Price and Welfare Effects of the Food Safety Modernization Act Produce Safety Rule

Peyton Ferrier, USDA–Economic Research Service

Chen Zhen, University of Georgia

John Bovay, University of Connecticut

January 8, 2019

Abstract

Implementation of the U.S. Food Safety Modernization Act (FSMA) Produce Safety Rule is expected to cost about 1.1 percent of revenue for covered farms producing raw and minimally processed fruits and vegetables in the United States. To simulate the price and welfare effects of the rule, we develop an equilibrium displacement model for 18 fruits and 20 vegetable commodities, drawing on recent estimates of the rule's commodity-level cost of compliance and new retail scanner data-based estimates of commodity-level price elasticity of demand. We find that consumer and farm prices increase by 0.66 and 2.05 percent respectively for fruits and 0.16 and 0.59 percent for vegetables. Costs associated with the rule's implementation across these commodities are estimated to reduce producer welfare by 0.28 percent for fruits and 0.48 percent for vegetables (as a share of revenue). If the rule's provisions were enacted unilaterally by growers of individual commodities, producer welfare losses would increase to 0.71 percent for fruits and 0.50 percent for vegetables. We also compare our estimates of the cost to producers of implementing the rules with the potential benefits to producers from the avoidance of costs associated with food-borne illness outbreaks.

JEL codes: Q11, Q13, Q18, L51, Q17

Disclaimer: The views and opinions expressed here do not represent those of the USDA or the Economic Research Service.

Introduction

The 2011 passage of the Food Safety Modernization Act (FSMA) marked the most comprehensive legislative change to the authority of the Food and Drug Administration (FDA) to regulate food since the 1930s (Johnson, 2011, 2014). The law empowered the FDA to impose new regulatory requirements on food producers and handlers, to expand requirements for and inspections of imports, and to issue mandatory recalls of food. Additionally, for the first time, the FDA was empowered to regulate production practices at the farm level. While certain retailers and producer groups have independently coordinated heightened requirements for improved food safety in production (Calvin et al., 2017; Adalja and Lichtenberg, 2016), the Produce Safety Rule is broadly applicable to nearly all produce—both imported and domestically produced—that is sold fresh (unprocessed) in the United States. A detailed description and analysis of the Produce Safety Rule can be found in Bovay, Ferrier, and Zhen (2018).

The costs of compliance with the FSMA Produce Safety Rule are substantial, decreasing as a share of revenue, and vary across commodities. This suggests that implementing the Produce Safety Rule will have differential effects across different types of producers and important implications for the relative prices of foods sold at retail. This article uses retail grocery store data at the national level to estimate demand systems for 18 fresh-fruit and 20 fresh-vegetable commodities affected by the FSMA Produce Safety Rule. Using existing estimates of farm prices as shares of retail prices and new estimates of the compliance costs of FSMA as they vary by farm size (Bovay, Ferrier, and Zhen, 2018), we then estimate cost pass-through and welfare effects of the Produce Safety Rule. Fruit and vegetables are often thought to be substitutes for each other at the commodity level, suggesting that specific commodity groups that implemented commodity-specific food-safety practices could lose welfare when consumers substituted to other commodities that were relatively lower in price. We find that the offsetting benefits associated with substitution in demand are small in magnitude and that any benefit a commodity group might gain from exemption from the Produce Safety Rule would stem primarily from avoiding the direct costs of compliance rather than through the higher prices of other fruits and vegetables.

More generally, the differential costs of compliance with FSMA across commodities implies that growers of some regulated commodities will benefit at the expense of others, as consumers shift to relatively inexpensive commodities. However, our empirical analysis suggests that the offsetting benefits associated with substitution in demand are small in magnitude and that any benefit a commodity group might gain from exemption from the Produce Safety Rule would stem primarily from avoiding the direct costs of compliance rather than through the higher prices of other fruits and vegetables. Nonetheless, we find that the costs of implementing the rule are likely less than the potential benefits to producers from the avoidance of costs associated with food safety outbreaks. Along with Bovay and Sumner (2018), this article is the first to analyze the economic implications of FSMA implementation.

The next section of this article gives background on the FSMA Produce Safety Rule and the economics of food-safety regulation. We then outline the models used in the simulation analysis. Next, we describe the data used to simulate supply shifts, the data used for demand system estimation and the demand system estimation itself. Finally, we describe simulated effects on prices and welfare and discuss implications of our analysis.

Background

The Food Safety Modernization Act was signed into law in early 2011, and the FSMA Produce Safety Rule is one of several major rules developed by FDA as a consequence of the legislation. In this section, we describe the regulatory requirements of the Produce Safety Rule and discuss the economic literature on food-safety regulation.

The FSMA Produce Safety Rule

Since the passage of FSMA in 2011, its potential effects on costs for small farms and market structure have been much discussed, although it has not been studied extensively in the economics literature. The Produce Safety Rule imposes costs on growers by mandating practices to curtail microbial contamination of fresh produce in five main areas: (1) testing of agricultural water, (2) use of biological soil amendments, (3) requirements regarding worker health and hygienic practices, (4) prevention of animal intrusion, and (5) documentation of sanitary standards. Compliance with the Produce Safety Rule has been required since January 2018 for growers of covered commodities with annual food sales of more than $500,000. Smaller growers will be allowed to begin complying in 2019 or 2020.[1]

In its Regulatory Impact Analysis, FDA (2015b) estimated somewhat disaggregated costs of compliance by farm size.[2] After accounting for exemptions, the FDA estimates suggest that the costs of compliance are 6.8 percent for very small, 6.0 percent for small farms, and 0.9 percent for large farms, as a share of the value of farm sales (Bovay, Ferrier, and Zhen, 2018).[3] By definition, large farms have a greater value of sales than small farms, so the Produce Safety Rule is estimated to cost only 1.1 percent across all farms (Bovay, Ferrier, and Zhen, 2018). However, the differential effects of compliance, across farm sizes and commodities, are expected to have important effects on prices and market structure.

Farms producing fruits or vegetables that will undergo processing that mitigates microbial pathogen risk are not required to implement the Produce Safety Rule for these crops, as the "kill step" obviates the need for the Produce Safety Rule's measures, which are primarily oriented towards controlling microbial growth. Similarly, the rule applies only to raw agricultural commodities (RACs) consumed in a raw state. While RACs include most fruits, certain vegetables (including asparagus, beets, and sweet corn) were exempted on grounds

---

[1] Growers of sprouts from beans or seeds were required to implement the Produce Safety Rule starting in January 2017.

[2] See table 1 for a breakdown of FDA's estimated costs of compliance, by regulatory component.

[3] Farms with less than $25,000 in fresh produce sales, along with farms selling locally with sales less than $500,000, were excluded from regulatory coverage.

that they are "rarely consumed raw in the United States" (FDA, 2015a, p. 37).[4]

While consumers bear the direct effects of food-borne illnesses, food-safety risks are affected by the actions of multiple agents in the food supply chain (along with the actions of consumers themselves). Because the producers', processors', and handlers' actions cannot be easily inferred by observing the final product, moral hazard is possible at multiple points along the supply chain (Hölmstrom, 1979; Cooper and Ross, 1985; Starbird, 2005a,b). Further complicating analysis is the potential for consumer behavior to offset risks introduced at the farm level, for example by washing or cooking raw ingredients. Peltzman (1976) emphasized that in cases where multiple agents (upstream and downstream) can affect the risk associated with end product use, mandating safety measures for upstream producers can cause downstream agents to reduce risk-mitigating behavior. For instance, consumers may be less likely to cook or throw out old produce items if they believe the probability of illness has been reduced by actions taken by farmers or processors.[5] While the reduced need for offsetting behavior is a potential consumer benefit, it may also lead to an over-estimation of the effect of regulations on the number of illnesses if such estimation assumes that consumer behavior did not change following implementation of a regulation (Miljkovic, Nganje, and Onyango, 2009).

Winfree and McCluskey (2005) described how the food-safety reputation of a commodity or industry can act as a common-property resource and how a food-borne illness outbreak associated with one good or brand might potentially depress demand for a related one. Spillovers of demand shocks appear to be common in within produce, especially when traceability is poor and misidentification of the outbreak's source is possible.[6] Calvin (2004)

---

[4] Proposed and revised versions of the Produce Safety Rule in 2013 and 2014 led to predictable discussions about goods that should be added to or removed from the list of exemptions. Commodities removed from the list of exempted commodities included: artichokes, Brussels sprouts, plantains, and several root vegetables (e.g., parsnips, taro, turnips, and yams). Commodities added to the list of exemptions included: dates, dill, peppermint, pecans, sour cherries, and several types of beans (navy, black, and great Northern).

[5] Triple-washed salad greens are an illustrative example.

[6] For this reason, the FSMA mandated that the Government Accountability Office study mechanisms for compensating producers harmed by FSMA-authorized FDA recalls later found to have incorrectly identified the source of an outbreak.

noted that, following a 1996 foodborne illness outbreak, the CDC initially warned consumers against consuming strawberries from California only to later attribute the source of the outbreak to raspberries from Guatemala. The European Union paid €210 million ($250 million) for damages incurred by Spanish vegetable farmers following EU officials incorrectly implicating those industries in an outbreak later attributed to German sprouts (Reuters, 2011). In a similar manner, U.S. tomato farmers were implicated in a 2008 *Salmonella* outbreak later attributed to peppers (Arnade, Kuchler, and Calvin, 2013). In each of these cases, producers of otherwise safe products suffered severe demand decreases and large monetary losses from outbreaks ultimately attributed to other producers (in fact, producers of entirely different commodities). As consumers rapidly eschew commodities thought to be unsafe, they may substitute to similar commodities (thought to be safe). In particular, Arnade, Calvin, and Kuchler (2009) found that alternative leafy greens (e.g., bulk lettuce) were shock substitutes, in that demand for the alternatives increased as consumers avoided buying spinach in the wake of an *E. coli* outbreak in 2006.

For these reasons, some fruit and vegetable producers and retailers have developed food-safety plans independently of FDA regulation to improve consumer quality assurance. These plans are typically voluntary in nature and, in some cases, may be widely subscribed to among segments of producers. For instance, approximately 99 percent of California producers subscribed to the Leafy Greens Marketing Agreement developed in response to the 2006 spinach outbreak (Calvin et al., 2017). Adalja and Lichtenberg (2016) found that producer organizations are more likely to adopt food-safety guidelines if their members represent a larger share of the market or have recently experienced a negative food-safety event. Unfortunately, the tendency for food-safety measures to be adopted after outbreaks or recalls prevents clear empirical identification of the effect of food-safety investments on food-safety perceptions and demand.

Even if the demand for a commodity is entirely unaffected by food-safety actions of other producers, an exempted commodity group may still benefit from the enactment of comprehensive safety rules mandated for other producers through simple price effects that encourage potential substitution to similar, now relatively lower-priced commodities. Under these same conditions, commodity groups that undertake such measures would benefit from comprehensive enactment of the Produce Safety Rule because it mitigates the potential for substitution effects induced by changes in relative prices. In light of these potential substitution effects, this paper presents estimates of both the value of each commodity's potential exemption from the Produce Safety Rule and the benefit producers of each commodity gain from the comprehensive enactment of the rule, relative to a unilateral producer-group decision to adopt equivalent private standards.

The Benefits of Food-Safety Regulation

While costly from a production standpoint, the Produce Safety Rule directly benefits consumers by reducing the likelihood and severity of food-borne illness. The Centers for Disease Control and Prevention attributed 46 percent of food-borne illnesses with a known food vehicle in the period 1998–2008 to produce (Painter et al., 2013). Total costs of food-borne illness—including hospitalization, loss of life, lost wages, and discomfort—are estimated to cost $3,360 per case and $36 billion annually (Minor et al., 2015). Most of these direct costs of illness are borne by consumers because liability-based lawsuits are often difficult to establish and outbreaks often cannot be directly traced to their source (Buzby, Frenzen, and Rasco, 2001; Buzby and Frenzen, 1999).

In its comparison with different scenarios for the Rule's costs, the FDA's Regulatory Impact Analysis only estimated benefits arising from averted illness as a result of safety measures mandated by the Produce Safety Rule, not benefits to producers through market effects. In practice, however, the Produce Safety Rule is also likely to provide some benefits to producers by reducing demand disruptions, recall costs, and liability costs and increasing consumer quality assurance. Parsing the linkage between the objective risks of food-borne illness associated with a food and consumers' subjective assessments of that food's value and desirability is a difficult process. Across foods, differences in the risks of food-borne illness are small and difficult to distinguish. Consumer risk perceptions are unlikely to change under ordinary circumstances but shocks, in the form of recall announcements or media attention, can cause large and likely disproportionate demand responses that often recede over time.[7] A large literature finds that, in general, consumer demand and related output prices fall in response to negative media coverage (Mazzocchi, 2006; Carter and Smith, 2007; Piggott and Marsh, 2004; Marsh, Schroeder, and Mintert, 2004), but that the size and duration of such shocks varies.[8]

Producer costs, however, extend beyond demand and price effects to include liability, recall or other costs. While recalls became more common across all foods (including fruits and vegetables) between 2004 and 2013, Page (2017) argued that this increase is more likely due to improvements in technologies and practices (such as faster detection methods and more frequent safety audits) and legal changes than due to declines in the underlying safety of foods. Recalls of fresh produce are far more likely (92 percent) than meat, poultry and seafood recalls (40 percent) to be caused by bacterial contamination (e.g., *Salmonella*, *Listeria moncytogenes*). Notably, fruit and vegetable recalls spiked in 2012 following *Salmonella* outbreaks in cantaloupe and imported mangos.

Public data on the size and frequency of liability payments is sparse, but available sources suggest they are small relative to the size of total damages (Buzby and Frenzen, 1999; Buzby, Frenzen, and Rasco, 2001). A distinct literature estimates the size and duration of decreases

---

[7] In the absence of a food safety shock, consumers' willingness to pay for a specific product's improved safety may be difficult to distinguish from separate but distinct quality and brand features. Following a food safety event, however, consumers likely overweight more readily available (i.e., more recent and proximate) information in forming expectations of the (health) risk (see Kahneman, 2011, p. 316). The reduced consumer demand that follows a food-safety event can vary in scope and duration, often for idiosyncratic reasons. Characterizing food safety as a common-property resource does not preclude the idea that food safety investments affect demand by mitigating the size and scope of demand shocks.

[8] For produce markets in particular, Arnade, Calvin, and Kuchler (2009) found that leafy greens are shock substitutes in that consumers substituted towards lettuce and other leafy green vegetables following the well-publicized 2006 *E. coli* outbreak in spinach and that retail expenditures on bagged spinach decreased 20 percent over a 68-week period. Rejesus, Safley, and Strik (2014) and Bovay and Sumner (2018) applied these findings to estimate the value to blackberry producers of technology that prevents food-borne illness outbreaks and to model demand responses to food-borne illness outbreaks in the fresh-tomato market, respectively.

in company valuations following food safety events, a method that conceptually should factor in all forms of producer costs (Lusk and Schroeder, 2002; Thomsen and McKenzie, 2001; Wang et al., 2002; Salin and Hooker, 2001).[9]

Modeling Setup

We use estimates of the commodity-level costs of compliance with FSMA to develop estimates of the welfare effects and cost pass-through of 18 fruits and 20 vegetables.[10] Specifically, we develop an equilibrium displacement model to estimate market conditions before and after the producers undertake costs associated with the rule. The welfare effects and the extent of cost pass through can be inferred directly from the estimates of the market equilibria before and after the rules are enacted. We then compare our estimates of the producer costs of complying with the Produce Safety Rule to estimates of producer benefits of the rule in terms of reduced demand disruptions. Empirical estimates used for calibration of the model are explained in later sections.

