The FDA Food Safety and Modernization Act and the Exemption for Small Firms

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Abstract

The FDA Food Safety Modernization Act of 2010 is new legislation that mandates, among other things, new food safety standards. The act includes a clause that exempts small firms from new regulatory requirements. This paper investigates the effects of a small firm exemption from more stringent food safety standards. The model compares food safety, total output and the number of market participants for different food safety regulation with and without an exemption for small firms. The numerical examples show that a more stringent food safety regulation increases food safety, increases the price of food, decreases the total output and decreases the number of firms. A new food safety standard with an exemption for small firms increases the average food safety but not as much as with a new standard alone. An exemption for small firms causes the total number of firms to increase.

Key words: Food safety, heterogeneous firms, regulation, regulatory exemption.

JEL classification: D21, M31, Q10, Q18.

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The FDA Food Safety Modernization Act (FFSMA) of 2010 amends the Food, Drug, and Cosmetic Act of 1938 with the stated objective to shift focus from food incident response of contamination prevention. The act comprises four titles.[1]

Under Title I, food facilities must identify and implement preventive controls to significantly minimize or prevent food hazards. Title I requires the FDA to issue guidance on how to reduce food contaminants and to set standards for the production and harvesting of safe fruits and vegetables. Title I also calls for the collection of fees for facility re-inspection, food recalls, voluntary importer program, and importer re-inspection. The title also includes exemptions for establishments that sell food directly to consumers with annual sales of less than $500,000, adjusted for inflation.

Title II focuses on the detection and response to food safety problems. The second title requires the allocation of more resources to the inspection of domestic facilities and to the inspection of food imports, and to establish a product tracing system. Title II specifies that the CDC must improve illness surveillance systems. In addition, title II gives authority to the FDA to order the recall of a food product.

The third title applies to the safety of imported food. It requires importers to verify that foreign suppliers comply with US food safety standards. Under title III, the FDA must develop a program to expedite review for participating importers. Title III also requires the FDA to reach out foreign governments to facilitate the inspection of foreign facilities, to set provisions to recognize third-party audits of foreign facilities and to refuse imports of food from foreign facilities that refuse inspection.

The miscellaneous provisions in title IV approve funding for some food safety centers and establish a protection mechanism for whistleblowers employed in facilities that violate food safety regulation.

The food industry initially supported the act. However, some industry groups removed their support following the late addition of exemptions for small firms in title I. The act includes exemptions for small firms to ease the burden of regulation on firms that could possibly shutdown their operations. Part of the controversy arises from that there is no justification to

[1] For a summary of the act see GovTrack.us (2010). Information that pre-dates the adoption of the act is also available at Johnson (2010).

exempt small firms on the basis that they supply safer food. Small food producers may even be those that supply the least safe food. Exempting small firms therefore goes against the objective of the regulation to make food safer.

Whether the act will significantly affect the safety of food in the United States is debatable. In particular, it will depend on how the FDA implements the provision of the act and whether congress will appropriate the estimated $1.4 billion for the act to be implemented over a five year period. Moreover, the support from the industry suggests that food facilities are already doing more than the act requires and that the effect on food safety will likely be small.

The FFSMA includes several provisions that affect food safety in various ways. In this paper, I summarize the effect of the act a single variable for food safety. This simplification means that the paper looks at the end result of regulation, i.e. how safe food is for consumers, rather than modeling the production process that yields to safe food. In practice, new food safety regulation that applies an exemption uniformly across industries may affect some industries more than others depending on firm size distribution. This paper simplifies by focusing on the market for single food product.

The paper analyses the effect of a small firm exemption compared to the situation before new food safety regulation is introduce and the situation where no exemption is given to small firms. I base my modeling approach on Pouliot (2010) that allows for firms to differ in their cost of producing a large quantity of food and in their cost of producing safe food. The model is flexible enough to show the effect of new regulation on the number of firms, the size of firms, the price and the average food safety under different distributions of firm size and food safety choices. However, unlike Pouliot (2010), it is difficult to show analytical results when an exemption for small firms is available. I therefore rely in this paper on numerical examples to show the effects of an exemption for small firms.

The following section lays the assumptions of the model and describes firms' choice under regulation with or without an exemption for small firms. The second section describes how I implement the numerical examples. I show and discuss in the third section results of the numerical solutions and their implications.

The model

The basis for this model is Pouliot (2010) who investigates the effect of mandatory traceability when firms are heterogeneous. Other papers consider models with heterogeneous firms. Maybe the most common explanation for firms of different sizes is quality of management, as in Lucas (1978). Models of firm size and food safety do not abound. Cho and Hooker (2007) consider heterogeneous and participation in voluntary food safety program. The authors find that firms with higher cost of food safety are less likely to participate in voluntary programs regardless of the financial incentives.

My model considers a population of N price taking and risk neutral heterogeneous firms in a market for a homogeneous food product. A firm i maximizes profits by choosing an output $q_i \geq 0$ and a level of food safety $s_i \in (0,1)$, which is measured as the probability that one unit of food does not cause illness. The variable for food safety summarizes all the efforts of a firm in making food safe. For simplicity, I consider a single variable for food safety that captures the risk of foodborne illnesses from all possible sources (e.g. pathogens, chemicals) and severity.

The profit of a firm i is given by

$$\Pi_i = P[Q]q_i - C[q_i, s_i : \alpha_i, \beta_i] - q_i(1-s_i)L, \tag{1}$$

where $P[Q]$ is the inverse demand for food that is a function of the total quantity of food delivered given by Q. The cost of producing food is given by the function $C[\cdot]$. The expression $q_i(1-s_i)L$ is the total expected penalty that a firm must pay for delivering unsafe food. I explain in detail each term in (1) below.

The model assumes that consumers do not observe the firm of origin and the safety of one food when making their purchase decisions. This simplifying assumption is consistent with the nature of many types of food products and many types of food contaminants. The following two justifications support the assumption. First, in general, consumers cannot observe the safety of food by sensory inspection and firms cannot make claims regarding the safety of a food product and will not differentiate food with respect to its safety (Golan et al. 2004). Thus, even though consumers may value enhanced food safety, they are unable to observe safety and therefore their priors remain constant despite increased effort by firms to deliver safe food. Second, most food products in developed countries are very safe and improvement in safety may yield only marginal changes. This does not mean however that a small increase in food safety does not have a significant economic impact.

