Optimal Policy Response to Food Fraud

Syed Imran Ali Meerza
University of Nebraska-Lincoln
smeerza2@unl.edu

Konstantinos Giannakas
University of Nebraska-Lincoln
kgiannakas2@unl.edu

Amalia Yiannaka
University of Nebraska-Lincoln
ayiannaka2@unl.edu

Selected Paper prepared for presentation at the 2018 Agricultural & Applied Economics Association Annual Meeting, Washington, D.C., August 5-August 7

Optimal Policy Response to Food Fraud

Abstract

This study analyzes the optimal response of the government to food fraud while accounting for the asymmetric effects of food fraud on consumers and producers, the endogeneity of the producer quality choice, and asymmetries in the probability of food fraud detection. While the government can, theoretically, deter food fraud through a significant increase in the certification costs and/or the monitoring-punishing system, the analysis shows that the optimal policy response depends on the efficiency of dishonest producers, the type of food fraud, the political objectives of the government, and the relative costs of different types of enforcement. In addition to accounting for the asymmetric effects of food fraud, the explicit consideration of agent heterogeneity and the endogeneity of the producer quality enables us to show that, contrary to what is traditionally beleived, the effect of enforcement on the purity of labeling and the average product quality depends on the efficiency of dishonest producers. Intriguingly, when the public law enforcement agency officials engage in bribery, the monitoring and punishment system without addressing corruption does not decrease the fraudulent behavior but, instead, increases the incentives to commit fraud.

Keywords: optimal policy response, food fraud, heterogeneity

1. Introduction

While food fraud is as old as commerce itself, its intensity and frequency have been on the rise in recent years due to the growing complexity of the multi-tiered agri-food system and the increased difficulty in detecting fraudulent behavior. For instance, the total number of confirmed food adulteration incidents in the two years from 2011 and 2012 was 60 percent higher than those between 1980 and 2010 (USP 2013). Similarly, the National Audit Office of the United Kingdom (UK) revealed that the confirmed food fraud incidents in the UK were 67 percent higher in 2012 than those in 2009 (Avery 2014). While the actual cost of food fraud is unknown since the objective of food fraud for economic gain is not to be detected; (Johnson 2014), the PwC Networ (2015) estimates that food fraud may cost the global food industry between $30 billion to $40 billion per year. The cost of food fraud to the UK food and drink industry have been extimated up to £11.2 billion (equivalent to $15.23 billion) per year (Gee et al. 2014).

Food fraud can be defined as the deliberate substitution, addition, tampering, or misrepresentation of food for economic gains (Spink and Moyer 2011). In this context, food fraud can be divided into two broad categories: food adulteration and mislabeling. While food adulteration can be defined as the intentional substitution or addition of substances in food product to reduce the production cost or increase the value of the product, mislabeling refers to acts of misrepresenting the food product. Food fraud is motivated by economic gains and is enabled by the fact that the information about the nature of credence goods is normally asymmetric. While certification and labeling resolve the information problem faced by consumers, imperfect enforcement of labeling/certification requirements creates opportunities for producers to mislabel or adulterate food products.

In recent years, food fraud scandals like the Chinese milk and European horsemeat scandals, have captured the attention of the media, consumers, and governments around the world and have raised serious concerns about food safety (Lotta and Bogue 2015). Food fraud has been recognized as an important and challenging issue threatening global food safety and security. Both the Congressional Research Service (CRS) and Governmental Accountability Office (GAO) of the United States have published several reports on food fraud. These reports address the food fraud concerns and highlight past and ongoing federal and congressional actions to strengthen the campaign against food fraud (CRS 2014 and GAO 2011). Similarly, the European Commission (EC) considers food fraud as one of the top five challenges for the overall

European economy (Anklam 2014). After the horsemeat scandal in Europe, the European Union (EU) acknowledged that, while food fraud is not a novel phenomenon, "combatting food fraud is a relatively new issue on the European agenda, and that in the past it has never been a key priority for legislation and enforcement at EU or national level" (European Parliament Report 2013). Recently, the European Parliament has adopted new regulatory measures to combat food fraud across the EU. Specifically, it has introduced along with significant requirements for food traceability, strict enforcement measures with strict penalties for fraudulent behavior (Putinja 2017)[1].

Similarly, the Canadian Food Inspection Agency (CFIA) has, historically, not punished to the full extent fraudulent behavior but tried, instead, to help those food businesses get back into compliance. However, since the mistrust in the veracity of labeling and authenticity of food products has been on the rise in recent years, CFIA is taking a strict and punitive approach for both mislabeling and food adulteration (Jameson and Paine 2016).[2] Combating food fraud has also become a key priority of the Chinese government after the milk scandal that damaged the reputation of China's food exports and was a big blow to the booming Chinese dairy industry (Huang 2014). In 2011, the Supreme People's Court of China decreed that convicted suspects in lethal cases of food fraud (i.e., cases in which people die due to food adulteration) would be given the death penalty, while convicted suspects in non-lethal cases of food fraud, such as mislabeling, would face extended imprisonment and increased fines (Danovich 2015).[3]

With many countries adopting different measures to strengthen the regulatory capacity to combat food fraud, the question that naturally arises is what is the optimal policy response to food fraud. Despite the increased prevalence of food fraud around the world, both the theoretical and the empirical guidance on which enforcement policy works best to combat food fraud are virtually absent. Exceptions are the studies by Hamilton and Zilberman (2006), Baksi and Bose (2007), and Spink et al. (2016).

Hamilton and Zilberman (2006) study the performance of an eco-certification policy in the presence of mislabeling. They find that the performance of the eco-certification policies depends on market structure. They also show that the average quality of the green product can be increased by imposing a positive per-unit certification cost. Baksi and Bose (2007) study the performance of labeling requirements both in the form of self-labeling and third-party labeling while assuming the former is costless and the latter requires a per unit fee. They find that while, in most cases, self-labeling is the socially optimal option, the third-party labeling becomes socially optimal when the per-unit monitoring cost is high and/or when the total number of firms to be monitored is low.

Spink et al. (2016) argue that it is effective to focus on reducing the net expected benefit of fraudulent behavior rather than on the criminals since there are different types of fraud and dishonest producers. In other words, the government should focus on key crime prevention-based approach to reduce the opportunity or motivation to commit fraud.[4] They also argue that several regulations and initiatives often focus only on the health hazards of food fraud instead of all economic consequences, de-emphasizing the economic impacts of food fraud scandals. While reviewing the theoretical literature on the economics of labeling, Bonroy and Constantatos (2014) also identify and explain the causes of undesirable side-effects of labeling, such as mislabeling. Regarding the enforcement policy to combat mislabeling, they argue that any given purity level of labeling in the high-quality market can be achieved through either imposing a positive per-unit certification cost or introducing a monitoring-punishing system.

While the aforementioned studies focus on the performance of different types of certification in the presence of mislabeling, this study develops a theoretical model to determine the optimal regulatory response to food fraud both in the form of food adulteration and mislabeling. Key differentiating attributes of our approach (and contributions of this study) are that it explicitly accounts for (1) heterogeneous consumers and producers (i.e., consumers differing in their preferences and producers differing in their productive efficiency), (2) the endogeneity of the producer quality choice, and (3) asymmetries in the probability of the food fraud detection.

The rest of the paper is organized as follows. The next section presents a model of heterogeneous consumers and producers and imperfectly competitive food companies and determines the market and welfare effects of relevant market agents involved when there is no fraud in the market. The following section focuses on consumer and producer decisions in the presence of food fraud both in the form of food adulteration and mislabeling. Section 4 determines the optimal policy response of the government to food fraud. Section 5 summarizes and concludes this paper.

2. Benchmark Case: No Food Fraud

2.1 Consumer Problem

Consider vertical product differentiation model where a consumer consumes one unit of either high-quality (h), low-quality (l) or substitute product (e.g., organic apple, conventional apple or orange). Assuming that the unit consumption represents a small share of total income, the consumer utility function can be written as:

(1) $U_h = U - P_h^c + \lambda_h \alpha,$ if a unit of the high-quality product is consumed

$U_l = U - P_l^c + \lambda_l \alpha,$ if a unit of the low-quality product is consumed

$U_a = U,$ if a unit of the substitute product is consumed

where U is a base level of utility derived from the consumption of a product. The terms U_h, U_l and U_a present the utility associated with the unit consumption of high-quality, low-quality and substitute products, respectively. To simplify the analysis, U_a represents a reservation level of utility which is equal to the base level of utility U. The parameters P_h^c and P_l^c are the prices of the high and low-quality products, respectively, while λ_h and λ_l are non-negative utility enhancement factors associated with the consumption of high and low-quality products, respectively. The characteristic α captures the heterogeneity in consumer preferences for the high and low-quality products. For simplicity and traceability, this study assumes that $\alpha \epsilon [0,1]$ and consumers are uniformly distributed between the polar values of α. Moreover, to allow for positive market shares of all vertically differentiated food products, we assume that $P_h^c > P_l^c$ and that the valuation of the quality difference between the high and low-quality products exceeds the high-quality price premium for all consumers (i.e., $\lambda_h - \lambda_l > P_h^c - P_l^c$).

The consumer purchasing decision is determined by the utilities derived from consuming the different food products. In this context, the consumer with differentiating attribute α_l: U_h=U_l is indifferent between consuming a unit of high-quality product and a unit of low-quality product, while the consumer with differentiating attribute α_l: U_l=U_a is indifferent between the low-quality product and the substitute product. Consumers with differentiating attribute $\alpha \epsilon [0, \alpha_a)$, $\alpha \epsilon (\alpha_a, \alpha_l)$, and $(\alpha_l, 1]$ prefer the substitute product, the low-quality product, and the high-quality product, respectively (see figure 1). Normalizing the mass of consumers to unity, $\alpha_a - \alpha_l$ and $1 - \alpha_l$ provide the consumer demands for the low-quality product and the high-quality product, respectively, as:

$$(2) \quad x_l = \alpha_l = \frac{\lambda_l P_h^c - \lambda_h P_l^c}{\lambda_l(\lambda_h - \lambda_l)}$$

(3) $x_h = 1 - \alpha_l = \frac{(\lambda_h - \lambda_l) - (P_h^c - P_l^c)}{(\lambda_h - \lambda_l)}$

The total welfare of consumers is given by the area under the effective utility curve (i.e., the dashed kinked line) in figure 1 and equals:

(4) $TCS = CS_a + CS_l + CS_h = \int_0^{\alpha_a} U_a d\alpha + \int_{\alpha_a}^{\alpha_l} U_l d\alpha + \int_{\alpha_l}^{1} U_h d\alpha$

2.2 Producer Problem

Consider now a producer who produces one unit of either high-quality (h), low-quality (l) or alternative product. The producer production decision is determined by comparing the net returns associated with the production of different food products. Let A denote the heterogeneity in producer efficiency and producers be uniformly distributed between the polar values of A (i.e., $A\epsilon[0,1]$). A producer with attribute A has the following net returns function:

(5) $\pi_h = P_h^f - w_h - \delta A$ if a unit of the high-quality product is produced

$\pi_l = P_l^f - w_l - \gamma A$ if a unit of the low-quality product is produced

