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Optimal Quality Inspections of Agricultural Foods in Farm-to-Consumer Direct Selling: Game-Based Approach

G. H. Han[1*], and K. J. Li[2]

ABSTRACT

Farm-to-Consumer Direct Selling (F2C) programs allow consumers to pre-order a share of a farm's produce so that the farmer benefits from guaranteed sales at a pre-agreed price, while the consumer benefits from receiving produce with a certain quality and the knowledge that they are supporting a local farmer. However, agricultural foods are a type of credence goods, and consumers have to trust that the supplied produce is indeed, as claimed, cultivated on the farm in accordance with the agreed cultivation practices, such as organic. In this study, we attempt to provide inspection bodies with a strategic inspection rate that respects the quality commitments of farms and examine how the inspection strategy influences consumers' benefits. We derive the equilibrium decisions of inspection bodies and farms based on a game model, using a closed-form analysis to develop the optimal inspection rate at which a farm maintains its commitment to food quality. Specifically, the inspection rate increases with food quality when the inspection cost is below a certain threshold. However, inspection bodies tend to dispense when the inspection cost exceeds a specified value. The consumer surplus in quality increases with the inspection rate when the inspection rate is below a certain threshold. However, when the inspection rate exceeds the threshold, additional inspections do not have marginal effects on consumer surplus in quality.

Keywords: Food quality, Inspection rate, Quality commitment.

INTRODUCTION

Modern agricultural practices have increased consumers' concerns regarding environmental awareness and the use of pesticides, and their residues in agricultural foods are normally perceived as unknown long-term harm to health. In the past 10 years, Short Food Supply Chains (SFSCs) have been developed in many countries where consumers purchase agricultural foods in local food systems (Fournier, 2018). Farm-to-Consumer direct selling (F2Cs) is one of the business models following SFSCs and has grown significantly. In the F2Cs business model, farms commit consumers a certain product quality on pre-orders and consumers obtain agricultural foods at harvest time (Cechin *et al.,* 2021). For consumers in local communities, farms typically commit to produce high-quality food with fewer pesticides; often using organic or biodynamic farming methods, and the farm has a guaranteed income (Aubert and Enjolras, 2017). Consumers who participate in F2Cs projects gain many benefits, including agricultural foods due to local delivery, the opportunity to experience open farm events, and committed production quality (Lacoste *et al.,* 2022). Thus, the recent trend of F2Cs reflects consumers' expectations for high-quality foods of original quality and safety (Deutsch *et al.,* 2013). F2Cs enable farms to

[1] School of International and Public Affairs, Shanghai JiaoTong University, 1954 Huahan Road, Shanghai 200030, P. R. China.

[2] School of International Relations and Public Affairs, Fudan University, 220 Hadan Road, Shanghai 200433, P. R. China.

*Corresponding author; e-mail: hanguanghua@sjtu.edu.cn

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obtain a fair share of their profits by eliminating intermediaries and adding a price premium. In the US market, F2Cs account for a significantly growing share of total agricultural food sales (Fournier, 2018). Approximately 19% of farms (14,308 farms) in California provided agricultural food directly to consumers by 2020 (USDA, 2022). By the end of 2015, approximately 1 million people in Europe obtained food directly through farms in F2Cs networks. Since the late 2000s, F2Cs farms have also developed rapidly in China, owing to a series of food safety scandals, and at least 200 F2C projects were launched in 2021 in Hainan Province, which is one of the smallest provinces in China. Some studies have suggested that COVID-19 demonstrated the vulnerability of supply chains and given rise to the prosperity of F2C farms (Chenarides *et al.,* 2021).

However, the quality of farm foods provided by F2C farms is vulnerable to severe information asymmetry (Hang *et al*., 2020). Agricultural food is a typical credence product with some qualities, such as the production method, that cannot be observed or ascertained by consumers; even during consumption. As a result, dishonest farms have a strong incentive to cheat consumers by claiming a high level of food quality and gaining high prices for selling low-quality food. For example, surveys in China have reported that some farms keep plots for familial food separate from those for supplies to consumers (Hansen, 2019). In familial food plots, farm owners produce high-quality agricultural foods by limiting the use of pesticides and fertilizers. However, they use excessive agrochemicals in other types of plots for good appearance and high productivity of agricultural foods. As price is one of the few possible indicators of non-observable quality for consumers, we find that price becomes a quality barometer for many consumers. For example, a restaurant patron may choose a more expensive option from a menu with the expectation that the quality will be higher than for a cheaper choice. In the case of F2C farms, consumers are willing to pay a premium for the unobservable quality attributes that are committed by the farmer. Given the potential for fraud in agriculture in which a premium is paid for non-observable attributes, surveillance through inspections hinders fraudulent behavior and is critically important in protecting consumers' willingness to pay when purchasing agricultural foods.

Although monitoring is deterrent, inspection authorities are sometimes ineffective and fail to prevent violations of produce quality. According to the quarterly enforcement report by the U.S. Department of Agriculture, 55% of the potential violations of organic regulations (470 farms) under investigation in the first quarter of 2022 were related to farms that were not certified but only produced products that they claimed to be organic (USDA 2022). Reports indicate that up to 7% of the so-called organic corn and 8% of the so-called organic soybeans grown in the US did not meet organic standards in 2016 (AP News, 2019).

Governments in many countries complete farm sampling at a fixed rate, which is unable to effectively deter speculative behavior. For example, the US FDA (Food and Drug Administration) mandates an inspection frequency of at least once every 5 years for non-high-risk farms and at least once every 3 years for high-risk farms (FDA, 2023). The same phenomenon was observed in China. The Shanghai Agricultural Authority completed the total number of annual samples based on a fixed ratio of 1.5 samples per thousand residents (MARA, 2023), where 20% of the samples were from small farms and 80% from other farms. Therefore, strategies to prevent fraudulent claims, such as through governmental inspection, are critically important (Liu *et al.,* 2021). At least three questions need to be answered in this context. First, how do farms determine food quality based on the intensity of government inspection rates? Second, what is the equilibrium inspection rate at which farms tend to deliver on a commitment? Third, how does the government determine the

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inspection rate given consumers' quality surplus and inspection cost? Finally, based on the answers of the above questions, we suggest government insights into inspecting the quality of farms' outputs.

