Welfare and Policy Analysis of Misperception on Food Quality

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Abstract: Focusing on information asymmetry, a model comprising consumers' and provider's decisions was built to analyze the behaviors of consumers and provider. The impacts on social welfare were also analyzed when misperception exists on food quality and the abilities in distinguishing the quality are different within consumers.

The numerical simulations reveal that, food provider will cheat in food quality to make profits, the social welfare will be decreased and consumers with better quality distinguishing ability will enjoy positive welfare gains when misperception exists. In such situation, the best policy to prevent provider from cheating consumers is to impose fines on unfaithful conducts instead of eliminating or off-shelf passively.

[Keywords]: Information Asymmetry, Misperception, Social Welfare Analysis, Food Quality

1. Introduction

Regarding market information asymmetry where consumers cannot identify product quality, two perspectives are commonly cited in economics to explain this phenomenon: First is the credence goods concept, which comes from Nelson (1970) and Darby and Karni's (1973) classification of products into search goods, experience goods, and credence goods based on different characteristics. The other is Lucas's (1968) misperception theory, which suggests that people often make incorrect decisions due to incomplete information collection or being overly subjective and confident.

In recent years, cognitive biases in consumer decision-making have received widespread attention. Taylor et al. (2024) in their study "Behavioral Economics in Consumer Decision-Making: Analyzing the Impact of Cognitive Biases" deeply explored how cognitive biases affect consumer behavior, particularly emphasizing the relationships between anchoring effects, availability heuristics, loss aversion, and consumer choices. Ruggeri et al. (2024)'s research "The persistence of cognitive biases in financial decisions across economic groups" investigated the rates of ten cognitive biases among individuals from different economic backgrounds, finding no significant differences in cognitive biases across groups, indicating that choices hindered by cognitive biases alone cannot explain upward economic mobility. Additionally, an article published in "Future Business Journal" discussed how cognition and emotion influence individual purchasing behavior and developed reliable and valid indicators for measuring impulsive buying behavior.

In terms of modeling consumer misperception, this paper builds upon Fulton and Giannakas (2004) and Wu Rongjie, Lai Chaohuang et al. (2007)'s market decision models under information asymmetry, further constructing a theoretical model to discuss market equilibrium under heterogeneous consumer settings where consumers develop misperceptions due to different abilities in identifying product quality. Meanwhile, through comparison with market equilibrium under complete information markets, it further discusses how consumer misperception phenomena affect social welfare distribution, while simulating the outcomes of eliminating information asymmetry and the intervention effects of different policies.

This paper is divided into four sections: besides this introductory section, the second section presents the theoretical model framework and comparative static analysis, using mathematical model derivation to describe the market equilibrium and economic implications of comparative static analysis. The third section provides numerical analysis of policy simulations under this theoretical model, through market scenario settings, comparing market welfare changes between complete and incomplete information markets, and further simulating the effects of three policies: removing substandard products from shelves, mandatory destruction, and imposing fines on manufacturers selling substandard products. The final section presents conclusions and policy recommendations.

2. Theoretical Model Design

This paper attempts to establish a two-commodity heterogeneous product market decision model, where a representative manufacturer is responsible for supplying high-quality (q_H) and low-quality (q_L) products to consumers. The low-quality product market is perfectly competitive, where manufacturers supply low-quality products at unit cost ($p_L = c_L$) ; however, in the high-quality product market, manufacturers have pricing power (p_H) , and due to consumers' incomplete information about product quality in the high-quality product market, manufacturers might sell mixed-quality products (q_m) containing a certain proportion of low-quality products as high-quality products to uninformed consumers. Individual consumers choose to purchase one unit of either high-quality or low-quality products under the manufacturer's set prices (p_L, p_H) and their "claimed quality" combinations (q_L, q_H) . Additionally, consumers have varying degrees of misperception regarding high-quality product quality. For simplification, the model assumes that manufacturers' procurement costs for high and low-quality products (c_L, c_H) are exogenous. Below, this paper explains the decision function design and market equilibrium solution for both consumers and manufacturers in this model.

2.1 Demand Side - Heterogeneous Consumer and Cognitive Misperception Settings

2.1.1 Utility Function of Heterogeneous Consumers

In setting up the demand side for heterogeneous consumers, this paper follows the utility function design for heterogeneous consumer preferences used in Tirole (1988), Ronnen (1991), Choi and Shin (1992), Ulrich (1997), Kirchhoff and Zago (2001), Fulton and Giannakas (2004) and other literature. Let there be N consumers, each consumer buys one unit of product from the market, and the utility function for consumer i consuming one unit of quality q product is:

$$U^i(a_i q, p_q) = a_i q - p_q, \quad a_i \in (a_{\mathrm{L}}, a_{\mathrm{H}}) \tag{1}$$

In equation (1), a_i represents the consumer's "quality preference coefficient" indicating their degree of preference for quality. The quality preference coefficient a_i for consumers' preference for a unit of product quality follows a uniform distribution of $a_i \in (a_L, a_H)$, with probability density function $g(a) = \dfrac{1}{a_H - a_L}$. Where $q = \{q_L, q_H\}$ represents the quality of that product, $p_q = \{p_L, p_H\}$ represents the unit price of low-quality or high-quality products. For consumer *i*, the utility from consuming one unit of product increases with product quality but decreases with price. However, the utility level increase from quality improvement varies by individual (depending on consumer's quality preference coefficient a_i).

2.1.2 Consumer Misperception Phenomenon in High-Quality Products

Due to consumers' incomplete ability to identify product quality, and the varying levels of identification ability among individuals, this paper defines the identification ability θ_i for the *i* th consumer in the product market as follows: consumers with identification ability θ_i can distinguish mixed quality products (q_m) with quality below $q_{\theta_i} = \theta_i q_H + (1-\theta_i) q_L$ from true high-quality products (quality of q_H), but cannot distinguish the difference between products with quality above q_{θ_i} and high-quality products.

In other words, consumers with identification ability of 1, can completely identify any mixed quality products between low-quality and high-quality products; consumers with identification ability of θ can identify any mixed quality (q_m) products with high-quality proportion (m) less than θ; while consumers with identification ability of 0 cannot distinguish between low-quality and high-quality products. However, due to the existence of misperception, every consumer believes their product quality identification ability is 1. Additionally, to facilitate theoretical and mathematical derivation, this paper assumes that consumers' ability to identify product quality is unrelated to their preference for quality.