$\pi_a = 0$ if a unit of an alternative product is produced

where π_h, π_l, and π_a are the net returns associated with unit production of high-quality product, low-quality product, and alternative product, respectively. The parameters P_h^f and P_l^f are the producer price for high-quality product and low-quality product, respectively; w_h and w_l are the production costs of high-quality product and low-quality product, respectively, which are outside the control of producers; and δ and γ are the cost enhancement factors associated with the production of the high-quality product and the low-quality product, respectively.[5]

The high-quality product receives a price premium, but it is more expensive to produce than the low-quality product (i.e., i.e., $P_h^f > P_l^f$ and $w_h > w_l$). To allow positive supply of all products in the market, it is assumed that $(P_h^f - w_h) > (P_l^f - w_l)$. In this context, the producer with differentiating attribute A_h: π_h=π_l is indifferent between producing a unit of high-quality product and a unit of low-quality product, while the producer with differentiating attribute A_l: π_l=π_a is indifferent between the low-quality product and the alternative product. Producers with differentiating attribute $A\epsilon[0, A_h)$, $A\epsilon(A_h, A_l)$, and $(A_l, 1]$ find it optimal to produce the high-quality product, the low-quality product, and the alternative product, respectively (see figure 2). Normalizing the mass of producers to unity, A_h and $A_l - A_h$ provide the supplies of the high-quality product and the low-quality product, respectively, as:

$$(6) \quad x_h = A_h = \frac{(P_h^f - P_l^f) + (w_l - w_h)}{(\delta - \gamma)}$$

$$(7) \quad x_l = A_l - A_h = \frac{\delta(P_l^f - w_l) - \gamma(P_h^f - w_h)}{\gamma(\delta - \gamma)}$$

2.3 Equilibrium Conditions

This section determines the market outcomes of the benchmark model. In this study, it is assumed that middlemen have market power both when buying the food product from producers and when selling the processed food product to consumers. The middlemen face the demand and supply curves which are derived in equations (2), (3), (6), and (7). Figure 3 presents the equilibrium conditions in the markets for the high and low-quality products when there is no fraud. The parameters θ_i^c and θ_i^f $(i = h, l)$ are conjectural variation elasticities which capture the degree of market power of middlemen when selling the processed food product to consumers and buying the food product from producers, respectively. The profit maximizing middlemen produce the quantity determined by the equality of the relevant marginal revenue and marginal outlay schedules. Once the optimal quantity is determined, the profit maximizing middlemen charge the maximum price consumers are willing to pay for this quantity and offer the minimum price that will induce producers to supply of necessary quantity of the food product.

3. Food Fraud

3.1 Food Adulteration

Food adulteration can be defined as acts of corrupting, debasing or making a food product impure by adding inferior elements. The main objective of food adulteration is to reduce the cost of production at the expense of consumer health (Sobhani 2015). In other words, to increase the profit margin, dishonest producers use different adulteration methods to reduce the cost of production, and then market the adulterated product as the high-quality product.

3.1.1 Consumer Problem

In the presence of food adulteration, there are two types of product in the market, i.e., the product marketed as high-quality and the low-quality product. However, the product marketed as high-quality, in the presence of food adulteration, includes both truthfully labeled high-quality and adulterated product. It should be noted that, in this study, the high-quality product refers the truthfully labeled high-quality product while the product marketed as high-quality includes both the truthfully labeled high-quality and adulterated products. In the presence of food adulteration, consumers assign a probability for the presence of adulterated product in the market and a probability of a health hazard from consuming an adulterated product, reducing the willingness to pay for product marketed as high-quality. Therefore, the utility derived from the consumption of the product marketed as the high-quality is given by:

(8) $U_{h,d} = \mu\left(U - P_{h,d}^{c} + \lambda_h \alpha\right) + (1-\mu)(U - P_{h,d}^{c} - \epsilon\psi) = U - P_{h,d}^{c} + \mu\lambda_h\alpha - (1-\mu)\epsilon\psi$

where $U - P_{h,d}^{c} + \lambda_h \alpha$ is the utility associated with the consumption of the high-quality product and $U - P_{h,d}^{c} - \epsilon\psi$ is the utility associated with the consumption of the adulterated product. The parameters μ and $(1-\mu)$ are the probability that the food products are high-quality product and adulterated product, respectively, the term ε is the probability of getting sick when consuming the adulterated product; and the parameter ψ is the total cost of receiving medical treatment.[6] In this context, the consumer utility function in the presence of food adulteration can be written as:

(9)
$$U_{h,d} = U - P^c_{h,d} + \mu\lambda_h\alpha - (1-\mu)\varepsilon\psi \quad \text{if a unit of the product marketed as high-quality is consumed}$$
$$U_{l,d} = U - P^c_{l,d} + \lambda_l\alpha \quad \text{if a unit of the low-quality product is consumed}$$
$$U_{a,d} = U \quad \text{if a unit of the substitute product is consumed}$$

where $U_{h,d}$, $U_{l,d}$, and $U_{a,d}$ are the utilities associated with the unit consumption of high-quality product, low-quality product, and the substitute product in the presence of food adulteration, respectively. All other variables are as previously defined.

Following the process developed earlier, we can derive the consumer demands for the low-quality and the high-quality products in the presence of food adulteration as:

(10)
$$x_{l,d} = \alpha_{l,d} - \alpha_{a,d} = \frac{\lambda_l P^c_{h,d} - \mu\lambda_h P^c_{l,d} + \lambda_l(1-\mu)\varepsilon\psi}{\lambda_l(\mu\lambda_h - \lambda_l)}$$

(11)
$$x_{h,d} = 1 - \alpha_{l,d} = \frac{(\mu\lambda_h - \lambda_l) - (P^c_{h,d} - P^c_{l,d}) - (1-\mu)\varepsilon\psi}{(\mu\lambda_h - \lambda_l)}$$

3.1.2 Producer Problem

In the presence of food adulteration, a producer can produce one unit of either high-quality (h), adulterated (d), low-quality (l) or alternate product. The producer production decision is determined by comparing the net returns associated with the production of different food products. A producer with differentiating attribute A has the following net returns function in the presence of food adulteration:

(12)
$$\pi_{h,d} = P^f_{h,d} - w_h - \delta A \quad \text{if a unit of the high-quality product is produced}$$
$$\pi^{ch}_{h,d} = P^f_{h,d} - \beta(w_h + \delta A) - \phi(A)\rho \quad \text{if a unit of the adulterated product is produced}$$
$$\pi_{l,d} = P^f_{l,d} - w_l - \gamma A \quad \text{if a unit of the low-quality product is produced}$$
$$\pi_{a,d} = 0 \quad \text{if a unit of an alternative product is produced}$$

where $\pi_{h,d}^{ch}$ is the net returns associated with the production of the adulterated product. The term $\beta(w_h + \delta A)$ presents the cost of producing an adulterated product (where $0 < \beta < 1$) which captures the idea of cost savings by using the adulteration method; and the parameters ϕ and ρ are the probability of fraudulent behavior being detected and the penalty for detected fraudulent behavior, respectively.[7] Moreover, the probability of detection takes values between zero to one, and it is assumed to be a linear function of the efficiency of producers, i.e., $\phi(A) = \phi_0 + \phi_1 A$. The terms ϕ_0 and ϕ_1 present the probability that producers will be detected by third parties (e.g., media and former employees etc.) and the audit probability, respectively. All other variables are as previously defined.

In the presence of food adulteration, a producer with differentiating attribute A will produce adulterated product when the gains from fraudulent behavior (i.e., $\{(w_h - \beta w_h) + (\delta - \beta\delta)A\}$) exceed the expected penalty (i.e., $\{(\phi_0 + \phi_1 A)\rho\}$). Depending on the nature of relationship between the net expected benefit of fraudulent behavior and the expected penalty, we can identify following four scenarios: (1) the net expected benefit of fraudulent behavior increases with the efficiency of producers (i.e., $w_h > (\beta w_h + \phi_0\rho)$ and $\delta A < (\beta\delta + \phi_1\rho)A$); (2) the net expected benefit of fraudulent behavior decreases with the efficiency of producers (i.e., $w_h < (\beta w_h + \phi_0\rho)$ and $\delta A > (\beta\delta + \phi_1\rho)A$); (3) the net expected benefit of fraudulent behavior is always positive regardless of the efficiency of producers (i.e., $w_h \geq (\beta w_h + \phi_0\rho)$ and $\delta A \geq (\beta\delta + \phi_1\rho)A$; and (4) the net expected benefit of fraudulent behavior is always negative regardless of the efficiency of producers (i.e., $w_h \leq (\beta w_h + \phi_0\rho)$ and $\delta A \leq (\beta\delta + \phi_1\rho)A$). However, in this study, we consider only scenarios 1 and 2 because of the co-existence of all products in the market. The scenarios 3 and 4 are exterior solutions; i.e., non-coexistence of the high-quality and the adulterated products.

Scenario 1

Following the process developed earlier, in the presence of food adulteration scenario 1, we can derive the supplies of the high-quality product, the adulterated product, and the low-quality product, respectively, as:

$$(13)\quad x_{h,d}^{tl} = A_{h,d} - A_{h,d}^{ch} = \frac{\{(\beta\delta + \phi_1\rho) - \delta\}\left(P_{h,d}^{f} - P_{l,d}^{f} + w_l\right) - \{(\beta\gamma + \phi_1\rho) - \gamma\}w_h + (\delta - \gamma)\phi_0\rho}{(\delta - \gamma)\{(\beta\delta + \phi_1\rho) - \delta\}}$$

$$(14)\quad x_{h,d}^{ch} = A_{h,d}^{ch} = \frac{w_h - \beta w_h - \phi_0\rho}{\{(\beta\delta + \phi_1\rho) - \delta\}}$$

$$(15)\quad x_{l,d} = A_{l,d} - A_{h,d} = \frac{\delta\left(P_{l,d}^{f} - w_l\right) - \gamma(P_{h,d}^{f} - w_h)}{\gamma(\delta - \gamma)}$$

Scenario 2

The supplies of the high-quality product, the adulterated product, and the low-quality product are given as:

$$(16)\quad x_{h,d}^{tl} = A_{h,d}^{tl} = \frac{\{(\beta w_h + \phi_0\rho) - w_h\}}{\{\delta - (\beta\delta + \phi_1\rho)\}}$$

$$(17)\quad x_{h,d}^{ch} = A_{h,d} - A_{h,d}^{t} = \frac{\{\delta - (\beta\delta + \phi_1\rho)\}\left[P_{h,d}^{f} - (\beta w_h + \phi_0\rho) - P_{l,d}^{f} + w_l\right] - \{(\beta\delta + \phi_1\rho) - \gamma\}[(\beta w_h + \phi_0\rho) - w_h]}{\{(\beta\delta + \phi_1\rho) - \gamma\}\{\delta - (\beta\delta + \phi_1\rho)\}}$$

$$(18)\quad x_{l,d} = A_{l,d} - A_{h,d} = \frac{(\beta\delta + \phi_1\rho)\left(P_{l,d}^{f} - w_l\right) - \gamma\{P_{h,d}^{f} - (\beta w_h + \phi_0\rho)\}}{\gamma\{(\beta\delta + \phi_1\rho) - \gamma\}}$$

3.1.3 System-wide effects of food adulteration

This section determines the market and welfare effects of food adulteration and then, compares these effects with that of the benchmark model (i.e. no food fraud).