For the purpose of this model, an alternative interpretation of the assumption that consumers do not observe food safety is that consumers' perception of food safety is constant. If that is the case, it does not matter in comparative static, that I will show later in the text, that food safety appears as a variable in the inverse demand function or not. Overall, the assumption that consumers do not observe food safety does not affect results if the induced increase in willingness to pay for food from food safety regulation is small.[2] This is likely the case because new food safety regulation does not yield a drastic change in the average safety of food, which is already very safe.

The cost of producing food depends on the quantity of food, q_i, and the safety food, s_i. I assume that the cost function is increasing and convex with respect to the output and the food safety. The safety of food is measured as the *ex ante* probability that food is safe and therefore takes a value between zero and one. Food is perfectly safe only at an infinite cost such that $C_s(q_i, s_i = 1) \to \infty$, where the subscript on the cost function denotes a partial derivative. Also, increasing food safety increases the marginal cost of food such that $C_{qs} \geq 0$.

Factors exogenous to each firm affect production costs for output and food safety. The parameter α_i captures the efficiency of a firm to produce a quantity of food while the parameter β_i captures the efficiency of a firm to produce safe food. The parameter α_i is specific to the marginal cost of output and is defined such that the marginal cost of output increases with respect to α, $C_{q\alpha} \geq 0$. I assume that α_i does not directly affect the marginal cost of food safety, $C_{s\alpha} = 0$. Similarly, the parameter β_i is specific to the marginal cost of producing safe food. The cost of producing safe food increases with respect to β, $C_{s\beta} \geq 0$ and β does not affect the marginal cost of output, $C_{q\beta} = 0$. I model the heterogeneity of firms by assuming that α and β

[2] In practice, consumers' willingness to pay for food with respect to food safety is not always constant. Following an outbreak, consumers may adjust their demand given the information presented to them about consumption risks. Most incidents have a marginal effect on food demand. However, in the case of the discovery of *E. coli* 0157 in bagged spinach in 2006, the shift in demand was severe and lasted more than a year. Arnade, Calvin and Kuchner (2009) find that expenditures in bagged spinach were still 10% below their level 68 weeks after the discovery of *E. coli*.

are jointly distributed following a function $f = f[\alpha, \beta]$ and a cumulative distribution function $F = F[\alpha, \beta]$.

Previous literature explains firm size differential by management abilities. In this model, management can explain firms' ability to produce a large output or to produce safe food but let me explore other explanations. In practice, in agriculture, factors such as climate, soil quality, social, regulatory and environmental conditions explain the heterogeneity of firms. For example, a firm may have a small α because it is located where the climate is ideal for the growth of an agricultural commodity. Similarly, a firm may have a small β because the risk of contamination from wildlife activity, e.g. bird dropping, is small because there is no wildlife habitat nearby. The function f describes how the conditions that favor a large output are link with the conditions that affect food safety across firms. It is possible that the factors that favor the growth of a crop also favor contamination. For instance, high moisture may increase yields but at the same time may facilitate the growth of molds that are toxic for humans. If that is the case, the function f is such that α and β are negatively correlated. Another possible case is that the best soil for a crop is absent of pests that can cause contamination such that α and β are positively correlated. The last possibility is that there is no relationship between the conditions that favor production and the factors that favor safety such that there is no correlation between α and β.

The last set of terms in expression (1) is the expected cost for delivering unsafe food. For each unit of food that is unsafe, with probability $1-s_i$, firm i must pay compensation to consumers affected, pay a fine or incur other expenses to regain its reputation. The parameter L is the expected cost given for a firm that delivers unsafe food. It summarizes the probability that the food incident is detected and traced to the firm of origin and the total expenses of the firm found responsible, including recall and liability costs. I ignore type II error in tracing the origin of unsafe food. This implies that a firm that delivers safe food is never assigned liability or fines for unsafe food delivered by another firm.

The model endogenizes the number of market participants. In the population of firms, some may find it profit maximizing to produce food other than the food product of interest in this model. The firms that do not enter the market for the food product remain as potential entrants. For example, farms in California can produce many crops but not all farms produce rice. For a given set of commodity prices, some farms will not produce rice and rather produce, for example, to produce corn, tomatoes, peppers or grapes. Farms choose different crops because of climate, soil quality, farm operator knowledge or available nearby infrastructure. Some farms enter the market for rice only when the price is sufficiently high.

Food safety regulation and no exemption for small firms

The FDA imposes food safety regulation of various forms to US food producers. For instance, food safety regulation may include minimum standards, good agricultural practices while in other cases regulation may require firms to implement a HACCP system. To simplify the model, let me assume that the outcome of FDA implementation of the FFSMA is that a uniform standard requires all firms to supply food that is safer than a minimum level such that $s_i \geq s^r$. That is, I assume that a set of standards and good agricultural practices can be summarized into a single standard for food safety s^r. Later I will write $r = \{0,1\}$ to denote old and new food safety regulation.

Food safety regulation may not bind for all firms. So let me begin by describing the behavior of firms that are not directly affected by food safety regulation. For interior solutions, the first order conditions for profit maximization with respect to output and food safety are given by

$$P[Q] - C_q - \left(1 - s_i^*\right) L = 0; \tag{2}$$

$$-C_s + q_i^* L = 0. \tag{3}$$

I use stars to identify solutions for the output and food safety. The second order conditions are $-C_{qq} < 0$, $-C_{ss} < 0$, and

$$C_{qq} C_{ss} - \left(C_{qs} - L\right)^2 > 0. \tag{4}$$

In addition, the participation condition says that a firm i produces only if delivering food yields a nonnegative profit

$$\Pi_i^{nc} = P[Q] q_i^* - C\left[q_i^*, s_i^* \middle| \alpha_i, \beta_i\right] - q_i^* \left(1 - s_i^*\right) L \geq 0. \tag{5}$$