For particular emphasis, to better describe this paper's assumption that each consumer has different identification abilities for high-quality product quality, which will result in different probabilities of discovering fake high-quality products when merchants sell mixed quality products as high-quality products, this paper further sets individual consumer's identification ability θ_i as a continuous distribution with probability density function $f(\theta)$.

In real life, people's sensitivity to product quality, such as taste perception and other sensory sensitivities, comes naturally from birth, varies among individuals, but most people fall in the middle range, with only a few having particularly acute or dull sensory abilities. In other words, the distribution of consumers' identification ability θi should be close to a normal distribution. However, considering that normal distribution is an unbounded continuous distribution that is not conducive to mathematical derivation, and given that this research needs to combine consumer identification ability θi with the proportion m of high-quality products in mixed quality products, this paper adopts the Epanechnikov distribution as the distribution function to describe consumers' identification ability θi in the market as shown in equation (2):

$$f(\theta) = 6[0.25 - (\theta - 0.5)^2] \quad , 0 \leqq \theta \leqq 1 \qquad (2)$$

Under this distribution, most consumers have a half-understanding of products, with most consumers' identification ability being moderate. Those with expert-level identification ability (approaching 1) and those with almost no knowledge (approaching 0) are in the minority, maintaining the spirit of normal distribution. Additionally, θ is between 0 and 1, consistent with this paper's design of consumer identification ability, and its bounded continuous distribution characteristics better meet the needs of theoretical derivation. The shape of the Epanechnikov function distribution is shown in Figure 1.

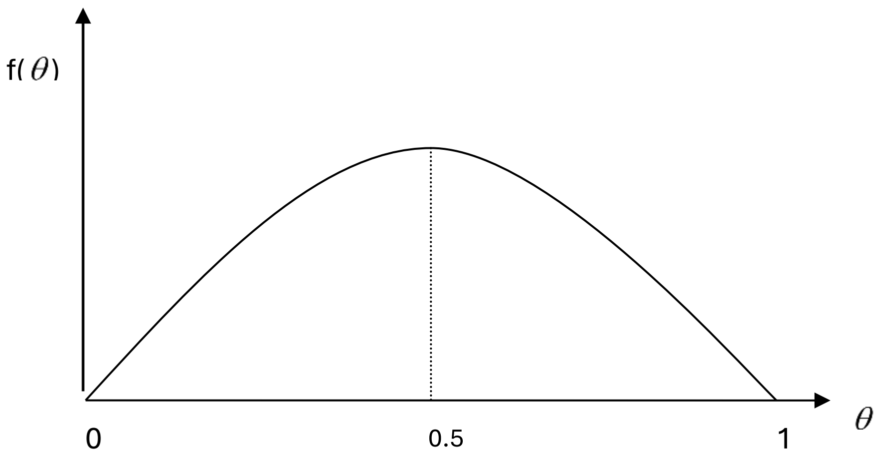

Figure 1 Distribution of All Consumers' Product Recognition

2.2 Supply Side - Seller Behavior Under Profit Maximization

The manufacturer claims to provide both high and low quality products, i.e., $q = \{q_L, q_H\}$ products in the market. Among these, the low-quality product market is a perfectly competitive market with complete information, meaning the price of low-quality products equals their unit cost（ $p_L = c_L$ ）. However, in the high-quality product market, the manufacturer is a price maker, and due to information asymmetry in the high-quality product market, consumers have misperceptions about high-quality product quality.

Therefore, in pursuing profit maximization, the manufacturer's decision factors include not only the price of high-quality products but can also involve fraud in high-quality product quality. For instance, the manufacturer might mix in a *1-m* proportion of low-quality products in one unit of claimed high-quality products. In other words, the fake high-quality product only has *m* proportion (pure degree of *m*) of high-quality product. Under no external intervention, this paper first assumes that suppliers will sell mixed quality products discovered by consumers at the low-quality product price p_L to those consumers. At this time, the manufacturer's decision function is as shown in equation (3):

$$\underset{p_H,m}{Max}\, E\pi = N_L(p_L - c_L) + N_H[F(m)(p_H - c_m) + (1 - F(m))(p_L - c_m)] \qquad (3)$$

In equation (3), N_L represents the number of consumers buying low-quality products, N_H represents the number of consumers buying high-quality products. m represents the concentration of high-quality products in mixed quality products. $q_m = mq_H + (1-m)q_L$ represents the true quality of one unit of mixed quality product, while $c_m = mc_H + (1-m)c_L$ represents the cost of one unit of mixed quality product.

Since this paper assumes that the price of low-quality products equals their unit cost, the first half of equation (3), $N_L(p_L - c_L) = 0$. In the latter half $N_H[F(m)(p_H - c_m) + (1 - F(m))(p_L - c_m)]$, $F(m)(p_H - c_m)$ represents the manufacturer's expected income from successfully selling mixed quality products as high-quality products to consumers. Since this paper assumes the probability density function of consumer identification ability θ_i is *f(θ)*, and when the manufacturer sells mixed quality products with high-quality content m as high-quality products, consumers with quality identification ability $\theta_i < m$ cannot detect the manufacturer's quality fraud. Therefore, the proportion of consumers unable to detect fake high-quality products is $F(m)=\int_0^m f(\theta)d\theta$. Similarly, $(1-F(m))(p_L-c_m)$ represents the manufacturer's expected income when their attempt to sell mixed quality products as high-quality products is detected by consumers. Additionally, when the expected profit from deception is lower than the profit without deception, the manufacturer can choose not to deceive consumers (*m=1*).