Equilibrium conditions

Figure 4 depicts the equilibrium conditions under food adulteration scenario 1. As mentioned earlier, in the presence of food adulteration, consumers decrease their willingness to pay for high-quality product which, in turn, reduces the demand for high-quality product. Therefore, in the presence of food adulteration, the demand curve for high-quality product shifts to the left (from D_h to $D_{h,d}$). Since, under scenario 1, only (some) high-quality producers find it optimal to produce adulterated product and sell it as the high-quality product, the supply curve of the product marketed as high-quality does not shift; however, it is kinked supply curve (S_h; includes supply of both the high-quality and the adulterated products). Comparing the equilibrium quantity, consumer price, and price received by producers of the product marketed as high-quality in the absence and presence of food adulteration, figure 1 panel A shows that both equilibrium quantity and prices decrease in the presence of food adulteration. In contrast, the demand for low-quality product increase (shifts from D_l to $D_{l,d}$) in the presence of food fraud, resulting increased equilibrium quantity ($x_{l,d}$), consumer price ($P^c_{l,d}$) and price received by producers ($P^f_{l,d}$) of the low-quality product (see figure 4 panel B).

Like scenario 1, the demand curve for the product marketed as high-quality (low-quality) product shifts to the left (right) under scenario 2. However, since, under scenario 2, both (some) high and low-quality producers find it optimal to produce adulterated product and sell it as the high-quality product, the supply curves of the product marketed as high-quality and the low-quality product shift to the right and the left, respectively. Consequently, the effect of food adulteration on the equilibrium quantity depends on the relative magnitude of the demand and supply effects of food adulteration. However, the equilibrium consumer price and price received by producers of the product marketed as high-quality (low-quality), like scenario 1, decrease (increase) in the presence of food adulteration scenario 2 irrespective of the relative magnitude of the demand and supply effects (see appendix I for detail).

Consumers

Figure 5 depicts the effects of food adulteration on consumer welfare. As shown earlier, in the presence of food adulteration, the uncertainty about the nature of the product marketed as high-quality and the probability of getting sick, reduce the utility associated with the production of product marketed as high-quality. Consequently, the utility curve associated with the production of high-quality product U_h shifts to $U_{h,d}$ in the presence of food adulteration. Moreover, in the presence of food adulteration, the increased equilibrium price of the low-quality product decreases the utility associated with the consumption of the low-quality product. Therefore, the utility function associated with the consumption of the low-quality product shifts downward from U_l to $U_{l,d}$. Thus, the welfare of both high-quality and low-quality product consumers decreases when the food adulteration occurs in the market.

Producers

Figure 6 presents the effects of food adulteration scenario 1 on producers. Since, in the presence of food adulteration, the equilibrium price of the high-quality (low-quality) product decreases (increases), the net returns curves associated with the production of the high-quality product and the low-quality product shifts downward and upward, respectively (dashed and dotted lines in figure 8, respectively). The bold line in figure 8 presents the net returns associated with the production of adulterated product. In this context, the most efficient producers (i.e., producers with $A\epsilon[0, A_{h,d}^{ch})$) find it optimal to engage in fraudulent behavior since the net returns associated with the production of adulterated product exceed those of the alternatives. Comparing the welfare effects in the absence and presence of food adulteration indicates that honest producers who continue to produce the high-quality product in the presence of food adulteration (i.e., producers with $A\epsilon(A_{h,d}^{ch}, A_{h,d}^{t})$) lose. In contrast, producers benefiting the most from food adulteration are those producing the adulterated product (i.e., producers with $A\epsilon[\,0, A_{h,d}^{ch})$),

followed by producers who continue to produce the low-quality product (i.e., producers with $A\epsilon(A_h, A_l)$).

Like scenario 1, in the presence of food adulteration, the net returns curve associated with the production of the high-quality (low-quality) product shifts downward (upward) under scenario 2. However, unlike scenario 1, producers with the intermediate level of efficiency (i.e., producers with $A\epsilon(A_{h,d}^{t},\ A_{h,d}^{ch})$) find it optimal to engage in fraudulent behavior under scenario 2. Moreover, the most efficient producers have no incentive to engage in fraudulent behavior under this scenario. Like scenario 1, while producers who continue to produce the high-quality product in the presence of food adulteration (i.e., producers with $A\epsilon[\,0, A_{h,d}^{t})$) lose, (many) producers of the adulterated product (producers with $A\epsilon(A_{h,d}^{/}, A_{h,d}^{ch})$) and producers of the low-quality product (i.e., producers with $A\epsilon(A_{h,d}^{ch}, A_l)$) are benefiting in the presence of food adulteration (see figure 7).[8]

3.2 Mislabeling

Compared with the case of food adulteration, the main difference of mislabeling is that the probability of getting sick if consumers buy mislabeled product is zero. For instance, when producers mislabel a conventional apple as an organic apple, consuming mislabeled apple is not harmful to human health. Therefore, we can get the consumer utility function in the presence of mislabeling by substituting the term $(1-\mu)\epsilon\psi$ is equal to zero. Moreover, substituting $w_l + \gamma A$ for $\beta(w_h + \delta A)$ in equation 12 provides the net returns function for producer in the presence of mislabeling.

Comparing the market and welfare effects of food adulteration and mislabeling reveals that the qualitative nature of analytical results is similar. However, the quantitative differences in analytical results provide key insights regarding economic impacts under food adulteration and mislabeling. For instance, since the probability of health hazard is zero under mislabeling, the reduction (increase) in the equilibrium price of the high-quality (low-quality) product is lower under mislabeling. Moreover, while the equilibrium quantity of the high-quality product is higher in the presence of mislabeling, the fraudulent behavior is more prevalent under mislabeling than under food adulteration (see supplementary material).

4. Government Problem

This section focuses on the design of optimal policy response to food fraud when enforcement is costly. The problem of the government can be seen as the determination of the enforcement policy that maximizes social welfare. Specifically, the problem of the government is to determine the optimal type and degree of policy response in the presence of food fraud, knowing the cost and impact of its decision on all interest groups involved, i.e., consumers, producers, and taxpayers. Similar to Bonroy and Constantatos (2014), we assume that the government has two policy instruments to achieve optimal policy response to food fraud: the positive change in the certification cost and the monitoring-punishing system.[9] The positive change in the certification cost can be achieved through either an increase in the high-quality product certification cost or any new regulation which increases the high-quality product certification cost such as food traceability and identity preservation.[10] The level of monitoring-punishing system is determined by the audit probability ϕ_1 and the penalties ρ. Since the penalties on detected mislabeling or adulteration are generally set elsewhere in the legal system, this enforcement parameter is exogenous to policymakers (Giannakas and Fulton 2000; 2002). Specifically, the public enforcement agency is assumed to take penalties ρ as given while choosing audit probability ϕ_1 to achieve the desired level of monitoring-punishing system. Therefore, policymakers control the positive change in the certification cost cf and the audit probability ϕ_1 to determine the type and degree to which fraudulent behavior in the agri-food marketing system is enforced.

In this section, while determining the optimal policy response to food fraud, both scenarios 1 and 2 are taken into account. Regarding the welfare effects of food fraud, as shown earlier, while both dishonest and low-quality producers gain, honest high-quality producers always lose in the presence of food fraud. Intriguingly, albeit the presence of food fraud affects producers differently, it is shown to reduce the welfare of both high and low-quality product consumers.

4.1 Under Food Adulteration:

The government problem in the presence of food adulteration is to maximize a non-equally weighted social welfare function. In this context, the government problem can be written as:

$$(19)\ \max_{cf,\phi_1} k.CS_d + l_1.PS_{h,d} + l_2.PS_{h,d}^{ch} + l_3.PS_{l,d} + m.[\omega\rho n - b\rho - \phi_1\psi - PH]$$

$$=> \max_{cf,\phi_1} k.CS_d\left(\lambda, P_{h,d}^{c}(cf), P_{l,d}^{c}, \mu(cf,\phi_1,\ \rho)\right) + l_1.PS_{h,d}(cf,\phi_0,\phi_1,\rho) +$$

$$l_2.PS_{h,d}^{ch}(cf,\phi_0,\phi_1,\rho) +\ l_3.PS_{l,d}(cf,\phi_0,\phi_1,\rho) + m.[\omega(\phi_1)\rho n - b\rho - \phi_1(k,l,m,\psi)$$

$$\psi(s,n) - PH(A_h^{ch}(cf,\phi_0,\phi_1,\rho),\epsilon)]$$

where the parameters $PS_{h,d}$, $PS_{h,d}^{ch}$, and $PS_{l,d}$ stand for surpluses of high-quality, dishonest, and low-quality producers, respectively. The consumer surplus and the percentage of audited farms getting caught while committing fraud are CS_d and ω, respectively.[11] The parameters n and ψ are the total number of producers and the total cost of auditing all producers, respectively.[12] The term $\omega\rho n$ captures the revenue associated with the monitoring and punishment of fraudulent behavior of producers, while the costs of punishment, monitoring, and public health are presented by the terms $b\rho$, $\phi_1\psi$ and PH, respectively.[13] In this context, the taxpayer surplus in the objective function is given by $TS = [\omega\rho n - b\rho - \phi_1\psi - PH]$. The weight placed by the government on the welfare of consumers, high-quality producers, dishonest producers, low-quality producers, and taxpayers are k, l_1, l_2, l_3, and m, respectively. The first order conditions for the problem specified in equation (19) are given as:

(20) $$\frac{\partial W}{\partial cf} = \overbrace{k\frac{\partial CS_d}{\partial P^c_{h,d}}\frac{\partial P^c_{h,d}}{\partial cf}}^{-} + \overbrace{k\frac{\partial CS_d}{\partial \mu}\frac{\partial \mu}{\partial cf}}^{+} + \overbrace{l_1\frac{\partial PS_{h,d}}{\partial cf}}^{+} + \overbrace{l_2\frac{\partial PS^{ch}_{h,d}}{\partial cf}}^{-} + \overbrace{l_3\frac{\partial PS_{l,d}}{\partial cf}}^{-} - \overbrace{m\frac{\partial PH}{\partial A^{ch}_h}\frac{\partial A^{ch}_h}{\partial cf}}^{-} = 0$$

$$\Rightarrow \quad k\frac{\partial CS_d}{\partial \mu}\frac{\partial \mu}{\partial cf} + l_1\frac{\partial PS_{h,d}}{\partial cf} + m\frac{\partial PH}{\partial A^{ch}_h}\frac{\partial A^{ch}_h}{\partial cf} = k\frac{\partial CS_d}{\partial P^c_{h,d}}\frac{\partial P^c_{h,d}}{\partial cf} + l_2\frac{\partial PS^{ch}_{h,d}}{\partial cf} + l_3\frac{\partial PS_{l,d}}{\partial cf}$$

(21) $$\frac{\partial W}{\partial \phi_1} = \overbrace{k\frac{\partial CS_d}{\partial \mu}\frac{\partial \mu}{\partial \phi_1}}^{+} + \overbrace{l_1\frac{\partial PS_{h,d}}{\partial \phi_1}}^{+} + \overbrace{l_2\frac{\partial PS^{ch}_{h,d}}{\partial \phi_1}}^{-} + \overbrace{l_2\frac{\partial PS_{l,d}}{\partial \phi_1}}^{-} - \overbrace{m\frac{\partial PH}{\partial A^{ch}_h}\frac{\partial A^{ch}_h}{\partial \phi_1}}^{-} + \overbrace{m\frac{\partial \omega}{\partial \phi_1}\rho n}^{+} - \overbrace{m\psi}^{+} = 0$$

$$\Rightarrow \quad k\frac{\partial CS_d}{\partial \mu}\frac{\partial \mu}{\partial \phi_1} + l_1\frac{\partial PS_{h,d}}{\partial \phi_1} + m\frac{\partial PH}{\partial A^{ch}_h}\frac{\partial A^{ch}_h}{\partial \phi_1} + m\frac{\partial \omega}{\partial \phi_1}\rho n = l_2\frac{\partial PS^{ch}_{h,d}}{\partial \phi_1} + l_2\frac{\partial PS_{l,d}}{\partial \phi_1} + m\psi$$

Equations (20) and (21) indicate that the optimal policy response to food fraud is determined by equating the marginal benefits of enforcement with the marginal costs of enforcement. The marginal benefits of enforcement in the presence of food adulteration include increased welfare of consumers and honest producers, and the penalties collected on detected fraudulent behavior. In contrast, the marginal costs of enforcement include decreased welfare of dishonest and low-quality producers, and the cost of auditing and penalties.