Equations (2) and (3) implicitly define the interior solutions for the quantity of food and the safety of the food delivered by a firm. Expression (5) determines whether the corner solution where output equals zero is profit maximizing. I denote the profit maximizing quantity of food of a firm i by $q_i^* \equiv q_i^*\left[\alpha_i, \beta_i, P^*\right]$ and the safety of the food delivered by the same firm as $s_i^* \equiv s_i^*\left[\alpha_i, \beta_i, P^*\right]$, where $P^* = P^*\left[\sum q_i^*\right]$ is the total quantity of food at equilibrium.[3]

To determine how output and food safety are affected by the parameters α_i and β_i, take the total derivatives of (2) and (3) keeping everything else constant. The effects of a change an increase in α_i on the output and the safety of food are given by

$$\frac{dq_i^*}{d\alpha_i} = -\frac{C_{q\alpha}C_{ss}}{C_{qq}C_{ss} - \left(C_{qs} - L\right)^2} \leq 0; \tag{6}$$

$$\frac{ds_i^*}{d\alpha_i} = \frac{\left(C_{qs} - L\right)C_{q\alpha}}{C_{qq}C_{ss} - \left(C_{qs} - L\right)^2}. \tag{7}$$

The denominator in (6) and (7) is positive from the second order condition for profit maximization in (4). Expression (6) says that firms with a higher marginal cost of output produce less food, everything else being equal.

The sign of the effect of α_i on the safety of food in (7) depends on the size of the shift in the marginal cost of output from an increase in the safety of food, C_{qs}, and the expected cost associated with the delivery of one unit of unsafe food, L. In practice, firms may incur significant expenses when producing unsafe food. For instance, firms may have to pay fines, may be unable to sell food for a period of time, pay compensation to affected consumers and incur costs related to regaining consumers' confidence. Whether the firm responsible of a food safety incident incurs all those costs depends on the capacity to trace the product to its origin. In cases when an incident involves a large number of people, health authorities conduct intensive investigations to find the origin of the contamination therefore increasing the expected cost of delivering unsafe food of a firm.

[3] These solutions use the fact that the price is given exogenously to individual firms. An alternative way to express the solutions for the output and safety is to account for the market price at equilibrium that depends on the total quantity of food, which depends on the size of the population of firms and the distribution of the cost parameters. However, the solutions with the price on the right-hand side are sufficient for the numerical solutions that I will show later in the text.

In deriving solutions for the price and the total output, the sufficient conditions for equilibrium are not limited to the sign of the second order conditions above. In particular, conditions for the monotonicity of the cumulative distribution function F, the number of firms and the demand curve must hold to guarantee a unique equilibrium. I will bypass a formal description of these conditions and assume they hold for the remainder of the paper.

In the remainder of the paper, I assume that the total of the expenses that a firm incurs for delivering unsafe food is larger than the change in the marginal cost of output from increased food safety.

Assumption 1: *The expected penalty associated with the delivery of unsafe food,* L*, is larger than the cross partial derivative of the cost function with respect to the output and the safety of food when evaluated at the profit maximizing output and food safety. That is* $L > C_{qs}$.

If assumption 1 holds, firms that have a lower cost of output also deliver safer food such that $ds_i^* / d\alpha_i \leq 0$ in (7). This implies that for a given β, firms with a small α, and therefore firms that deliver a large quantity of food from the sign in (6), deliver safer food.

The effects of increasing β_i on the output and the safety of food are given by

$$\frac{dq_i^*}{d\beta_i} = \frac{\left(C_{qs} - L\right) C_{s\beta}}{C_{qq}C_{ss} - \left(C_{qs} - L\right)^2}; \tag{8}$$

$$\frac{ds_i^*}{d\beta_i} = \frac{-C_{qq}C_{s\beta}}{C_{qq}C_{ss} - \left(C_{qs} - L\right)^2} \leq 0. \tag{9}$$

The effects of β_i on output and food safety are analogous to the effects of α_i. If assumption 1 holds, expression (8) says that firms that have a lower cost of producing safe food also produce a larger output. Expression (9) says that firms with a lower marginal cost of producing safe food deliver safer food.

The price also affects the output and the safety of food. Comparative static with respect to the price yields

$$\frac{dq_i^*}{dP} = \frac{C_{ss}}{C_{qq}C_{ss} - \left(C_{qs} - L\right)^2} \geq 0; \tag{10}$$

$$\frac{ds_i^*}{dP} = -\frac{C_{qs} - L}{C_{qq}C_{ss} - \left(C_{qs} - L\right)^2} \geq 0. \tag{11}$$

That is, an increase in the price yields an increase in the output and an increase in the safety of food given that assumption 1 holds.

Let me now turn to firms that are constrained by food safety regulation. For those firms, and let me assume that at least one market participant is constrained by regulation, the safety of food is $s_i = s^r$ and output solves the first order condition given by

$$P[Q] - C_q - \left(1 - s^r\right)L = 0, \tag{12}$$

with the second order condition $-C_{qq} < 0$. The participation condition for firms constrained by food safety regulation is

$$\Pi_i^c = Pq_i^r - C\left[q_i^r, s^r \middle| \alpha_i, \beta_i\right] - q_i^r\left(1 - s^r\right)L \geq 0, \tag{13}$$

where $q_i^r \equiv q_i^r\left[\alpha_i, \beta_i, s^r, P\right]$ is the quantity of food of a firm i that solves (12).

Comparative static on the output of firms constrained by food safety regulation follows the signs in expressions (6), (8) and (10). From (12) and assumption 1, I can show that increased food safety regulation increases output of individual firms

$$\frac{dq^r}{ds} = \frac{L - C_{qs}}{C_{qq}} \geq 0. \tag{14}$$

That is, a firm which the standard is binding scales up its production following increase stringency in a food safety standard. This is true even though that (14) ignores the induced change in the price of food. The increase in production occurs because increase food safety because it induces cost saving in expected penalty from delivering unsafe food, therefore decreasing the marginal cost of output.