Equilibrium Displacement Model

Equilibrium displacement models (EDMs) have wide application within applied policy analysis, including analysis of the economic effects of agricultural policies, to allow for comparative static analysis of a market event across upstream and downstream elements of the supply chain (see, e.g., Wohlgenant, 1989; Davis and Espinoza, 2000; Alston et al., 2007; Okrent and Alston, 2012). First, an initial market equilibrium is assumed to hold across the linked markets under consideration where supply and demand relationships are explicitly specified. Next, a reduced form of the model is derived, typically by translating key supply and demand

---

[9] While recalls can mitigate larger retail liability costs when products are known to be unsafe, the size and scope of a recall may act as a signal of the size of the underlying food-safety risk. Pouliot and Sumner (2012) find that food traceability investments that limit the size and scope of recalls and its associated demand shocks. While ex post producer liability costs of food-borne illness shift the incidence of damages from producers to consumers, Pouliot and Sumner (2008) find that traceability increases the incentives for firms to improve food quality and safety by increasing liability costs.

[10] These are the fresh-produce commodities for which scanner data were available.

relationships to more easily manipulated elasticity relationships. Then, an exogenous market shock, policy or restriction is simulated to show how the equilibrium moves from an initial to a new state after the shock. Finally, relevant welfare or policy metrics are developed to describe the event.

In our model, we assume that each retail food product (Q) requires two production inputs, farm-level (unprocessed wholesale) food (X) and marketing inputs (MI). For instance, to sell an apple at the retail level, a grocery store purchases wholesale apples from farmers and marketing inputs (store space, shelving, cashier labor, electricity, advertising, delivery trucks, etc.). We consider N goods within our model and the one-to-one correspondence allows n to index retail food (Q_n), wholesale food (X_n), and the specific marketing input requirement of retail food (MI_n). The prices of Q_n, X_n, and MI_n are denoted respectively as P_n, W_n, and PMI_n, all being $N \times 1$ in dimension. The A_n term captures any potential demand increase associated with food being safer for having adopted the FSMA mandated measures.

For retail food, we define consumers' demand function as Q_N^D in (1) and retailers' cost function as C_n in (2), where constant average costs are imposed for each good. Furthermore, if retail markets are competitive, price equals average cost, which implies the latter expression in (2). For wholesale foods, we define the demand function as X_n^D in (3) and the supply function as X_n^S in (4). As an input, wholesale food's demand function can be defined as the derivative with respect to W of the retail food cost function in (2). The assumption that markets are competitive and that price equals cost at the retail level fixes the retail surplus at the constant level of zero.

The added costs of implementing FSMA regulations for wholesale producers is modeled as a percentage reduction in the prices farmers receive at the wholesale level, h_n. For example, if the cost of implementing FSMA regulations is 2.7% for watermelons, then farmers receive 97.3% of the prices paid (W). Hence, we define wholesale food supply X_n^S as a function of W_n and h_n. For marketing inputs, we define the demand function as MI_n^D in (5) and the supply function as MI^S in (6). Like the demand for individual wholesale foods, the demand for marketing inputs is the derivative of the retail food cost function in (2) with respect to PMI. The supply of marketing depending solely on PMI. These equations are, collectively:

$$Q_N^D = Q_N^D\left(P_N, A_N\right) \qquad \text{Retail Food Demand} \tag{1}$$

$$C_n = c_n\left(W_n, PMI\right) \times Q_n \qquad \text{Retail Food Cost} \tag{2}$$

$$P_n = c_n\left(W_n, PMI\right)$$

$$\begin{aligned} X_n^D &= \frac{\partial c_n}{\partial W_n} \times Q_n \qquad \text{Wholesale Food Demand} \\ &= g_n\left(W_n, PMI\right) \times Q_n \end{aligned} \tag{3}$$

$$X_n^S = X_n^S\left(W_n \times \left(1 \quad h_n\right)\right) \qquad \text{Wholesale Food Supply} \tag{4}$$

$$\begin{aligned} MI_n^D &= \frac{\partial c_n}{\partial PMI} \times Q_n \qquad \text{Marketing Input Demand} \\ &= k_n\left(W_n, PMI\right) \times Q_n \end{aligned} \tag{5}$$

$$MI^S = MI^S\left(PMI\right) \qquad \text{Marketing Input Supply} \tag{6}$$

Appendix A shows how equations (1) through (6) can be represented in terms of elasticities and cost shares following total differentiation. Specifically, where:

η_n are the Marshallian demand elasticities for retail food (Q),

$_n$ are the Hicksian demand elasticities for the inputs (X),

$_{MI}$ are the Hicksian demand elasticities for the marketing input (MI),

ε_n are the elasticities of wholesale food supply, and

s_n are the cost shares of X in the production of Q.

To reorganize equations (1) through (6) into matrix form, denote $d\ln$ as the change in a variable's log value (so that $d\ln P = \frac{dP}{P}$, $d\ln Q = \frac{dQ}{Q}$, and so on). Let $_N$ be an $N \times 1$ matrix with each element equaling $_n = 1 \quad h_n$, where h_n is the percentage cost shift for commodity n. For simplicity, we assume that $\partial Q_n^D / \partial A_n = 0$ for all commodities and that the supply of marketing inputs is perfectly elastic (a specification that allows us to eliminate an equation from the matrix solution). These rearrangements of equations (1) through (6) and assumptions yield equations (7) through (11):

$$d\ln Q_n \quad \eta_n d\ln P_n = 0 \tag{7}$$

$$d\ln P_n \quad s_n d\ln W_n = 0 \tag{8}$$

$$d\ln X_n \quad {}_n d\ln W_n \quad d\ln Q_n = 0 \tag{9}$$

$$d\ln X_n \quad \varepsilon_n d\ln W_n = \varepsilon_n d\ln \quad {}_n \tag{10}$$

$${}_{MI} d\ln W_n + d\ln Q_n \quad d\ln MI_n = 0. \tag{11}$$

Additionally, where $\quad {}_{X,MI}$ is the elasticity of substitution between X_n and MI for each Q_n, $\quad {}_n$ and $\quad {}_{MI}$ can be specified as $\quad (1 \quad s_n) \quad {}_{X,MI}$ and $(1 \quad s_n) \quad {}_{X,MI}$, respectively. Equations (7) through (11) can then be represented as $AZ = D$ where:

$$A = \begin{bmatrix} I_N & \eta_N & 0_N & 0_N & 0_N \\ 0_N & I_N & 0_N & s_N & 0_N \\ I_N & 0_N & I_N & (I_N \quad s_N) \quad {}_{X,MI} & 0_N \\ 0_N & 0_N & I_N & \varepsilon_N & 0_N \\ I_N & 0_N & 0_N & (I_N \quad s_N) \quad {}_{X,MI} & I_N \end{bmatrix},$$

$$Z = \begin{bmatrix} d\ln Q_N & d\ln P_N & d\ln X_N & d\ln W_N & d\ln MI_N \end{bmatrix}', \text{ and}$$

$$D = \begin{bmatrix} 0 & 0 & 0 & \varepsilon_N \ln \quad {}_N & 0 \end{bmatrix}'.$$

Each element in A is itself an $N \times N$ matrix while each element in Z and D are $N \times 1$. In our model, the FSMA regulations cause the terms to shift from 0 to $(1 \quad h_n)$. The solutions for Z are obtained as:

$$Z = A^{\quad 1} \times D. \tag{12}$$

The solution for Z can be used in conjunction with the initial equilibrium (Q_0, P_0, X_0,

W_0, and MI_0) to calculate new equilibrium retail quantities ($(1 + d\ln Q) \times Q_0$) and prices ($(1 + d\ln P) \times P_0$), wholesale (farm) quantities ($(1 + d\ln X) \times X_0$) and prices ($(1 + d\ln W) \times W_0$), and marketing inputs ($(1 + d\ln MI) \times MI_0$).

Welfare Changes

The new equilibrium values are also used to calculate the welfare changes in terms of the (retail) consumer surplus (CS_n) and (farm) producer surplus (PS_n). Our assumption that the supply of marketing inputs is perfectly elastically supplied precludes the possibility of a marketing input supplier surplus. The general formulas for the producer and consumer surplus are:

$$\begin{aligned} dCS_n &\approx P_{0,n} d\ln P_n \times (Q_{0,n} \times (1 + 0.5 d\ln Q_n)) \\ &\approx E_{0,n}(d\ln P_n \times (1 + 0.5 d\ln Q_n)) \qquad (13) \\ dPS_n &\approx W_{0,n} \times (d\ln W_n \quad h_n) \times (X_{0,n} \times (1 + 0.5 d\ln X_n)) \\ &\approx R_{0,n} \times (d\ln W_n \quad h_n) \times (1 + 0.5 d\ln X_n), \qquad (14) \end{aligned}$$

where $E_{0,n}$ is consumer expenditure for the n^{th} good ($P_{0,n} \times Q_{0,n}$) and $R_{0,n}$ is farm revenue from the n^{th} good. Summing across all N goods, equations (13) and (14) yield:

$$CS_N \approx E_{0,N} \sum_n (w_n \times (d\ln P_n \times (1 + 0.5 d\ln Q_n)) \qquad (15)$$

$$PS_N \approx \sum_n R_{0,n} (d\ln W_n \quad h_n)(1 + 0.5 d\ln X_n), \qquad (16)$$

where $E_{0,N}$ is consumer expenditure across all N goods ($P_{0,N} \cdot Q_{0,N}$) and w_n is the average share of consumer expenditure for the n^{th} good.

Cumulatively across all goods, the change in consumer surplus as a share of all consumer spending ($cs \approx \sum_n dCS \times E$) and producer surplus as a share of all farm revenue ($ps \approx$

$\sum_n dPS \times R$) are:

$$cs \approx \sum_n \quad (d \ln P_n \times (1 + 0.5 d \ln Q_n)) \tag{17}$$

$$ps \approx \sum_n ((d \ln W_n \quad h_n)(1 + 0.5 d \ln X_n)). \tag{18}$$

Cost Pass-Through

For an individual commodity, the cost of implementing FSMA on farms is borne by both retail consumers, who pay higher prices, and farm producers, who incur additional costs not recouped through increased demand. Specifically, the shares of that price increase transmitted to consumers and producers are CPT and FPT,[11] or:

$$CPT_n \approx d \ln P_n / h_n \tag{19}$$

$$FPT_n \approx - d \ln W_n / h_n. \tag{20}$$

Typically, CPT will be smaller than FPT as the potential for consumer substitution away from a good further mutes the initial price change. However, in some cases, substitution effects may potentially cause demand substitution to a particular good. As a matter of theory, CPT can be greater than FPT.

Valuing Exemptions and Comprehensive Implementation

As discussed, a few dozen produce commodities are considered "rarely consumed raw" and are, consequently exempted from the Produce Safety Rule. We estimate the change in producer surplus if commodities were to be exempted from coverage under the Produce Safety Rule. We also estimate the producer surplus loss from the full implementation of the FSMA Produce Safety Rule, across all commodity groups, relative to the unilateral decision

---

[11] CPT and FPT stand for cost pass-through and farm pass-through, respectively.

of a single industry to require that its members adopt FSMA-like food-safety standards.[12]

The value to producer group n of (a counterfactual) exemption from FSMA is calculated as the difference between the change in producer surplus when setting $h_n = 0$ (while leaving the other costs shift values unchanged) and the change in producer surplus under . If similar fresh fruits and vegetables are substitutes, then the value of the exemption, in terms of the change in producer surplus, will exceed the savings in costs associated with compliance. If substitute commodities are covered by the FSMA Produce Safety Rule, their prices would rise upon implementation and demand for the exempt commodities would increase. For similar reasons, comprehensively enacting FSMA regulations across all commodities will have a small negative impact on producer welfare (compared to the unilateral adoption of similar standards) if substitution effects are strong.

Parameters Used for Simulating Supply Shifts

To simulate shifts in the supply of produce commodities as a result of implementing FSMA, we draw on estimates of the costs of complying with FSMA, estimates of farm price shares of retail prices, estimates of price elasticities of supply, and estimates of elasticities of substitution in supply. We now describe these estimates.

Farm Costs of Implementing the FSMA Produce Safety Rule

The FDA's Regulatory Impact Analysis (FDA, 2015b) estimates differences in compliance costs between farm sizes, but not between commodities. In our simulations, we use new estimates of the recurring costs of complying with FSMA as they vary by commodity, developed in Bovay, Ferrier, and Zhen (2018) based on FDA's estimates by farm size. In Bovay, Ferrier, and Zhen (2018), using detailed data from the USDA National Agricultural Statistics Service's 2012 Census of Agriculture, we first calculated the share of each regulated farm's

---

[12] See Bovay (2017) for discussion of the collective adoption of food-safety standards in the absence of federal regulation.

acreage used for growing each produce commodity. Then, assuming that each commodity's distribution of acreage is equal to the distribution of production across farm sizes, we estimated average costs of implementing the Produce Safety Rule, by commodity, based on the distribution of farm size (sales) for each commodity. In Bovay, Ferrier, and Zhen (2018), we note that compliance costs will differ based on each commodity's current state of food-safety practices which depends on local idiosyncrasies, state laws, and agreements already in place between producer groups or producers and retailers, and that FDA's cost estimates may therefore be overestimates.

Table 2 shows our estimates of the cost of implementation for the 18 fruits and 20 vegetables considered in this study (as developed in Bovay, Ferrier, and Zhen, 2018), which enter our model as h_n (see equation 4). Among vegetables, romaine and head lettuce have the lowest implementation costs at 0.3 to 0.4 percent of revenue while snap beans has the highest at 3.0 percent.[13] Among fruits, honeydew has the lowest cost of implementation, at 0.3 percent, while mangos have the highest at 3.6 percent. Table 2 also indicates the share of the domestically consumed good that is imported and whether the commodity is covered or exempted from the final Produce Safety Rule.

Cost Shares

To estimate the share of the retail commodity's costs that is derived from the cost of wholesale agricultural costs, we divide the wholesale price by the retail price index. We obtain wholesale prices from the USDA's Agricultural Marketing Service while retail prices are calculated as a weighted average of observed prices within our IRI InfoScan retail scanner dataset. Table 2 provides estimates of these cost shares. In general, our shares are higher than those found by Stewart (2006). By construction, the share of the retail price attributable to marketing inputs is the residual share $(1 \quad s_n)$ in our two-input production function.

---

[13] Commodity-level costs of compliance are estimated as a share of revenue; perfect competition within commodities is assumed in the simulation analysis that follows.

Elasticities of Supply

To parameterize the elasticity of supply and the elasticity of input substitution, we reviewed the existing literature. While supply elasticities have been estimated for many of the goods we consider, estimation methods and the data used within the analyses vary considerably across goods. For instance, a common method for estimating supply response is to regress current production of the commodity on an estimate of the expected price, which is itself based on lagged prices. These specifications are typically specific to the region or country and can be sensitive to modeling choices on how price expectations are formed. Then, this relationship can be used to determine the amount that supply changes in response to a change in the expected average price both in the short run and the long run.

Estimated values of supply elasticities vary considerably, as seen in Table 3. For example, supply elasticity estimates for carrots range from 0.02 to 6.67. Because of the tremendous variation in estimated supply elasticities and concerns about the reliability of these estimates, we conducted our simulations with three different values for the elasticity of supply (high, medium, and low values), and used the same values for multiple commodities rather than applying the commodity-level estimates from the literature.[14] Orchard and certain perennial vegetables (asparagus and artichokes) often require several years before they begin bearing. For these crops, we used 0.8, 0.5, and 0.2 as the high, medium, and low values of the supply elasticity. Annual crops can potentially show quicker adjustment to the price changes. For annual crops, we used 1.0, 0.7, and 0.4 as the high, medium, and low values of the supply elasticity. Table 3 details our specifications for these different scenarios.[15]

---

[14] Bovay and Sumner (2018) similarly assumed a range of supply elasticity values rather than using unreliable estimates from the literature.

[15] We assume that all cross-price elasticities of supply are zero so that all the off-diagonal elements of ε_N are zero.