2.3 Market Supply and Demand Decision Model

Under the premises of consumers pursuing maximum utility and manufacturers pursuing maximum profit, based on the market supply and demand function settings from equations (1) and (3) above, this paper's constructed market decision model under consumer misperception of product quality is shown in equation (4):

$$\begin{cases} \text{Consumer Decision}: MaxU^i(a_i q, p_q)=a_i q-p_q, \quad a_i\in U(a_L,a_H) \\ \qquad s.t \quad \{(p_L,q_L),(p_H,q_H)\} \\ \text{Firm Decision}: \underset{p_H,m}{Max}\, E\pi = N_L(p_L-c_L)+N_H[F(m)(p_H-c_m)+(1-F(m))(p_L-c_m)] \\ \quad st.\mathrm{F}(m)=3m^2-2m^3, \quad 0\le m\le 1 \\ \qquad N_L=NG(ax), \quad N_H=N[1-G(ax)], \quad N=N_L+N_H \end{cases}$$

(4)

2.3.1 Consumer Purchase Decisions

In this paper's model (4), under the pursuit of maximum utility, consumers decide to purchase one unit of either high-quality or low-quality products based on the manufacturer's claimed high-quality and low-quality product prices. Moreover, individual consumers' preference for product quality a_i is $a_i\in(a_L,a_H)$, so each consumer will decide whether to purchase high-quality or low-quality products based on their own preference level (degree of emphasis) for product quality. Specifically, consumers with high quality preference coefficient a_i tend to purchase high-quality products at higher prices, while consumers with low quality preference coefficients tend to purchase cheaper low-quality products.

Because a_i is continuous, under given high and low-quality prices, there exists a quality preference coefficient *ax*. For consumers with quality preference coefficient *ax*, the welfare level (U_L) obtained from purchasing low-quality products at p_L equals the welfare level (U_H) obtained from purchasing high-quality products at p_H . Given its special economic implications, this paper refers to consumers with this quality preference coefficient *ax* as "boundary consumers."

The value of the boundary consumer's quality preference coefficient *ax* can be obtained by setting equal utilities when substituting high and low quality and price combinations into the utility function, resulting in the boundary consumer's quality preference coefficient being $ax = \frac{p_H - p_L}{q_H - q_L}$. The derivation process for *ax* is as follows:

$$
\begin{aligned}
& U_L = a_i q_L + Y - p_L = a_j q_H + Y - p_H = U_H \\
& \text{令} a_i = a_j = ax \\
& \Rightarrow ax(q_H - q_L) = p_H - p_L \\
& \Rightarrow ax = \frac{p_H - p_L}{q_H - q_L}
\end{aligned}
$$

Consumer purchase decisions can be explained using Figure 2: In Figure 2, under fixed high and low-quality product prices, consumers with quality preference coefficient a_i lower than *ax* will choose to purchase low-quality products at p_L , while consumers with quality preference coefficients higher than *ax* will purchase high-quality products at p_H . The dotted line represents the consumer welfare level after purchasing one unit of product at market equilibrium for consumers with quality preference coefficient a_i. As shown in Figure 2, for consumers with quality preference coefficient a_i. lower than *ax* (left of *ax*), their consumer welfare level is $U_L = a_i q_L - p_L$, while for consumers with quality preference coefficient a_i higher than *ax* (right of *ax*), their consumer welfare level is $U_H = a_i q_H - p_H$.

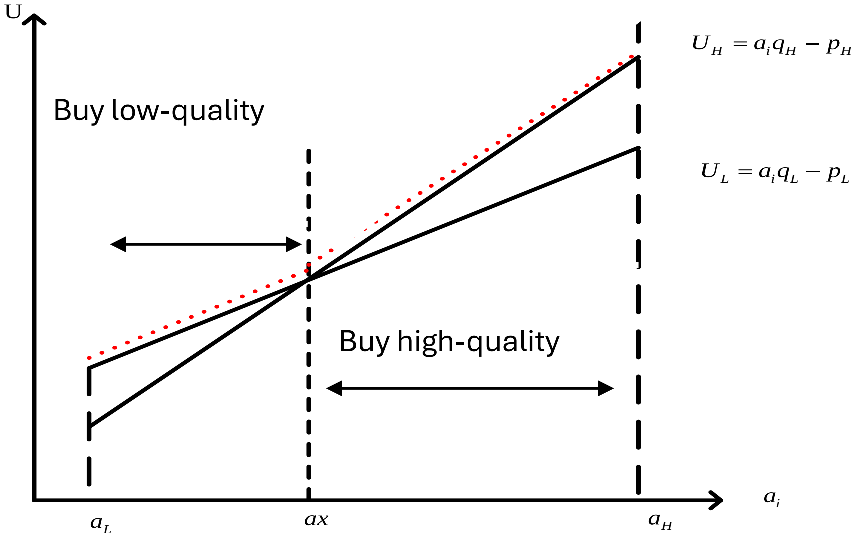

Figure 3 Consumer Purchase Decision

Since this model sets consumers' quality preference coefficient as a uniform distribution of $a_i \in (a_L, a_H)$, with probability density function $g(a) = \dfrac{1}{a_H - a_L}$, we can obtain that among N consumers, an expected value of N_H consumers will choose to purchase high-quality products, while an expected value of N_L consumers will choose to purchase low-quality products. Here, N_H and N_L are shown in equations (5) and (6) respectively:

$$N_H = N \int_{a_x}^{a_H} g(a)da = N[1 - G(ax)] \tag{5}$$

$$N_L = N \int_{a_L}^{ax} g(a)da = NG(ax) = N - N_H \tag{6}$$

2.3.2 Seller's Decision

Substituting the consumer's decision ($ax = \dfrac{p_H - p_L}{q_H - q_L}$) into the manufacturer's profit function, we obtain equation (7):

$$E\pi = NG(ax)(p_L - c_L) + N(1 - G(ax))[F(m)(p_H - c_m) + (1 - F(m))(p_L - c_m)] \quad (7)$$

Under the manufacturer's pursuit of profit maximization, solving the first-order conditions $\frac{\partial E\pi}{\partial p_H} = 0$ and $\frac{\partial E\pi}{\partial m} = 0$, while satisfying the second-order conditions $\frac{\partial^2 E\pi}{\partial {p_H}^2} < 0$ and $\frac{\partial^2 E\pi}{\partial m^2} < 0$, we obtain the system of simultaneous first-order equations for profit maximization as shown in equation (8):

$$\begin{cases} \frac{\partial \pi}{\partial p_H} = N\{g(\hat{a})\frac{\partial \hat{a}}{\partial p_H}(p_L - c_L) - g(\hat{a})\frac{\partial \hat{a}}{\partial p_H}[F(m)(p_H - c_m) + (1 - F(m))(p_L - c_m)] \\ \qquad + (1 - G(\hat{a}))F(m)\} = 0 \\ \frac{\partial \pi}{\partial m} = N(1 - G(\hat{a}))[f(m)(p_H - c_m) + F(m)(c_L - c_H) - f(m)(p_L - c_m) + (1 - F(m))(c_L - c_H)] = 0 \end{cases} \quad (8)$$