MATERIALS AND METHODS

Agricultural Quality Management by Governmental Sample Inspection

The development of the F2C farm cannot be separated from the interaction and coordination between government-market-society. The farm of product customization, on which this study focuses, is a farm rooted in local community and provides consumers with customized services such as the adoption of green products and direct provision in the form of individual and group purchases. Farms cater to middle-class urban families, whose demand for quality of life is higher to enjoy more comfortable services and higher-quality products at a higher price. They adopt and personalize farm products as members of the farm of product customization. Thus, farms in F2Cs business model are a new type of local farming system that can provide local employment, foster rural social development, and generate potential social benefits. Since the ordered agricultural foods are high-quality and high-priced, farms in F2Cs business model have a strong incentive to reduce product quality to achieve greater profits. To benefit consumers, the government needs to oversee farms to ensure the quality of agricultural products through sampling inspection strategies. At the same time, the government should also recognize the potential social welfare farms provide to activate the market vitality of farms and provide robust policy support for farms. Figure 1 outlines the decisions of supply chain members.

The interaction process for stakeholders is shown in Figure 1. As crops are costly in terms of time and capital, farms in F2Cs provide opportunities to preorder the amount of agricultural food. The development of online implementations and cellphone applications helps farms publish the quality (q_F) of crops to potential consumers. Subsequently, customers browse the quality information provided by farms and place their pre-orders. Subsequently, the farm commits to providing agricultural products with consumer quality q. The government then inspects the agricultural products with probability γ to check whether they meet the committed quality requirements. The farm is fined if the quality of the agricultural food is lower than the committed level. Agricultural foods are transported directly from farms to consumers and the transaction is complete (Han *et al.*, 2023).

Based on the interaction between stakeholders of farms, we attempt to answer the following research questions: How should the government determine the sampling rate of agricultural products for farms in F2Cs? Should the government control the sampling rate within a specific range for the sake of social welfare (i.e., considering both the profits of the farm and the interests of consumers)? What factors affect the government's determination of the sampling rate of agricultural products? To address these issues, this study constructed a game model between the government and farms to study the optimal sampling strategy

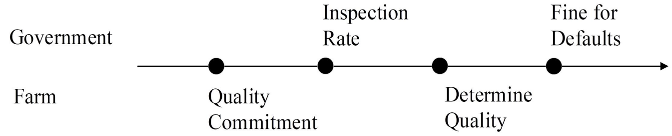

Figure 1. Sequence of events.

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of the government for farm products. To maximize social welfare, by combining game theory and data simulation, we strive to provide scientific policy suggestions for quality and safety regulation of agricultural products in farms.

The Stackelberg Game model is used to evaluate the interaction between the government and farms, in which the government is the leader of the Stackelberg game because of its authority, and the farm is the follower. The order of the game is as follows. First, the government sets the sampling rate of agricultural products. Second, farms determine the quality of their agricultural products. Referring to many studies based on game theory, we make some assumptions to build the Stackelberg Game in this study. Both the government and farms are rational decision-makers, and they aim to maximize their interests, that is, social welfare for governments and expected profits from farms. Modern agricultural trial data have been used to estimate the agricultural output (Sharifzadeh *et al.*, 2021; Malekhoseini *et al.*, 2019). For example, farms estimate yields based on within-season data (e.g., rainfall, temperature, management, and soil) and forecast demand using a variety of data (e.g., historical market data, preference trends, and food scandals). Similarly to some existing studies (Filippi *et al.,* 2019; Akbarpour *et al.*, 2014; Lotfi *et al.,* 2020), we assume the market demand is predictable (Equation 2) and the values of exogenous variables, that is, price of lands area (s), randomness of outputs (ε), and basic market Demand (D) are publicly known to decision makers.

Game Based Decision Models

A farm outputs agricultural products with cost *c* per acreage and the agricultural products' quality is denoted by *q*. If quality *q* is found to be less than the committed product quality q_F, fines (γ) are imposed by the government for each unit. Thus, the farm's profit function is formulated by Eq. 1 as follows:

$$\Pi_F = p\,min(D, \alpha s\varepsilon) - cs - \gamma(q_F - q)^+ s\beta \quad (1)$$

Where p is the selling price for each unit of agriculture products. β is the inspection rate of government beta is the inspection rate of government.

In Equation 1, the first item $p\,min(D, \alpha s\varepsilon)$ represents the sales income of the farm, the second item cs represents the cost of the farm to have quality$q$, and the third item $\gamma(q_F - q)^+ s\beta$ represents the penalty faced by the farm when it is randomly inspected. In many studies, the uncertainty of outputs is normally modeled as a proportional random yield (Yano and Lee, 1995). Referring to Peng *et al.* (2023) and Tang and Kouvelis (2011), we assume the agricultural production per acreage is random and formulated as $\alpha\varepsilon$, where α is the average output per acreage, and ε is a random variable. The value of α and distribution of ε are known to farms and the government. In addition, according to some studies (Zhai and Han, 2022; Hansen *et al.,* 2021), the relationship between the production input and the quality of agricultural products follows quadratic functions. Therefore, we assume the agricultural products' cost as $c = \theta q^2$, where parameter θ is a positive coefficient. The farm's decision-making variable is the quality of agricultural products. The market demand is directly related to the quality of the farm's produce and sales price p, and its sensitivity parameters are κ and λ. Referring to some previous studies (Hobbs and Pang, 2007; Liu *et al.,* 2021; Cárdenas-Barrón *et al.,* 2021), we formulate a linear market demand function as follows:

$$Demand = D_0 + \kappa q - \lambda p.$$

Since the quality of the farms' claimed product isq_F, the market demand is given by Equation (2).

$$D = D_0 + \kappa q_F - \lambda p \quad (2)$$

Consumer surplus is an economic measure of consumer benefits on the purchase value

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(Dubé and Misra 2023). Consumer surplus refers to the additional benefit the consumer pays less than the reference value they would like to pay (Wang *et al.,* 2022). The basic quality of agricultural foods that the farm provides is q, and the marginal surplus from purchasing the farm product is $q - q_0$. The total amount of agricultural products sold is $min(D, \alpha s\varepsilon)$, where D is the consumer's Demand, and $\alpha s\varepsilon$ is the output. The shaded area in Figure 2 depicts the consumer surplus on product quality.