Result 1: When the most efficient producers engage in fraudulent behavior (Scenario 1), an increase in the certification cost (a) does not reduce fraudulent activities, (b) decreases the average product quality, and (c) decreases the supply of product marketed as high-quality.

Figure 8.1 shows the economic impacts of certification under food adulteration when the most efficient producers engage in fraudulent behavior. As shown previously, under scenario 1, producers with differentiating attributes $A\epsilon[0, A_{h,d}^{ch})$ engage in fraudulent behavior, while producers with differentiating attributes $A\epsilon(A_{h,d}^{ch}, A_{h,d}^{t})$ produce the high-quality product and producers with differentiating attribute $A\epsilon(A_{h,d}^{t}, A_{l,d})$ find it optimal to produce the low-quality product. In this context, an increase in the certification cost will increase both the price and production cost of the high-quality product with the increase in cost exceeding that in the price.[14] Therefore, an increase in the certification cost under scenario 1 results in an inward shift of the net returns curves associated with the production of the high-quality and the adulterated products (i.e. e_2 shifts to e_3 and f_1 shifts to f_2, respectively). The intersection of the net returns curve associated with the production of low-quality g_1 and the net returns curve associated with the production of high-quality product e_3 determines the new market supply of the product marketed as high-quality $A_{h,d,cf}^{t}$, decreasing the total supply of the product marketed as high-quality by $A_{h,d}^{t} - A_{h,d,cf}^{t}$. While the supply of the product marketed as high-quality decreases after increasing the certification cost, the supply of the adulterated product remains the same since the net expected benefit of fraudulent behavior for most efficient producers (i.e. producers with differentiating attributes $A\epsilon[0, A_{h,d}^{ch})$), remains the same. However, under scenario 1, food fraud can be completely deterred by increasing the certification cost in such a way that the total certification cost is equal to the high-quality price premium $P_{h,d} - P_{l,d}$. It is important to note that, at this high certification cost, there will be no incentive for producers to produce the high-quality product.[15] Therefore, when the most efficient producers are engaged in fraudulent behavior, an increase in the certification cost through the introduction of food traceability, for instance, does not reduce fraudulent activities.[16] What it does reduce the average product quality in the market.

Result 2: When producers with the intermediate level of efficiency engage in fraudulent behavior (Scenario 2), an increase in the certification cost (a) reduces fraudulent activities, (b) increases the average product quality, and (c) decreases the supply of product marketed as high-quality.

As shown previously, when the net expected benefit of fraudulent behavior decreases with the efficiency of producers (Scenario 2, the total supply of product marketed as high-quality increases (supply effect of food adulteration). On the other hand, in the presence of food adulteration, the demand for high-quality product decreases (demand effect of food adulteration). Figure 8.2 shows the effects of an increase in the certification cost under scenario 2 when the supply effect dominates the demand effect of food adulteration. In this context, like scenario 1, an increase in the certification cost by cf results in inward shift of the net returns curves associated with the production of high-quality and adulterated foods (i.e. e_5 shifts to e_6 and f_3 shifts to f_4, respectively). Consequently, the intersection of the new net returns curve associated with the production of adulterated food f_4 and the net returns curve associated with the production of low-quality food g_2 determines the new supply of product marketed as high-quality $A^{ch}_{h,d,cf}$, which is lower than that before increasing the certification cost. Unlike Scenario 1, the total supply of adulterated product decreases by $A^{ch}_{h,d,cf} - A^{ch}_{h,d}$, while the total supply of high-quality product remains the same, improving the average product quality in the market. Under scenario 2, an increase in the certification cost reduces the net expected benefit of fraudulent behavior and discourages fraud. In particular, when an increase in the certification cost is such that the net returns curves associated with the production of low-quality and adulterated product intersect at the point j_2, the net expected benefit of fraudulent behavior for all dishonest producers becomes either zero or negative, resulting in complete food fraud deterrence. In this context, the increase in the certification cost that completely deters fraudulent activities is:

$$(22)\quad cf_d^* = \frac{\{\delta - (\beta\delta + \phi_1\rho)\}[(P_{h,d,cf} - w_h) - (P_{l,d} - w_l)] - (\delta - \gamma)\{(\beta w_h + \phi_0\rho) - w_h\}}{\{\delta - (\beta\delta + \phi_1\rho)\}}$$

It is important to note that, while an increase in the certification cost improves the average product quality and reduces fraudulent activities under scenario 2, an increase in the certification cost over cf_d^* results in diminishing average product quality in the market.[17] Moreover, the qualitative nature of analytical results does not change when we consider the demand effect dominates the supply effect of food adulteration under scenario 2. The increase in the certification cost that completely deters fraudulent activities when the demand effect dominates the supply effect is:[18]

$$(23)\quad cf_d^{**} = \frac{\{(\beta\delta + \phi_1\rho) - \delta\}[(P_{h,d,cf} - w_h) - (P_{l,d} - w_l)] - (\delta - \gamma)(w_h - \beta w_h - \phi_0\rho)}{\{(\beta\delta + \phi_1\rho) - \delta\}}$$

Result 3: When the government wants to deter food fraud (which is equivalent to maximizing the welfare of consumers and/or welfare of honest high-quality producers), the optimal policy response depends on the efficiency of dishonest producers and the relative costs of different types of enforcement.

The government places high weight on the welfare of consumers and/or honest high-quality producers and positive but relatively low weight on other groups involved when its objective is to deter fraud. When the weight placed on consumers and/or honest high-quality producers is significantly high that the benefits of enfocement exceed the costs (i.e., marginal benefits of enforcement ≥ marginal costs of enforcement), the optimal policy response is to increase the enforcement.

Scenario 1

Figure 9.1 shows the effects of the monitoring-punishing system when the most efficient producers are engaged in fraudulent behavior. The slope of the net returns function associated with the production of adulterated product (i.e., f_1 curve) is $\beta\delta + \phi_1\rho$. When the government increases the audit probability ϕ_1, the slope of the net returns function associated with the production of adulterated product increases which, in turn, reduces the net expected benefit of fraudulent behavior. Therefore, when the most efficient producers are engaged in fraudulent behavior, the monitoring-punishing system decreases the number of dishonest producers and improves the average product quality in the market.

It is important to note that food fraud can be completely deterred under scenario 1 when the slope of the net returns function associated with the production of adulterated product becomes infinite (which is equivalent to $\phi_1\rho = \infty$). Since the audit probability ϕ_1 takes value between 0 and 1, it is not possible to completely deter food fraud under scenario 1 by increasing the audit probability. However, when ρ is endogenous to policymakers, it is possible to completely deter food fraud by setting perfect monitoring-punishing system. Specifically, the optimal choice is to establish small probability of harsh punishment for the fraudulent behavior in the agri-food marketing system. Posed in a different way, optimal choice, in this context, is to set $(\phi_1\rho)_d^* = \infty$ in such way that $\lim_{\rho\to\infty}(\phi_1 = 0)$.[19]

In contrast, as shown in result 1, when the most efficient producers are engaged in fraudulent behavior, an increase in the certification costs does not reduce fraudulent activities but, instead, reduces the market share of the high-quality product.

Scenario 2

In figure 9.2, the curve f_3 presents the net returns associated with the production of adulterated product when producers with intermediate level of efficiency are engaged in fraudulent behavior. Like scenario 1, an increase in the auditing probability ϕ_1 increases the slope of the curve f_3 (steeper), resulting in a reduction in the net expected benefit of fraudulent behavior. When the objective of the government is to completely deter food fraud, the optimal choice is to increase the audit probability ϕ_1 in such a way that the f_3 curve intersects the point k^*, resulting in no benefit of fraudulent behavior for all producers. Specifically, the increase in the audit probability that completely deters fraudulent activities is:

$$(24)\quad \phi_{1,d}^* = \frac{(\delta-\gamma)\left(P_{h,d}-\beta w_h-\phi_0\rho\right)-\beta\delta\left[\left(P_{h,d}-w_h\right)-\left(P_{l,d}-w_l\right)\right]-\left[\delta\left(P_{l,d}-w_l\right)-\gamma\left(P_{h,d}-w_h\right)\right]}{\left[\left(P_{h,d}-w_h\right)-\left(P_{l,d}-w_l\right)\right]\rho}$$

Similar to an increase in certification costs, the monitoring-punishing system can completely deter food fraud when the producers with the intermediate level of efficiency are engaged in fraudulent behavior. However, both an increase in the certification cost and the monitoring-punishing system are costly for the society; the former reduces the surpluses of consumers and producers, while the latter increases the taxpayer cost. Therefore, under scenario 2, while food fraud can be completely deterred through either increasing the certification cost or introducing a monitoring-punishing system, the optimal policy choice depends on the relative costs of different types of enforcement.

While the monitoring-punishing system reduces the net expected benefit of fraudulent behavior regardless of the relative efficiency of different producer groups, the effectiveness of an increase in the certification costs in deterring food fraud depends on the efficiency of dishonest producers. Specifically, an increase in the certification costs deters food fraud when producers with intermediate level of efficiency are engaged in fraudulent behavior; however, it does not reduce food fraud when it is the most efficient producers that are engaged in fraudulent behavior. Therefore, when the most efficient producers commit fraud, the optimal policy response is the monitoring-punishment system. In contrast, the optimal policy response depends on the relative costs of different types of enforcement when producers with the intermediate level of efficiency commit fraud. Put in a different way, while the government can, theoretically, deter food fraud through a significant increase in the certification costs and/or monitoring-punishing system, the optimal policy response depends on the efficiency of dishonest producers and the relative costs of different types of enforcement.

Result 4: When the government wants to increase the average product quality in the market while deterring food adulteration, the monitoring-punishing system is better than imposing higher certification cost.

While both the monitoring-punishing system and an increase in the certification cost reduce the net expected benefit of fraudulent behavior, the latter also increases the production cost of the high-quality product. Therefore, while the monitoring-punishing system always increases the average product quality, the effect of increasing certification costs on the average product quality depends on the efficiency of dishonest producers.