2.3.3 Market Equilibrium Solution

After solving the simultaneous equations in equation (8), we obtain the manufacturer's optimal pricing p_H^* and the claimed high-quality product's true high-quality product purity m^* in the high-quality product market as:

$$p_H^* = \frac{-a_H(q_H - q_L)(15c_L + \sqrt{3}\sqrt{a_H(q_H - q_L)[8c_H - 8c_L + 3a_H(q_H - q_L)]}) - 3a_H^2(q_H - q_L)^2 + \sqrt{3}\sqrt{a_H(q_H - q_L)[8c_H - 8c_L + 3a_H(q_H - q_L)]}}{\sqrt{3}\sqrt{a_H(q_H - q_L)[8c_H - 8c_L + 3a_H(q_H - q_L)]} - 15(q_H - q_L)}$$

$$m^* = \frac{5}{4} - \frac{\sqrt{a_H(q_H - q_L)[8c_H - 8c_L + 3a_H(q_H - q_L)]}}{4\sqrt{3}a_H(q_H - q_L)}$$

At this time, the manufacturer's expected profit Eπ is:

$$E\pi = \frac{N}{72(a_H - a_L)(q_H - q_L)}[-8c_H + 8c_L + 3a_H(q_H - q_L) + \sqrt{3}\sqrt{a_H(q_H - q_L)[8c_H - 8c_L + 3a_H(q_H - q_L)]}]$$

And the boundary consumer's quality preference coefficient ax is:

$$ax = \frac{a_H[3a_H(q_H - q_L) + \sqrt{3}\sqrt{a_H(q_H - q_L)[8c_H - 8c_L + 33a_H(q_H - q_L)]}]}{15a_H(q_H - q_L) - \sqrt{3}\sqrt{a_H(q_H - q_L)[8c_H - 8c_L + 33a_H(q_H - q_L)]}}$$

Substituting ax into equation (5), we can obtain the number of consumers who will purchase high-quality products in the market:

$$N_H = \frac{2Na_H[6a_H(q_H-q_L)-\sqrt{3}\sqrt{a_H(q_H-q_L)[8c_H-8c_L+33a_H(q_H-q_L)]}]}{(a_H-a_L)[15a_H(q_H-q_L)-\sqrt{3}\sqrt{a_H(q_H-q_L)[8c_H-8c_L+33a_H(q_H-q_L)]}]}$$

Similarly, substituting ax into equation (6), we can obtain the number of consumers who will purchase low-quality products:

$$N_L = \frac{N[3a_H(a_H-5a_L)(q_H-q_L)+\sqrt{3}(a_H+a_L)\sqrt{a_H(q_H-q_L)[8c_H-8c_L+33a_H(q_H-q_L)]}]}{(a_H-a_L)[15a_H(q_H-q_L)-\sqrt{3}\sqrt{a_H(q_H-q_L)[8c_H-8c_L+33a_H(q_H-q_L)]}]}$$

It's worth mentioning that in the above model, if we set the mixed quality product's high-quality product ratio $m^*=1$ in equation (8), this model becomes a monopolistic pricing model under complete information. At this time, the manufacturer's optimal pricing is $p_H=\frac{1}{2}[c_H-c_L+a_H(q_H-q_L)]$, and its monopoly profit is $\pi=\dfrac{N[c_H-c_L+a_H(q_H-q_L)]^2}{4(a_H-a_L)(q_H-q_L)}$.

Similarly, if we set $p_H=c_H$, then this model becomes a deception decision model in an asymmetric information competitive market. At this time, the manufacturer's optimal deception strategy is to sell products with purity $m^*=\dfrac{1}{6}(3+\sqrt{3})\to 0.788675$ as high-quality products, and about $F(0.788675)=88.49$ % of consumers in the high-quality product market are deceived. At this time, the manufacturer's expected profit is $E\pi=\dfrac{n(c_H-c_L)[-c_H+c_L+a_H(q_H-q_L)]}{6\sqrt{3}(a_H-a_L)(q_H-q_L)}$.

The equilibrium solution discussed in this paper for manufacturer deception in the high-quality product market must satisfy the following two propositions:

Proposition 1: When the manufacturer adopts a deception strategy $\pi^{asy}(p_H^*,m^*)$ asy in the high-quality product market, its mixed ratio satisfies $\dfrac{1}{2}<m^*<1$ 。

Proof: Under the first-order condition, $m^*=\dfrac{1}{2}\pm\dfrac{\sqrt{3}\sqrt{(3p_H-2c_H+c_L)(p_H-c_L)}}{6(p_H-c_L)}$, Then, at the optimal price p_H, there will be two m^* , but considering the

$F(m^*)(p_H^* - c_{m^*}) + (1-F(m^*))(p_L^* - c_{m^*})$ part in equation (3), one can see that the first half is beneficial to manufacturer profit, so the manufacturer's decision should be in the $F(m^*) > (1-F(m^*)$ portion, that is, $\frac{1}{2} < m^* < 1$, thus proving the proposition. ◦

Proposition 2: When the manufacturer adopts deception behavior in the high-quality product market（$m^* < 1$）, the seller's expected profit（π^{asy}）must be higher than the profit without deception π^m under complete information.

Proof: Under the model's basic assumptions, the manufacturer's behavior is to maximize profit, so if there exists a decision combination（p_H^*, m^*）that makes $\pi^{asy}(p_H^*, m^*) > \pi^m(p_H^{'}, 1)$, the manufacturer will adopt the deception strategy, thus proving the proposition.