The price is the same for all firms. Therefore whether a firm is constrained by regulation or not depends on its cost. It is possible to derive a limit in the cost efficiency parameters space that separates constrained and unconstrained firms. Let me write that $\alpha^r = \alpha^r\left[\beta\right]$ is the limit implicitly defined by

$$\Pi_i^c - \Pi_i^{nc} = 0 \tag{15}$$

where Π_i^c is given by expression (13) and Π_i^{nc} is given by expression (5).[4] When expression (15) holds with equality it defines the pairs α and β where firms are indifferent between being constrained by the regulation or not. It is the least cost efficient firms that are constrained by the

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[4] I could equivalently write the limit as $\beta^r\left[\alpha\right]$, the inverse function of $\alpha^r\left[\beta\right]$.

regulation. Thus, for $\alpha_i[\beta_i] \le \alpha_i^r[\beta_i]$, a firm i is not constrained by the regulation. For $\alpha_i[\beta_i] > \alpha_i^r[\beta_i]$, a firm i is constrained by the regulation.

Some firms will choose not to enter the market because the market price is too low given their cost of producing food and complying with for safety regulation. Those are the least efficient firms. Therefore, when (13) holds with equality it defines the limit between the firms that enter and are constrained by the regulation and the firms that choose not to enter the market. I write that limit as $\bar{\alpha} \equiv \bar{\alpha}[\beta]$.

Food safety standard and small firm exemption

The FDA Food Safety Modernization Act includes new food safety standards and Title I of the act includes and exemption for firms with annual sales less than $500,000 . Similar to the new FDA regulation, this section considers food safety standard s^0 and s^1, with $s^1 > s^0$. The variable s^0 represents the old food safety regulation and s^1 is the new food safety regulation that is implemented with an exemption for firms with less than R dollars in sales. That is, firms that are exempted from the new regulation are not required to comply with the level of food safety s^1 but must comply with the minimum of food safety s^0.

The exemption creates many possibilities to consider for profit maximization as constraints apply differently to firms depending on their size. Firms compare their profit under the different options available and choose the one that yields the highest profit. I describe each of these options below.

As in the previous section, food safety regulation does not affect all firms. Profit maximization by firms that are not constrained by the new regulation and profit maximization of firms that are constrained by the new regulation but that have sales larger than R are as described in the previous section. I will therefore focus in this section on firms that use the exemption for small firms.

Firms that benefit from the exemption maximize their profit given by expression (1) under the constraint that $P[Q]q_i \le R$ and that $s_i \ge s^0$. It is possible that for some firms that both constraints hold with equality such that $q_i^e = R/P[Q]$ and $s_i^e = s^0$. I use the superscript e to identify solutions when an exemption for small firms is available.

For some other firms only one constraint holds with equality. For the firms for which the revenue constraint holds with equality, the output is simply given by $q^e = R/P[Q]$. That is, because I consider a single market and that the price is exogenous to firms, the maximum revenue for eligibility to the exemption becomes a constraint on the output. Given that for those firms it is profit maximizing to produce food safer than s^0, the first order condition with respect to food safety defines food safety

$$-C_s + \frac{R}{P[Q]} L = 0 . \tag{16}$$

The second order condition is $-C_{ss} < 0$.

For some firms, profit maximization is such that $s_i^e = s^0$ but $q_i^e < \underline{R}/P[Q]$. For those firms, profit maximization with respect to the output requires that (12) holds with equality letting $s^r = s^0$.

Finally, some firms benefit from the exemption without any constraint holding with equality such that $q_i^e < \underline{R}/P[Q]$ and $s_i \geq s^0$. For those firms, the first order conditions for profit maximization are given by (2) and (3).

Numerical solutions

I described above profit maximization under different regulatory settings but I did not describe market equilibria where prices adjust to the total output of firms participating in the market. A change in food safety regulation affects the cost of firms, therefore affecting output and the price of food. Thus, a correct comparative static analysis of food safety regulation requires incorporating into the model market equilibrium.

Finding market equilibrium requires finding the total output. For the case where only food safety regulation applies, it is not too difficult to write an expression for the total output by integrating the output of individual firms using the limits α^r and $\overline{\alpha}$ (Pouliot, 2010). However, it is difficult to define limits when small firms can use an exemption to avoid a new food safety standard. In such case, the limits in the α and β spaces that identify the constraints that bind are no longer well-behaved monotonous function but in some cases stepwise functions. To simplify, in what follows, I find equilibria and show the effect of the exemption by relying on numerical examples under different distributions of the efficiency parameters.

Functional forms and procedure to find solutions

I describe in this section the assumptions of the numerical solutions and the procedure to find those solutions. The numerical exercise assumes that the profit of a firm i is given by

$$\Pi_i = P[Q]q_i - C[q_i, s_i : \alpha_i, \beta_i] - q_i(1-s_i)L$$

where the cost function is

$$C(q_i, s_i : \alpha_i, \beta_i) = b_0 + b_q\alpha_i q_i + b_s\beta_i \frac{s_i}{1-s_i} + \frac{1}{2}\alpha_i c_q q_i^{\ 2} + c_{qs} q \frac{s}{1-s}.$$

This functional form assures that the cost function is convex with respect to the output and that food is perfectly safe only at an infinite cost. Table 1 shows the parameter values for the cost function. Parameters are the same across scenarios except for the parameter c_q in the third scenario. I discuss these scenarios in detail below.

I describe in what follows the procedure to find numerical solutions for profit maximization for three possible cases: 1) a firm is not constrained by food safety regulation only; 2) a firm is constrained by regulation; and 3) a firm for which the exemption is constraining but food safety is above the minimum standard. I will not describe the case where both the exemption and the food safety standard are constraining. Solutions for the output and the safety of food are obvious in that case as I describe in the previous section. A firm maximizes its profit by choosing a quantity and safety of food while taking into account the available options under the applicable regulation, including the option of exiting the market.