Elasticities of Substitution in Supply

To our knowledge, only Wohlgenant (1989) has systematically estimated the elasticity of substitution between agricultural commodity production and marketing inputs for vegetables, and only for vegetables as a broad aggregate category. Instead, analysts using EDMs often assume that marketing inputs and wholesale commodities are used in fixed proportions which implies that the elasticity of substitution is zero (see, e.g., Okrent and Alston, 2012). Besides making the models tractable, the fixed proportions assumption is intuitively appealing: selling one retail apple requires one wholesale apple as an input. However, fixed proportions in production is a limiting case, and any departure from it ($_{X,MI} > 0$) will tend to make the wholesale demand for the commodity more elastic and dampen the retail-level price increase of a FSMA cost shift. We assumed the elasticity of substitution ($_{X,MI}$) was 0.54 for all vegetables (based on Wohlgenant, 1989) and 0 for all fruits.

Demand Model

We assume two-stage budgeting, where the consumer allocates total expenditures between subgroups of fruits and vegetables and a numeraire good in the first stage and across foods (i.e., fruit or vegetables) within each subgroup in the second stage. For the first stage demand, we specify a linear system of equations

$$Q_{mit} = A_{mit} + \sum_{j=1}^{10} [B_{ij} \times \ln P_{mjt}] + {}_{iy} \ln y_{mt} + \tilde{}_{iy} (\ln y_{mt})^2 , \tag{21}$$

where Q_{mit} is the per capita quantity of the i^{th} fruit or vegetable subgroup sold in market m and time t, P_{mjt} is the aggregate price index for subgroup j, 10 is the number of fruit and vegetable subgroups plus a numeraire, y_{mt} is per capita income, and A, B, , and $\tilde{}$ are parameters.[16] For second stage demand, we choose the quadratic almost ideal demand

---

[16] We also estimated the first-stage demand using the nonlinear QUAID functional form. However, numerical difficulty occurred where the variance-covariance matrix for the parameter estimates was not symmetric

system (QUAIDS) (Banks, Blundell, and Lewbel, 1997) as the functional form. Compared with the almost ideal demand system (AIDS), QUAIDS has more flexible Engel curves but retains the exact aggregation property of AIDS so that market-level data can be used to make inferences about consumer behavior. The conditional budget share equation within a fruit or vegetable subgroup is

$$w_{mit} = \alpha_{mit} + \sum_{j=1}^{n} \left[\; {}_{ij} \times \ln p_{mit} + \; {}_{i} \frac{\ln x_{mt}}{a(p_{mt})} \quad + \frac{{}_{i}}{b(p_{mt})} \times \left[\ln \left[\frac{x_{mt}}{a(p_{mt})} \right. \right. \right. {}^{2} , \tag{22}$$

where w_{mit} is the expenditure share of fruit or vegetable category i in market m and time t, p_{mit} is the price index of category j, n is the number of fruit or vegetable categories within the group, x_{mt} is total fruit and vegetable expenditure, and α, , , and are parameters. The $a\,(p_{mt})$ and $b\,(p_{mt})$ terms are defined as:

$$\ln\left(a\left(p_{mt}\right)\right) = a_0 + \sum_{i=1}^{n} \left(a_{i,0}\right) \times \ln\left(p_{mit}\right) + 0.5 \sum_{i=1}^{n} \sum_{j=1}^{n} \; {}_{ij} \ln\left(p_{mit}\right) \ln\left(p_{mjt}\right) \tag{23}$$

and

$$b(p_{mt}) = \prod_{i=1}^{n} p_{mit} \;{}^{i}, \tag{24}$$

respectively. In the empirical analysis we specify the intercepts A_{mit} and α_{mit} to be linear functions of a constant and a list of demand shifters.

Data

Fruit and vegetable sales data come from the IRI InfoScan retail scanner data set that the USDA Economic Research Service (ERS) acquired to support its food market and policy research. Our sample covers 65 quadweeks (i.e., 4-weekly periods) between January 6, 2008 and December 29, 2012. In InfoScan, there are 65 markets and 8 standard whitespaces

---

positive definite.

(i.e., remaining areas).[17] This gives a balanced panel dataset with 4,680 market-quadweek observations.[18]

We have sales data on 18 fruits and 20 vegetables. To reduce unit value bias (Deaton, 1988), we created a Fisher Ideal price index for each fruit and vegetable. The Fisher Ideal price index is a superlative index that approximates the true cost of living index for a class of expenditure function (Diewert, 1976). This allows us to account for item substitution without explicitly estimating an item-level demand model for each fruit and vegetable (Zhen et al., 2011). We constructed the Fisher Ideal price index for fruit or vegetable j as

$$p_{mjt} = \sqrt{\frac{\left(\frac{\sum p_{kmt} q_{k0}}{\sum p_{k0} q_{k0}}\right)}{\left(\frac{\sum p_{kmt} q_{kmt}}{\sum p_{k0} q_{kmt}}\right)}}, \tag{25}$$

where p_{kmt} and q_{kmt} are the price and volume sales of product k in market m and quadweek t, respectively, and p_{k0} and q_{k0} are the base price and per capita volume of product k set at their sample means. Within each category, we defined item at the brand (name brand, no brand, private label), organic (organic, nonorganic), and type (fresh, frozen) levels. This yields a maximum of 12 unique items for each food.

We multiplied annual Regional Price Parities from the Bureau of Economic Analysis with monthly Consumer Price Index from the Bureau of Labor Statistics to obtain a panel of cost-of-living index at the Metropolitan Statistical Area (MSA) level. These index values

---

[17] We dropped the Green Bay, WI market from the sample due to insufficient retail data for the study period.

[18] The InfoScan dataset at ERS contains barcode-level point of sale data. Some retailers provided sales data at the store level but others only at the Retail Market Area (RMA) level. The exact RMA definition varies from one retailer to another but a typical RMA contain a cluster of counties. We aggregate store-level data to the IRI market level. For RMA-only retailers, IRI reports the number of stores and addresses under each RMA. To impute IRI market-level sales for these retailers, we divided RMA-level sales by store number to get average sales per store and allocate RMA sales to each IRI market based on the number of stores the retailer has in each IRI market. The number of InfoScan retailers in each market changes over time. For market m, we multiplied total sales by the ratio of average store count to store count at t to compensate secular variation in total sales due to store entry and exit from the InfoScan program. We then divided total sales by market population to produce per capita estimates.

were then weighted by county population to construct P_{mNt}, price of the numeraire, in equation (21).

To correct for price endogeneity due to unobserved demand shocks, we created an instrumental variable for each P_{mjt} in equation (21) and p_{mjt} in equation (22) by taking the weighted average price of all other markets, where the weight is the inverse squared distance (in 100 miles) between market m and other markets. Identification of the price coefficients in demand equations (21) and (22) relies on common supply shocks across markets and the assumption that remaining demand shocks are uncorrelated across markets once the intercept terms A_{mit} and α_{mit} include enough demand shifters.

Unconditional Elasticities

In the spirit of Edgerton (1997), the unconditional price elasticity of demand for fruit or vegetable i with respect to price of fruit or vegetable j is derived as

$$e_{ij}^{U} = \frac{\partial \ln q_i^U}{\partial \ln p_j} = \frac{\partial \ln q_i}{\partial \ln p_j} + \frac{\partial \ln q_i}{\partial \ln x_{G_i}} \frac{\partial \ln x_{G_i}}{\partial \ln P_{G_i}} \frac{\partial \ln P_{G_i}}{\partial \ln p_j} = e_{ij}\delta_{ij} + e_i \left(\delta_{ij} + e_{G_iG_j}\right) \bar{w}_j, \qquad (26)$$

where we drop the time and market subscripts to simplify notation; the superscript U denotes unconditional demand; e_{ij} and e_i are conditional Marshallian price elasticity and expenditure elasticity at the second budgeting stage, respectively; δ_{ij} is the Kronecker delta equal to 1 if i and j are from the same fruit or vegetable subgroup, and 0 otherwise; G_i denotes the subgroup that i belongs to; $e_{G_iG_j}$ is the first-stage unconditional elasticity for subgroup G_i with respect to the aggregate price index of subgroup G_j; and $\bar{w}_j$ is the mean budget share of j within its subgroup. If there is only one fruit or vegetable in subgroup G_i, then $e_{ii} = -1$ and $e_i = 1$.

Empirical Specification

We group the 18 fruits and 20 vegetables into 5 fruit and 4 vegetable subgroups. The classification scheme largely follows that of MyPlate except we further divided MyPlate's Other Fruit group into citrus fruit, stone fruit, and other fruit subgroups. The 9 subgroups and their constituents are presented in tables 4 and 5.

We have two alternative specifications of demand shifters that go into the intercept terms A_{mit} and α_{mit}. The first specification includes a constant, 71 market-specific fixed effects (base=Los Angeles), 4 yearly fixed effects (base=2008), and 12 time-of-the-year dummies (base=first quadweek of a year). The second specification includes, besides the constant and market fixed effects, 64 quadweek fixed effects (base=first quadweek of the 65-quadweek sample). Compared to the second specification, the first specification has the advantage of parsimony while presumably accounting for much of demand shocks through the market, year and seasonal fixed effects. The second specification further controls for possible quadweek-specific demand shocks. However, it may over-parameterize the nonlinear QUAID model and inadvertently remove national supply shocks that would have helped identification of the price coefficients. Therefore, we use the first specification as the baseline and only resort to the second specification when necessary.

We estimate equations (21) and (22) by full information maximum likelihood (FIML). We employed the parametric specification of Moschini and Moro (1994) for singular equation systems to account for autocorrelation in the conditional QUAID model. Autocorrelation in equation (21) was also corrected using the n-parameter approach of Moschini and Moro (1994) but without the parametric restrictions implied by singular equation systems. In addition to instrumenting all prices by the Hausman-type instruments, we instrumented subgroup expenditure x_{Gmt} by total expenditures on fruit and vegetables (fresh and frozen).

Including market, year, and seasonal fixed effects in A_{mit} and α_{mit} worked well for the first stage demand equation (21) and conditional QUAID (22) for all subgroups except dark-green vegetables, where own-price elasticity at the sample mean for kale is statistically insignificant at 0.05. After adding 64 quadweek fixed effects to the A_{mit} and α_{mit} terms for dark-green vegetables, kale has an own-price elasticity of 0.78 (t-value=12.66; see table 9). We take this as the preferred specification for conditional dark-green vegetable demand, while all other demands use the first specification of A_{mit} and α_{mit} as the preferred one.

Demand Estimates

Tables 6, 7, 8, and 9 provide the own- and cross-price elasticities of our demand model for fruits, vegetables and the commodity aggregates, along with the expenditure elasticities. In these tables, the diagonal terms are the own-price elasticities of demand and are all of the expected sign (negative) for normal goods. For all fruits and vegetables considered in our analysis, income elasticities that are positive but less than one indicate necessities. Fruits and vegetables are substitutes where their cross-price elasticities are positive and complements where their cross-price elasticities are negative. While there is no a priori theoretical reason for why fruits or vegetables would necessarily be complements or substitutes, the finding that many of these goods are complements has strong implications for our analysis regarding the value of FSMA exemptions. A FSMA rule that raises the cost (and price) of substitutes for an exempted fruit or vegetable commodity would necessarily benefit producers of the exempted commodity by increasing demand for the exempted commodity. On the other hand, if fruit and vegetable commodities are often complements, then FSMA-induced cost shifts may potentially reduce the welfare of producers of exempted goods.

Simulation Results

We use the EDM framework, including our estimated commodity-level farm and price shifts as developed in Bovay, Ferrier, and Zhen (2018), assumptions about farm prices as a share of the retail dollar based on Stewart (2006), and demand parameters from the QUAIDS model to simulate market-equilibrium effects of FSMA implementation. Confidence bounds for key findings are found using Monte Carlo simulation.[19] We draw conclusions about the effects on producers, retail prices, and consumer welfare, and discuss the counterfactual welfare effects of (1) unilateral adoption of FSMA-like practices and (2) exemptions for individual commodities.

Cost Pass-Through of FSMA

To calculate the pass through of costs of FSMA compliance to consumers, we first use the EDM to calculate the effects on the variables $d\ln P$, $d\ln Q$, $d\ln W$, $d\ln X$, and $d\ln MI$ from the cost shift embedded in the term in equation (10), and then use equations (19) and (20) to calculate specific Cost Pass-Through (CPT) and Farm Pass-Through (FPT) values. These values are given for fruits and vegetables in Tables 10 and 11.

The estimated CPT varies across commodities. For the fruits in our study, farm prices rise by 91.3 percent of the farm cost of implementing the regulations while consumer prices rise 27.9 percent of the farm cost of compliance, or by 0.2 percent of total farm costs. For the vegetables in our study, farm prices rise by 41.9 percent of the farm cost of implementing the regulation while consumer prices rise by 10.8 percent of the farm cost of compliance.[20]

Welfare Effects of FSMA Regulation Costs

Equation (18) and the market-equilibrium shifts are used to calculate the producer welfare effect under the assumption that improved food-safety outcomes as a result of the FSMA regulations do not affect the demand for regulated commodities.[21] Estimated shifts in pro-

---

[19] Specifically, we draw 1000 values based on our estimated covariance matrix for the demand elasticities. We then recalculate all our simulated effects with each of those new sets of parameters. In our tables, we report the 95% confidence bounds only for fruit and vegetables in aggregate, and for all commodities in aggregate.

[20] CPT is not calculated for asparagus, kale, and sweet corn as these vegetables were exempted from the final FSMA Produce Safety Rule.

[21] Improved food safety may also plausibly increase demand for a good. However, this (hypothesized) effect is subtle and difficult to identify. Bovay (2017) estimated wholesale demand for fresh-market tomatoes before and after members of that industry adopted Good Agricultural Practices, standards for on-farm food-safety practices that closely resemble the effect of the Produce Safety Rule, and found no evidence of increased demand for tomatoes from regions that had collectively adopted GAPs, after the date of required GAPs

ducer and consumer surplus are presented in Tables 12 and 13. Fruit and vegetable farmer welfare is simulated to fall by 0.28 and 0.48 percent (of farm revenue), respectively. Among fruits, producer surplus losses were highest for avocados and lowest for nectarines (where the produce welfare improves due to strong substitution effects). Among vegetables, producer surplus losses were highest for snap beans and squash and lowest for cauliflower, celery, broccoli, and the three lettuce varieties (excluding the three vegetables exempt from the regulations).[22] Tables 12 and 13 provide the consumer and producer welfare estimates under our alternative supply specifications for our three different values (high, middle, and low) for the elasticities of supply.

In general, the effects on producer surplus are small. As discussed, some of the fruit commodities with the highest estimated producer losses are tropical fruits with small-scale U.S. production. But even in the most extreme case, these producers lose only 1.8 percent of revenue (aggregated to the commodity level). Fruit producer groups that gain from the implementation of FSMA as the result of substitution include the stone fruits and some but not all melons. Producers of most vegetable commodities are projected to lose, with losses up to 1.6 percent of revenue at the commodity level. Producers of exempt commodities (sweet corn and asparagus) and of artichokes (a high-value crop grown on a large scale) are expected to gain up to 0.8 percent of revenue at the commodity level.

---

adoption. We know of no existing estimates of positive demand for foods grown under better food-safety practices.

[22] It is important to note that our analysis does not disaggregate welfare effects for foreign and domestic producers and does not consider costs for foreign producers under the Foreign Supplier Verification Program, assuming instead that foreign producers' costs are identical to U.S. producers' costs for the same commodity. The disaggregated data on distribution of farm acreage and sales is only available for the United States, and accurate simulation of the costs of implementing FSMA in other countries, using the same methods, would have required farm-level data or gross simplifying assumptions, as in Bovay and Sumner (2018). When import shares are large, as in the cases of the fruits avocados, mangos, and bananas, and the vegetables artichokes, cucumbers, peppers, and tomatoes (see Table 2), the producer surplus loss will fall more significantly on foreign suppliers.