Therefore, when propositions one and two hold, we can obtain the manufacturer's optimal decision combination（p_H^*, m^*）under consumer product quality information asymmetry as:

$$p_H^* = \frac{-a_H(q_H-q_L)(15c_L+\sqrt{3}\sqrt{a_H(q_H-q_L)[8c_H-8c_L+3a_H(q_H-q_L)]})-3a_H^2(q_H-q_L)^2+\sqrt{3}\sqrt{a_H(q_H-q_L)[8c_H-8c_L+3a_H(q_H-q_L)]}}{\sqrt{3}\sqrt{a_H(q_H-q_L)[8c_H-8c_L+3a_H(q_H-q_L)]}-15(q_H-q_L)}$$

$$m^* = \frac{5}{4} - \frac{\sqrt{a_H(q_H-q_L)[8c_H-8c_L+3a_H(q_H-q_L)]}}{4\sqrt{3}a_H(q_H-q_L)}$$

And the following lemmas 1, 2 and 3[1]:

Lemma 1 $3a_H(q_H-q_L) < \sqrt{3}\sqrt{a_H(q_H-q_L)[8c_H-8c_L+3a_H(q_H-q_L)]} < 6a_H(q_H-q_L)$

Lemma 2 $8c_H - 8c_L < 9a_H(q_H-q_L)$

Lemma 3 $(8c_H-8c_L)-3a_H(q_H-q_L) < \sqrt{3}\sqrt{a_H(q_H-q_L)[8c_H-8c_L+3a_H(q_H-q_L)]}$

Furthermore, from lemmas 1 and 3, we can obtain lemma 4:

Lemma 4 $(4c_H-4c_L) < \sqrt{3}\sqrt{a_H(q_H-q_L)[8c_H-8c_L+3a_H(q_H-q_L)]}$

Through the above propositions and lemmas, this paper can further discuss the comparative static analysis results of this theoretical model as shown in Table 1[1] ◦ In Table 1, the rows from top to bottom sequentially represent the costs of high and low-quality products; the quality of high and low-quality products (technological progress) and the upper and lower limits of quality preference coefficients (consumer perception of products) and other exogenous variables. The columns represent important endogenous variables, from left to right sequentially representing manufacturer profit, product prices in the high-quality market, the proportion of true high-quality products in what the manufacturer claims as high-quality products, and the number of consumers purchasing high and low-quality products at market equilibrium. The symbol "+" represents a positive correlation between changes in exogenous and endogenous variables, "-" represents a negative correlation, while "0" represents no effect from exogenous variable changes on endogenous variables.

Table 1: Summary of Model Comparative Static Analysis Results

Exogenous Variables	Key Endogenous Variables				
	Firm Profit	Firm Profit	Firm Profit	Firm Profit	Firm Profit
Change in High-Quality Product Cost	−	+	−	−	+
Change in Low-Quality Product Cost	+	+	+	+	−
Change in High-Quality Product Demand	+	+	+	+	−
Change in Low-Quality Product Demand	−	−	−	−	+
Change in Upper Limit of Quality Preference Coefficient	+	+	+	+	−
Change in Lower Limit of Quality Preference Coefficient	+	**0**	**0**	+	−

Note: The symbols **"+"** indicate a positive change, **"-"** indicate a negative change, and **"0"** indicates no impact.

The impact of variables moves in the same direction. A "−" indicates a negative relationship, meaning the variables move in opposite directions. A "0" signifies that changes in exogenous variables have no effect on the endogenous variable.

[1] For relevant documentation, please refer to Appendix II.

2.4 Welfare Analysis

In this section, consumers in the market for high-quality products can be further divided into two types: deceived and non-deceived. A more nuanced analysis of market welfare is as follows:

In an information asymmetry market where consumers have a false perception of product quality, the welfare of product suppliers (provider's welfare) is $PW = E\pi(p_H^*, m^*) = N(1-G(ax))[F(m^*)(p_H^* - c_{m^*}) + (1-F(m^*))(p_L - c_{m^*})]$.

Consumer welfare in the market for low-quality products is

$$CW_L = N\int_{a_L}^{ax}(aq_L - p_L)g(a)da$$

.

In the high-quality market, consumer welfare can be divided into two types: deceived consumers and discerning connoisseurs who recognize and reject manufacturers' deceptive practices.

i. Deceived Consumers：

Real Utility: $CW^R{}_{Hmis} = F(m^*)N\int_{a_x}^{a_H}(aq_{m^*} - p_H)g(a)da$

Illusory Utility: $CW^{UR}{}_{Hmis} = F(m^*)N\int_{a_x}^{a_H}(aq_H - p_H)g(a)da$

Unrealized Utility Loss: $Loss^{UR} = CW^{UR}{}_{Hmis} - CW^R{}_{Hmis} = F(m^*)N\int_{a_x}^{a_H}[a(q_H - q_{m^*}) - p_H]g(a)da$

ii. The connoisseur of discerning high-quality products, who can see through manufacturers' deceptive claims, expects a standard of consumer benefits:

$$CW_{Hspr} = (1-F(m^*))N\int_{a_x}^{a_H}(aq_{m^*} - p_L)g(a)da$$

The total market welfare can be obtained by summing the producer and consumer welfare mentioned above as SW^R, and is

$$SW^{R} = PW + CW_{L} + CW_{Hmis}^{R} + CW_{Hspr}$$

If consumers are completely unaware of being deceived (due to the existence of an illusion effect), and in this case, when consumers do not perceive any loss, and businesses gain illegal benefits, the overall market welfare will be greater than in a situation with full information, that is

$$SW^{UR} = PW + CW_{L} + CW_{Hmis}^{UR} + CW_{Hspr} > SW^{R}.$$

Since market welfare analysis requires further data calculations, this paper will, in the next section, analyze the differences in market equilibrium and welfare distribution between two scenarios through numerical analysis. This will facilitate the assessment of how an information asymmetry market, set up under consumer misperception, compares to a market with full information, and the resulting unnecessary losses. Additionally, it will further evaluate the effectiveness and drawbacks of three policies: 1) mandatory removal of substandard products, 2) forced destruction of substandard products, and 3) penalties for unethical manufacturers.