We let D= 0 and have the value of q_0, i.e., $q_0 = \frac{\lambda p - D_0}{K}$. Meanwhile, we assume another parameter q_A which follows Equation (3).

$$q_A = \arg_q [(D_0 + \kappa q - \lambda p) = min(D, as\varepsilon)] \quad (3)$$

Consumer surplus-in-quality (CS) is thus formulated by Equation (4).

$$CS = \frac{1}{2}[(q_F - q_A) + (q_F - q_0)]\, min(D, as\varepsilon) \quad (4)$$

The government is the principal body of social governance, and its decision-making objective is to maximize social welfare. Schlee (2007) and Zhang and Choi (2021) suggested using linear functions to represent social welfare across supply chains. Thus, we focused on the partners in the target supply chain, including farms, consumers, and governments. The linear function of the government's social welfare function U_G can be formulated by Equation (5).

$$U_G = \phi\Pi_F + \varphi cs + \gamma(q_F - q)^+ s\beta - \gamma c_G s \quad (5)$$

The first term in Equation (5) represents the government's concern for farms. The second term formulates the government's concern for consumer interests. The third item is the penalty if the sampling inspection is not qualified, and the fourth item is the cost of sampling inspection (where γ is the sampling rate, c_G is the sampling cost per unit, s is the total planting area). The government's decision variable is the sampling rate γ. The coefficients of Φ and φ are positive, representing the government's concerns regarding the utility of farms' profits and consumer surplus. Thus, we have $\Phi + \varphi$=1, which serves as a constraint in the analysis.

RESULTS

Farm's Equilibrium Decisions

The government first determines the sampling rate according to the sequence of events, and the farm determines the production input based on the sampling rate. We first solve Eq. 1 by backward induction to obtain the farm's decision about quality q.

Proposition 1. Given a sampling rate γ, the farm's decision on the quality of agricultural foods is $q^* = min(q_F, \frac{\beta\gamma}{2\theta})$.

Proof. See appendix.

Proposition 1 shows that when the sampling rate is less than $\frac{2\theta q_F}{\beta}$, the actual

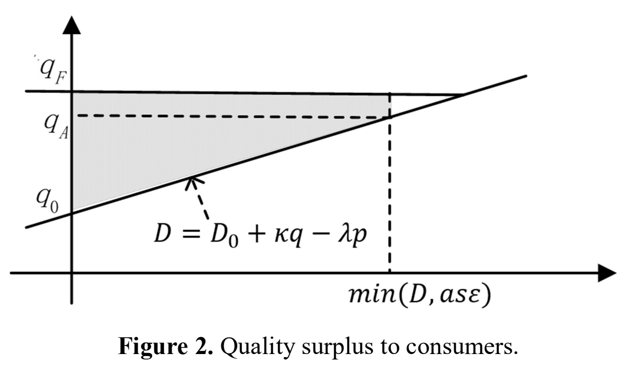

Figure 2. Quality surplus to consumers.

quality of the farm produce is lower than the committed quality. If the sampling rate was greater than $\frac{2\theta q_F}{\beta}$, the farm was planted according to the committed quality. Furthermore, we find that higher on-farm quality engagement represents a higher sampling rate. In other words, the higher the farm's commitment to quality, the greater the potential loss of surplus-in-quality. Failing to produce in line with the committed quality results in greater loss of consumer surplus. Second, without monitoring, firms have greater incentives to manufacture food for high profits. In this study, Corollary 1 was derived from the analysis of the specific impact of changing the sampling rate on the quality of agricultural foods.

Corollary 1. $\frac{\partial q^*}{\partial \gamma} = 0$ only if $\gamma \geq \frac{2\theta q_F}{\beta}$; $\frac{\partial q^*}{\partial \gamma} > 0$ only if $\gamma < \frac{2\theta q_F}{\beta}$.

Proof. See appendix.

As shown in Corollary 1, when the sampling rate is less than the threshold value $\frac{2\theta q_F}{\beta}$, the quality of farm products increases with the increase in sampling rate, which is closer to the committed quality. When the sampling rate was higher than the threshold value $\frac{2\theta q_F}{\beta}$, the farm would plant according to the committed quality, and the improvement of sampling rate do not lead to the improvement of agricultural product quality.

3.2 Government's Strategical Inspections Rate

The farm's decision on the quality of agricultural food is obtained by Proposition 1, and we then introduce the farm's decision q^* into the government's social welfare function (Equation 3). Finally, we obtain the government's decision γ^* in Proposition 2.

Proposition 2. The government's optimal sampling rate is

$$\gamma^* = min\{\frac{2\theta q_F}{\beta}, \left(\frac{2c_G s\theta - \beta(\varphi\, min(D, \alpha s\varepsilon) + 2(1-\emptyset)q_F s\theta)}{\beta^2(-2+\emptyset)s}\right)^+\}$$

.

Proof. See Appendix.

The farm works with more consumer involvement, resulting in strong producer-consumer relationships, and the core design develops cohesion with consumers' budgets to obtain quality food. This highlights that the quality of farms' agricultural foods increases consumers' willingness to pay. However, agricultural foods are credence goods, and consumers' knowledge about quality is only the farm's claim when they make deals ahead of the selling season. Governments' sampling checks, therefore, help identify immoral behavior against claims. Proposition 2 proposes three conditions for calculating the value of γ, indicating that the government's sampling rate depends on many exogenous social variables. In particular, government's optimal sampling rate is affected by farms' claimed quality q_F and fine rate β.

Farms are often motivated to overstate the quality of products to include more pre-orders. On the other hand, they have no intention of improving quality because quality of agricultural foods is unknown and unrecognizable to consumers. Since consumers enter into agreements with farms before the selling season, farms often claim to provide high-quality agricultural food, but in most cases, food quality is not measured. A game analysis of government and supply chain partners suggests that inspections benefit supply chains and society (Zhai and Han, 2022). However, the government has limitations in terms of human resources and budgets (Van Dooren *et al.,* 2012). Given the limited capacity for administrative enforcement, Proposition 2 suggests a strategic method for the government to develop food quality inspections.