Some firms that are not constrained by food safety regulation choose a level of food safety above the minimum level required by regulation. As discussed earlier in the text, another possibility is that a firm benefits from a small firm exemption while its safety of food is above the previous food safety minimum and that its revenue are below the maximum level that define the exemption such that $s^0 > s_i > s^1$ and $R_i < R$. The first order conditions for profit maximization for interior solutions are

$$\frac{\partial \Pi_i}{\partial q_i} = P - b_q\alpha_i - \alpha_i c_q q_i - c_{qs}\frac{s}{1-s} - (1-s_i)L = 0 \qquad (17)$$

and

$$\frac{\partial \Pi_i}{\partial s_i} = -\left(b_s \beta_i + c_{qs} q\right)\left(\frac{1}{1-s} + \frac{s}{\left(1-s\right)^2}\right) + q_i L = 0 . \tag{18}$$

The expressions for the positive solutions for the output and the safety of food from solving (17) and (18) are too cumbersome to be useful. Thus, rather than using analytical solutions in the script for the numerical exercise, I rely on numerical optimization. The procedure involves first solving (18) with respect to the safety of food conditional on output. The positive root is

$$s_i\left(q_i\right) = 1 - \frac{\sqrt{q_i L\left(c_{qs} q + b_s \beta_i\right)}}{q_i L} . \tag{19}$$

Then, I solve numerically for the output by plugging the solution for the safety of food given in (19) into (17) and then find the value for q_i such that (17) holds. Given the solution for q_i, I find the solution for s_i using (19).

Finding solutions when food safety regulation is constraining to a firm is straightforward. Simply set the safety of food equal to the applicable food safety regulation level in (17) and find the solution for the output which is given by

$$q_i^r = \frac{1}{\alpha_i c_q}\left(P - b_q \alpha_i - c_{qs} \frac{s^r}{1-s^r} - \left(1-s^r\right) L\right). \tag{20}$$

For some firms, it is profit maximizing to limit output and benefit from the small exemption to avoid more constraining food safety regulation. For those firms the exemption sets the output such that $q_i = q^r = R/P[Q]$. The safety of food is then given by plugging the output in expression (19).

The solutions for the output and the safety of food for individual firms depend on the market price which depends on the total output. Although no firm has market power, a change in food safety regulation affects the behavior of individual firms and the market equilibrium in the aggregate. The supply consists of the sum of all individual firm's output at a given price and regulation. For the demand, recall that I assume that it depends only on the quantity of food. For the numerical examples, I use a constant elasticity demand given by

$$Q = 25,000 P^{-0.8} . \tag{21}$$

To find the market equilibrium, I use a procedure based on the Newton-Raphson method to find the root of a function. I start the procedure by setting the price at a value that I know is above the market price.[5] I calculate at that price the total supply given the regulation that applies by maximizing the profit of all firms individually. I also calculate the quantity demanded. Because the price is higher than the market equilibrium I find an excess supply. I then repeat this process with a price slightly smaller. These first calculations initialize the search for the equilibrium. From the first two calculations, I can update the price using the slope of the excess supply as in the Newton-Raphson method. I then repeat this process until the excess supply sufficiently approaches zero, which gives the market equilibrium.

The method does not always assure that the excess supply converges toward zero because the number of firms is discrete. That is, it is possible that for a price slightly above the equilibrium that a firm participates in the market. However, the next iteration may yield a price slightly below the equilibrium and at that price the firm exits the market. The next update may then yield a price above the equilibrium in which the firms participates in the market. This process may then repeat without convergence toward equilibrium. In such case, I limit the number of iterations to 100 and calculate the equilibrium quantity as the mean of the quantity supplied and the quantity demanded for the last two iterations. I then calculate the price using the demand curve. Note that using such approximation has a very small effect on the result. The firm that is at the margin of entering or exiting the market is small and therefore has a marginal effect on the total output and the mean safety of food.

Other parameter assumptions

The numerical examples consider an initial food safety regulation of $s^0 = 0.980$. New regulation increases the minimum food safety standard to $s^1 = 0.985$. Exemption for the new food safety regulation may be available for firms with revenue less than $R = 100$. I assume that there are potentially 1,000 firms entering the market. The expected liability cost is $L = 400$. Table 1 summarizes the values of the parameters

I find numerical solutions for four distributions of the efficiency parameters. The four panels of figure 1 show scatter plot of α on the horizontal axis and β on the vertical axis. Firms

[5] The procedure is also robust to a seed for the price that is below the market equilibrium.

are identified either by a star, a crux, a saltire or a dot. In those examples the parameters α and β are both defined in the zero-one domain. For each panel, I generate 1,000 random pairs of α and β. I then remove the smallest 0.9% of the values for α and then the smallest 0.9% of the values for β such each panel contains 982 firms. I truncate the distributions to assure that no firm has significant market power.[6] In panel A, there is no correlation between α and β. In panel B, the parameters α and β are negatively correlated implying that large firms have a larger cost of supplying safe food. The parameters α and β are positively correlated in panel C. In panel D, I consider two groups of firms: 1) a small number of firms that have a small α but a large β and 2) a large number of firms that have a large α but a small β. The market in panel D is one with a few large firms (small α) and many small firms (small β). Small firms can deliver safe food at a lower cost than the large firms.

Figure 1 identifies firms using different symbols. These symbols identify firms according to their choice of output and food safety in the case when an exemption for small firms is available. The next section shows results of the numerical exercises and describes the key for the symbols in figure 1.

Results of numerical exercise

I summarize the results of the numerical exercise in figure 1, figure 2 and table 2. Figure 1 shows the choices of firms according to their cost efficiency. Figure 2 shows the output and the food safety of market participants. Table 2 summarizes the aggregate measure for the output, the price, the weighted average safety of food and the number of firms.

The symbols in figure 1 identify firms according to their choice of output and food safety when an exemption is available. In each panel of figure 1, the (blue) dots identify firms that do not enter the market. The (dark red) triangles identify firms with food safety equal to s^1 and with revenue greater than R. The (red) saltires identify firms with food safety equal to s^0 and with revenue smaller than R. The (green) crux identify firms with food safety between s^0 and s^1 and with revenue smaller than R. Finally, the (black) stars identify firms that do not enter the market

[6] This was indeed the case in one scenario where a firm with a very small α and a very β ended up with an 80% market share.

when the minimum food safety is s^1 but enter the market when an exemption is available. Note that in the four scenarios no firm produces food safer than s^1.