3. Analysis of Market Welfare and Policy Intervention Effects

In this section, a set of external variables are proposed to simulate the market environment, using the equilibrium solution of market decision model (9). This section will first provide a detailed data analysis of market equilibrium and welfare distribution under conditions of complete and asymmetric information. Then, within the same context, the effects and advantages/disadvantages of three policies—mandatory removal of fraudulent products, forced destruction of fraudulent products, and imposing fines on dishonest manufacturers—will be further discussed.

$$\begin{cases} \text{消費者決策：} Max U^{i}(a_i q, p_q) = a_i q - p_q \\ \qquad s.t \ \ \{(p_L, q_L), (p_H, q_H)\}, \ \ a_i \in U(a_L, a_H) \\ \text{廠商決策：} \underset{p_H, m}{Max}\, E\pi = N_L(p_L - c_L) + N_H[F(m)(p_H - c_m) + (1 - F(m))(p_L - c_m)] \\ st.\mathrm{F}(m) = 3m^2 - 2m^3, \ \ 0 \le m \le 1 \\ \qquad N_L = NG(ax), \ \ N_H = N[1 - G(ax)], \ \ N = N_L + N_H \end{cases}$$

（9）

In terms of scenario settings, this paper sets the market to have *N=100* consumers, with their quality preference coefficients $a_i \in U(1,100)$. The low-quality product has a quality value of $q_L = 0.1$ ， and a unit cost of 10. The high-quality product has a quality value of $q_H = 1$ ， and a unit cost of 50. Additionally, to make the numerical analysis results more accessible to readers, this paper slightly adjusts the consumer utility function without affecting the model structure and conclusions during numerical analysis to:

$$U_i = 10 + a_i q - p_q$$

as shown in equation (9).

3.1 Analysis of Market Equilibrium under Complete and Asymmetric Information

In a complete information market environment, consumers know the true quality information of products and are not affected by misperception phenomena. Therefore, the market environment is equivalent to a monopoly market under complete information. Consequently, the market equilibrium and welfare analysis under complete and asymmetric information are shown in Table 2.

From Table 2, we can see that in a complete information market, the manufacturer provides 71.94 units of low-quality products and 28.06 units of high-quality products, with high-quality products priced at approximately 75. At this time, about 28 people choose to purchase low-quality products, and about 72 people choose to purchase high-quality products. In terms of market welfare distribution, the manufacturer enjoys an excess profit of about 701, consumer welfare in the low-quality market is about 263.386, with average consumer welfare of 3.661 per person; while consumer welfare in the high-quality market is about 592.34, averaging 21.111 per person; total consumer welfare is 855.73, and overall market welfare is approximately 1557.19.

In a market with consumer misperception and information asymmetry, the manufacturer provides 70.0699 units of low-quality products and 29.9301 units of high-quality products. The manufacturer engages in quality fraud, with high-quality products having only about 88% purity (quality of 0.8924), priced at 73.33. At this time, about 70.07% of consumers choose to purchase low-quality products, while about 29.93% choose to purchase high-quality products. Among consumers buying high-quality products, approximately 28.75 will be deceived, with only 1.18% of consumers able to avoid deception and benefit.

Table 2: Summary of Numerical Simulation Results under Complete and Incomplete Market Information

	Complete Information Market	Complete Information Market
Independent Firm Decision $\{p_H^*, m^*, (q_{m^*})\}$	{75, 1 ,（1）}	{73.3323, 0.880441,（0.892379）}
Supply Quantity (Low Quality, Fake High Quality)	（71.9416, 28.0584）	（70.0699, 29.9301）
EPS (Expected Firm Profit)	701.459	766.666
$\{ECS_L, EN_L, \frac{ECS_L}{EN_L}\}$	{263.386, 71.9416, 3.6611}	{250.042, 70.0699, 3.56846}
$\{ECS_{Hspr}, EN_{Hspr}, \frac{ECS_{Hspr}}{EN_{Hspr}}\}$	{529.343, 28.0584, 21.1111}	{89.7928, 1.1812, 76.0185}
$\{CS^R{}_{Hmis}, N_{Hmis}, \frac{CS^R{}_{Hmis}}{N_{Hmis}}\}$	—	{364.713, 28.7489, 12.6862}
$ECS_H = ECS_{Hspr} + ECS^R{}_{Hmis}$	529.343（21.1111/人）	454.506（15.18558/人）
$ECS = ECS_L + ECS_H$	855.73	704.547
ESW= EPS + ECS	1557.19	1471.21
Perceived Bliss from Ignorance	0	263.517
Phantom Surplus SW	1557.19	1734.73

Source: Compiled by this study.

In terms of market welfare distribution, the manufacturer's profit is about 766.67; consumer welfare in the low-quality market is about 250.042, with average consumer welfare of about 3.5685 per person; while consumer welfare in the high-quality market is about 454.506, with average consumer welfare of 15.1856 per person; total market welfare is approximately 1471.21.

Comparing equilibrium under the two market environments reveals that in a market with consumer misperception and information asymmetry, the manufacturer will use prices lower than monopoly pricing to attract more consumers to purchase fake high-quality products. In the final market equilibrium, whether it's overall market welfare or average consumer welfare in individual high and low-quality markets, all are lower than the equilibrium solution under a complete information market.

In other words, in this model, under a market environment with consumer misperception and information asymmetry, manufacturers can profit from quality fraud in high-quality products, but consumer welfare losses exceed manufacturers' improper gains, ultimately leading to decreased overall social welfare. The theoretical model results align with most economic literature's conclusion that information asymmetry causes overall consumer welfare loss or social welfare loss (inefficient distribution).

In the above analysis results, overall consumers lose about 151.2 due to information asymmetry, while overall social welfare loss is about 86. Therefore, in this paper's market environment, eliminating product quality information asymmetry can increase overall social welfare levels by 86. Furthermore, this paper points out that when the government considers consumer perception, it can consider investing in policies to eliminate market information asymmetry, with a reasonable cost range between 86 and 151.2.

Upon further analyzing consumer behavior in the high-quality product market under misperception, this paper can better describe two interesting phenomena that exist in real life: the "ignorance is bliss effect" and the "connoisseur reward effect":

i. Perceived Bliss from Ignorance

When consumers in the high-quality market are still unaware of being deceived (believing they bought products with quality $q_H = 1$) , a phenomenon will appear where consumer welfare increases due to information asymmetry, as shown below:

364.713 + 236.517(Perceived Bliss from Ignorance) = 628.229(illusion utility)> 364.713

Moreover, due to the existence of the ignorance is bliss effect, if the manufacturer's deceptive behavior isn't exposed in the short term, the market welfare under consumer ignorance is 1734.73, higher than the 1557.19 under complete information, creating an illusion that market welfare increases due to market information asymmetry.

ii. Connoisseur Reward Effect

In the high-quality market, consumers with high quality identification ability (hereinafter referred to as connoisseurs) have an expected consumer welfare of 76.0185 per person, much higher than the 21.11 per person under complete information and the 12.686 per person average welfare of deceived consumers. This represents that connoisseurs can obtain additional benefits in an information asymmetric market, a phenomenon this paper calls the "connoisseur reward effect."