Scenario 1

Under scenario 1, an increase in the certification cost reduces the average product quality. For example, increasing the certification cost by cf raises the production cost of high-quality food and honest producers with differentiating attribute $A\epsilon(A_{h,d,cf}, A_{h,d})$ find it optimal to switch from the production of high-quality to the production of low-quality. Therefore, increasing the certification cost by cf reduces the total supply of high-quality product by $A_{h,d} - A_{h,d,cf}$,which with the total supply of adulterated product remaining the same, results in lower average product quality (see Figure 8.1).

Moreover, under scenario 1, food adulteration can be completely deterred when the government increases the certification cost in such a way that the certification cost is equal to the high-quality price premium (see Figure 8.1). However, there is no incentive for producers to produce high-quality product when there is no premium for this product. Put in a different way, when the certification cost is equal to the high-quality premium, the net returns curve associated with the production of high-quality remains below the net returns curve associated with the production of low-quality for all producers (i.e., producers with differentiating attribute $A\epsilon[0,1]$, resulting in the high-quality product being drove out of the market. Therefore, an increase in the certification cost decreases the average product quality in the market under scenario 1.

On the other hand, under this scenario, the monitoring-punishing system not only reduces the fraudulent behavior but also increases the average product quality. For instance, an increase in the audit probability from ϕ_1 to $\phi_1^{/}$ shifts the net returns function associated with the production of adulterated product from f_1 to f_2, decreasing the fraudulent activities. Consequently, the total supply of high-quality product increases by $A_{h,d}^{ch} - A_{h,d,p}^{ch}$ (see Figure 9.1), improving this way the average product quality. Therefore, under scenario 1, when the government wants to increase the average product quality in the market while deterring food adulteration, the monitoring-punishing system is better than imposing higher certification costs.

<u>Scenario 2</u>

When producers with intermediate level of efficiency engage in fraudulent behavior (scenario 2), an increase in the certification cost increases the average product quality. For instance, when the supply effect dominates the demand effect of food adulteration under scenario 2, an increase in the certification by cf reduces the total supply of adulterated product by $A^{ch}_{h,d,cf} - A^{ch}_{h,d}$, improving the average product quality in the market. In this context, the food adulteration can be deterred when an increase in the certification cost is such that the net returns curves associated with the production of low-quality and adulterated food intersect at the point j_2. Consequently, while the total supply of high-quality food remains the same (i.e., $A^{t}_{h,d}$), the total supply of low-quality food increases by $A^{ch}_{h,d} - A^{t}_{h,d}$, and the total supply of adulterated product falls to zero (see Figure 8.2).

When the government increases audit probability to combat food adulteration in the market, the average product quality also increases. Specifically, when the supply effect dominates the demand effect of food adulteration under scenario 2, the fraudulent activities can be completely deterred by increasing the audit probability in such a way that $\phi_1 = \phi^*_{1,d}$. Increasing the audit probability to $\phi^*_{1,d}$ results in either zero or negative net expected benefit of fraudulent behavior regardless of the efficiency of producers and increases the total supply of high and low-quality products by $A_{h,d,p} - A^{t}_{h,d}$ and $A^{ch}_{h,d} - A_{h,d,p}$, respectively (see Figure 9.2). Comparing with the case of increasing the certification costs, the analysis reveals that, while fraudulent activities can be completely deterred through either increasing the certification cost or the monitoring-punishing system under scenario 2, the latter increases the average product quality more since it increases the total supply of high-quality product by $A_{h,d,p} - A^{t}_{h,d}$ more than that of the former. Therefore, the monitoring-punishing system is the optimal choice when the government wants to increase the average product quality in the market while deterring food adulteration.

Result 5: While the purity of labeling can be improved either through an increase in the certification costs and/or the monitoring-punishing system when producers with the intermediate *level of efficiency engage in fraudulent behavior, the former decreases the purity of labeling when the most efficient producers engage in fraudulent behavior.*

According to Hamilton and Zilberman (2006), the purity of labeling can be defined as the proportion of high-quality product sales out of the total product marketed as high-quality:[20]

$$(25) \quad p = \frac{x_h^t}{x_h^t + x_h^{ch}}$$

where p is the level of purity taking values between 0 and 1; x_h^t and x_h^{ch} are the equilibrium quantities of high-quality product and adulterated product, respectively.

<u>Scenario 1</u>

When the most efficient producers engage in fraudulent behavior, an increase in the certification cost does not reduce fraudulent behavior, but decreases, instead, the purity of labeling. For instance, when the certification cost increases by cf, producers with differentiating attribute $A\epsilon(A_{h,d,cf}, A_{h,d})$ switch from the production of high-quality to the production of low-quality product; while all dishonest producers (i.e., producers with differentiating attribute $A\epsilon[0, A_{h,d}^{ch})$) continue to adulterate their product (see Figure 8.1). Therefore, an increase in the certification cost under scenario 1 decreases the purity of labeling by:

$$(26) \quad \Delta p_{cf} = p_{d,cf} - p_{d,1} = \frac{-\overbrace{(w_h - \beta w_h - \phi_0 \rho)(\delta - \gamma) cf}^{+}}{\underbrace{\{(\beta\delta + \phi_1\rho) - \delta\}}_{+} \underbrace{\left[(P_{h,d}^f - P_{l,d}^f) - (w_h - w_l) - cf\right]}_{+} \underbrace{\left[(P_{h,d,cf}^f - P_{l,d}^f) - (w_h - w_l) - cf\right]}_{+}} < 0$$

where $p_{d,1}$ and $p_{d,cf}$ present the level of purity in the market before and after increasing the certification cost under scenario 1, respectively. As shown previously, the monitoring-punishing system reduces fraudulent behavior under scenario 1, which, in turn, increases the purity of labeling (see Figure 9.1). For instance, when the government increases the audit probability from ϕ_1 to $\phi_1^{/}$, the purity of labeling increase by:

(27) $\Delta p_{d,mp} = p_{d,mp} - p_{d,2} => \Delta p_{d,mp} = \overbrace{\rho(\delta - \gamma)}^{+} \overbrace{(\phi_1^{/} - \phi_1)}^{+} > 0$

where $p_{d,2}$ and $p_{d,mp}$ present the purity of labeling under the audit probability ϕ_1 and $\phi_1^{/}$, respectively.

<u>Scenario 2</u>

When the producers with intermediate level of efficiency engage in fraudulent behavior, both an increase in the certification cost and the monitoring-punishing system increase the purity of labeling in the market. For instance, the unit purity in the market can be achieved either through increasing the certification cost by cf_d^{**} or to increase the monitoring-punishing system by $\phi_{1,d}^{*}$ (see equations 23 and 24).

4.2 Under Mislabeling

Result 6: The level of enforcement to deter food fraud depends on the efficiency of dishonest producers and the type of food fraud.

Comparing the high-quality price premium under mislabeling and food adulteration, analytical results in the previous chapter show that, while the high-quality price premium decreases in the presence of food fraud, the fall in the high-quality price premium is lower under mislabeling than under food adulteration. The high-quality price premium being higher under mislabeling than under food adulteration, results in higher prevalence of fraudulent behavior under mislabeling.

<u>Scenario 1</u>

As mentioned earlier, the total number of dishonest producers is more under mislabeling than under food adulteration and the detection probability is asymmetric. Therefore, the degree of audit probability under mislabeling needs to be higher than under food adulteration to eliminate the incentive to commit fraud for all dishonest producers. When the penalties are endogenous to policymakers, the food fraud can be completely deterred by enforcing the perfect monitoring-punishing system irrespective of the food fraud type. As mentioned previously, the optimal choice is to set severe punishment in such way that $\lim_{\rho\to\infty}(\phi_1 = 0)$.[21]

<u>Scenario 2</u>

Since the high-quality price premium is higher under mislabeling than under food adulteration, and the detection probability is asymmetric, the degree of enforcement that eliminates the incentive to commit fraud for all producers is greater under mislabeling than under food adulteration. Specifically, the difference between the optimal degree of audit probability under mislabeling $\phi_{1,m}^*$ and under food adulteration $\phi_{1,d}^*$ is:[22]

$$(28) \quad \phi_{1,m}^* - \phi_{1,d}^* = \frac{\{\delta - (\beta\delta + \phi_1\rho)\}\left(P_{h,m} - P_{h,d}\right)}{\{(\beta w_h + \phi_0\rho) - w_h\}\rho} > 0$$

indicating that the optimal degree of audit probability is higher under mislabeling than that under food adulteration. Similarly, the optimal level of certification costs under mislabeling and under food adulteration is:

$$(29) \quad cf_m^* - cf_d^* = (P_{h,m} - P_{h,d}) > 0$$

implying that the optimal increase in the certification cost is higher under mislabeling than under food adulteration. Therefore, the degree of enforcement to deter food fraud depends on the efficiency of dishonest producers and the type of food fraud.

4.3 Corruption in the Public Sector

The previous analysis and results are based on the assumption that there is no corruption in the public sector, i.e., when producers are caught mislabeling or adulterating their product, they will face the relevant penalty. Consider now the case of a corrupt public sector. By corruption this study refers following two forms of corruption: political corruption and bureaucratic corruption. Political corruption takes place when policymakers use their political power to sustain their status, power, and wealth (Amundsen 1999). According to Transparency International (TI), in the presence of political corruption, it is private rather than public interests that dictate policy decisions. On the other hand, the bureaucratic corruption is defined as the corruption in public administration where public officials allow private agents privileges that they are not legally entitled to, in return for a payment (Ackerman 1998). The basic distinction between the political and bureaucratic corruption is that the former occurs at the stage of policy decision while the latter occurs at the stage of policy implementation.[23]

Result 7: When the government considers the welfare maximization of dishonest producers, its optimal choice is no enforcement.

When the policymakers are corrupt, the group of dishonest producers can influence the government policy decisions through lobbying, resulting laws and regulations regarding food safety are systematically abused by the corrupt policymakers, ignored or tailored to maximize the welfare of dishonest producers. Specifically, while maximizing welfare of the society, the corrupt policymakers place high weight on the welfare of dishonest producers and positive but relatively low weight on consumers, honest producers, and taxpayers. Therefore, in this context, the costs of enforcement exceed the benefits (i.e., marginal costs of enforcement ≥ marginal benefits of enforcement), implying complete allowance of fraudulent behavior.[24] When the penalties on detected food fraud are set elsewhere in the legal system (i.e., are exogenous to the government), the only way the government can allow fraudulent behavior is by setting $c = \phi_1 = 0$. While the government does not spend resources to detect fraudulent behavior in this case, the probability that dishonest producers will be detected by third parties is positive. In other words, the detection probability of fraudulent behavior is not equal to zero when the penalties on detected food fraud are exogenous to corrupt government. Consequently, the product marketed as high-quality includes both high-quality and adulterated/mislabeled products.[25]

However, when the penalties are endogenous to corrupt government, the government can allow fraudulent behavior by setting $c = \phi_1 = \rho = 0$ (i.e., no enforcement). In this context, the detection probability of fraudulent behavior is equal to zero. Consequently, all the product marketed as high-quality is actually adulterated/mislabeled product, maximizing the welfare of dishonest producer irrespective of the scenario and the type of food fraud. Equations (30) and (31) present the dishonest producer welfare under food adulteration and under mislabeling when there is no enforcement, respectively.

$$(30) \qquad PS_{h,d}^{ch} = \frac{\left[\left(P_{h,d} - \beta w_h\right) - \left(P_{l,d} - w_l\right)\right]\left[\left(P_{h,d} - \beta w_h\right)(\beta\delta - 2\gamma) + \beta\delta\left(P_{l,d} - w_l\right)\right]}{2(\beta\delta - \gamma)^2}$$

$$(31) \qquad PS_{h,m}^{ch} = \frac{\left(P_{h,m} - w_h - \tau\right)^2}{2\gamma}$$

Result 8: When the government increases the audit probability to combat food fraud without reducing bureaucratic corruption in the public enforcement agency, the incentive for collusion between dishonest producers and corrupted enforcers increases.