Furthermore, we found that the optimal sampling rate is directly influenced and positively affected by the farm's committed quality q_F by corollary 2.

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Corollary 2. The farm keeps its claim q_F only if $q_F \le \frac{\beta\,\varphi\, min(D,\alpha s\varepsilon)-2c_G s\theta}{2\beta s\theta}$.

Proof. See appendix.

Farms strategically determine the quality of situation-respecting outputs to maximize expected profits. Corollary 2 states the condition under which the farm retains the commitment of production quality q_F. In the agricultural production phase. Since the threshold $\frac{\beta\,\varphi\, mi\ \ (D,\alpha s\varepsilon)-2c_G s\theta}{2\beta s\theta}$ increases with the government's fine β for unfilled commitments and decreases with the government's inspection cost c_G, Corollary 3 emphasizes that fine and inspection costs are direct and frequent implicit measures in regulation. For instance, the U.S. Congress permits a maximum penalty of \$ 11,000 per violation for adulterated organic agricultural products set by Congress (ECFR, 2022), while the regulatory framework, called the National Organic Program (NOP), carries out enforcement activities in a nationwide manner by supervising the violation of regulations and levying financial penalties. Corollary 2, however, suggests that there is an optimal portfolio for employing the measures in practice. Regional or national laws normally specify fines for violations of illegal activities as long as government or regulatory frameworks inspect firms and enforce laws.

According to the solutions of Scenario 2 (Table 1), we reduce $\frac{2c_G s\theta-\beta(\varphi\, min(D,\alpha s\varepsilon)+2(1-\emptyset)q_F s\theta)}{\beta^2(-2+\emptyset)s} \ge \frac{2\theta q_F}{\beta}$ in Scenario 2 (Table 1), and arrive at $\beta \ge \frac{2c_G s\theta}{\varphi\, min(D,\alpha s\varepsilon)+2q_F s\theta-4\theta q_F}$. Let $\beta^* = \frac{2c_G s\theta}{\varphi\, min(D,\alpha s\varepsilon)+2q_F s\theta-4\theta q_F}$; we have the relationships between the farm's optimal solution of q^* and government fines β towards unfilled commitments during inspection (Figure 3). Figure 3 suggests a threshold of fines β^* for the farms maintains their quality commitments q_F, indicating that the government enables the pre-estimation of the effectiveness of fines before deliberating on the amounts of fines.

Corollary 2 considers the circumstances under which farms tend to breach their commitments and provides the government appropriate inspection rates. At the same time, Corollary 3 also suggests the situations in which farms deliver on the commitment of output quality, to which condition government inspection is unnecessary and wastes regulatory resources.

Corollary 2 sheds light on farms' determinations of output quality, so the next question is how often government samples are due to farm behavior. The solutions of Proposition 2 imply that we have the government' optimal decisions about the

Table 1. Equilibrium solutions.

	Government's Inspection Rate γ^* Farm' Quality Decision q^*	Conditions
Scenario 1	$\gamma^*=0$ $q^*=0$	$\frac{2c_G s\theta-\beta(\varphi\, min(D,\alpha s\varepsilon)+2(1-\emptyset)q_F s\theta)}{\beta^2(-2+\emptyset)s} < 0$
Scenario 2	$\gamma^*=\frac{2\theta q_F}{\beta}$ $q^*=q_F$	$\frac{2c_G s\theta-\beta(\varphi\, min(D,\alpha s\varepsilon)+2(1-\emptyset)q_F s\theta)}{\beta^2(-2+\emptyset)s} \ge \frac{2\theta q_F}{\beta}$
Scenario 3	$\gamma^*=\frac{2c_G s\theta-\beta(\varphi\, min(D,\alpha s\varepsilon)+2(1-\emptyset)q_F s\theta)}{\beta^2(-2+\emptyset)s}$ $q^*=\frac{\beta\gamma^*}{2\theta}$	$0<\frac{2c_G s\theta-\beta(\varphi\, min(D,\alpha s\varepsilon)+2(1-\emptyset)q_F s\theta)}{\beta^2(-2+\emptyset)s}<\frac{2\theta q_F}{\beta}$

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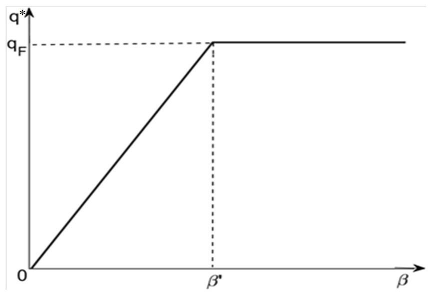

Figure 3. The relations between fine β and food quality q^*.

sample rate.

Corollary 3. [a] Government's sampling rate γ^* increases by q_F only if $c_G < \frac{\beta(min(D,\alpha s\varepsilon)\varphi+2s\theta q_F F-2s\theta\emptyset q_F)}{2s\theta}$. [b] Government does not take samples when the government sample cost $c_G \geq \frac{\beta(min(D,\alpha s\varepsilon)\varphi+2s\theta q_F-2s\theta\emptyset q_F)}{2s\theta}$.

Proof. See appendix.

Corollary 3[a] and Corollary 3[b] suggest the government's sample strategies by considering farms' decision preferences (in Corollary 2, Figure 4). Specifically, the government's authority does not sample to monitor the output quality only if the cost of sampling exceeds a threshold. According to Corollary 3[b], the threshold is positively affected by government officials' concerns regarding consumer surplus $\emptyset$. In other words, government who is more concerned about consumer surplus tends to incur a relatively high cost in monitoring the quality of agricultural outputs. Maslow's hierarchy of needs theory suggests that the top priority needs of many Highly Indebted Poor Countries (HIPCs) are food insecurity other than food quality.

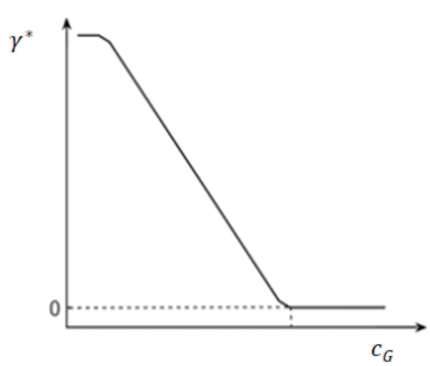

Figure 4. The relation between c_G and γ^*.