Value of Comprehensive Enactment and Exemptions

Producers of commodities that are exempt from the FSMA Produce Safety Rule may benefit when producers of substitute commodities face a cost increase. Under this same logic, the comprehensive enactment of the Produce Safety Rule offsets some of the producer surplus loss faced by producers of individual commodities since it causes the price of substitute goods to rise. Appendix B shows that the effect of the regulation on the new equilibrium can be decomposed into two effects. The total effect of the regulation is equal to the sum of the direct effects of the cost increase and the indirect effect from raising costs facing producers of other commodities (the comprehensive enactment effect). The value of an exemption is the total effect minus the direct effect.

Tables 14 and 15 provide estimates of the new equilibrium in the counterfactual case in which each commodity group unilaterally undertook collective standards for food safety with the same costs as the FSMA Produce Safety Rule.[23] Tables 16 and 17 provide estimated welfare effects in terms of the producer and consumer surplus change for specific commodities along with their (share-weighted) averages across fruits and vegetables. For fruits, average producer welfare falls by 0.28 percent under comprehensive enactment but 0.71 percent under unilateral enactment. This large difference suggests that coordinating the timing of cost-raising food safety investments across fruit producers mitigates much of the harm to a specific commodity producer through higher costs. For vegetables, producer welfare falls by 0.48 percent under comprehensive enactment but 0.50 percent under unilateral enactment.[24] The value of an exemption from FSMA rules (as a share of industry revenue) is the difference between the producer surplus effects of comprehensive and unilateral enactment and this is the largest for nectarines and artichokes among fruits and vegetables respectively.

---

[23] Values for kale, asparagus, and sweet corn are omitted because they were excluded from coverage under the final Produce Safety Rule.

[24] If the three exempted vegetables are excluded, producer welfare falls by 0.59 percent under comprehensive enactment but only 0.56 percent under unilateral enactment. Moreover, welfare loss is smaller under unilateral enactment for 10 of the 17 non-exempt vegetables but only 1 of 18 fruits.

Comparison of Costs and Indirect Benefits to Producers

We find that the Produce Safety Rule will cost fruit producers 0.28 percent of total revenue and vegetable producers 0.48 percent of total revenue in direct costs. The Rule, however, will also likely provide these same producers significant indirect benefits by reducing the likelihood of food safety events involving recall costs, liability costs and periods of reduced demand. If these indirect benefits are larger than the direct costs under unilateral enactment, then producer groups would have had incentive to undertake food-safety standards collectively. If these indirect benefits are less than the direct costs of unilateral enactment, but larger than the direct costs of comprehensive enactment, producer groups would have had incentive to support legislative or regulatory efforts that mandated comprehensive enforcement of produce-safety rules.

We use recent historical evidence on the demand response to outbreaks of food-borne illness caused by produce commodities to suggest the magnitude of public-health benefits from FSMA implementation. Between 2003 and 2012, the FDA (2015) reported an annual average of 4.8 outbreaks resulting in 629 illnesses, 104 hospitalizations and 4.5 deaths for produce commodities covered by FSMA, not including sprouts. FDA (2015b, p. 58) estimates that the Produce Safety Rule will reduce the risk of contamination for covered produce by 56.4 percent. If outbreaks occur with a 12.6 percent probability for a generic produce commodity[25] and the typical outbreak reduces producer revenue by 10 percent for one year, then the Produce Safety Rule may reduce producer losses by approximately 0.71% on an annual basis (= 56.4% × 12.6% × 10%). If a typical outbreak reduced producer revenue by 20 percent for a year, then the Produce Safety Rule would reduce producer losses by approximately 1.42%. These values are somewhat larger than our estimates of the cost of the Produce Safety Rule, 0.28 percent for fruit producers and 0.48 percent for vegetable producers. However, outbreaks that reduce revenues by 10 or 20 percent are extraordinary events. Although Arnade, Calvin, and Kuchler (2009) found that the major outbreak of *E.*

---

[25] 4.8 outbreaks per year, divided by the 38 produce commodities under study in this article.

coli in bagged spinach from California in 2006 reduced expenditures on bagged spinach by \$202 million (20 percent of revenue) over the following 68-week period, event studies tend to focus on prominent and severe outbreaks for which demand effects can be readily identified. In terms of market disruption, the spinach outbreak was particularly severe because there were few actions consumers could have undertaken at home (short of cooking) that would have reduced the underlying health risk. Given that most outbreaks of food-borne illness generate substantially less market disruption, the (collective) benefit to producers of reduced outbreaks of food-borne illness as a consequence of the Produce Safety Rule are likely about the same magnitude as the cost of implementing food-safety practices under the Produce Safety Rule.

Conclusion

While its public health benefits could be somewhat large and tangible, the requirements for on-farm food-safety practices under the Food Safety Modernization Act are expected to impose substantial costs on producers. Using new findings on the size and distribution of regulatory costs across producers, we estimate that, absent any offsetting effect on consumer demand, the implementation costs of the Produce Safety Rule will reduce producer welfare by 0.28 percent for fruit and 0.48 percent for vegetables. Commodity producers are unable to fully pass along the increased cost of production to buyers. Specifically, for fruits as an aggregate, farm prices are estimated to rise by 91.3 percent of the farm cost of implementing the regulation while consumer prices are estimated to rise by 27.9 percent of the farm cost. For vegetables as an aggregate, farm prices rise by 41.9 percent of the farm cost of implementing the regulation while consumer prices rise by 10.8 percent of the farm cost.

The comprehensive enactment of a cost-raising regulation across producers of similar goods has the potential to cause less producer welfare loss than the unilateral enactment of the same regulation by individual producers. We find this effect to be substantial for the fruits, but not the vegetables, covered by the Produce Safety Rule and attribute this difference the different substitution patterns between the groups. For similar reasons, we show that producers of fruit and vegetable commodities that see bigger losses from unilateral enactment would also see a greater value to an exemption from the regulations requirements with the caveat that this analysis assumes that improved food safety does not impart to commodities a direct demand-enhancing effect.

Estimating the benefits to producers of the reduced likelihood of food-safety problems under the Rule is difficult owing to the paucity of data. While event studies have shown that certain outbreaks caused large and prolonged demand shocks for certain commodities, these studies are selective and may not be generalizable to fruits and vegetables as a whole. Under certain assumptions on the severity and likelihood of outbreaks causing demand reductions following the rule, we find that these indirect producer benefits exceed our estimated direct costs for most, but not all producers, under comprehensive enactment. This finding supports previous analyses that show possible benefits for producer groups that voluntarily undertake efforts to improve food safety. Moreover, a larger number of producer groups experience net benefits to the rule under comprehensive enactment. Substantial uncertainty surrounds our estimates of the size of indirect producer benefits from improved food safety and reduced market disruption. Understanding these effects is increasingly important as regulatory initiatives seek to ensure the safety of foods in increasingly long and distant supply chains.

References

Adalja, A., and E. Lichtenberg. 2016. "Foodborne Illness Outbreaks, Collective Reputation, and Voluntary Adoption of Industry-wide Food Safety Protocols by Fruit and Vegetable Growers." Annual Meeting, Agricultural and Applied Economics Association July 31-August 2, 2016, Boston, Massachusetts, `http://ageconsearch.umn.edu/bitstream/235865/2/AAEA_P9730_Adalja_Lichtenberg_final.pdf`.

Alston, J.M., J.M. Crespi, H.M. Kaiser, and R.J. Sexton. 2007. "An evaluation of California's mandated commodity promotion programs." *Applied Economic Perspectives and Policy* 29:40–63.

Arnade, C., L. Calvin, and F. Kuchler. 2009. "Consumer Response to a Food Safety Shock: The 2006 Food-Borne Illness Outbreak of *E. coli* O157:H7 Linked to Spinach." *Applied Economic Perspectives and Policy* 31:734–750.

Arnade, C., F. Kuchler, and L. Calvin. 2013. "Consumers' response when regulators are uncertain about the source of foodborne illness." *Journal of Consumer Policy* 36:17–36.

Banks, J., R. Blundell, and A. Lewbel. 1997. "Quadratic Engel curves and consumer demand." *The Review of Economics and Statistics* 79:527–539.

Bovay, J. 2017. "Demand for collective food-safety standards." *Agricultural Economics*, doi:10.1111/agec.12375.

Bovay, J., P. Ferrier, and C. Zhen. 2018. "Estimated Costs for Fruit and Vegetable Producers To Comply With the Food Safety Modernization Act's Produce Rule." USDA Economic Research Service Economic Information Bulletin No. 195.

Bovay, J., and D.A. Sumner. 2018. "Economic Effects of the U.S. Food Safety Modernization Act." *Applied Economic Perspectives and Policy*, doi:10.1093/aepp/ppx039.

Buzby, J.C., and P.D. Frenzen. 1999. “Food safety and product liability.” *Food Policy* 24:637–651.

Buzby, J.C., P.D. Frenzen, and B. Rasco. 2001. “Product liability and microbial foodborne illness.” USDA Economic Research Service, Agricultural Economic Report No. 799, `https://www.ers.usda.gov/webdocs/publications/41289/18932_aer799.pdf`.

Calvin, L. 2004. “Response to US foodborne illness outbreaks associated with imported produce.” USDA Economic Research Service, Agriculture Information Bulletin Number 789-5, `https://www.ers.usda.gov/webdocs/publications/42543/19326_aib789-5_1_.pdf`.

Calvin, L., H. Jensen, K. Klonsky, and R. Cook. 2017. “Food Safety Practices and Costs Under the California Leafy Greens Marketing Agreement.” USDA Economic Research Service Economic Information Bulletin No. EIB-173, `https://www.ers.usda.gov/webdocs/publications/83771/eib-173.pdf`.

Carter, C.A., and A. Smith. 2007. “Estimating the market effect of a food scare: The case of genetically modified Starlink corn.” *The Review of Economics and Statistics* 89:522–533.

Cooper, R., and T.W. Ross. 1985. “Product warranties and double moral hazard.” *The RAND Journal of Economics* 16:103–113.

Davis, G.C., and M.C. Espinoza. 2000. “A unified approach to sensitivity analysis in equilibrium displacement models: Reply.” *American Journal of Agricultural Economics* 82:241–243.

Deaton, A. 1988. “Quality, Quantity, and Spatial Variation of Price.” *The American Economic Review* 78:418–430.

Diewert, W.E. 1976. “Exact and superlative index numbers.” *Journal of Econometrics* 4:115–145.

Edgerton, D.L. 1997. “Weak separability and the estimation of elasticities in multistage demand systems.” *American Journal of Agricultural Economics* 79:62–79.

FDA. 2015a. “21 CFR Parts 11, 16, and 112: Standards for the Growing, Harvesting, Packing, and Holding of Produce for Human Consumption.” `https://www.gpo.gov/fdsys/pkg/FR-2015-11-27/pdf/2015-28159.pdf`.

—. 2015b. “Standards for the Growing, Harvesting, Packing and Holding of Produce for Human Consumption - Final Regulatory Analysis - Unfunded Mandates Reform Act Analysis.” Federal Register.

Hölmstrom, B. 1979. “Moral hazard and observability.” *The Bell Journal of Economics* 10:74–91.

Johnson, R. 2011. “The FDA Food Safety Modernization Act (P.L. 111-353).” Congressional Research Service Report, Volume R40443.

—. 2014. “The U.S. Food Safety System: A Primer.” Congressional Research Service Report, Volume RS22600.

Kahneman, D. 2011. *Thinking, Fast and Slow*. New York: Farrar, Straus, and Giroux.

Lusk, J.L., and T.C. Schroeder. 2002. “Effects of meat recalls on futures market prices.” *Agricultural and Resource Economics Review* 31:47–58.

Marsh, T.L., T.C. Schroeder, and J. Mintert. 2004. “Impacts of meat product recalls on consumer demand in the USA.” *Applied Economics* 36:897–909.

Mazzocchi, M. 2006. “No news is good news: Stochastic parameters versus media coverage indices in demand models after food scares.” *American Journal of Agricultural Economics* 88:727–741.

Miljkovic, D., W. Nganje, and B. Onyango. 2009. “Offsetting behavior and the benefits of food safety regulation.” *Journal of Food Safety* 29:49–58.

Minor, T., A. Lasher, K. Klontz, B. Brown, C. Nardinelli, and D. Zorn. 2015. "The per case and total annual costs of foodborne illness in the United States." *Risk Analysis* 35:1125–1139.

Moschini, G., and D. Moro. 1994. "Autocorrelation specification in singular equation systems." *Economics Letters* 46:303–309.

Okrent, A.M., and J.M. Alston. 2012. "The Effects of Farm Commodity and Retail Food Policies on Obesity and Economic Welfare in the United States." *American Journal of Agricultural Economics* 94:611–646.

Page, E.T. 2017. "Trends in Food Product Recalls: 2004-2013." USDA Economic Research Service, Economic Research Report, forthcoming.

Painter, J.A., R.M. Hoekstra, T. Ayers, R.V. Tauxe, C.R. Braden, F.J. Angulo, and P.M. Griffin. 2013. "Attribution of foodborne illnesses, hospitalizations, and deaths to food commodities by using outbreak data, United States, 1998–2008." *Emerging Infectious Diseases* 19:407.

Peltzman, S. 1976. "Toward a more general theory of regulation." *The Journal of Law and Economics* 19:211–240.

Piggott, N.E., and T.L. Marsh. 2004. "Does food safety information impact US meat demand?" *American Journal of Agricultural Economics* 86:154–174.

Pouliot, S., and D.A. Sumner. 2008. "Traceability, liability, and incentives for food safety and quality." *American Journal of Agricultural Economics* 90:15–27.

—. 2012. "Traceability, recalls, industry reputation and product safety." *European Review of Agricultural Economics* 40:121–142.

Rejesus, R.M., C.D. Safley, and B.C. Strik. 2014. “Demand and Welfare Impacts of a Potential Food Safety Event in the Blackberry Industry.” Agricultural and Applied Economics Association Annual Meeting, July 27–29, 2014, Minneapolis, Minnesota.

Reuters. 2011. “EU raises farmers’ E.coli aid offer to 210 mln euro.” `http://news.trust.org//item/20110608164100-nr138/`, June 8, 2011.

Salin, V., and N.H. Hooker. 2001. “Stock market reaction to food recalls.” *Review of Agricultural Economics* 23:33–46.

Sato, R., and T. Koizumi. 1973. “On the elasticities of substitution and complementarity.” *Oxford Economic Papers* 25:44–56.

Starbird, S.A. 2005a. “Moral hazard, inspection policy, and food safety.” *American Journal of Agricultural Economics* 87:15–27.

—. 2005b. “Supply chain contracts and food safety.” *Choices* 20:123–128.

Stewart, H. 2006. “How Low Has the Farm Share of Retail Food Prices Really Fallen?” USDA Economic Research Report, Economic Research Report No. 24.

Thomsen, M.R., and A.M. McKenzie. 2001. “Market incentives for safe foods: an examination of shareholder losses from meat and poultry recalls.” *American Journal of Agricultural Economics* 83:526–538.

Wang, Z., V. Salin, N.H. Hooker, and D. Leatham. 2002. “Stock market reaction to food recalls: a GARCH application.” *Applied Economics Letters* 9:979–987.

Winfree, J.A., and J.J. McCluskey. 2005. “Collective reputation and quality.” *American Journal of Agricultural Economics* 87:206–213.

Wohlgenant, M.K. 1989. “Demand for Farm Output in a Complete System of Demand Functions.” *American Journal of Agricultural Economics* 71:241–252.

Zhen, C., M.K. Wohlgenant, S. Karns, and P. Kaufman. 2011. "Habit Formation and Demand for Sugar-Sweetened Beverages." *American Journal of Agricultural Economics* 93:175–193.

Table 1: Estimated Average Costs of Implementing FSMA by Category

	Regulatory Component	Estimated Annual Costs of Compliance	Share of Total Cost
1.	Agricultural Water	$49 Mil.	13.70%
2.	Fertilizer Compost of Animal Origin	$9 Mil.	2.50%
3.	Worker Health/Hygiene Measures	$81 Mil.	22.60%
4.	Animal Intrusion Measures	$38 Mil.	10.60%
5.	Sanitary Standards (Equip., Tools, Bldgs.)	$59 Mil.	16.50%
6.	Recordkeeping and Other Costs	$122 Mil.	34.10%
	Total (Excluding Sprouts Rule)	$358 Mil.	100%

Source: FDA (2015b).

