−0.361, −0.131)	−0.0356 (−0.0383, −0.0346)
Mexico not covered	34.4 (10.4, 95.8)	11.1 (−0.573, 28.7)	1.38 (−9.18, 5.41)	1.09 (0.233, 1.41)	0.181 (0.00185, 0.297)	0.00351 (−0.0150, 0.0100)

Source: Authors' simulations.

Note: Farms must have at least $25,000 in annual produce sales to be covered by the FSMA Produce Safety Rule. Qualified farms have less than $500,000 in food sales and meet other criteria outlined in the text. Definitions of other farm sizes, for the purposes of this article, are as follows: Very small = $25,000 to $249,999 in produce sales; Very large = $10 million or more.

Table 6 Simulated Changes in Revenue and Market Shares, by GAPs Adoption Status, after Implementation of FSMA—Fully Covered U.S. Farms only

Producer category	**Mean change in revenue (percentage) (95% confidence bounds)**			**Mean change in market share (percentage points) (95% confidence bounds)**		
	Scenario A	**Scenario B**	**Scenario C**	**Scenario A**	**Scenario B**	**Scenario C**
GAPs adopters	24.4	8.19	0.769	8.21	2.84	0.283
	(10.0, 36.1)	(3.09, 17.0)	(0.295, 1.17)	(4.58, 8.77)	(1.21, 3.40)	(0.106, 0.334)
GAPS non-adopters	−40.3	−30.2	−32.1	−1.89	−0.855	−0.267
	(-73.4, -8.31)	(-46.9, 7.67)	(-43.7, -6.92)	(-2.42, -0.383)	(-1.13, -0.332)	(-0.302, -0.0902)

Source: Authors' simulations.

practice, any changes in practices would accentuate the simulated effects that show a relative advantage for large and exempt tomato farms.

Table 5 demonstrates similar patterns for individual regions within the United States and for Mexico as well. The largest farms are generally expected to gain revenues and market shares from the implementation of FSMA, and the smallest regulated farms are expected to incur substantial losses.

Finally, we examine the results of our simulation analysis with regard to growers that have already adopted GAPs or similar standards. Table 6 shows that the revenue of U.S. growers that have already adopted GAPs increases by up to 24% after the implementation of FSMA. For these growers, market share increases by up to 8 percentage points. In sharp contrast, U.S. growers that have not already adopted GAPs lose around 40% of their revenue and also lose market share. The pattern is similar when comparing farms outside the United States by GAPs adoption status, although estimated effects are not presented here.

Concluding comments

The Food Safety Modernization Act (FSMA) significantly expands the food-safety regulatory authority of the U.S. Food and Drug Administration (FDA). The FDA has issued several rules to which essentially all producers, processors, and shippers of non-animal-based food sold to consumers in the United States must adhere. These standards relate to production practices, many of which have already been formalized as private standards to which producers in certain industry organizations currently comply.

This article developed and executed a simulation model to demonstrate the likely effects on farm size and related distributions of the pending implementation of FSMA, which applies different requirements depending on, for example, the value of sales, farm location, and commodity grown. The simulations indicate that the wholesale price of fresh tomatoes will increase slightly—by up to 2.4%—because of the costs of implementing FSMA and a slight increase in demand relative to a scenario without FSMA and with more frequent food-borne illness outbreaks. The quantity of fresh tomatoes marketed will remain approximately the same under FSMA implementation, though changes in both price and quantity will see different seasonal fluctuations because of differences in market shares for foreign and domestic producers over the course of the year.

Small farms that do not qualify for partial or full exemptions from FSMA will be disadvantaged relative to other growers—both larger and smaller. Farms that have already adopted the food-safety practices known as GAPs, which closely resemble the requirements of FSMA, will gain advantage over competitors that have not adopted GAPs. Thus, most of the gain in market share for U.S. growers will be gains for growers in Florida and California that have already adopted GAPs. The share of fresh tomatoes imported is likely to decrease by up to 6 percentage points because importers face additional regulatory burden in the form of the Foreign Supplier Verification Program—although under some sets of assumptions, the market share of imports will increase slightly. These considerations raise policy issues related to equity across U.S. farms and potentially in the context of international trade relations and agreements.

Naturally, our analysis has limitations. We consider only the effect of FSMA implementation on the wholesale price of fresh tomatoes, and not on the retail price of fresh tomatoes. As with any analysis, we rely on many simplifying assumptions, starting with the interpolation of the FDA's estimates of the cost of compliance with FSMA as the basis for our supply curve shifts. We use a sensitivity analysis to vary assumptions for certain key unknowns, such as the share of farms that have already undertaken some standardized food-safety practices, but other parameters are taken as fixed (rather than randomly distributed). Food-borne illness outbreaks are so rare and so difficult to detect and measure that, even after FSMA is implemented, the effects of FSMA on human health outcomes will be unknowable. As discussed in the online supplementary appendix, limited data on the history of food-borne illness outbreaks associated with fresh tomatoes—before and after GAPs adoption—suggests that the adoption of food-safety standards may reduce the likelihood of food-borne illness outbreaks by 75%. Other assumptions like these carry the analysis, so we must emphasize that the estimated effects of FSMA on market shares and revenues, as well as on wholesale prices, should be understood as illustrative, and that the general story told by these simulations deserves more attention than the estimates themselves.

We close by suggesting areas for further research. Supply response deserves further attention. Standard economic reasoning suggests that by raising the cost of growing some produce commodities but not others, the implementation of FSMA will likely result in a shift in production in favor of the commodities that are not covered by the Produce Safety Rule. Substitutions in consumption and production are important considerations for evaluating the effects of FSMA. The political economy of FSMA rules, including a comparison of standards already adopted by some farms and firms with FSMA rule requirements, raises many issues and would make fascinating case studies. Finally, the relationship of the FSMA rules to international trade agreements raises many issues of law and economics.

Supplementary Material

The appendices are available as supplementary material at http://aepp.oxfordjournals.org/.

Acknowledgements

This paper benefitted from the helpful comments of Julian Alston, Wei Zhang, Richard Sexton, Peyton Ferrier, Chen Zhen, Fred Kuchler, Rolf Müller, and numerous seminar participants. The authors greatly appreciate the helpful comments of the editor, Spiro Stefanou, and two anonymous referees. The authors are grateful to Kathy Lynch and Bob Dubman for connecting us with the farm-level Census of Agriculture data, and to Yixing Tian for research assistance.

Funding

Generous research funding support was provided by the USDA ERS Cooperative Agreement No. 58–4000–0–0047 and the Giannini Foundation of Agricultural Economics.

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