Each panel of figure 1 shows zero-profit lines. The black dashed line shows the pairs α and β where the profit equals zero when the minimum food safety is s^0. The black lines show the pairs α and β where profit equals zero at the new minimum food safety s^1 and no exemption is available. Finally, the gray lines show the pairs α and β where profit equals zero when the minimum food safety is s^1 but when small firms can benefit from an exemption.

Before discussing the effect of the small firms exemption, let me discuss the effect of increasing the minimum food safety standard from s^0 to s^1. In each panel of figure 1, the effect of increasing the minimum food safety standard from s^0 to s^1 is to shift the zero profit line toward the origin (from the dashed black dashed line to the black line), implying that the number of firms decreases. In the four scenarios, the minimum food safety level s^1 is binding for all firms. Table 2 shows that, of course, food safety increases as the minimum standard becomes more stringent. Table 2 also shows that the exit of small firms causes the total output to decrease, the average firm size to increase and the price of food to increase. Firms that remain in the market increase their output because their marginal cost of output shifts to the left, see expression (14), and because the price of food increases.

Let me now discuss the effect of the exemption for a food safety standard s^1 when comparing the market equilibrium with s^0 as the minimum food safety. Table 2 shows that in all scenarios that the safety of food increases. For scenarios A-C, the total quantity of food decreases, causing the price to increase, the number of firms increases and the average size of firms decreases. The decrease in the average size of firms is caused by firms choosing to reduce their output to comply with the regulation and by the entry of small firms. Scenario D shows a different outcome with practically no change in the total output, the average price of food, the number of firms and the average size of firms. This is because the more stringent regulation along with the exemption shifts the zero profit line by little in the α and β where firms are distributed, as panel D in figure 1 shows.

Looking at figure 1, the zero profit line for the initial food safety (dashed black line) is close to the zero profit line with the exemption (gray line). Note that the line does not shift toward or away from the origin but rather rotates counter-clockwise and changes curvature. The rotation implies that the exemption favors firms with a relatively large cost of output (large α but small β) while not benefiting firms that have a relatively large cost of food safety (large α but small β). This does not mean however that the exemption favors large firms that produce food not as safe as small firms. I will show in figure 2 how food safety relates to the size of firms.

The comparison of the outcome of the numerical solutions with s^1 as the minimum food safety standard and the outcome when an exemption is available yield the same conclusions under the four scenarios. Table 2 shows that food is safer when no exemption is available, the price is lower when the exemption is available, the total quantity is larger when the exemption is available and the number of firms is larger when the exemption is available.

Figure 1 shows how the exemption affects firms' choice of food safety. First, the firms between the gray line and the continuous black line, identified by stars, are firms that would not participate in the market without the exemption. The safety of food from those firms is at least as large as the minimum food safety standard s^0. Looking at the distance between the gray line and the black line, the exemption tends to favor firms with median values for the parameters α and β. The exemption does not affect the food safety choice of the larger firms that are constrained at s^1 (triangles in figure 1). Some firms use the exemption but produce food that is safer than the minimum s^0 (cruxes in figure 1). The saltires show the firms that use the exemption but choose to produce food as safe as the minimum standard s^0. The firms identified by a crux, a saltire or a star in figure 1 are firms that use the exemption to produce food below s^1.

Figure 1 shows why it is difficult to analytically define the limits between the firms that use the exemption and those that do not. For example, for α that equals about 0.4 in panel A) of figure 1, when the exemption is available a firm may be constrained to produce at s^1, may use the exemption and produce food safer than the minimum s^0 but smaller than s^1, may use the exemption and be constrained at s^0, or may find it more profitable not to participate in the market depending on the value of β. Fixing a value for β and looking at profit maximization for different values of α, a similar conclusion can be made.

Figure 2 shows on the horizontal axis the output by individual firms and on the vertical axis the safety of food for each firm. Each dot, crux or saltire represents one farm that participates in the market given the regulation in place. The dots show output and food safety choices at the initial regulation s^0. Each panel of figure 1 shows that food safety tends to increase with respect to the output. The (blue) cruxes show output and food safety choices when a minimum food safety s^1 applies. In each panel, all firms are constrained by the food safety regulation such that all firms participating in the market are along a line at $s^1 = 0.985$. The (red) saltire show the output and food safety when firms can use an exemption for small firms. Notice in panels A), B) and C) that many firms find it profit maximizing to restrict their output to avoid the new food safety requirements. For instance, in panel A), many firms restrict their output at about 4.45 units, the output that corresponds to the exemption. The exemption then creates a gap such that the smallest firm that does not use the exemption produces about 5.8 units. Although firms restrict their output, many choose to deliver food that is safer than s^0 because of market incentives.

Summary and conclusion

Many perceive the FDA Food Safety Modernization Act of 2010 as new legislation that will have a significant impact on food safety in the United States. Among other things, the legislation requires the FDA to issue new food safety standards, gives new powers to the FDA to order food recalls, the allocation of additional inspection resources and new requirements for imports. The food industry largely supported the act until the addition of a clause exempting small firms from new requirements. One concern is that the exemption reduces the food safety gain of the new regulation. This paper investigates the effects of a small firm exemption from more stringent food safety standard.

The model considers many competitive firms that differ in their marginal cost of output and their marginal cost of food safety. A distribution function describes how firms differ in their costs. Each firm maximizes profit with respect to its output and food safety given the regulation in place. The model endogenizes the number of market participants by letting firms enter and exit the market. The initial situation is one where a minimum food safety standard applies that is not binding for all firms. I compare that situation to one with a more stringent food safety standard and one with a more stringent food safety standard accompany with an exemption for small firms.

The numerical examples show that increasing the stringency of a food safety standard, of course, increases the average safety of food. However, more stringent food safety regulation increases the price of food, decreases the total output and decreases the number of firms. An exemption for small firms increases the average food safety but not as much as with an increase standard alone. One interesting effect of the exemption for small firms is that the total number of firms increases. The new food safety regulation causes firms to reduce their output, either because firms must meet the new food safety standard or to benefit from the exemption to small firms. This causes an increase in the price that makes it profitable for small firms to enter the market while benefiting from the exemption to small firms.