3.2 Policy Simulation Design

This paper will further discuss the effects of three policies - 1. mandatory removal of substandard products from shelves, 2. mandatory destruction of substandard products, and 3. imposing fines on unscrupulous manufacturers - in a market with consumer misperception about product quality. For simplification, this paper assumes that the government or relevant authorities passively accept reports from consumers (connoisseurs) about substandard products in the market. Moreover, connoisseurs are assumed to have a sense of justice and no moral hazard exists.

3.2.1 Policy of Mandatory Removal of Substandard Products

For example, when relevant authorities receive reports that certain supermarket's claimed organic foods (high-quality products) contain a certain proportion of non-organic foods, after authorities order the removal of these products, the supermarket does not need to destroy this batch of food. A more realistic handling approach is for the supermarket to move these unqualified organic foods to the regular food (low-quality product) section for sale. This is because while these foods may not meet organic food standards, they are perfectly fine to sell as regular food. Therefore, for manufacturers, the effect of mandatory removal policy is equivalent to this paper's design where manufacturers and consumers privately settle with low-quality product prices. At this time, the manufacturer's decision function remains:

$$\underset{p_H,m}{Max}\, E\pi = N(1-G(ax))[F(m)(p_H - c_m) + (1-F(m))(p_L - c_m)]$$

However, this policy has different effects on consumers: when the batch of fake high-quality products is removed and sold in the low-quality product market due to being reported, all consumers can purchase products with quality q_{m*} at price p_L .Under this policy, there is $F(m^*)$ probability that the manufacturer hasn't encountered connoisseurs, and probability that all consumers get a bargain. At this time, the expected consumer welfare ECW is:

$$ECW =$$

$$F(m^*)\{N_L^*\int_{a_L}^{ax}(10+aq_L - p_L)g(a)da + N_H^*\int_{ax}^{a_H}(10+aq_{m*} - p_H)g(a)da\}$$

$$+(1-F(m^*))N\{\frac{N_L^*}{N}\int_{a_L}^{a_H}(10+aq_L - p_L)g(a)da + \frac{N_H^*}{N}\int_{a_L}^{a_H}(10+aq_{m*} - p_L)g(a)da\}$$

In other words, when no one has discovered fake high-quality products, there will be both high and low-quality product markets. If a connoisseur reports the manufacturer's fraud, then all products can only be sold in the low-quality product market. At this time, the true expected consumer welfare in the high-quality product market ECW_H^R is：

$$ECS_H^R = F(m^*)N_H^*\int_{ax}^{a_H}(10+aq_{m*}-p_H)g(a)da$$

While in the high-quality product market, the illusory expected consumer welfare ECW_H^{UR} is：

$$ECW_H^{UR} = F(m^*)N_H^*\int_{ax}^{a_H}(10+aq_H-p_H)g(a)da$$

The unrealized expected consumer loss $ELoss^{UR}$ in the high-quality product market is:

$$ELoss^{UR} = ECW_H^{UR} - ECW_H^R = F(m^*)N_H^*\int_{ax}^{a_H}(10+a(q_H-q_{m*}))g(a)da$$

And the expected consumer welfare ECW_L in the low-quality product market is:

$$\begin{aligned}ECW_L &= F(m^*)\{N_L^*\int_{a_L}^{ax}(10+aq_L-p_L)g(a)da\} \\ &+(1-F(m^*))N\{\frac{N_L^*}{N}\int_{a_L}^{a_H}(10+aq_L-p_L)g(a)da+\frac{N_H^*}{N}\int_{a_L}^{a_H}(10+aq_{m*}-p_L)g(a)da\}\end{aligned}$$

Moreover, the connoisseurs who could profit in a market without policy intervention now can only purchase products along with all other consumers in the low-quality product market (having reported substandard products out of justice), so under this policy, the connoisseurs' total expected surplus ECW_{spr} can be expressed as:

$$ECW_{spr} = (1-F(m^*))N\{\frac{N_L^*}{N}\int_{ax}^{a_H}(10+aq_L-p_L)g(a)da+\frac{N_H^*}{N}\int_{ax}^{a_H}(10+aq_{m*}-p_L)g(a)da\}$$

It's worth noting that due to connoisseurs' righteous actions which successfully deter manufacturers' deceptive behavior, they also lose the "connoisseur reward" advantage they had when privately settling with manufacturers.

3.2.2 Policy of Mandatory Destruction of Substandard Products

Following from above, under a policy where authorities order mandatory destruction of reported products, manufacturers face a total loss in the high-quality product market when reported. At this time, the supply-side manufacturer's decision function in equation (5) is rewritten as:

$$\underset{p_H, m}{Max}\, E\pi = N(1-G(ax))[F(m)(p_H - c_m) + (1-F(m))(0-c_m)]$$

And the expected consumer welfare ECW in the market is rewritten as:

$$ECW =$$
$$F(m^*)\{N_L^* \int_{a_L}^{ax} (10 + aq_L - p_L) g(a) da + N_H^* \int_{ax}^{a_H} (10 + aq_{m*} - p_H) g(a) da\}$$
$$+ (1-F(m^*)) N_L^* \int_{a_L}^{a_H} (10 + aq_L - p_L) g(a) da$$

Similarly, when no fake high-quality products have been discovered, both high and low-quality product markets will exist. If encountered by a connoisseur who reports the manufacturer's fraud, the fake high-quality products must be completely destroyed, leaving only low-quality products available for purchase in the market. At this time, the true expected consumer welfare ECW_H^R in the high-quality product market is:

$$ECW_H^R = F(m^*) N_H^* \int_{ax}^{a_H} (10 + aq_{m*} - p_H) g(a) da$$

The illusory expected consumer welfare ECW_H^{UR} in the high-quality product market is:

$$ECW_H^{UR} = F(m^*) N_H^* \int_{ax}^{a_H} (10 + aq_H - p_H) g(a) da$$

The unrealized expected consumer loss $ELoss^{UR}$ in the high-quality product market is:

$$ELoss^{UR} = ECW_H^{UR} - ECW_H^R = F(m^*)N_H^* \int_{ax}^{a_H} [10 + a(q_H - q_{m*})]g(a)da$$