This helps to explain the difference in consumer surplus-of-quality concerns and, thus, different sample rates across administrative regions. The next issue is how much to sample, as long as government decides to collect samples to monitor the quality of agricultural foods. Proposition 2 suggests the decisions of the sample, while Corollary 3[a] highlights the relationship between the sample rate and farms' claimed quality. The government increases the sampling rate by the claimed quality only if the government decides to have the samples in its possession. These behavior patterns are compressive to farms, and they face a high risk of breaking their commitment of food quality. This is because consumers cannot measure the quality of agricultural foods, and farms have incentives to provide low-quality foods to fulfill orders. Solution for the optimal sample rate helps to constrain farms' immoral behavior.

Observations by Simulations

The analytical results explore farms' and government behaviors, equilibrium solutions, and managerial intuitions for strategy samples in different situations in Section 3. How do exogenous factors affect decisions? What is the role of consumer surplus and social welfare in influencing factor value? What is the impact of the sampling strategy on market demand, consumer surplus, and social welfare? Because it is computationally prohibited to suggest solutions, we devise simulations and present some observations. The initial parameter values are assumed to be as follows, $\theta = 1.5$, $\beta = 30$, $s = 50$, $c_G = 5$, $\emptyset = 0.6$, $q_F = 5$, $\varphi = 0.4$, $D_0 = 500$, $k = 30$, $\lambda = 7$, $p = 10$, $\varepsilon \sim N(300,20)$. We performed simulations as a result of the constraints $\Phi + \varphi$=1. First, we examine the effects of government

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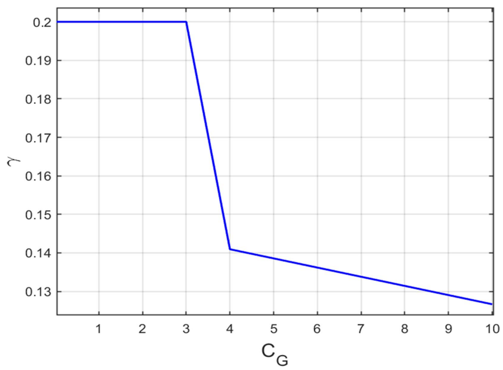

Figure 5. The influence of sampling cost on the sampling rate.

sample cost on the sample rate of government. Simulations suggest that the sampling rate both directly affects and decreases as a function of sampling cost (Figure 5). These results are straightforward and reflect the facts of many governmental practices. This sampling rate positively affects consumers' quality surplus (Figure 3), highlighting that government provides sufficient budgets to ensure inspection. Governments in many developed countries have sufficient budgets to conduct inspections. Developing countries, on the contrary, lack the capital to conduct an appropriate monitoring frequency. Covid-19 is exacerbated since 65% of poorer countries are cutting their budgets due to the onset of the pandemic (Word Bank, 2021). Figure 5 also suggests that the sampling rate is a constant value when the inspection cost is less than a threshold ($c_G \leq 3$ in Figure 5), which indicates that government allows a certain sampling rate to be maintained as long as the cost of sampling is less than the threshold.

Figure 6 illustrates the relationship between the sampling cost and consumer surplus on quality. We observe that consumers' surplus-in-quality is positively affected by the sampling rate below a certain threshold level, whereas it remains at a certain level when the sampling rate is greater than some threshold $\gamma = 0.5$. This observation indicates that farms maintain their quality commitment of $q^*=q_F$ and that the additional sampling rate is not beneficial for consumers' feed quality. As a result, unrestrained inputs sometimes indicate a potential budget waste, and this observation highlights the need for the government to pay particular attention to an optimal sampling rate. There is empirical evidence that wasteful government spending is a common problem in many areas, including street protests and wasteful government projects (Liebman and Mahoney 2017). Most importantly, the efficiency of government investments is often difficult to measure because profits, revenues, and the like cannot qualify outputs. Despite attempts by the government in many countries to reduce waste from budgets, it is difficult to estimate the volume of waste in the early stages. Given the low quality and wasteful expenditure, this study suggests a simple approach to estimating the optimal expenditure in administration and guiding the determination of the annual budget in inspections.

Given that the government makes sampling decisions to maximize total social welfare, its sampling rates are subject to their concerns about the interests of farms and consumers. In this study, we denote the government's concern about the farm's benefits as a variable φ and the concern about consumers' benefits as φ (Equation 5).

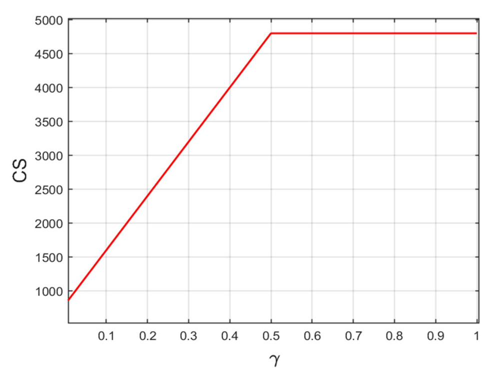

Figure 6. The influence of sampling rate on consumer quality surplus.

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Intuitively, the consumers' quality surplus increases due to the government's concern about consumers' benefits, but decreases due to the concerns about farm benefits. However, the consumer's quality surplus is independent of the government's concerns about both consumers and firms in certain situations ($0 \leq \Phi \leq 0.02$ or $0.981 \leq \Phi \leq 1$, Figure 7). When $0 \leq \Phi \leq 0.02$, the government does not conduct the inspection; thus, the farm outputs agricultural foods of basic quality. The consumer's surplus from quality is, therefore, independent of the government's inspection rate.

Meanwhile, the government has an inspection rate as high as $0.981 \leq \Phi \leq 1$ and the farm outputs agricultural foods with the claimed quality qf. Because of $\Phi + \varphi$ $=1$, we also find that consumer surplus from quality is independent of the government's concerns about firms' benefits to the extent that $0 \leq \varphi \leq 0.02$ and $0.981 \leq \varphi \leq 1$.

This observation sheds light on the fact that the government's concerns may not benefit consumers. However, consumers' surplus-in-quality is negatively affected by the government's concerns about consumers' interests in a quality surplus. Because food is a credence good, consumers cannot identify its quality, which calls for governments to pay more attention and concern to consumers' interests in quality surplus.