Consider now the situation where a public law enforcement agent may accept payment from producers in return for not reporting their fraudulent behavior.[26] Incorporating the possibility of corruption in the enforcement agency changes the net returns function associated with the production of adulterated/mislabeled product. In particular, a producer with differentiating attribute A has the following net returns function in the presence of bureaucratic corruption:

(32) $\pi_{h,d,br} = P^{f}_{h,d,br} - w_h - \delta A,$ if a unit of the high-quality product is produced

$\pi^{ch}_{h,d,br} = P^{f}_{h,d,br} - \beta(w_h + \delta A) - (\phi_0 + \phi_1 A)[\tau B + (1-\tau)\rho],$

if a unit of the adulterated product is produced

$\pi_{l,d,br} = P^{f}_{l,d,br} - w_l - \gamma A,$ if a unit of the low-quality product is produced

$\pi_{a,d,br} = 0,$ if a unit of an alternative product is produced

where the parameters B and τ represent the cost of the bribe and the probability of collusion with the public enforcers, respectively. All other variables are as previously defined. While dishonest producers are willing to pay a bribe when $B < \rho$, the corrupt public enforcers are willing to accept the bribe when $B > 0$. The dishonest producers remain indifferent when $B = \rho$; however, without loss of generality, it is assumed that bribery does not occur in this case.

It is important to note that when the government increases the audit probability to combat food fraud without addressing corruption in the public enforcement agency, the gain from collusion rises significantly for both dishonest producers and corrupt enforcers. Specifically, when the government increases the audit probability to deter food adulteration without addressing the corruption, the difference in the expected penalty under food adulteration without and with bribery, i.e., $[\phi_0 + \phi_1 A][\tau(\rho - B)]$, increases which, in turn, rises the incentive for collusion between dishonest producers and corrupt enforcers. The difference between the expected penalty of food adulteration without and with bribery also increases with an increase in the probability of collusion with public enforcers.[27]

5. Conclusion

What is the optimal regulatory response to food fraud? Since over the last few years, the intensity and frequency of food fraud have been on the rise, the prominence and importance of this question have grown. Intriguingly, despite the economic and social relevance of food fraud, an economic analysis of the optimal regulatory response to food fraud has not been considered previously. This study develops a theoretical model to determine the optimal regulatory response to food fraud with particular emphasis being placed on the optimal enforcement policy of the government. Key differentiating attributes of this research are that it explicitly accounts for the asymmetric impacts of food fraud (due to the consumer and producer heterogeneity), the endogeneity of the producer quality choice, and asymmetries in the probability of the food fraud detection when considering the optimal policy of the government.

While the government can, theoretically, deter food fraud through a significant increase in the certification costs and/or monitoring-punishing system, the analysis shows that the optimal policy response depends on the efficiency of dishonest producers, the type of food fraud, the political objectives of the government, and the relative costs of different types of enforcement. Specifically, analytical results show that when producers with an intermediate level of efficiency commit fraud, the optimal policy response depends on the relative magnitude of the cost of different types of enforcement. In contrast, when the most efficient producers commit fraud, the optimal policy response is the monitoring-punishing system regardless of the relative costs of different types of enforcement. Moreover, when the government wants to increase the average product quality/market share of the high-quality product while deterring food fraud, the monitoring-punishing system should be preferred to a significant increase in the certification cost. Analytical results also reveal that, contrary to what is traditionally believed, the effect of enforcement policy on the purity of labeling depends on the efficiency of dishonest producers.

When the primary goal of the government is to completely deter food fraud, the optimal degree of enforcement depends on the efficiency of dishonest producers and the type of food fraud. In particular, while the degree of enforcement that completely deters food fraud does not depend on the food fraud type when the most efficient producers engage in fraudulent behavior, the food fraud type plays a key role in determining the degree of enforcement that completely deters food fraud when the producers with intermediate level of efficiency engage in fraudulent behavior.

Incorporating the public-sector corruption (both in the form of political and bureaucratic corruption) in this study is critical in understanding the behavior of the corrupt public sector in the presence of food fraud. Analytical results indicate that when the government increases the audit probability to combat food fraud without monitoring the corruption in the public enforcement agency, the likelihood that dishonest producers collude with corrupt enforcers increases. Moreover, this study shows that the optimal level of enforcement depends on the political preferences and objectives of the government since food fraud increases the surplus of particular groups of producers while decreasing consumer surplus and increasing public health costs. Specifically, when the government places high weight on the surplus of dishonest producers, its optimal choice is to leave fraudulent behavior almost unpunished. Put in a different way, in the presence of political corruption, the group of dishonest producers can maximize their surplus by influencing the policy decisions through lobbying.

In addition to providing insights on the optimal policy response to food fraud, the results of this study can provide assistance in explaining differences in the type and degree of enforcement to combat food fraud observed in different countries. This analysis can also provide an important theoretical grounding to empirical studies on the impact of policy choices on producers' decisions to commit fraud.

References

Ackerman, S. 1998. "Corruption and Government: Causes, Consequences, and Reform," 1st Edition.

Anklam, E. 2014. "A Joint Effort to Ensure the Safety and Integrity of Our Food," Paper presented at Conference on Food Fraud, European Commission, Rome, October.

Avery, J. 2014. "Fighting Food Fraud," Briefing Report, European Parliamentary Research Service, 16th January.

Baksi, S. and Bose, P. 2007. "Credence Goods, Efficient Labelling Policies, and Regulatory Enforcement," *Environmental & Resource Economics*, Vol. 37, pp. 411-430.

Becker, G. 1974. "Crime and Punishment: An Economic Approach," *Journal of Political Economy*, Vol. 76 (2), pp. 169-217.

Bonroy, O. and Constantatos, C. 2014. "On the Economics of Labels: How Their Introduction Affects the Functioning of Market and the Welfare of All Participants," *American Journal of Agricultural Economics*, Vol. 97 (1), pp. 239-259.

Bristow, M. 2009. "Chinese Executes Two Over Tainted Milk Powder Scandal," *BBC News* 24th November.

Charlebois, S., Sterling, B., Haratifar, S., and Naing, S. 2014. "Comparison of Global Food Traceability Regulations and Requirement," *Comprehensive Reviews in Food Science and Food Safety*, Vol. 13 (2014), pp. 1104-1123.

Danovich, T. 2015. "After Years of Scandal, China Overhauls Food-Safety Laws," *TakePart Magazine* 28th September.

European Parliament. "Draft Report on the Food Crisis, Fraud in the Food Chain and the Control Thereof,' 8 October 2013.

France, A. 2015. "Company Boss Imprisoned for Role in Gutter Oil Scandal," *China Daily* 29th July.

Gee, J., Jack, L., and Button, M. 2014. "Minimizing Fraud and Maximizing Value in the UK Food and Drink Sector 2014," PKF and Center for Counter Fraud Studies Report, University of Portsmouth.

Giannakas, K., and Fulton, M. 2000. "The Economics of Coupled Farm Subsidies under Costly and Imperfect Enforcement," *Agricultural Economics*, Vol. 22(2000), pp. 75-90.

—–. 2002. "The Economics of Decoupled Farm Payments under Costly and Imperfect Enforcement," *Canadian Journal of Agricultural Economics*, 50(3): 297-315.

Hamilton, S.F., and Zilberman, D. 2006. "Green Markets, Eco-certification, and Equilibrium Fraud," *Journal of Environmental Economics and Management*, Vol. 52 (3), pp. 627–644.

Huang, Y. 2014. "The 2008 Milk Scandal Revisited," *Forbes* 16th July.

Inge, A. 1999. "Political Corruption: An Introduction to the Issues," Chr. Michelsen Institute Development Studies and Human Rights Working Paper No. 7.

Jameson, G. and Paine, S. 2016. "Canada Gets Serious About Prosecuting Food Fraud," *The Huffington Post* 8th July.

Lotta, F. and Bogue, J. 2015. "Defining Food Fraud in the Modern Supply Chain," *European Food and Feed Law Preview*, Vol. 10 (2), pp. 114-122.

McKeown, D. and Lundie, R. 2009. "Conscience Vote during the Howard Government 1996-2007," Research Paper No. 20 2008-09, Department of Parliamentary Services, Parliament of Australia, Australia.

Morgan, A., Boxall, H., Lindeman, K., and Anderson, J. 2011. "Effective Crime Prevention Interventions for Implementation by Local Government," Research and Public Policy Series 120, Department of Attorney General and Justice, State of New South Wales, Australia.

Polinsky, M. and Shavell, S. 2001. "Corruption and Optimal Law Enforcement," *Journal of Public Economics*, Vol. 81 (2001), pp. 1–24.

Putinja, I. 2017. "Europe Introduces Food Inspection Rules to Tackle Fraud," *Olive Oil Times* 22nd March.

PwC Network. 2015. "Tackling Food Fraud," Food Trust Snapshot: Food Fraud.

Rasul, C. 2013. "Alarming Situation of Food Adulteration," *Bangladesh Medical Journal Khulna*, Vol. 46 (1 & 2), pp. 1-2.

Spink, J., Neal, F., Douglas, M., and Yongning, W. 2016. "Food Fraud Prevention: Policy, Strategy and Decision-Making - Implementation Steps for a Government Agency or Industry," *CHIMIA International Journal for Chemistry*, Vol. 70 (5), pp. 320-328.

Sundstorm, F., Williams, J., Deynze, A., and Bradford, K. 2002. "Identity Preservation of Agricultural Commodities," Agricultural Biotechnology in California Series, Publication No. 8077.

US Congressional Research Service, "Food Fraud and Economically Motivated Adulteration," 2014.

US Government Accountability Office. "Food and Drug Administration Better Coordination Could Enhance Efforts to Address Economic Adulteration and Protect the Public Health," in 'Report to Congressional Requesters', October 2011, GAO-12-46.