Table 2: Estimates of FSMA Produce Safety Rule Cost Shifts by Commodity

Fruit	Cost Shift	Import Share	Wholesale Cost Share	Exempt?	Vegetables	Cost Shift	Import Share	Wholesale Cost Share	Exempt?
1. Strawber.	1.3%	12.6%	36.22%	No	1. Broccoli	0.4%	19.5%	24.13%	No
2. Cantaloupes	1.4%	43.6%	20.46%	No	2. Kale	0.0%	NA	18.00%	Yes
3. Honeydew	0.7%	42.0%	19.89%	No	3. Leaf Let.	0.4%	5.4%	10.60%	No
4. Waterm.	2.7%	32.9%	57.94%	No	4. Rom. Let.	0.3%	5.4%	11.26%	No
5. Grapefruit	1.7%	2.9%	79.44%	No	5. Spinach	0.8%	4.8%	18.00%	No
6. Oranges	2.2%	12.5%	78.94%	No	6. Carrots	1.0%	15.1%	38.89%	No
7. Tanger.	1.3%	28.0%	78.94%	No	7. Bell Pep.	1.3%	59.3%	14.33%	No
8. Apricots	2.2%	3.5%	32.34%	No	8. Chile Pep.	2.6%	NA	14.33%	No
9. Cherries	2.7%	7.9%	8.78%	No	9. Squash	2.5%	NA	12.16%	No
10. Nectar.	1.2%	8.7%	34.43%	No	10. Tomatoes	1.1%	52.5%	29.01%	No
11. Peaches	2.3%	8.7%	31.28%	No	11. Sw. Corn	0.0%	NA	20.46%	Yes
12. Plums	2.3%	26.9%	28.60%	No	12. Artich.	0.4%	80.5%	16.60%	No
13. Apples	2.2%	7.5%	80.98%	No	13. Asparagus	0.0%	NA	38.24%	Yes
14. Avocados	3.5%	81.4%	33.00%	No	14. Cabbage	1.6%	8.2%	10.15%	No
15. Bananas	3.5%	99.9%	33.00%	No	15. Caulifl.	0.4%	14.1%	63.94%	No
16. Grapes	2.1%	46.1%	38.78%	No	16. Celery	0.4%	6.1%	10.68%	No
17. Mangos	3.6%	99.9%	33.00%	No	17. Cucumbers	2.1%	73.5%	9.93%	No
18. Pears	3.0%	19.8%	46.87%	No	18. Head Let.	0.3%	6.9%	15.97%	No
					19. Onions	1.7%	18.3%	53.33%	No
					20. Snap Beans	3.0%	31.4%	49.80%	No
Average	2.33%				Average	1.15%			
Max	3.57%				Max	4.55%			
Min	0.70%				Min	0.31%			

Sources: Bovay, Ferrier, and Zhen (2018); Stewart (2006).

Table 3: Supply Elasticities for Fruits and Vegetables

	Supply Elasticities Used in Simulations			Range of Empirical			Supply Elasticities Used in Simulations			Range of Empirical	
Fruits	Low	Med.	High	Estimates	Sources	Vegetables	Low	Med.	High	Estimates	Sources
1. Strawberries	0.4	0.7	1	[0.68, 1.40]	F	1. Broccoli	0.4	0.7	1	[0.12, 3.77]	J
2. Cantaloupes	0.4	0.7	1	[0.03, 0.17]	A,G	2. Kale	0.4	0.7	1	[0.56, 0.77]	
3. Honeydew	0.4	0.7	1	[0.20, 1.16]	J	3. Lettuce (Leaf)	0.4	0.7	1	[1.19, 1.19]	J,D,E,F
4. Watermelons	0.4	0.7	1	[0.14, 0.60]	G,J	4. Lettuce (Rom.)	0.4	0.7	1	NA	J,D,E,F
5. Grapefruit	0.2	0.5	0.8	NA		5. Spinach	0.4	0.7	1	[0.28, 2.80]	A,F
6. Oranges	0.2	0.5	0.8	NA		6. Carrots	0.4	0.7	1	[0.02, 6.67]	G,J
7. Tangerines	0.2	0.5	0.8	NA		7. Peppers (Bell)	0.4	0.7	1	[0.12, 3.5]	F,H
8. Apricots	0.2	0.5	0.8	NA		8. Peppers (Chile)	0.4	0.7	1	NA	
9. Cherries, Sweet	0.2	0.5	0.8	NA		9. Squash	0.4	0.7	1	[0.12, 0.12]	H
10. Nectarines	0.2	0.5	0.8	NA		10. Tomatoes	0.4	0.7	1	[0.04, 0.72]	
11. Peaches	0.2	0.5	0.8	[0.80, 1.20]	F	11. Sweet Corn	0.4	0.7	1	[0, 1.06]	F,J,C
12. Plums	0.2	0.5	0.8	NA		12. Artichokes	0.2	0.5	0.8	NA	
13. Apples	0.2	0.5	0.8	[0.76, 1.31]	F	13. Asparagus	0.2	0.5	0.8	[0.17, 1.11]	F,J
14. Avocadoes	0.4	0.7	1	0.05	K	14. Cabbage	0.4	0.7	1	[0.39, 0.93]	F,G
15. Bananas	0.4	0.7	1	NA		15. Cauliflower	0.4	0.7	1	[0.22, 4.35]	J
16. Grapes	0.2	0.5	0.8	NA		16. Celery	0.4	0.7	1	[0.10, 0.23]	J
17. Mangoes	0.4	0.7	1	NA		17. Cucumbers	0.4	0.7	1	[0.14, 1.11]	F,J,H
18. Pears	0.2	0.5	0.8	0.29	L	18. Lettuce (Head)	0.4	0.7	1	[0.32, 0.39]	J,D,E,F
						19. Onions (Bulb)	0.4	0.7	1	[0.10, 1.13]	A,G,H
						20. Snap Beans	0.4	0.7	1	[0.12, 0.75]	

Sources:

A. Seale, Zhang, and Traboulsi (2013)
B. Russo, Green, and Howitt (2008)
C. Mérel, Simon, and Yi (2011)
D. Clevenger and Shelley (1974)
E. Hammig and Mittelhammer (1980)
F. Onyango and Bhuyan (2000)
G. Ornelas and Shumway (1993)
H. Málaga, Williams, and Fuller (2001)
I. Hammig and Mittelhammer (1982)
J. Buxton (1992)
K. Peterson and Orden (2008)
L. Wann and Sexton (1992)

Table 4: Descriptive Statistics Of IRI Storescan Data Used in Demand Estimation (Fruit)

Subgroups	Fruits	Budget Share		Per Capita Expend. ($/4 weeks)		Per Capita Quantity (lb/4 weeks)		Unit Value ($/lb)	
		Avg.	Std.	Avg.	Std.	Avg.	Std.	Avg.	Std.
I. Berries	1. Strawberries	0.07	0.03	0.38	0.23	0.17	0.12	2.56	0.61
II. Melons	2. Cantaloupe	0.02	0.01	0.10	0.07	0.17	0.14	0.66	0.20
	3. Honeydew	0.00	0.00	0.02	0.01	0.02	0.02	0.96	0.20
	4. Watermelon	0.03	0.03	0.18	0.19	0.41	0.52	0.71	0.32
III. Citrus Fruits	5. Grapefruit	0.01	0.00	0.04	0.02	0.04	0.03	0.92	0.20
	6. Oranges	0.03	0.01	0.17	0.09	0.17	0.11	1.07	0.27
	7. Tangerines	0.02	0.02	0.12	0.11	0.09	0.09	1.43	0.26
IV. Stone Fruits	8. Apricots	0.00	0.00	0.00	0.01	0.00	0.00	3.28	0.63
	9. Cherries	0.02	0.03	0.13	0.21	0.04	0.07	3.91	0.86
	10. Nectarines	0.01	0.01	0.05	0.07	0.03	0.04	1.92	0.43
	11. Peaches	0.01	0.02	0.09	0.11	0.06	0.07	1.88	0.51
	12. Plums	0.01	0.01	0.04	0.04	0.02	0.03	1.94	0.44
V. Other Fruits	13. Apples	0.10	0.03	0.56	0.24	0.38	0.17	1.49	0.21
	14. Avocado	0.03	0.01	0.15	0.10	0.06	0.05	2.67	0.61
	15. Bananas	0.09	0.02	0.50	0.20	0.87	0.32	0.58	0.10
	16. Grapes	0.08	0.02	0.46	0.21	0.25	0.12	1.96	0.45
	17. Mangoes	0.01	0.00	0.03	0.02	0.02	0.02	1.76	0.45
	18. Pears	0.01	0.01	0.07	0.04	0.05	0.03	1.48	0.20

Table 5: Descriptive Statistics Of IRI Storescan Data Used in Demand Estimation (Vegetables)

Subgroups	Fruits	Budget Share		Per Capita Expend. ($/4 weeks)		Per Capita Quantity (lb/4 weeks)		Unit Value ($/lb)	
		Avg.	Std.	Avg.	Std.	Avg.	Std.	Avg.	Std.
VI. Dark-Green Vegetables	19. Broccoli	0.03	0.01	0.18	0.09	0.10	0.05	1.78	0.17
	20. Kale	0.00	0.00	0.01	0.01	0.00	0.00	1.46	0.35
	21. Leaf Lettuce	0.01	0.00	0.04	0.02	0.02	0.01	1.90	0.39
	22. Rom. Lettuce	0.02	0.00	0.09	0.05	0.04	0.02	2.34	0.37
	23. Spinach	0.01	0.00	0.05	0.03	0.02	0.01	2.33	0.28
VII. Red and Orange Vegetables	24. Carrots	0.04	0.01	0.21	0.10	0.16	0.08	1.32	0.13
	25. Bell Peppers	0.04	0.01	0.22	0.11	0.10	0.05	2.13	0.36
	26. Chili Peppers	0.00	0.00	0.02	0.02	0.01	0.02	1.99	0.64
	27. Squash	0.02	0.01	0.09	0.07	0.07	0.08	1.46	0.35
	28. Tomatoes	0.09	0.02	0.51	0.24	0.24	0.11	2.20	0.40
VIII. Starchy Vegetables	29. Sweet Corn	0.03	0.01	0.15	0.09	0.13	0.12	1.52	0.54
IX. Other Vegetables	30. Artichokes	0.00	0.00	0.01	0.01	0.01	0.01	2.33	0.55
	31. Asparagus	0.02	0.01	0.09	0.05	0.03	0.02	3.10	0.59
	32. Cabbage	0.01	0.00	0.06	0.03	0.08	0.05	0.71	0.15
	33. Cauliflower	0.01	0.00	0.05	0.02	0.04	0.02	1.26	0.25
	34. Celery	0.02	0.01	0.10	0.06	0.08	0.04	1.34	0.42
	35. Cucumbers	0.02	0.01	0.12	0.08	0.08	0.05	1.55	0.34
	36. Head Lettuce	0.02	0.00	0.12	0.05	0.10	0.04	1.20	0.22
	37. Onions	0.05	0.01	0.27	0.12	0.25	0.11	1.07	0.20
	38. Snap Beans	0.01	0.01	0.07	0.05	0.04	0.03	1.98	0.30

Table 6: Unconditional Own and Cross-Price Elasticities

	Strawberries	*Cantaloupe*	*Honeydew*	*Watermelon*	*Grapefruit*	*Oranges*	*Tangerines*	*Apricots*	*Cherries*	*Nectarines*	*Peaches*	*Plums*	*Apples*	*Avocado*	*Bananas*	*Grapes*	*Mangoes*	*Pears*
1. Strawb.	-1.426	0.078	0.012	0.095	0.002	0.012	0.007	0.004	0.136	0.063	0.107	0.07	0.103	0.027	0.091	0.089	0.006	0.013
2. Cantal.	-0.111	-1.363	0.043	0.209	-0.025	-0.144	-0.085	0.00	-0.01	-0.005	-0.008	-0.005	0.302	0.08	0.268	0.261	0.018	0.038
3. Honeydew	-0.091	0.354	-1.478	0.214	-0.02	-0.118	-0.069	0.00	-0.008	-0.004	-0.006	-0.004	0.247	0.066	0.22	0.214	0.014	0.031
4. Watermelon	-0.108	0.182	0.016	-1.285	-0.024	-0.141	-0.083	0.00	-0.01	-0.005	-0.008	-0.005	0.296	0.079	0.262	0.255	0.017	0.038
5. Grapefr.	0.02	0.003	0.00	0.004	-0.726	0.406	0.225	0.00	0.004	0.002	0.003	0.002	0.001	0.00	0.001	0.001	0.00	0.000
6. Oranges	0.213	0.032	0.005	0.039	-0.017	-1.132	0.16	0.001	0.038	0.017	0.03	0.02	0.009	0.002	0.008	0.008	0.001	0.001
7. Tanger.	0.277	0.042	0.007	0.051	-0.051	0.103	-1.338	0.002	0.049	0.023	0.039	0.025	0.012	0.003	0.011	0.01	0.001	0.002
8. Apricots	0.102	0.134	0.021	0.163	0.005	0.031	0.019	-1.095	-0.703	-0.044	-0.047	0.607	0.513	0.136	0.455	0.442	0.03	0.065
9. Cherries	0.128	0.168	0.027	0.205	0.007	0.04	0.023	-0.027	-1.72	0.078	-0.009	0.066	0.644	0.171	0.572	0.556	0.037	0.082
10. Nect.	0.124	0.162	0.026	0.198	0.007	0.038	0.023	-0.006	0.19	-1.588	0.067	-0.218	0.622	0.165	0.552	0.536	0.036	0.079
11. Peaches	0.123	0.162	0.026	0.197	0.007	0.038	0.022	-0.005	0.012	0.041	-1.402	-0.193	0.618	0.165	0.549	0.534	0.036	0.079
12. Plums	0.084	0.111	0.018	0.135	0.004	0.026	0.015	0.041	0.326	-0.113	-0.156	-1.156	0.423	0.113	0.375	0.365	0.025	0.054
13. Apples	0.05	0.017	0.003	0.02	0.003	0.02	0.012	0.00	0.007	0.003	0.006	0.004	-0.503	-0.015	-0.113	0.043	-0.004	0.022
14. Avocado	0.037	0.012	0.002	0.015	0.003	0.015	0.009	0.00	0.005	0.003	0.004	0.003	-0.007	-0.879	0.17	0.176	0.027	0.097
15. Bananas	0.035	0.012	0.002	0.014	0.002	0.014	0.008	0.00	0.005	0.002	0.004	0.003	-0.074	0.053	-0.557	0.067	0.055	0.059
16. Grapes	0.085	0.028	0.004	0.034	0.006	0.034	0.02	0.00	0.013	0.006	0.01	0.006	-0.072	0.009	-0.087	-0.833	0.016	0.006
17. Mangoes	0.046	0.015	0.002	0.019	0.003	0.019	0.011	0.00	0.007	0.003	0.005	0.004	-0.05	0.115	0.803	0.35	-1.806	0.064
18. Pears	0.03	0.01	0.002	0.012	0.002	0.012	0.007	0.00	0.004	0.002	0.004	0.002	0.243	0.209	0.43	0.21	0.033	-1.466

Cell values refer to the change in log quantity for goods in each row in responses to the change in log price of goods in each column.