DISCUSSION

Often, the government accurately allocates inspection resources across many market entities in day-to-day work. In fact, the inspection budgets in many countries are inadequate for full inspections. As the wealthiest country in the world, the U.S. lacks sufficient budgets for Food and Drug Administration (FDA) regulations, leading to budget challenges, including using electronic data and implementing innovative and efficient trial designs. As of 2019, the FDA was down $855 million in funding, so, the life cycle of technological innovation had to create a logjam. As a result, the limited budget calls for government to align routine inspections considering situations in which strategic regulation suggests strategic methods of government to maximize social welfare. Thus, the government's inspection of agricultural food quality is essential for actuating farms to meet their food quality commitments. On the other hand, government strategic inspection rates depend on the government's knowledge of agricultural commitments (Proposal 2). This finding highlights the need for the government to construct a farm quality commitment database and requires the farm

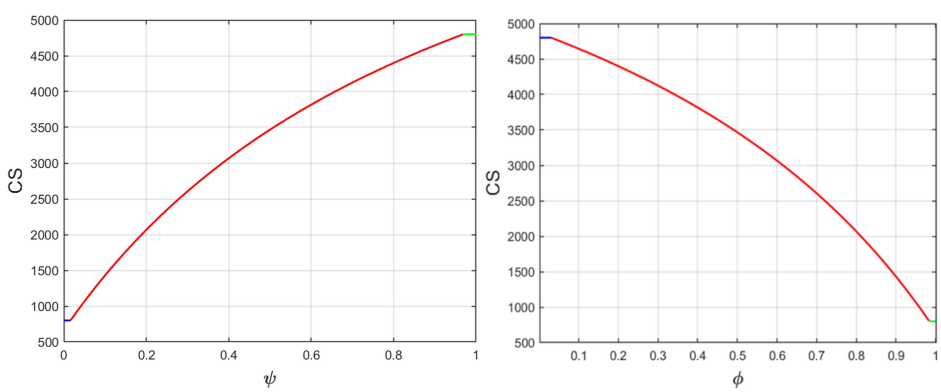

Figure 7. The influence of the government's concerns on consumers' and farms' interests on consumers' surplus-in-quality.

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to place food commitment in the database when they commit during the selling season.

Indeed, many countries have developed a basic database of farms (including land type, location, and products) to make it easier for the government to provide corresponding services to registered farms. Consequently, F2C farms can easily log into core data and report quality commitments. With government agencies facing thousands of farms, an inspection of the quality of agricultural products incurs enormous costs and enforcement resources. Therefore, the government must quit from inspection when the inspection cost exceeds a threshold (Corollary 3). In many countries, e-government services have been developed in the last few decades, and information technology has helped the government effectively complete market supervision. As a result, this study also suggests that government should employ information technology to conduct inspections at a low cost.

The game approach helps analyze the behavior of decision-makers and has been introduced in food safety inspection recently. For example, Rossiter and Hester (2017) examined how the test error of biosecurity inspection affects importers' decisions, that is, import or not. Song and Zhuang (2017) formulated games between the government, retailers, and farmers, indicating that collusion between farms and retailers reduces the effectiveness of quality inspection. Consumers' monitoring of food safety is important, and Lau *et al.* (2020) provided the payoff of a monitoring game between producers and consumers. Considering consumer monitoring costs, this study suggests that consumers tend to monitor the quality of organic foods. Industrial organizations have an advantage in food safety inspection, and an analysis based on a game theoretical model suggests an optimal inspection policy for traceable and untraceable products (Yao and Zhu, 2020). The existing studies have suggested solutions to the problems in quality inspection toward different business practices. Because of the challenges of food quality inspection in the new trend of the F2C business mode, this study employs a game model to explore the decision between the government and farms, suggesting the optimal inspection rate.

CONCLUSIONS

Farm-to-Consumer (F2C) direct selling, as a new form of business, not only has the characteristics of a shared economy but also contains the concept of manorial farming. To the best of our knowledge, few studies have explored the regulation of agricultural food quality in F2C direct selling. Therefore, this study aims to study and discuss measures of product inspection of farms by constructing a Stackelberg Game model between the government and farms, by considering farms' risks and social welfare.

According to the analysis of the relationship between the government and farms, we propose a strategic design of the government inspection rate for agricultural foods. However, this study has some limitations. First, we considered a one-period transaction between consumers and farms. In practice, consumers may pre-estimate food quality through credit on farms and update their perceptions of food quality in long-term transactions. Thus, it is also interesting to explore how consumers update their perceptions of farm food quality, and how consumers' perceptions affect farm quality decisions and government decisions on inspection. Second, we included the government and farms in the game model. Social organizations and media, for example, have also played a supervisory role in society recently. Extension research may include social organizations and media in the game model. Third, we did not consider the information sharing of governmental inspections. However, government information sharing on inspection quality affects consumer decisions in the long term. Therefore, future studies should explore how

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government information sharing affects equilibrium decisions and the corresponding inspection strategies.

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Appendix

Proof of Proposition 1.

The profit function of the farm is as follows:

$$\Pi_F = p\,min(D, \alpha s\varepsilon) - cs - r(q_F - q)^+ s\beta$$

The following classification discussion is conducted:

1) If $q \geq q_F$, then $(q_F - q)^+ = 0$. The profit function of the farm is:

$$\Pi_F = p\,min(D, \alpha s\varepsilon) - \theta Q^2 s$$

The first derivatization of Π_F with respect to the product quality q was calculated as follows:

$$\Pi_F{}' = -2\theta sq$$

Depending on the conditions, it can be concluded that:

$$\Pi_F{}' < 0$$

Therefore, $\Pi_F$decreases with product quality q. Therefore, the farm's profit π_f achieves its maximum value when q^*=q_F.

2) If $q < q_F$, then $(q_F - q)^+ = (q_F - q)$. The profit function of the farm is:

$$\Pi_F = p\,min(D, \alpha s\varepsilon) - \theta Q^2 s - \gamma(q_F - q)s\beta$$

The first derivation of Π_F with respect to product quality q is calculated π_f:

$$\Pi_F{}' = -2\theta sq + s\beta\gamma$$

The second derivation of Π_F with respect to product quality q can be calculated as follows:

$$\Pi_F{}'' = -2\theta s$$

Depending on the conditions, it can be concluded that:

$$\Pi_F{}'' < 0$$

The farms' expected profit is therefore convex on q. Thus, there is a maximum farm's profit when q^*=$\frac{\beta\gamma}{2\theta}$.