The exemption discriminates against large firms in favor of small firms. There is no basis to discriminate between small and large firms on their supply of safe food. Large firms are even those that tend to deliver the safest food. The exemption also creates a form of cross-subsidization. Some firms decrease their output to benefit from the exemption for small firms. This causes the price of food to increase and small firms to enter the market while benefiting from the exemption.

The model considers an industry that produces a homogenous food product. In practice, small firms may produce food differentiated from food produced by large firms. Small and large firms may also sell their food through different marketing channels. Considering product differentiation would have a small effect on the results of this model. In a model with product differentiation, in the market covered by large firms, the price does not change by much because the output of large firms increase slightly and a very few firms, if none, exit the market. However, in the market covered by small firms, some firms reduce their output to use the exemption. The net effect of the exit of firms and the decrease in the price of the product sold by large firms is to increase the price for the product of small firms, therefore causing the entry of some small firms. The price of the food from small firms should increase by more when products are differentiated because the increase in the output of large firms becomes an indirect effect. Thus, product differentiation should yield the entry of a larger number of firms. The average safety of food increases in both markets but it is undetermined whether the average safety of all food increases by more allowing for product differentiation.

Further work will include calculating the effect the small firm exemption on consumer s' welfare. On one side, the quantity of food is larger when an exemption for small firms is available. However, food is not as safe. The effect of the new regulation on consumer welfare is therefore undetermined without further analysis.

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Figures

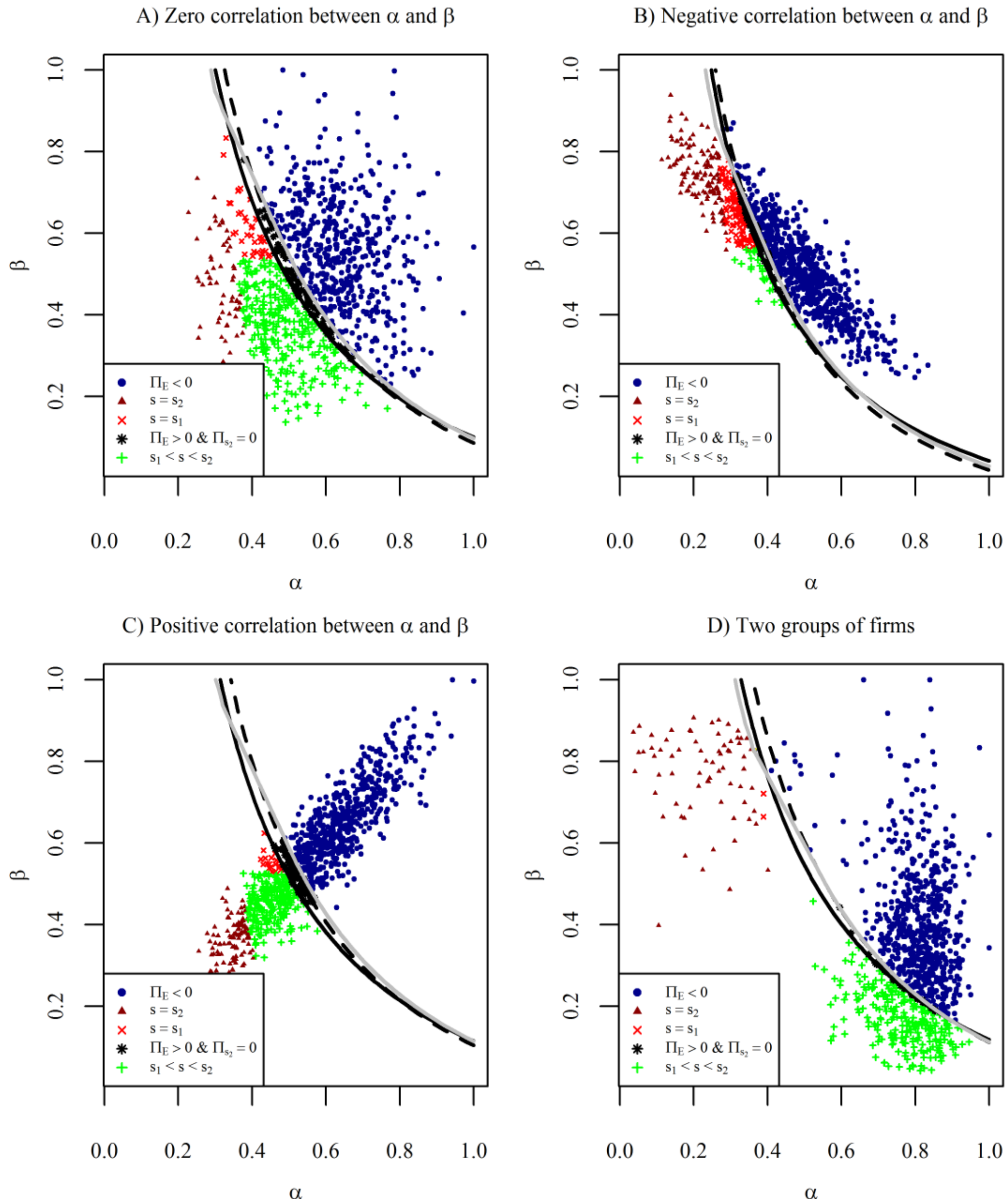

Figure 1: Scatter plots of cost parameters distribution and zero profit lines

Notes: The symbols identify firms according to their choice of output and food safety when an exemption for small firms is available. The (blue) dots are firms that do not enter the market. The (dark red) triangles are firms with food safety equal to s^1 and with revenue greater than R. The (red) saltires are firms with food safety equal to s^0 and with revenue smaller than R. The (green) crux are firms with food safety between s^0 and s^1 and with revenue smaller than R. The (black) stars are firms that do not enter the market when the minimum food safety is s^1 but enter the market when an exemption is available.