Table 7: Unconditional Own and Cross-Price Elasticities

	Strawberries	Cantaloupe	Honeydew	Watermelon	Grapefruit	Oranges	Tangerines	Apricots	Cherries	Nectarines	Peaches	Plums	Apples	Avocado	Bananas	Grapes	Mangoes	Pears
19. Broccoli	-0.046	0.029	0.005	0.035	0.007	0.041	0.024	0.00	0.009	0.004	0.007	0.005	-0.101	-0.027	-0.09	-0.087	-0.006	-0.013
20. Kale	-0.029	0.018	0.003	0.022	0.004	0.026	0.015	0.00	0.005	0.003	0.004	0.003	-0.063	-0.017	-0.056	-0.054	-0.004	-0.008
21. Leaf Let.	-0.023	0.014	0.002	0.018	0.004	0.02	0.012	0.00	0.004	0.002	0.003	0.002	-0.05	-0.013	-0.045	-0.043	-0.003	-0.006
22. Rom. Let.	-0.025	0.016	0.003	0.019	0.004	0.023	0.013	0.00	0.005	0.002	0.004	0.002	-0.055	-0.015	-0.049	-0.048	-0.003	-0.007
23. Spinach	-0.012	0.008	0.001	0.009	0.002	0.011	0.006	0.00	0.002	0.001	0.002	0.001	-0.027	-0.007	-0.024	-0.023	-0.002	-0.003
24. Carrots	0.053	0.028	0.004	0.034	-0.017	-0.096	-0.057	0.00	0.004	0.002	0.003	0.002	-0.027	-0.007	-0.024	-0.023	-0.002	-0.003
25. B. Pep.	0.067	0.036	0.006	0.043	-0.021	-0.122	-0.072	0.00	0.005	0.002	0.004	0.003	-0.034	-0.009	-0.03	-0.029	-0.002	-0.004
26. Ch. Pep.	0.052	0.027	0.004	0.033	-0.016	-0.094	-0.055	0.00	0.004	0.002	0.003	0.002	-0.026	-0.007	-0.023	-0.022	-0.002	-0.003
27. Squash	0.081	0.043	0.007	0.052	-0.025	-0.147	-0.087	0.00	0.006	0.003	0.005	0.003	-0.041	-0.011	-0.036	-0.035	-0.002	-0.005
28. Tomatoes	0.08	0.042	0.007	0.051	-0.025	-0.145	-0.086	0.00	0.006	0.003	0.005	0.003	-0.04	-0.011	-0.036	-0.035	-0.002	-0.005
29. Corn	0.162	0.113	0.018	0.138	0.007	0.041	0.024	0.003	0.091	0.042	0.071	0.047	0.296	0.079	0.263	0.255	0.017	0.038
30. Artichokes	-0.023	0.013	0.002	0.016	0.00	-0.002	-0.001	0.00	0.00	0.00	0.00	0.00	-0.037	-0.01	-0.032	-0.032	-0.002	-0.005
31. Asparagus	-0.028	0.016	0.003	0.02	0.00	-0.002	-0.001	0.00	0.00	0.00	0.00	0.00	-0.045	-0.012	-0.039	-0.038	-0.003	-0.006
32. Cabbage	-0.02	0.012	0.002	0.015	0.00	-0.002	-0.001	0.00	0.00	0.00	0.00	0.00	-0.033	-0.009	-0.029	-0.028	-0.002	-0.004
33. Caulifl.	-0.024	0.014	0.002	0.017	0.00	-0.002	-0.001	0.00	0.00	0.00	0.00	0.00	-0.039	-0.01	-0.035	-0.034	-0.002	-0.005
34. Celery	-0.024	0.014	0.002	0.017	0.00	-0.002	-0.001	0.00	0.00	0.00	0.00	0.00	-0.038	-0.01	-0.034	-0.033	-0.002	-0.005
35. Cucumbers	-0.026	0.015	0.002	0.019	0.00	-0.002	-0.001	0.00	0.00	0.00	0.00	0.00	-0.042	-0.011	-0.037	-0.036	-0.002	-0.005
36. Head Let.	-0.026	0.015	0.002	0.018	0.00	-0.002	-0.001	0.00	0.00	0.00	0.00	0.00	-0.041	-0.011	-0.037	-0.036	-0.002	-0.005
37. Onions	-0.031	0.018	0.003	0.022	0.00	-0.002	-0.001	0.00	0.00	0.00	0.00	0.00	-0.05	-0.013	-0.045	-0.043	-0.003	-0.006
38. Snap Beans	-0.013	0.008	0.001	0.009	0.00	-0.001	-0.001	0.00	0.00	0.00	0.00	0.00	-0.021	-0.006	-0.018	-0.018	-0.001	-0.003

Cell values refer to the change in log quantity for goods in each row in responses to the change in log price of goods in each column.

Table 8: Unconditional Own and Cross-Price Elasticities

	Broccoli	Kale	Leaf Lettuce	Rom. Lettuce	Spinach	Carrots	Bell Peppers	Chili Peppers	Squash	Tomatoes	Sweet Corn	Artichokes	Asparagus	Cabbage	Cauliflower	Celery	Cucumbers	Head Lettuce	Onions	Snap Beans
1. Strawberries	-0.025	-0.002	-0.005	-0.012	-0.006	0.056	0.059	0.006	0.023	0.141	0.079	-0.002	-0.016	-0.011	-0.009	-0.019	-0.023	-0.024	-0.052	-0.013
2. Cantaloupe	0.146	0.015	0.029	0.069	0.033	-0.112	-0.117	-0.012	-0.046	-0.282	-0.157	-0.001	-0.011	-0.007	-0.006	-0.013	-0.015	-0.016	-0.035	-0.009
3. Honeydew	0.12	0.012	0.024	0.056	0.027	-0.092	-0.096	-0.01	-0.038	-0.231	-0.128	-0.001	-0.009	-0.006	-0.005	-0.011	-0.013	-0.013	-0.029	-0.007
4. Watermelon	0.143	0.015	0.029	0.067	0.032	-0.11	-0.115	-0.012	-0.045	-0.276	-0.153	-0.001	-0.011	-0.007	-0.006	-0.013	-0.015	-0.016	-0.035	-0.009
5. Grapefruit	0.012	0.001	0.002	0.006	0.003	0.01	0.011	0.001	0.004	0.026	0.021	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.001	0.000
6. Oranges	0.123	0.013	0.025	0.058	0.028	0.106	0.111	0.012	0.043	0.266	0.217	0.00	0.002	0.001	0.001	0.002	0.003	0.003	0.006	0.002
7. Tangerines	0.16	0.016	0.032	0.075	0.036	0.138	0.144	0.015	0.056	0.346	0.282	0.00	0.003	0.002	0.001	0.003	0.004	0.004	0.008	0.002
8. Apricots	-0.35	-0.036	-0.07	-0.164	-0.078	0.07	0.073	0.008	0.029	0.175	-0.101	-0.001	-0.011	-0.007	-0.006	-0.013	-0.016	-0.017	-0.036	-0.009
9. Cherries	-0.439	-0.045	-0.088	-0.207	-0.098	0.087	0.092	0.01	0.036	0.22	-0.127	-0.002	-0.014	-0.009	-0.008	-0.017	-0.02	-0.021	-0.045	-0.012
10. Nectarines	-0.424	-0.043	-0.085	-0.199	-0.095	0.084	0.088	0.009	0.035	0.212	-0.123	-0.002	-0.013	-0.009	-0.007	-0.016	-0.019	-0.02	-0.044	-0.011
11. Peaches	-0.422	-0.043	-0.085	-0.198	-0.094	0.084	0.088	0.009	0.034	0.211	-0.122	-0.002	-0.013	-0.009	-0.007	-0.016	-0.019	-0.02	-0.043	-0.011
12. Plums	-0.289	-0.029	-0.058	-0.136	-0.065	0.057	0.06	0.006	0.024	0.145	-0.083	-0.001	-0.009	-0.006	-0.005	-0.011	-0.013	-0.014	-0.03	-0.008
13. Apples	-0.021	-0.002	-0.004	-0.01	-0.005	0.012	0.012	0.001	0.005	0.03	0.026	-0.001	-0.009	-0.006	-0.005	-0.011	-0.013	-0.013	-0.029	-0.007
14. Avocado	-0.015	-0.002	-0.003	-0.007	-0.003	0.009	0.009	0.001	0.004	0.022	0.019	-0.001	-0.006	-0.004	-0.004	-0.008	-0.009	-0.01	-0.021	-0.005
15. Bananas	-0.015	-0.001	-0.003	-0.007	-0.003	0.008	0.009	0.001	0.003	0.021	0.018	-0.001	-0.006	-0.004	-0.003	-0.007	-0.009	-0.009	-0.02	-0.005
16. Grapes	-0.035	-0.004	-0.007	-0.017	-0.008	0.02	0.021	0.002	0.008	0.05	0.044	-0.002	-0.015	-0.01	-0.008	-0.018	-0.021	-0.023	-0.049	-0.013
17. Mangoes	-0.019	-0.002	-0.004	-0.009	-0.004	0.011	0.011	0.001	0.004	0.027	0.024	-0.001	-0.008	-0.005	-0.005	-0.01	-0.012	-0.012	-0.027	-0.007
18. Pears	-0.013	-0.001	-0.003	-0.006	-0.003	0.007	0.007	0.001	0.003	0.018	0.016	-0.001	-0.005	-0.004	-0.003	-0.006	-0.007	-0.008	-0.017	-0.004

Cell values refer to the change in log quantity for goods in each row in responses to the change in log price of goods in each column.

Table 9: Unconditional Own and Cross-Price Elasticities

	Broccoli	Kale	Leaf Lettuce	Rom. Lettuce	Spinach	Carrots	Bell Peppers	Chili Peppers	Squash	Tomatoes	Sweet Corn	Artichokes	Asparagus	Cabbage	Cauliflower	Celery	Cucumbers	Head Lettuce	Onions	Snap Beans
19. Broccoli	-0.733	-0.005	-0.032	-0.134	-0.057	0.063	0.066	0.007	0.026	0.159	0.077	-0.001	-0.012	-0.008	-0.006	-0.014	-0.016	-0.017	-0.037	-0.01
20. Kale	0.133	-0.779	0.009	0.06	-0.021	0.039	0.041	0.004	0.016	0.099	0.048	-0.001	-0.007	-0.005	-0.004	-0.009	-0.01	-0.011	-0.023	-0.006
21. Leaf Lettuce	0.085	0.011	-0.328	-0.241	-0.004	0.031	0.033	0.003	0.013	0.079	0.038	-0.001	-0.006	-0.004	-0.003	-0.007	-0.008	-0.009	-0.019	-0.005
22. Romaine Lettuce	-0.066	0.017	-0.108	-0.454	0.085	0.035	0.036	0.004	0.014	0.087	0.042	-0.001	-0.006	-0.004	-0.003	-0.008	-0.009	-0.009	-0.02	-0.005
23. Spinach	0.097	0.008	0.018	0.243	-0.623	0.017	0.018	0.002	0.007	0.042	0.021	0.00	-0.003	-0.002	-0.002	-0.004	-0.004	-0.005	-0.01	-0.003
24. Carrots	-0.028	-0.003	-0.006	-0.013	-0.006	-0.939	0.299	0.069	0.161	-0.279	0.015	0.001	0.012	0.008	0.006	0.014	0.016	0.017	0.037	0.01
25. Bell Peppers	-0.036	-0.004	-0.007	-0.017	-0.008	0.249	-0.958	-0.011	0.052	-0.207	0.018	0.002	0.015	0.01	0.008	0.018	0.021	0.022	0.048	0.012
26. Chili Peppers	-0.027	-0.003	-0.005	-0.013	-0.006	0.624	-0.061	-1.396	0.105	0.055	0.014	0.001	0.011	0.007	0.006	0.013	0.016	0.017	0.037	0.009
27. Squash	-0.043	-0.004	-0.009	-0.02	-0.01	0.32	0.095	0.02	-1.857	0.366	0.022	0.002	0.018	0.012	0.01	0.021	0.025	0.027	0.057	0.015
28. Tomatoes	-0.042	-0.004	-0.008	-0.02	-0.009	-0.18	-0.12	-0.006	0.061	-0.796	0.022	0.002	0.017	0.011	0.01	0.021	0.025	0.026	0.057	0.015
29. Sweet Corn	0.33	0.034	0.066	0.155	0.074	-0.017	-0.018	-0.002	-0.007	-0.043	-2.078	0.004	0.029	0.019	0.016	0.034	0.041	0.043	0.093	0.024
30. Artichokes	0.017	0.002	0.003	0.008	0.004	0.002	0.002	0.00	0.001	0.005	0.039	-3.108	0.318	0.611	0.141	0.26	-0.356	-0.226	1.158	0.605
31. Asparagus	0.021	0.002	0.004	0.01	0.005	0.002	0.002	0.00	0.001	0.006	0.047	0.037	-1.545	0.07	0.073	-0.047	0.087	0.135	0.448	0.015
32. Cabbage	0.016	0.002	0.003	0.007	0.003	0.002	0.002	0.00	0.001	0.004	0.035	0.114	0.125	-1.357	0.033	0.162	-0.037	0.123	0.267	0.035
33. Cauliflower	0.018	0.002	0.004	0.009	0.004	0.002	0.002	0.00	0.001	0.005	0.041	0.031	0.14	0.033	-1.362	0.092	0.124	0.095	0.04	0.171
34. Celery	0.018	0.002	0.004	0.008	0.004	0.002	0.002	0.00	0.001	0.005	0.041	0.026	-0.029	0.084	0.043	-0.515	-0.03	-0.002	-0.283	0.082
35. Cucumbers	0.02	0.002	0.004	0.009	0.004	0.002	0.002	0.00	0.001	0.006	0.044	-0.032	0.066	-0.026	0.046	-0.032	-0.738	-0.07	0.079	0.027
36. Head Lettuce	0.02	0.002	0.004	0.009	0.004	0.002	0.002	0.00	0.001	0.006	0.044	-0.019	0.094	0.045	0.033	-0.008	-0.065	-0.517	-0.286	0.048
37. Onions (excluding green)	0.024	0.002	0.005	0.011	0.005	0.003	0.003	0.00	0.001	0.007	0.053	0.041	0.129	0.036	-0.003	-0.126	0.016	-0.153	-0.747	-0.012
38. Snap Beans	0.01	0.001	0.002	0.005	0.002	0.001	0.001	0.00	0.00	0.003	0.022	0.091	0.055	0.04	0.129	0.15	0.091	0.134	0.103	-1.131

Cell values refer to the change in log quantity for goods in each row in responses to the change in log price of goods in each column.