In summary, the farm's decision regarding product quality is as follows for a given sampling rate γ: $q^* = min(q_F, \frac{\beta\gamma}{2\theta})$.

□Proof ends.

Proof of Corollary 1.

Proposition 1 states that when the sampling rate is γ, the farm's product quality decision is

$q^* = min(q_F, \frac{\beta\gamma}{2\theta})$.

Accordingly, the following classification discussion is conducted.

If the sampling rate is $\gamma \geq \frac{2\theta q_F}{\beta}$,$q^* = q$, we have $\frac{\partial q^*}{\partial\gamma} = 0$. If the sampling rate is $\gamma < \frac{2\theta q_F}{\beta}$,$q^*$=$\frac{\beta\gamma}{2\theta}$, we have $\frac{\partial q^*}{\partial\gamma} = \frac{\beta}{2\theta} > 0$. To summarize the results, we have:

$$\begin{cases} \frac{\partial q^*}{\partial\gamma} = 0 & \gamma \geq \frac{2\theta q_F}{\beta} \\ \frac{\partial q^*}{\partial\gamma} > 0 & \gamma < \frac{2\theta q_F}{\beta} \end{cases}$$

□Proof ends.

Proof of Proposition 2.

Case 1. $\gamma \geq \frac{2\theta q_F}{\beta}$. When sampling rate $\gamma \geq \frac{2\theta q_F}{\beta}$, the optimal quality is $q^* = q_F$ by Proposition 1. We introduce q^* into the farm's and government's objective functions, and illustrate them as follows:

$$\Pi_F(q^*) = p\,min(D, \alpha s\varepsilon) - \theta q_F{}^2 s$$

$$U_G(q^*) = \phi\Pi_F{}^* + \varphi cs - \gamma c_G s$$

The first- and second-order derivations of $U_G{}^*$ with respect to the sampling rate γ were obtained as follows:

$$U_G{}' = -c_G s; U_G{}'' = 0$$

Thus, the government's utility U_G decreases with sampling rate γ. Because of $\gamma \geq \frac{2\theta q_F}{\beta}$, we have the optimal sampling rate $\gamma^* = \frac{2\theta q_F}{\beta}$ in case 1.

Case 2. $\gamma \leq \frac{2\theta q_F}{\beta}$. When $\gamma \leq \frac{2\theta q_F}{B}$, we have the farm's optimal solution $q^* = \frac{\beta\gamma}{2\theta}$. We introduce q^* into both the farm and the government's objective function as follows:

$$\Pi_F(q^*) = p\,min(D, \alpha s\varepsilon) - \theta\left(\frac{\beta\gamma}{2\theta}\right)^2 s - \gamma\left(q_F - \frac{\beta\gamma}{2\theta}\right)s\beta$$

$$U_G(q^*) = \phi\Pi_F{}^* + \varphi cs + \gamma(q_F - \frac{\beta\gamma}{2\theta})s\beta - \gamma c_G s$$

We then have the first- and second-order derivations of U_G by the sampling rate γ as follows:

$$U_G{}' = \frac{\beta^2(-2+\emptyset)\gamma s - 2c_G s\theta + \beta(\varphi\ min(D,\alpha s\varepsilon) - 2(-1+\emptyset)q_F s\theta)}{2\theta}$$

$$U_G{}'' = \frac{\beta^2(-2+\emptyset)s}{2\theta}$$

Because $\emptyset < 1$, we have $U_G{}'' < 0$. Thus, the government's social welfare function U_G is concave by γ. We let $U_G{}' = 0$, and have

$$\gamma = \frac{2c_G s\theta - \beta(\varphi\, min(D,\alpha s\varepsilon) - 2(-1+\emptyset)q_F s\theta)}{\beta^2(-2+\emptyset)s}$$

Thus, $U_G{}'$ have its maximum value when $\gamma = \frac{2c_G s\theta - \beta(\varphi\, min(D,\alpha s\varepsilon) - 2(-1+\emptyset)q_F s\theta)}{\beta^2(-2+\emptyset)s}$. Meanwhile, we have the constraint $\gamma \leq \frac{2\theta q_F}{\beta}$ in case 2 and γ is a non-negative value. Because $U_G{}'$ is concave by γ, we have the government's optimal sampling rate for maximum social welfare $\gamma^* = min(\frac{2\theta q_F}{\beta}, \left(\frac{2c_G s\theta - \beta(\varphi\, min(D,\alpha s\varepsilon) - 2(-1+\emptyset)q_F s\theta)}{\beta^2(-2+\emptyset)s}\right)^+)$.

□Proof ends.

Proof of Corollary 2.

If $c_G \geq \beta(q_F - \emptyset q_F + \frac{\Phi\ min(D,\alpha s\varepsilon)}{2S\theta})$, we have $\frac{2c_G s\theta - \ (\varphi\, min(D,\alpha s\varepsilon) + 2(1-\emptyset)q_F s\theta)}{\beta^2(-2+\emptyset)s} \leq 0$ and the government's sampling rate γ^* equals to zero based on proposition 2. Thus, we conclude that the government's sampling rate γ^* Is independent on q_f only if $c_G \geq \beta(q_F - \emptyset q_F + \frac{\Phi\ min(D,\alpha s\varepsilon)}{2S\theta})$.