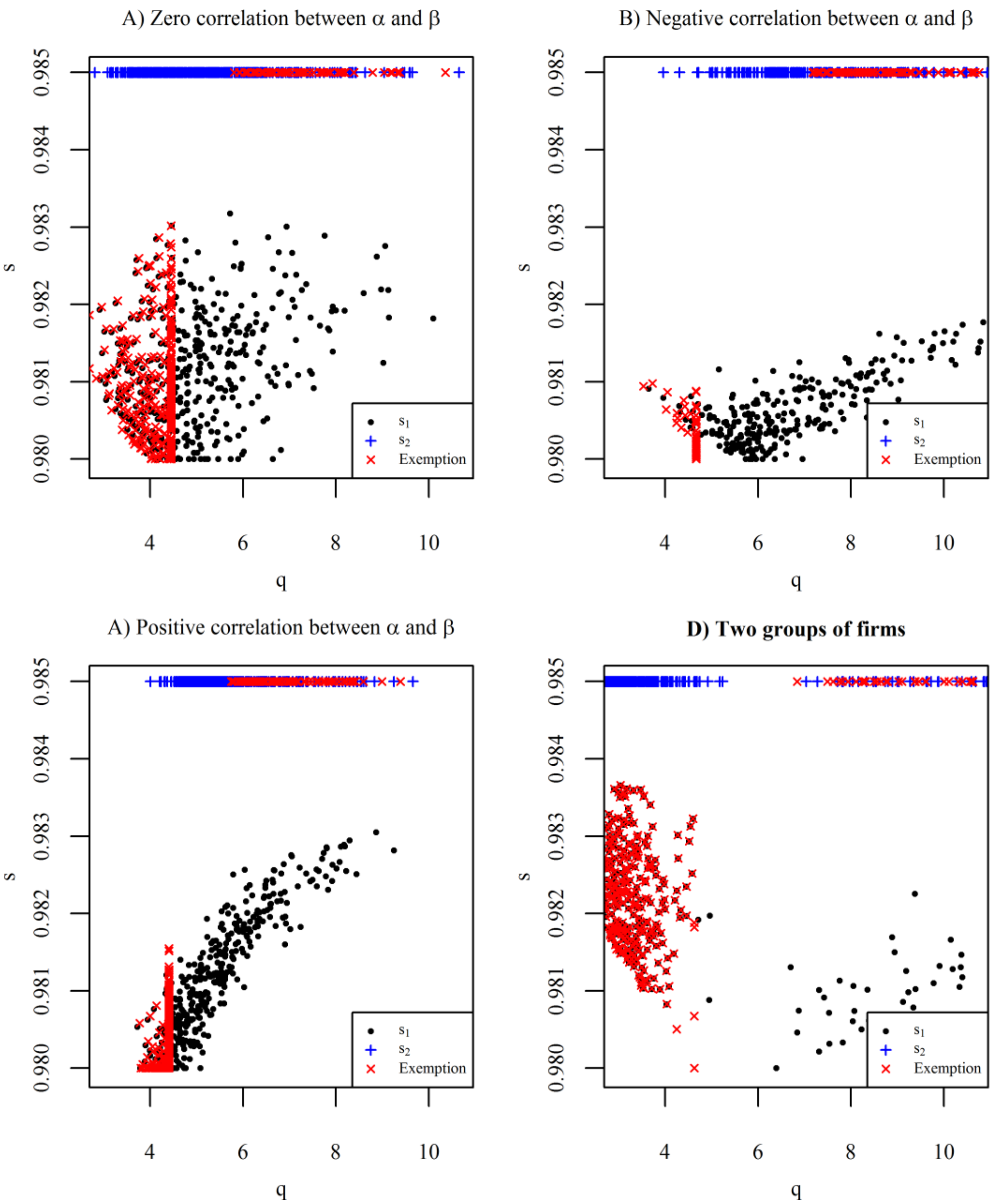

Figure 2: Scatter plots of food safety and output

Notes: The dots show output and food safety choices at the initial regulation s^0. The (blue) cruxes show output and food safety choices when a minimum food safety s^1 applies. The (red) saltire show the output and food safety when firms can use an exemption for small firms.

Tables

Table 1: Parameter assumptions

Regulation parameters		
$\underline{s}^0 = 0.980$	$\underline{s}^1 = 0.985$	$\underline{R} = 100$
$\pi = 400$	Number of firms = 500	
A) Cost parameters: zero correlation between α and β		
$b_0 = 5$	$b_q = 2$	$b_s = 0.5$
$c_q = 4$	$c_{qs} = 0.1$	
B) Cost parameters: negative correlation between α and β		
$b_0 = 5$	$b_q = 2$	$b_s = 0.5$
$c_q = 4$	$c_{qs} = 0.1$	
C) Cost parameters: positive correlation between α and β		
$b_0 = 5$	$b_q = 2$	$b_s = 0.5$
$c_q = 4$	$c_{qs} = 0.1$	
D) Cost parameters: two groups of firms		
$b_0 = 5$	$b_q = 2$	$b_s = 0.5$
$c_q = 3$	$c_{qs} = 0.1$	

Table 2: Numerical examples solutions

A) Zero correlation between α and β			
	$\underline{s}^0$	$\underline{s}^1$	Exemption
Price	22.31	22.71	22.48
Total output	2,085	2,055	2,073
Average output	4.98	5.40	4.67
Food safety	0.981	0.985	0.982
Number of firms	419	377	444
B) Negative correlation between α and β			
	$\underline{s}^0$	$\underline{s}^1$	Exemption
Price	21.24	21.71	21.41
Total output	2,169	2,131	2,155
Average output	7.40	8.292	6.67
Food safety	0.981	0.985	0.983
Number of firms	293	257	323
C) Positive correlation between α and β			
	$\underline{s}^0$	$\underline{s}^1$	Exemption
Price	22.57	22.94	22.71
Total output	2,066	2,039	2,055
Average output	5.37	5.84	5.00
Food safety	0.981	0.985	0.982
Number of firms	385	345	411
D) Two groups of firms			
	$\underline{s}^0$	$\underline{s}^1$	Exemption
Price	21.60	21.86	21.60
Total output	2,140	2,120	2,139
Average output	6.13	6.64	6.13
Food safety	0.982	0.985	0.984
Number of firms	349	319	349