Figures

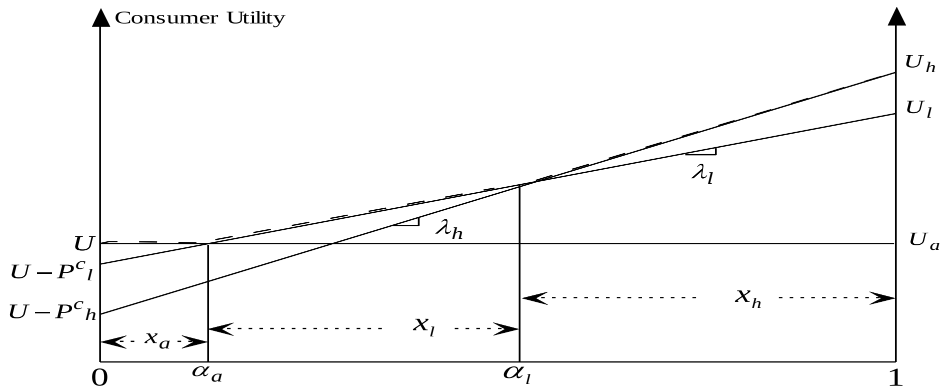

Figure 1. Consumption decisions and welfare effects under no fraud

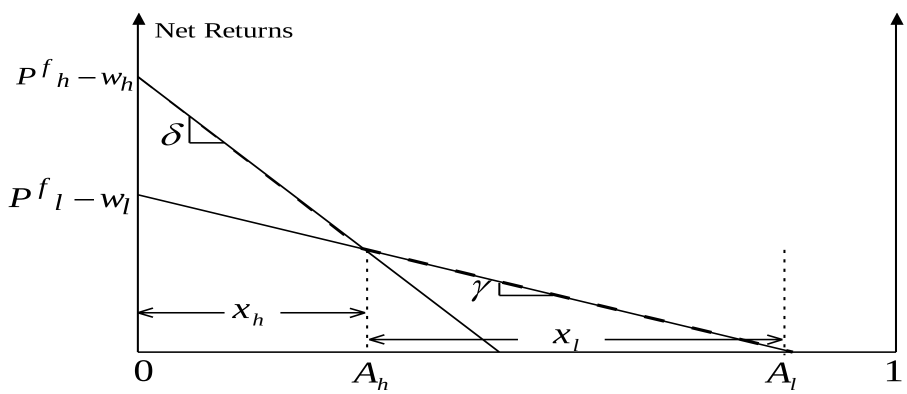

Figure 2. Producer decisions and welfare effects under no fraud

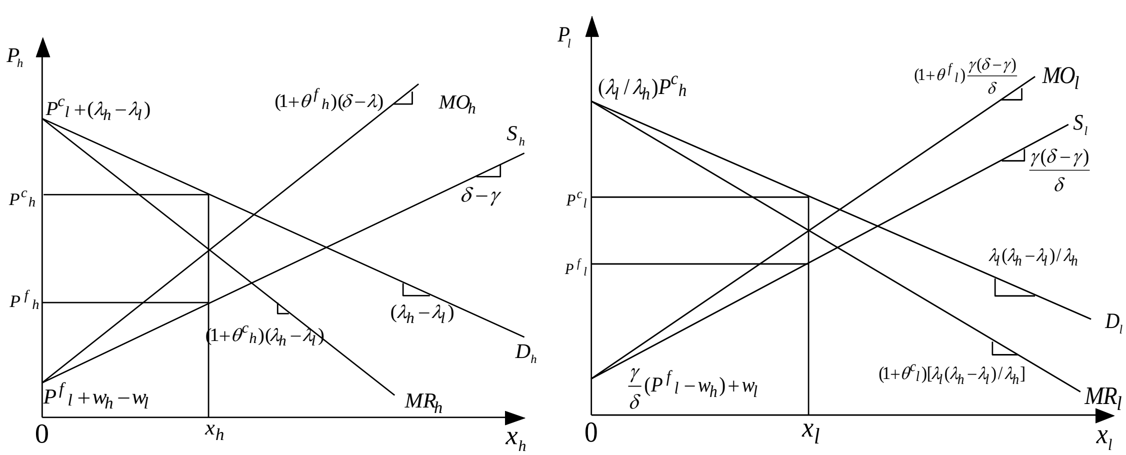

Figure 3. Equilibrium conditions of the high-quality (h) and the low-quality (l) products under no fraud

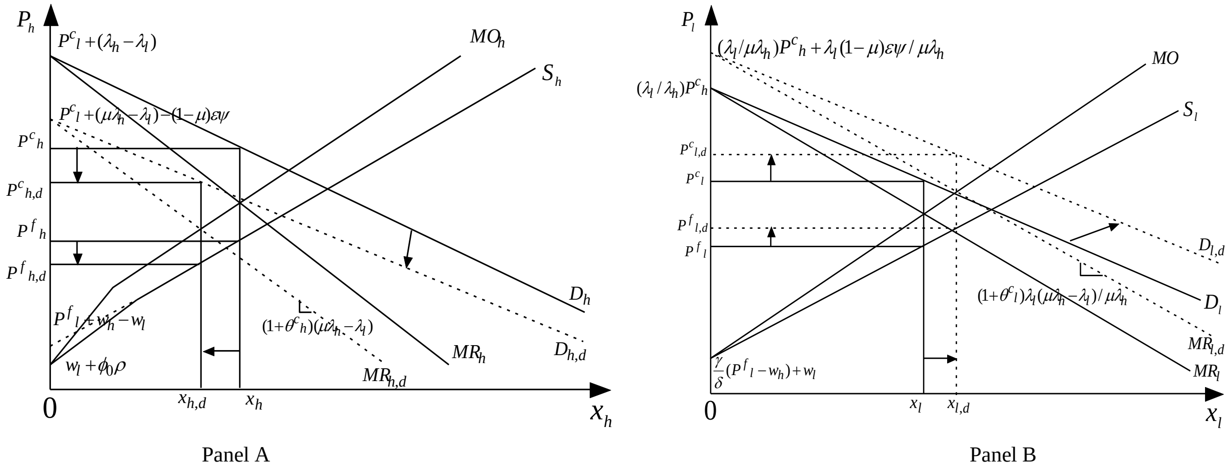

Figure 4: Equilibrium conditions under food adulteration (Scenario 1)

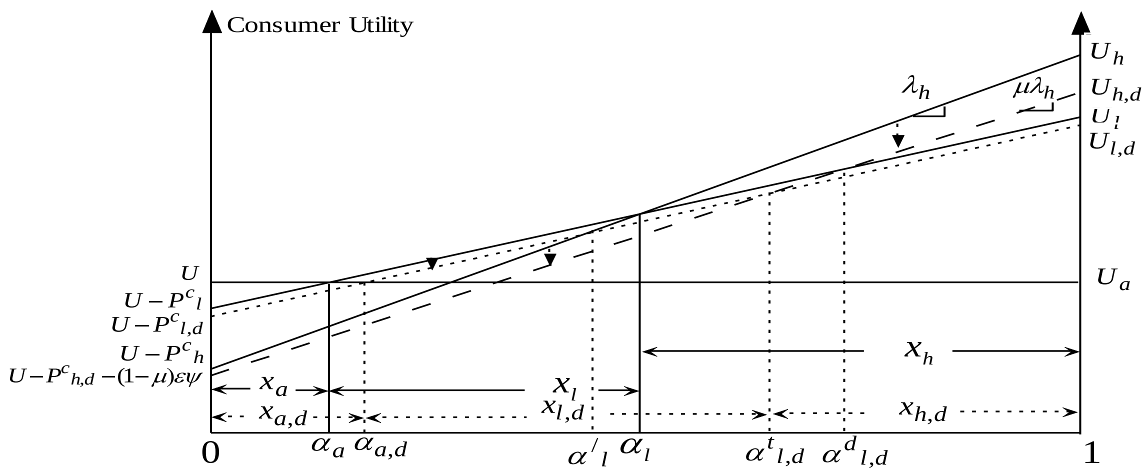

Figure 5. Effects of food adulteration on consumers

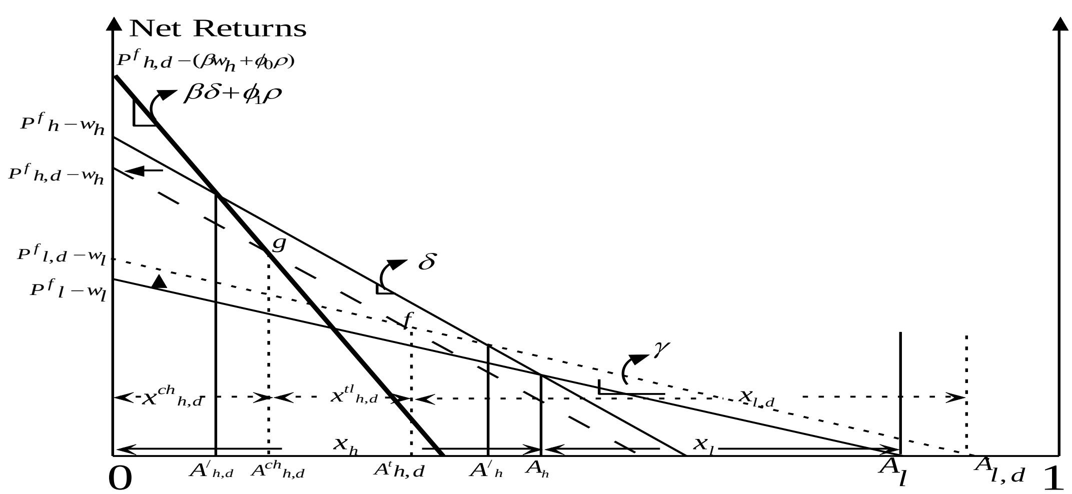

Figure 6. Effects of food adulteration on producers (Scenario 1)

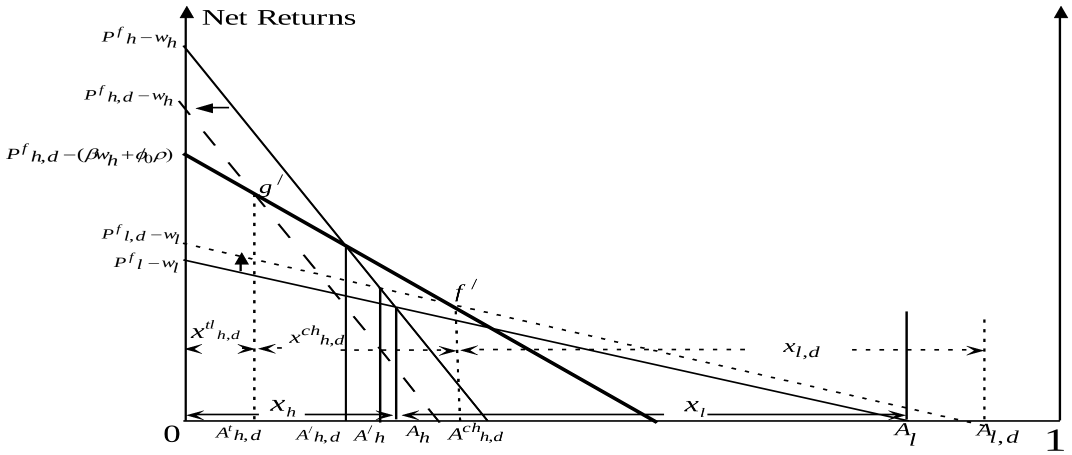

Figure 7. Effects of food adulteration on producers (Scenario 2 when the supply effect dominates the demand effect of food adulteration)