In $c_G < \beta(q_F - \emptyset q_F + \frac{\Phi\ min(D,\alpha s\varepsilon)}{2S\theta})$, we find $\frac{2c_G s\theta - \beta(\varphi\, min(D,\alpha s\varepsilon) + 2(1-\emptyset)q_F s\theta)}{\beta^2(-2+\emptyset)S}$ is a positive value. Therefore, we have $\gamma^* = min\{\frac{2\theta q_F}{\beta}, \left(\frac{2c_G s\theta - \beta(\varphi\, min(D,\alpha s\varepsilon) + 2(1-\emptyset)q_F s\theta)}{\beta^2(-2+\emptyset)s}\right)\}$ at this condition. Because $0 < \emptyset < 1$, we have the terms $\frac{2c_G s\theta - \beta(\varphi\, min(D,\alpha s\varepsilon) + 2(1-\emptyset)q_F s\theta)}{\beta^2(-2+\emptyset)s}$ increase by q_F. Meanwhile, $\frac{2\theta q_F}{\beta}$ increased with q_F. We conclude that γ^* increases by q_F when $c_G < \beta(q_F - \emptyset q_F + \frac{(\Phi\, min(D,\alpha s\varepsilon))}{2S\theta}$.

□Proof ends.

Proof of Corollary 3[a]

Figure 2 shows the three equilibrium solutions with decision trees. Scenario 3 gives us the solution $\gamma^* = \frac{2c_G s\theta - \beta(\varphi\, min(D,\alpha s\varepsilon) + 2(1-\emptyset)q_F s\theta)}{\beta^2(-2+\emptyset)s}$ and $q^* = \frac{\beta\gamma^*}{2\theta} = \frac{2c_G s\theta - \beta(\varphi\, min(D,\alpha s\varepsilon) + 2(1-\emptyset)q_F s\theta)}{2\theta\beta(-2+\emptyset)s}$. Meanwhile, $\{\gamma^*, q_F\} = \{\frac{2\theta q_F}{\beta}, q_F\}$ in scenario 2. Both γ^* and q^* increased with q_F in scenarios 2 and 3. We also note that $\{\gamma^*, q^*\} = \{0,0\}$ in scenario 1, which indicates that γ^* and q^* are independent of q_F.

Proposition 2 shows that the solutions of equilibrium only fall into scenarios 2 or 3 only if $\frac{2c_G s\theta - \beta(\varphi\, min(D,\alpha s\varepsilon) - 2(-1+\emptyset)q_F s\theta)}{\beta^2(-2+\emptyset)s} > 0$ (denoted by t for expression convenience). Given by $\emptyset < 1$, we minimize t and have $c_G < \frac{\beta(\varphi\, min(D,\alpha s\varepsilon) + 2s\theta q_F - 2s\theta\emptyset q_F)}{2S\theta}$. Thus, we can conclude that both γ^* and q^*

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increase by q_F only if $c_G < \frac{\beta(\varphi\, min(D,\alpha s\varepsilon)+2S\theta q_F-2s\theta\emptyset q_F)}{2s\theta}$.

□Proof ends.

Proof of Corollary 3[b].

Proposition 1 states that the farm decides to maintain a commitment to quality $q^* = q_F$ only if $q_F \leq \frac{\beta\gamma}{2\theta}$. In order words, the farm keeps its commitment if $\gamma \geq \frac{2\theta q_F}{\beta}$.

Meanwhile, Proposition 2 indicate $\gamma^* \geq \frac{2\theta q_F}{B}$ only if $\frac{2c_G s\theta-\beta(\varphi\, min(D,\alpha s\varepsilon)-2(-1+\emptyset)q_F s\theta)}{\beta^2(-2+\emptyset)S} \geq \frac{2\theta q_F}{\beta}$. Thus, we reduce $\frac{2c_G S\theta-\beta(\varphi\, min(D,\alpha s\varepsilon)-2(-1+\emptyset)q_F s\theta)}{\beta^2(-2+\emptyset)S} \geq \frac{2\theta q_F}{\beta}$ and have $q_F \leq \frac{\beta\, \varphi\, min(D,\alpha s\varepsilon)-2c_G s\theta}{2\beta s\theta}$. Therefore, we have $q^* = q_F$ only if $q_F \leq \frac{\beta\varphi\, min(D,\alpha s\varepsilon)-2c_G s\theta}{2\beta s\theta}$.

□Proof ends.

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بازرسی کیفیت بهینه مواد غذایی کشاورزی در فروش مستقیم از مزرعه به مصرف کننده: رویکرد بازی-محور

گ. ه. هان، و ک. ج. لی

چکیده

برنامه‌های فروش مستقیم از مزرعه به مصرف‌کننده (F2C) به مصرف‌کنندگان این امکان را می‌دهد که بخشی از محصول مزرعه را از پیش‌سفارش کنند تا کشاورز از فروش تضمین‌شده با قیمت از پیش توافق شده بهره مند شود، در حالی که مصرف‌کننده با آگاهی از اینکه آنها از یک کشاورز محلی حمایت می کنند از دریافت محصول با کیفیت معین سود می‌برد. با این حال، غذاهای کشاورزی نوعی کالای معتبر (credence goods) هستند و مصرف‌کنندگان باید اعتماد کنند که محصولات دریافت‌شده، در واقع در مزرعه ،طبق تعهدات قبلی، با شیوه‌های کشت، مانند شیوه ارگانیک، کشت شده است. در این پژوهش، تلاش ما ارایه نرخ بازرسی استراتژیک برای سازمان‌های بازرسی است که به تعهدات کیفی مزارع احترام می‌گذارد. نیز بررسی می‌کنیم که چگونه استراتژی بازرسی بر منافع مصرف‌کنندگان تأثیر می‌گذارد. ما تصمیم‌های تعادلی سازمان های بازرسی و مزارع را برای دستیابی به نرخ بازرسی بهینه استخراج می‌کنیم که با استفاده از یک تحلیل فرم بسته (closed-form analysis) بر پایه یک مدل بازی (game model) است و در آن مزارع تعهد خود را به کیفیت غذا حفظ می‌کند. به طور مشخص، زمانی که هزینه بازرسی زیر یک آستانه مشخص باشد نرخ بازرسی با کیفیت غذا افزایش می یابد. با این حال، نهادهای بازرسی تمایل دارند زمانی که هزینه بازرسی از مقدار مشخص شده‌ای بیشتر شود، این کار را انجام دهند. زمانی که نرخ بازرسی زیر یک آستانه مشخص باشد، مازاد کیفیت مصرف کننده (consumer surplus in quality) با نرخ بازرسی افزایش می یابد. با این حال، زمانی که نرخ بازرسی از آستانه فراتر رود، بازرسی های اضافی اثرات حاشیه ای بر مازاد کیفیت مصرف کننده ندارد.

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