Table 10: Shifts in Equilibrium Prices, Quantities, and Welfare and Cost Pass-Through (Fruit)

Commodity	Expend. Shares	$d\ln Q$	$d\ln P$	CPT (Cons.)	$d\ln X$	$d\ln W$	$d\ln MI$	CPT (Farm)
1. Strawberries	6.9%	0.01%	0.49%	37.75%	0.01%	1.33%	0.01%	101.6%
2. Cantaloupe	1.7%	0.15%	0.34%	23.67%	0.15%	1.64%	0.15%	115.7%
3. Honeydew	0.3%	0.31%	0.23%	32.60%	0.31%	1.15%	0.31%	163.9%
4. Watermelon	3.1%	-0.75%	0.94%	35.38%	-0.75%	1.62%	-0.75%	61.1%
5. Grapefruit	0.7%	0.01%	0.31%	18.26%	0.01%	1.75%	0.01%	102.0%
6. Oranges	3.1%	0.03%	0.36%	16.61%	0.03%	2.24%	0.03%	103.7%
7. Tangerines	2.2%	0.22%	0.24%	17.79%	0.22%	1.80%	0.22%	134.0%
8. Apricots	0.1%	0.29%	0.85%	42.07%	0.29%	2.63%	0.29%	130.1%
9. Cherries	2.0%	0.25%	0.95%	35.27%	0.25%	3.23%	0.25%	119.7%
10. Nectarines	0.9%	0.88%	0.58%	47.33%	0.88%	2.99%	0.88%	243.4%
11. Peaches	1.5%	0.30%	0.93%	40.57%	0.30%	2.93%	0.30%	127.2%
12. Plums	0.6%	0.33%	0.86%	37.26%	0.33%	3.00%	0.33%	130.3%
13. Apples	10.5%	-0.24%	0.42%	19.20%	-0.24%	1.72%	-0.24%	79.0%
14. Avocado	2.8%	-0.97%	1.56%	44.28%	-0.97%	2.20%	-0.97%	62.4%
15. Bananas	9.1%	-0.33%	1.01%	29.06%	-0.33%	3.06%	-0.33%	88.1%
16. Grapes	8.5%	-0.37%	0.49%	23.82%	-0.37%	1.34%	-0.37%	65.2%
17. Mangoes	0.6%	-0.49%	0.97%	27.07%	-0.49%	2.93%	-0.49%	82.0%
18. Pears	1.3%	0.04%	0.68%	22.98%	0.04%	3.10%	0.04%	104.3%
Average (Fruit)	100.0%	-0.20%	0.66%	27.92%	-0.20%	2.05%	-0.20%	91.32%
95% Conf. Inter.		[-0.26,-0.13]	[0.63,0.69]	[26.22,29.7]	[-0.26,-0.13]	[1.94,2.16]	[-0.26,-0.13]	[85.63,97.24]

Table 11: Shifts in Equilibrium Prices, Quantities, and Welfare and Cost Pass-Through (Vegetables)

Commodity	Expend. Shares	$d\ln Q$	$d\ln P$	CPT (Cons.)	$d\ln X$	$d\ln W$	$d\ln MI$	CPT (Farm)
19. Broccoli	3.3%	-0.15%	0.03%	5.89%	-0.21%	0.14%	-0.09%	31.1%
20. Kale	0.1%	-0.07%	-0.01%	–	-0.04%	-0.06%	-0.09%	–
21. Leaf Lettuce	0.7%	-0.07%	0.02%	4.66%	-0.15%	0.17%	0.01%	43.9%
22. Rom. Lettuce	1.5%	-0.07%	0.01%	4.42%	-0.13%	0.12%	-0.02%	39.2%
23. Spinach	0.8%	-0.07%	0.07%	8.46%	-0.28%	0.45%	0.13%	53.4%
24. Carrots	3.8%	-0.05%	0.10%	10.49%	-0.29%	0.56%	0.20%	57.5%
25. Bell Peppers	3.9%	-0.16%	0.16%	12.29%	-0.44%	0.67%	0.12%	52.1%
26. Chili Peppers	0.4%	-0.20%	0.20%	7.78%	-0.87%	1.43%	0.46%	54.3%
27. Squash	1.6%	-0.40%	0.27%	10.69%	-0.92%	1.22%	0.11%	48.9%
28. Tomatoes	9.2%	-0.16%	0.16%	14.77%	-0.37%	0.54%	0.05%	50.9%
29. Sweet Corn	2.8%	0.86%	0.18%	–	0.54%	0.77%	1.18%	–
30. Artichokes	0.2%	0.23%	0.15%	41.03%	0.06%	0.47%	0.41%	131.1%
31. Asparagus	1.5%	0.11%	0.04%	–	0.06%	0.12%	0.15%	–
32. Cabbage	1.0%	-0.19%	0.20%	12.83%	-0.53%	0.84%	0.16%	53.0%
33. Cauliflower	0.9%	-0.06%	0.06%	14.19%	-0.14%	0.22%	0.03%	52.2%
34. Celery	1.9%	-0.17%	0.01%	2.94%	-0.22%	0.11%	-0.11%	26.1%
35. Cucumbers	2.1%	-0.16%	0.16%	7.59%	-0.69%	1.15%	0.38%	54.3%
36. Head Lettuce	2.2%	-0.19%	0.01%	1.80%	-0.21%	0.03%	-0.18%	10.0%
37. Onions	4.9%	-0.41%	0.45%	26.14%	-0.62%	0.84%	-0.20%	49.0%
38. Snap Beans	1.4%	-0.22%	0.24%	8.09%	-0.97%	1.64%	0.54%	55.0%
Average (Veg)	100.0%	-0.11%	0.16%	10.82%	-0.34%	0.59%	0.12%	41.88%
95% Conf. Inter.		[-0.18,-0.04]	[0.14,0.17]	[9.34,12.34]	[-0.39,-0.3]	[0.52,0.65]	[0.03,0.22]	[35.53,48.45]
Average (All)	100.0%	-0.16%	0.44%	20.37%	-0.26%	1.40%	-0.06%	69.50%
		[-0.22,-0.1]	[0.41,0.46]	[19.01,21.8]	[-0.31,-0.21]	[1.32,1.48]	[-0.12,0.01]	[64.37,74.85]

Notes: $d\ln Z = \frac{dZ}{Z}$ for $Z = Q, P, X, W, MI$. Q and P represent output quantity and price, respectively. X is the quantity of farm inputs, W is the price of farm inputs, and MI is the quantity of marketing (non-farm) inputs. CPT = Cost Pass-Through.

Table 12: Consumer and Producer Welfare Changes Under Alternative Elasticity of Supply Specifications (Fruit)

	Medium		Low		High	
Commodity	Δ CS	Δ PS	Δ CS	Δ PS	Δ CS	ΔPS
1. Strawberries	-0.49%	0.02%	-0.46%	-0.06%	-0.50%	0.03%
2. Cantaloupe	-0.34%	0.22%	-0.31%	0.11%	-0.34%	0.23%
3. Honeydew	-0.23%	0.45%	-0.23%	0.45%	-0.22%	0.39%
4. Watermelon	-0.93%	-1.03%	-0.72%	-1.40%	-1.05%	-0.82%
5. Grapefruit	-0.31%	0.03%	-0.31%	0.04%	-0.31%	0.03%
6. Oranges	-0.36%	0.08%	-0.35%	0.00%	-0.36%	0.08%
7. Tangerines	-0.24%	0.46%	-0.26%	0.64%	-0.22%	0.34%
8. Apricots	-0.85%	0.61%	-0.82%	0.52%	-0.83%	0.55%
9. Cherries	-0.95%	0.53%	-0.88%	0.28%	-0.95%	0.53%
10. Nectarines	-0.58%	1.77%	-0.66%	2.14%	-0.52%	1.43%
11. Peaches	-0.93%	0.63%	-0.87%	0.42%	-0.93%	0.60%
12. Plums	-0.86%	0.70%	-0.83%	0.62%	-0.45%	-0.31%
14. Avocado	-1.56%	-1.32%	-1.23%	-1.78%	-1.75%	-1.05%
15. Bananas	-1.01%	-0.41%	-0.91%	-0.71%	-1.05%	-0.28%
16. Grapes	-0.49%	-0.72%	-0.33%	-1.15%	-0.56%	-0.52%
17. Mangoes	-0.96%	-0.64%	-0.84%	-1.03%	-1.02%	-0.46%
18. Pears	-0.68%	0.13%	-0.62%	-0.16%	-0.69%	0.18%
Average (Fruit)	-0.66%	-0.28%	-0.56%	-0.55%	-0.70%	-0.18%
95% Conf. Int.	[-0.7,-0.63]	[-0.39,-0.17]	[-0.61,-0.51]	[-0.72,-0.38]	[-0.73,-0.68]	[-0.26,-0.1]

Table 13: Consumer and Producer Welfare Changes Under Alternative Elasticity of Supply Specifications **(Vegetables)**

	Medium		Low		High	
Commodity	Δ CS	Δ PS	Δ CS	Δ PS	Δ CS	ΔPS
19. Broccoli	-0.03%	-0.30%	-0.01%	-0.36%	-0.04%	-0.25%
20. Kale	0.01%	-0.06%	0.01%	-0.06%	0.01%	-0.05%
21. Leaf Lettuce	-0.02%	-0.22%	-0.01%	-0.27%	-0.02%	-0.18%
22. Rom. Lettuce	-0.01%	-0.19%	-0.01%	-0.23%	-0.02%	-0.16%
23. Spinach	-0.07%	-0.39%	-0.05%	-0.51%	-0.08%	-0.32%
24. Carrots	-0.10%	-0.41%	-0.08%	-0.56%	-0.12%	-0.32%
25. Bell Peppers	-0.16%	-0.62%	-0.11%	-0.80%	-0.19%	-0.50%
26. Chili Peppers	-0.20%	-1.20%	-0.15%	-1.57%	-0.24%	-0.96%
27. Squash	-0.27%	-1.27%	-0.19%	-1.62%	-0.32%	-1.04%
28. Tomatoes	-0.16%	-0.52%	-0.11%	-0.68%	-0.19%	-0.42%
29. Sweet Corn	-0.18%	0.78%	-0.19%	0.80%	-0.16%	0.70%
30. Artichokes	-0.15%	0.11%	-0.11%	0.01%	-0.16%	0.16%
31. Asparagus	-0.04%	0.12%	-0.03%	0.10%	-0.04%	0.12%
32. Cabbage	-0.20%	-0.75%	-0.15%	-0.97%	-0.24%	-0.60%
33. Cauliflower	-0.06%	-0.21%	-0.04%	-0.27%	-0.07%	-0.16%
34. Celery	-0.01%	-0.31%	-0.01%	-0.37%	-0.02%	-0.26%
35. Cucumbers	-0.16%	-0.96%	-0.12%	-1.27%	-0.19%	-0.78%
36. Head Lettuce	-0.01%	-0.30%	0.00%	-0.34%	-0.01%	-0.26%
37. Onions	-0.45%	-0.87%	-0.32%	-1.11%	-0.53%	-0.72%
38. Snap Beans	-0.24%	-1.34%	-0.18%	-1.76%	-0.28%	-1.07%
Average (Veg)	-0.16%	-0.48%	-0.12%	-0.63%	-0.18%	-0.38%
95% Conf. Int.	[-0.17,-0.14]	[-0.54,-0.41]	[-0.13,-0.1]	[-0.7,-0.55]	[-0.2,-0.17]	[-0.44,-0.33]
Average (All)	-0.44%	-0.37%	-0.36%	-0.59%	-0.47%	-0.27%
95% Conf. Int.	[-0.46,-0.42]	[-0.45,-0.29]	[-0.4,-0.33]	[-0.7,-0.47]	[-0.49,-0.45]	[-0.33,-0.21]

Table 14: Shifts in Equilibrium Prices, Quantities, and Welfare and Cost Pass-Through Associated with Commodity Groups Unilaterally Implementing FSMA Regulations (Fruit)

Commodity	Expend. Shares	$d\ln Q$	$d\ln P$	CPT (Cons.)	$d\ln X$	$d\ln W$	$d\ln MI$	CPT (Farm)
Strawberries	6.9%	-0.39%	0.28%	21.47%	-0.39%	0.76%	-0.39%	57.78%
Cantaloupe	1.7%	-0.28%	0.21%	14.77%	-0.28%	1.03%	-0.28%	72.19%
Honeydew	0.3%	-0.15%	0.10%	14.07%	-0.15%	0.50%	-0.15%	70.72%
Watermelon	3.1%	-0.97%	0.75%	28.47%	-0.97%	1.30%	-0.97%	49.14%
Grapefruit	0.7%	-0.18%	0.25%	14.31%	-0.18%	1.38%	-0.18%	79.96%
Oranges (Navel)	3.1%	-0.29%	0.26%	11.85%	-0.29%	1.60%	-0.29%	73.96%
Tangerines	2.2%	-0.18%	0.13%	9.84%	-0.18%	0.99%	-0.18%	74.12%
Apricots	0.1%	-0.42%	0.39%	19.23%	-0.42%	1.20%	-0.42%	59.45%
Cherries (Sweet)	2.0%	-0.68%	0.40%	14.97%	-0.68%	1.37%	-0.68%	50.77%
Nectarines	0.9%	-0.23%	0.15%	12.15%	-0.23%	0.77%	-0.23%	62.49%
Peaches	1.5%	-0.55%	0.39%	17.15%	-0.55%	1.24%	-0.55%	53.76%
Plums	0.6%	-0.45%	0.41%	17.63%	-0.45%	1.42%	-0.45%	61.64%
Apples	10.5%	-0.21%	0.43%	19.88%	-0.21%	1.78%	-0.21%	81.74%
Avocado	2.8%	-1.17%	1.36%	38.50%	-1.17%	1.92%	-1.17%	54.26%
Bananas	9.1%	-0.49%	0.93%	26.93%	-0.49%	2.83%	-0.49%	81.62%
Grapes	8.5%	-0.39%	0.48%	23.17%	-0.39%	1.31%	-0.39%	63.40%
Mangoes	0.6%	-1.16%	0.65%	18.26%	-1.16%	1.98%	-1.16%	55.33%
Pears	1.3%	-0.58%	0.41%	13.69%	-0.58%	1.85%	-0.58%	62.12%
Average (Fruit)	100.0%	-0.45%	0.53%	21.46%	-0.45%	1.61%	-0.45%	68.55%
Conf. Int.		[-0.46,-0.44]	[0.52,0.53]	[21.25,21.68]	[-0.46,-0.44]	[1.6,1.63]	[-0.46,-0.44]	[67.93,69.21]

Table 15: Shifts in Equilibrium Prices, Quantities, and Welfare and Cost Pass-Through Associated with Commodity Groups Unilaterally Implementing FSMA Regulations

Commodity	Expend. Shares	$d\ln Q$	$d\ln P$	CPT (Cons.)	$d\ln X$	$d\ln W$	$d\ln MI$	CPT (Farm)
Broccoli	3.3%	-0.03%	0.05%	10.42%	-0.14%	0.24%	0.07%	55.00%
Kale	0.1%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Leaf Lettuce	0.7%	-0.01%	0.02%	6.11%	-0.12%	0.22%	0.10%	57.62%
Romaine Lettuce	1.5%	-0.01%	0.02%	6.42%	-0.09%	0.18%	0.08%	57.02%
Spinach	0.8%	-0.05%	0.07%	8.88%	-0.26%	0.47%	0.17%	56.10%
Carrots	3.8%	-0.09%	0.10%	9.81%	-0.32%	0.52%	0.14%	53.81%
Bell Peppers	3.9%	-0.15%	0.16%	12.42%	-0.43%	0.68%	0.13%	52.72%
Chili Peppers	0.4%	-0.27%	0.20%	7.46%	-0.91%	1.37%	0.36%	52.09%
Squash	1.6%	-0.47%	0.25%	10.16%	-0.96%	1.16%	0.02%	46.44%
Tomatoes	9.2%	-0.13%	0.17%	15.51%	-0.35%	0.57%	0.09%	53.45%
Sweet Corn	2.8%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Artichokes	0.2%	-0.09%	0.03%	8.57%	-0.13%	0.10%	-0.06%	27.38%
Asparagus	1.5%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Cabbage	1.0%	-0.25%	0.19%	11.93%	-0.57%	0.78%	0.07%	49.26%
Cauliflower	0.9%	-0.08%	0.06%	13.06%	-0.16%	0.21%	0.01%	48.00%
Celery	1.9%	-0.01%	0.03%	6.38%	-0.13%	0.24%	0.10%	56.80%
Cucumbers	2.1%	-0.12%	0.17%	7.80%	-0.67%	1.18%	0.43%	55.85%
Head Lettuce	2.2%	-0.02%	0.03%	10.31%	-0.10%	0.19%	0.07%	56.93%
Onions (excluding green)	4.9%	-0.35%	0.49%	28.27%	-0.58%	0.91%	-0.12%	53.02%
Snap Beans	1.4%	-0.26%	0.24%	7.89%	-1.00%	1.60%	0.48%	53.66%
Average (Veg)	100.0%	-0.13%	0.15%	11.98%	-0.36%	0.56%	0.09%	48.26%
95% Conf. Int.		[-0.14,-0.13]	[0.15,0.15]	[11.85,12.12]	[-0.36,-0.35]	[0.56,0.57]	[0.08,0.1]	[47.89,48.67]
Average (All)	100.0%	-0.31%	0.36%	17.28%	-0.41%	1.15%	-0.21%	59.59%
Conf. Int.		[-0.31,-0.3]	[0.36,0.37]	[17.15,17.41]	[-0.41,-0.4]	[1.14,1.16]	[-0.22,-0.2]	[59.22,60]

Notes: $d\ln Z = \frac{dZ}{Z}$ for $Z = Q, P, X, W, MI$. Q and P represent output quantity and price, respectively. X is the quantity of farm inputs, W is the price of farm inputs, and MI is the quantity of marketing (non-farm) inputs. CPT = Cost Pass-Through.