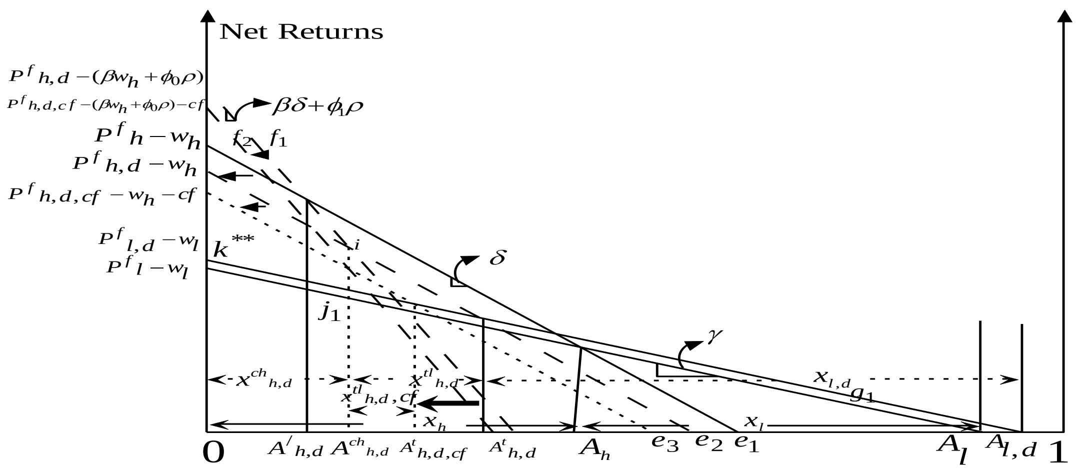

Figure 8.1. Effects of an increase in the certification cost on food adulteration (Scenario 1)

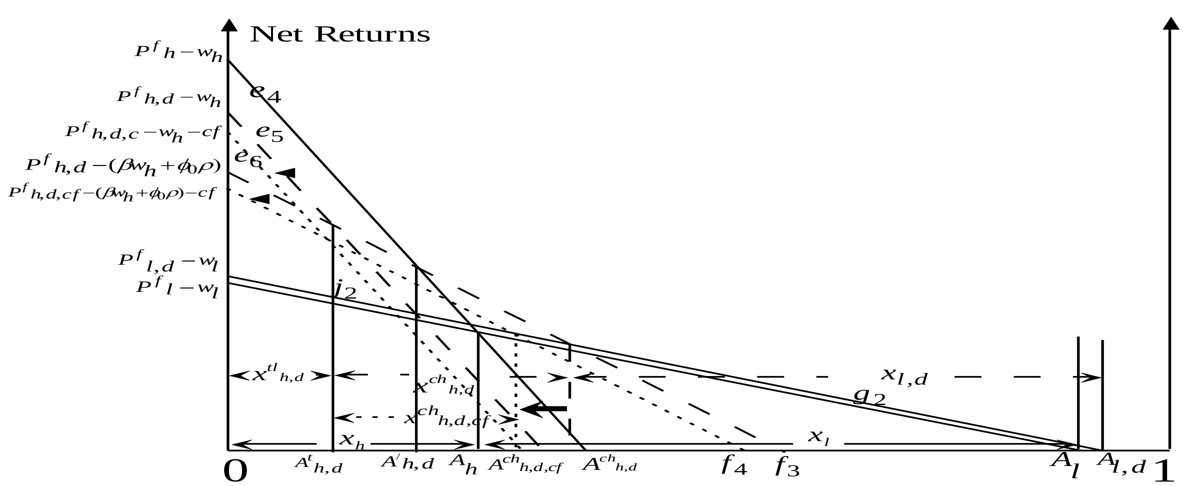

Figure 8.2. Effects of an increase in the certification cost on food adulteration (Scenario 2) when the supply effect dominates the demand effect of food adulteration

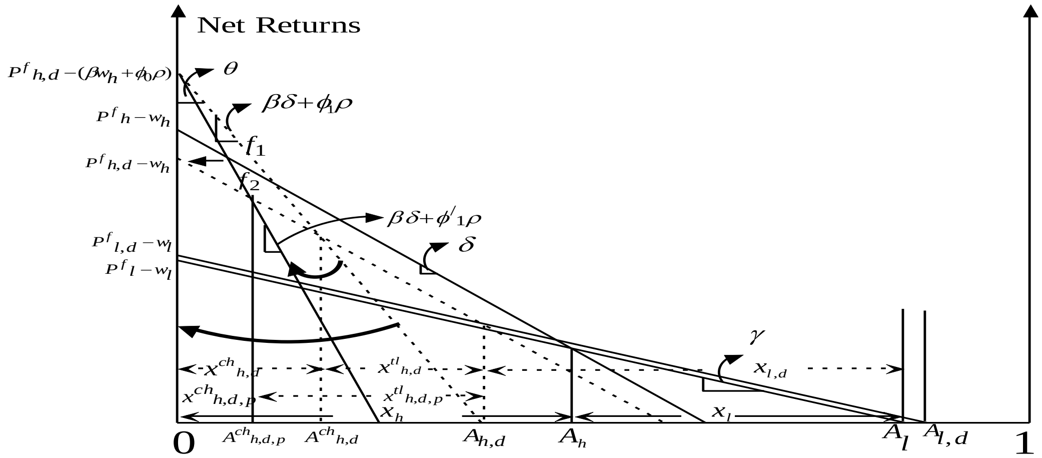

Figure 9.1. Effects of monitoring-punishing system when the most efficient producers commit fraud (scenario 1)

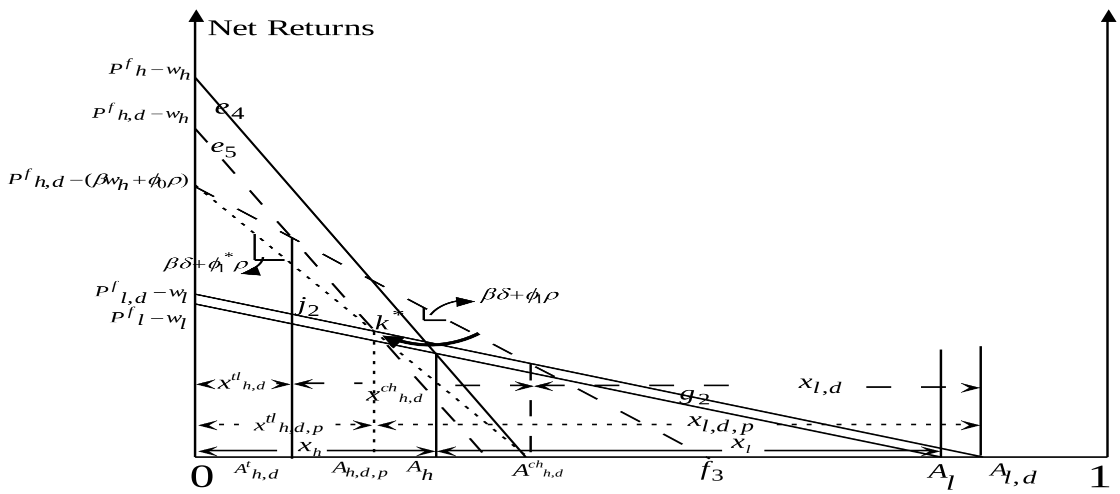

Figure 9.2. Effects of the monitoring-punishing system under scenario 2 when the supply effect dominates the demand effect of food adulteration

Notes

---

[1] Lack of strong deterrence is one of the major factors contributing to recent incidence of food fraud (Avery 2014).
[2] Traditionally, fraud in the agri-food marketing system results in lesser penalties than those imposed for other types of crime.
[3] The Chinese court ordered the execution of two individuals and sentenced nineteen others to prison terms over the Chinese milk scandal (Bristow 2009).
[4] Crime prevention approach focuses on reducing the motivation to commit crime. In other words, it refers to the array of strategies which are implemented by individuals, businesses, communities and government to target different social and environmental factors which increase the probability of crime (Morgan et al. 2011).
[5] w_h includes both the input cost and the certification cost. However, w_l does not include the certification cost.
[6] For simplicity of the model, it is assumed that the health cost of food adulteration is fixed.
[7] $(1-\beta)(w_h+\delta A)$ is the cost savings resulting from food adulteration.
[8] All these results hold irrespective of the relative magnitude of the demand and supply effect of food adulteration.

[9] Bonroy and Constantatos (2014) suggests that fraudulent behavior in the high-quality market can be reduced either through the positive certification cost or the monitoring-punishing system.
[10] Food traceability is a system which tracks any food throughout the supply chain, from farm to fork (Charlebois et al. 2014). Identity preservation (IP) is a system of production, processing, and distribution practices which maintains the purity of agricultural commodities (Sundstrom 2002).
[11] CS_d captures the welfare of both high and low-quality product consumers.
[12] $\psi = ns$, where the parameters n and s are the total number of producers and marginal cost of audit.
[13] The size of the b depends on the type of punishment. While $b > 1$ for imprisonment, torture, parole and probation, $b \approx 0$ for fines (Becker 1974).
[14] The costly certification will increase the price of the high-quality product by an amount less than the increase in the production cost of high-quality under the assumption that demand and supply are not completely inelastic and elastic, respectively (Bonroy and Constantatos 2014).
[15] When the certification cost is equal to the high-quality price premium, the net return curves associated with the production of high-quality and adulterated food intersect at the point k^{**}. Moreover, under scenario 1, when an increase in the certification cost is significantly high that the net return curves associated with the production of high-quality and adulterated food intersect at the point below j_1, the incidence of fraudulent behavior decreases. However, at this high certification cost, the honest high-quality producers have no incentive to produce high-quality product. Specifically, although there will be supply of product marketed as high-quality, the total supply of truthfully labeled high-quality product will be zero.
[16] Unless the certification cost is significantly high that the honest high-quality producers have no incentive to produce high-quality product.
[17] At this high certification cost, some honest high-quality producers find it optimal to produce low-quality product.
[18] See supplementary material.
[19]See appendix A1.
[20] In the presence of food adulteration, the product marketed as high-quality includes both the high-quality product and the adulterated product.
[21] The total number of dishonest producers is $A_{h,m}^{ch} - A_{h,d}^{ch}$ more under mislabeling. See appendix for detail.
[22] The optimal degree of enforcement refers the degree of enforcement at which food fraud can be completely deterred.
[23]These forms of corruption are common in countries with weak or absent democratic institutions (TI).
[24] The weight placed on the welfare of dishonest producers l_2 is significantly high that the marginal costs of enforcement exceeds the marginal benefits.
[25] When consumers have complete information that the corrupt government allows fraudulent behavior and the penalty is endogenous to the government, consumers will not pay the premium for the product marketed as high-quality and at the equilibrium, only the low-quality product is supplied to the market. On the other hand, when consumers have complete information that the corrupt government allows fraudulent behavior but the penalty is exogenous to the government, consumers perception about food fraud depends on the role of media as a watchdog. If consumers believe that the media is actively involved in detecting food fraud, the demand for high-quality product remains positive.
[26] Polinsky and Shavell (2001) first incorporates the possibility of corruption into the theory of optimal law enforcement.
[27] For example, when $\phi_0 = 0.05$, $\phi_1 = 0.05$, $A = 0.5$, $\tau = 0.5$, $\rho = \$1000$ and $B = \$500$; the expected penalty under food adulteration without bribery is \$300, while the expected penalty under food adulteration with bribery is \$75. Therefore, the difference between the expected penalty under food adulteration without and with bribery is \$225. Suppose, the government increases ϕ_1 to 0.10 and ρ to $\$1500$ but it does not control the corruption in the public enforcement agency i.e., the probability of collusion with the public enforcers remains the same. In this context, the difference between the expected penalty under food adulteration with and without bribery is \$300. Therefore, the incentive for producers to collude with the corrupted enforcers increases significantly when the government increases audit probability and/or penalty without taking sufficient measures to control the corruption in the public enforcement agency.