Table 16: Consumer and Producer Welfare Changes Under Alternative Elasticity of Supply Specifications - Unilateral

	Medium		Low		High	
Commodity	Δ CS	Δ PS	Δ CS	Δ PS	Δ CS	ΔPS
1. Strawberries	-0.28%	-0.55%	-0.21%	-0.73%	-0.32%	-0.44%
2. Cantaloupe	-0.21%	-0.39%	-0.17%	-0.57%	-0.23%	-0.30%
3. Honeydew	-0.10%	-0.20%	-0.08%	-0.29%	-0.11%	-0.16%
4. Watermelon	-0.75%	-1.34%	-0.54%	-1.70%	-0.89%	-1.10%
5. Grapefruit	-0.25%	-0.34%	-0.19%	-0.67%	-0.27%	-0.23%
6. Oranges	-0.26%	-0.56%	-0.18%	-1.02%	-0.28%	-0.38%
7. Tangerines	-0.13%	-0.35%	-0.09%	-0.63%	-0.15%	-0.24%
8. Apricots	-0.39%	-0.82%	-0.24%	-1.27%	-0.46%	-0.60%
9. Cherries	-0.40%	-1.32%	-0.23%	-1.91%	-0.49%	-1.01%
10. Nectarines	-0.15%	-0.46%	-0.10%	-0.74%	-0.17%	-0.33%
11. Peaches	-0.39%	-1.06%	-0.23%	-1.57%	-0.48%	-0.80%
12. Plums	-0.40%	-0.88%	-0.26%	-1.40%	-0.47%	-0.64%
13. Apples	-0.43%	-0.40%	-0.34%	-0.79%	-0.47%	-0.26%
14. Avocado	-1.35%	-1.61%	-1.01%	-2.09%	-1.57%	-1.30%
15. Bananas	-0.93%	-0.64%	-0.82%	-0.98%	-0.99%	-0.46%
16. Grapes	-0.48%	-0.75%	-0.31%	-1.21%	-0.55%	-0.54%
17. Mangoes	-0.65%	-1.59%	-0.49%	-2.08%	-0.75%	-1.28%
18. Pears	-0.41%	-1.12%	-0.26%	-1.79%	-0.47%	-0.81%
Average (Fruit)	-0.53%	-0.71%	-0.40%	-1.09%	-0.59%	-0.53%
95% Conf. Int.	[-0.54,-0.53]	[-0.73,-0.7]	[-0.41,-0.4]	[-1.11,-1.07]	[-0.6,-0.59]	[-0.55,-0.52]

Table 17: Consumer and Producer Welfare Changes Under Alternative Elasticity of Supply Specifications - Unilateral

	Medium		Low		High	
Commodity	Δ CS	Δ PS	Δ CS	Δ PS	Δ CS	ΔPS
19. Broccoli	-0.05%	-0.20%	-0.03%	-0.26%	-0.05%	-0.16%
20. Kale	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
21. Leaf Lettuce	-0.02%	-0.17%	-0.02%	-0.22%	-0.03%	-0.13%
22. Rom. Lettuce	-0.02%	-0.13%	-0.02%	-0.18%	-0.02%	-0.11%
23. Spinach	-0.07%	-0.37%	-0.06%	-0.49%	-0.09%	-0.30%
24. Carrots	-0.10%	-0.45%	-0.07%	-0.58%	-0.11%	-0.36%
25. Bell Peppers	-0.16%	-0.61%	-0.12%	-0.79%	-0.19%	-0.50%
26. Chili Peppers	-0.20%	-1.25%	-0.14%	-1.62%	-0.23%	-1.02%
27. Squash	-0.25%	-1.33%	-0.18%	-1.67%	-0.30%	-1.11%
28. Tomatoes	-0.17%	-0.50%	-0.12%	-0.65%	-0.19%	-0.40%
29. Sweet Corn	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
30. Artichokes	-0.03%	-0.26%	-0.01%	-0.31%	-0.04%	-0.22%
31. Asparagus	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
32. Cabbage	-0.19%	-0.80%	-0.14%	-1.02%	-0.22%	-0.66%
33. Cauliflower	-0.06%	-0.22%	-0.04%	-0.28%	-0.07%	-0.19%
34. Celery	-0.03%	-0.18%	-0.02%	-0.24%	-0.03%	-0.15%
35. Cucumbers	-0.17%	-0.93%	-0.12%	-1.23%	-0.19%	-0.75%
36. Head Lettuce	-0.03%	-0.14%	-0.03%	-0.19%	-0.04%	-0.11%
37. Onions	-0.49%	-0.81%	-0.36%	-1.04%	-0.56%	-0.66%
38. Snap Beans	-0.24%	-1.38%	-0.17%	-1.80%	-0.27%	-1.12%
Average (Veg)	-0.15%	-0.50%	-0.11%	-0.65%	-0.18%	-0.41%
95% Conf. Int.	[-0.15,-0.15]	[-0.5,-0.49]	[-0.11,-0.11]	[-0.65,-0.64]	[-0.18,-0.18]	[-0.41,-0.4]
Average (All)	-0.36%	-0.62%	-0.27%	-0.90%	-0.41%	-0.48%
95% Conf. Int.	[-0.18,-0.18]	[-0.41,-0.4]	[-0.28,-0.27]	[-0.91,-0.88]	[-0.41,-0.41]	[-0.48,-0.47]

Appendix A. Derivation of Equilibrium Displacement Model

To derive the equilibrium displacement model, we take the total derivative for each of equations (1) through (6) and then rearrange terms to organize the equations in terms of elasticities $(\eta, \varepsilon, \quad)$, budget shares (ω) and log changes in variables (noting that $\frac{dX}{X} = d\ln X$, $\frac{dP}{P} = d\ln P$, and so on). Equation (1) becomes:

$$
\begin{aligned}
dQ &= \sum_{k=1}^{N} \frac{\partial Q_n^D}{\partial P_k} dP_n + \frac{\partial Q_n^D}{\partial A_N} \\
d\ln Q &= \sum_{k=1}^{N} \frac{\partial Q_n^D}{\partial P_k} \frac{P_n}{Q_n^D} d\ln P_n + \frac{\partial Q_n^D}{\partial A_N} \frac{A_N}{Q_n^D} d\ln A_N \\
d\ln Q &= \sum_{k=1}^{N} \eta_{nk} d\ln P_n.
\end{aligned}
$$

Equation (2) becomes:

$$
\begin{aligned}
d\ln P_n &= \frac{\partial c_n}{\partial W_n} \frac{W_n}{P_n} d\ln W_n + \frac{\partial c_n}{\partial PMI} \frac{PMI}{P_n} d\ln PMI \\
d\ln P_n &= \frac{X_n W_n}{Q_n P_n} d\ln W_n + \frac{MI_n PMI}{Q_n P_n} d\ln PMI \\
d\ln P_n &= s_n d\ln W_n + (1 \quad s_n) d\ln PMI.
\end{aligned}
$$

Equation (3) becomes:

$$
\begin{aligned}
dX_n &= \frac{\partial g_n}{\partial W_n} dW_n + \frac{\partial g_n}{PMI} dPMI + dQ_n \\
d\ln X_n &= \frac{\partial g_n}{\partial W_n} \frac{W_n}{X_n} d\ln W_n + \frac{\partial g_n}{\partial PMI} \frac{PMI}{X_n} d\ln PMI + \frac{Q_n}{X_n} d\ln Q_n \\
d\ln X_n &= \quad {}_n d\ln W_n + 0 + d\ln Q.
\end{aligned}
$$

Equation (4) becomes:

$$\begin{aligned}
dX_n &= \frac{\partial X_n^S}{\partial W_n} dW_n + \frac{\partial X_n^S}{\partial B_n} d \quad {}_n \\
d \ln X_n &= \frac{\partial X_n^S}{\partial W_n} \frac{W_n}{X_n} d \ln W_n + \frac{\partial X_n^S}{\partial \beta_n} \frac{\quad {}_n}{X_n} d \ln \quad {}_n \\
d \ln X_n &= \varepsilon_n d \ln W_n + \varepsilon_n d \ln \quad {}_n.
\end{aligned}$$

Equation (5) becomes:

$$\begin{aligned}
dMI_n^D &= \frac{\partial k_n}{\partial W_n} dW_n + \frac{\partial k_n}{\partial PMI} dPMI + dQ_n \\
d \ln MI_n^D &= \frac{\partial k_n}{\partial W_n} \frac{W_n}{MI_n} d \ln W_n + \frac{\partial k_n}{\partial PMI} \frac{PMI}{MI_n} d \ln PMI + \frac{Q_n}{X_n} d \ln Q_n \\
d \ln MI_n &= \quad {}_{MI} d \ln W_n + 0 + d \ln Q_n.
\end{aligned}$$

Equation (6) becomes:

$$\begin{aligned}
dMI &= \frac{\partial MI^S}{\partial PMI} dPMI \\
d \ln MI &= \frac{\partial MI^S}{\partial PMI} \frac{PMI}{MI} d \ln PMI \\
d \ln MI &= \varepsilon_{MI} d \ln PMI.
\end{aligned}$$

If the supply of marketing inputs is perfectly elastic, then $\varepsilon_{MI} = \infty$ and $\frac{1}{\varepsilon_{MI}} = 0$. These substitutions allow the last equation to be dropped as $d \ln PMI = 0$ and the other equations to be simplified to:

$$
\begin{aligned}
d\ln Q_n \quad \eta_n d\ln P_n &= 0\\
d\ln P_n \quad s_n d\ln W_n &= 0\\
d\ln X_n \quad {}_n d\ln W_n \quad d\ln Q_n &= 0\\
d\ln X_n \quad \varepsilon_n d\ln W_n &= \varepsilon_n \ln \quad {}_n\\
d\ln Q_n + {}_{MI} d\ln W_n \quad d\ln MI_n &= 0.
\end{aligned}
$$

The variables ${}_N$ and ${}_{MI}$ can be shown to equal $(1 \quad s_x) \; {}_{x,mi}$ and $(1 \quad s_x) \; {}_{x,mi}$, respectively. Note that q_i is produced with two inputs x_n and MI. Following equation (2) and suppressing subscripts, let the unit cost of $q = c(w, pmi)$ where w and pmi are the prices of the respective inputs. Following Sato and Koizumi (1973), we define the elasticity of substitution as:

$$
\begin{aligned}
{}_{x,mi} &= \frac{c \times c_{w,pmi}}{c_w \times c_{pmi}}\\
&= \frac{c \times c_{w,pmi}}{c_w \times c_{pmi}}\\
&= \frac{c_{w,pmi}}{c_w} \frac{c}{c_{pmi}},
\end{aligned}
$$

where

$$
\begin{aligned}
c_{w,pmi} &= \frac{\partial c^2}{\partial w \partial pmi}\\
x = c_x &= \frac{\partial c}{\partial w}\\
mi = c_{pmi} &= \frac{\partial c}{\partial pmi}.
\end{aligned}
$$

.

Note that the Hicksian cross-price elasticities of demand for input x are:

$$
\begin{aligned}
{}_{mi} &= \frac{\partial c_w}{\partial pmi}\frac{pmi}{c_w} \\
&= \frac{\partial c^2}{\partial w \partial pmi}\frac{pmi}{c_w} \\
&= \frac{c_{w,pmi}}{c_w} pmi.
\end{aligned}
$$

Therefore,

$$
\begin{aligned}
{}_{w,mi} &= \frac{c_{w,mi}}{c_w}\frac{c}{c_{pmi} \times pmi} \\
&= {}_{pmi}\frac{c}{c_{pmi}} \\
&= \frac{1}{1 \quad s_x} {}_{pmi} \\
{}_{mi} &= (1 \quad s_x) {}_{x,mi}.
\end{aligned}
$$

To solve for ${}_{n}$, note that:

$$c = w \times c_w + (pmi)c_{pmi}$$

and that:

$$\partial c = w\frac{\partial c_w}{\partial w} + (pmi)\frac{\partial c_{pmi}}{\partial w} = 0.$$

Since $\frac{\partial c_{pmi}}{\partial w} = \frac{\partial c^2}{\partial w \partial pmi} = \frac{\partial c_w}{\partial pmi}$, multiply by $\frac{1}{w}$ and simplify to get:

$${}_{n} + {}_{mi} = 0$$

so that:

$$ {}_{n} = \quad (1 \quad s_{n}) \quad {}_{x,mi}. $$

Appendix B. Relationship between of Comprehensive and Unilateral Enactment

Denote Z_{Full} as the effects on P, Q, W, X, and MI from the Produce Safety Rule when all non-exempted commodities must incur the costs of regulatory compliance (i.e., comprehensive enactment), denoted D_{Full}. Reorder the rows of A, Z, and D so that:

$$
A = \begin{bmatrix}
I_N & \quad \eta_N & 0_N & 0_N & 0_N \\
0_N & I_N & 0_N & s_N & 0_N \\
I_N & 0_N & I_N & (I_N \quad s_N) \quad {}_{x,MI} & 0_N \\
I_N & 0_N & 0_N & (I_N \quad s_N) \quad {}_{x,MI} & I_N \\
0_N & 0_N & I_N & \varepsilon_N & 0_N
\end{bmatrix}
$$

$$
Z = \Big[dlQ_N \quad dlP_N \quad dlX_N \quad dlMI_N \quad dlW_N \quad {}'
$$

$$
D = \Big[0 \quad 0 \quad 0 \quad 0 \quad \varepsilon_N \quad {}_N \quad {}' \quad .
$$

Let $S = N \times k$. Partition the matrices A and D as follows:

$$
A = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix}
$$

$$
D = \begin{bmatrix} D_{11} \\ D_{21} \end{bmatrix},
$$

where the dimensions of A_{11} and D_{11} are $[(S \quad N) \times (S \quad N)]$ and $[(S \quad N) \times 1]$.

Note that inverse of $A \quad {}^{1}$ is:

$$
A \quad {}^{1} = \begin{bmatrix} B_{11} & B_{12} \\ B_{21} & B_{22} \end{bmatrix}
$$

where

$$\begin{aligned} B_{11} &= A_{11} \quad A_{12}A_{22}^{1}A_{21} \quad ^{1} \\ B_{12} &= \quad A_{11} \quad A_{12}A_{22}^{1}A_{21} \quad ^{1} A_{12}A_{22}^{1} \\ B_{21} &= \quad A_{22} \quad A_{21}A_{11}^{1}A_{12} \quad ^{1} A_{21}A_{11}^{1} \\ B_{22} &= A_{22} \quad A_{21}A_{11}^{1}A_{12} \quad ^{1} \end{aligned}$$

so that:

$$Z = \begin{bmatrix} B_{11}D_1 & B_{12}D_2 \\ B_{21}D_1 & B_{22}D_2 \end{bmatrix},$$

where the dimensions of $B_{11}D_1 \quad B_{12}D_2$ are $[(S \quad N) \times 1]$ and the dimensions of $B_{21}D_1$ $B_{22}D_2$ are $[N \times 1]$. If producers of the N^{th} good unilaterally undertake the producer safety rules, then $D_1 = 0$.

Note that the value of an exemption of the N^{th} good is described by the Z values where $D_2 = 0$ so that

$$Z_{D_2=0} = \begin{bmatrix} B_{11}D_1 \\ B_{21}D_1 \end{bmatrix}.$$

Similarly, the value of comprehensive enactment of the N^{th} good is the difference between the Z values under full enactment and the Z values when $D_1 = 0$. The values when $D_1 = 0$

are:

$$Z_{D_1=0} = \begin{bmatrix} B_{12}D_2 \\ B_{22}D_2 \end{bmatrix}.$$

This shows that the total effect for the N^{th} producer is sum of the direct effect of the cost (through D_2) and the indirect effect of the increase in costs for other producers (through D_1).