And the expected consumer welfare ECW_L in the low-quality product market is:

$$ECW_L = F(m^*)N_L^* \int_{a_L}^{ax} (10 + aq_L - p_L)g(a)da + (1 - F(m^*))N \int_{a_L}^{a_H} (10 + aq_L - p_L)g(a)da$$

Similarly, connoisseurs who could previously profit in an unregulated market can now only purchase low-quality products, without even the opportunity to get bargains (as in the removal policy). Under the destruction policy, the original connoisseurs' total expected surplus ECW_{spr} is:

$$ECW_{spr} = (1 - F(m^*))N \int_{ax}^{a_H} (10 + aq_L - p_L)g(a)da$$

It should be noted that in this paper's model structure, the low-quality product market is set as a perfectly competitive market, so low-quality products can be supplied infinitely at p_L meaning there won't be a phenomenon of consumers being unable to purchase low-quality products. Additionally, when the government adopts a mandatory destruction strategy for deceptive behavior, if it cannot deter manufacturers' deceptive behavior (making manufacturers not sell fake products), there will be a social resource waste (waste) phenomenon:

$$\text{waste} = N(1 - G(ax))(1 - F(m))(0 - c_m)$$

3.2.3 Policy of Imposing Fines on Unscrupulous Manufacturers

Following from above, when relevant authorities receive reports that a supermarket's claimed organic foods contain chemical additives, under a policy of imposing fines on such unscrupulous manufacturers, the supply-side manufacturer's decision function in equation (4) is rewritten as:

$$\underset{p_H, m}{Max}\, E\pi = N(1 - G(ax))[F(m)(p_H - c_m) + (1 - F(m))(p_L - c_m - fine)]$$

In this discussion, since the effect of fines is to increase the opportunity cost of manufacturer deception, its effectiveness in suppressing manufacturers from exploiting product quality information asymmetry to deceive consumers is undoubted. Therefore, this section's focus is on finding a fine level with economic theoretical foundation. In other words, finding a fine level that makes the manufacturer's expected profit from deception lower than the profit without deception (complete information solution), as follows:

$$\underset{p_H,m}{Max}\, E\pi(p_H,m) = N_H[F(m)(p_H - c_m) + (1-F(m))(p_L - c_m - fine)] \le \pi(p_{Hm},1)$$

3.2.4 Numerical Analysis Results

Based on the numerical simulation analysis results of three policies - mandatory removal of substandard products, mandatory destruction of substandard products, and imposing fines on unscrupulous manufacturers - the results are summarized in Table 3. From these results, we can observe:

In terms of deterring manufacturer fraud (improving high-quality product purity), imposing fines exceeding 55.2045 per unit of substandard product achieves the effect of product quality reaching 1. This is followed by the destruction policy achieving about 0.91, while the removal policy shows no effect, with real product quality remaining at 0.8924 in the high-quality product market.

From the perspective of reducing consumer welfare losses, the fine policy performs best with consumer welfare at 855.73, eliminating consumer welfare losses. The removal policy ranks second at 802.671. The removal policy creates a wealth redistribution effect, increasing low-quality market consumer welfare from about 3.568/person to 6.147/person. The destruction policy performs worst, with total consumer welfare at only 661.25, even lower than the 704.547 under no policy intervention.

Regarding overall market welfare, the destruction policy performs worst. Due to resource waste (waste = 38.5266), overall market welfare under the destruction policy at 1417.98 is lower than the 1471.21 under no intervention. Imposing fines of 55.2045 or above per unit allows the market equilibrium to return to complete information equilibrium. The removal policy performs best, using a wealth redistribution-like effect to achieve higher overall social welfare than monopoly market welfare under complete information.

Table 3 Numerical Analysis Results of Simulated Policy Effects

Observation	Policy Means		
	Removing Substandard Products From Shelves	Mandatory Destruction	Imposing Fines
Monopoly Firm's Decision $\{p_H^*, m^*, (q_{m^*})\}$	{73.332, 0.8804, （0.8924） }	{73.6578, 0.8994, （0.9094）}	{75, 1，（1）}
Supply Quantity (Low Quality, High Quality)	（70.0699, 29.9301）	（70.4353, 29.5647）	（71.9416, 28.0584）
EPS (Firm's Expected Profit)	766.666	756.723	701.459
$\{ECW_L, EN_L, \mathrm{E}(\frac{CW_L}{N_L})\}$	{437.958, 71.2511, 6.14668}	{259.773, 71.2733, 3.64475}	{263.386, 71.9416, 3.6611}
$\{ECW_{spr}, EN_{spr}, \mathrm{E}(\frac{CW_{spr}}{N_{spr}})\}$ Included in the expected profit of the low-quality product market already.	{33.9255, 1.1812 , 28.2713}	{7.15361, 0.837998,8.5361}	（Same as under full information.）
$\{ECW^R{}_{Hmis}, N_{Hmis}, \frac{ECW^R{}_{Hmis}}{N_{Hmis}}\}$	{364.713,29.9301, 12.6862}	{401.48, 29.5647, 13.5797}	{529.343, 28.0584, 21.1111}
$ECW_H = ECW^R{}_{Hmis}$	364.713（ 12.6862/人）	401.48（13.5797/人）	529.343（21.1111/人）
$ECW = ECW_L + ECW_H$	802.671	661.253	855.73
ESW= $PW + ECW_L + ECW_H$	1569.34	1417.98	1557.19
Expected Illusion Utility	263.517	222.108	0
ESW under Ignorance is Bliss	1832.85	1640.09	1557.19
Special Phenomenon	Wealth Redistribution Effect	Waste=38.5266	fine$\geq$55.2045

Based on the above analysis comparison, this paper finds that the fine policy is relatively superior to the removal policy because fines can completely deter fraudulent behavior. While both are equally ineffective at deterring fraud, the destruction policy may slightly improve quality but causes social resource waste. The manufacturer still enjoys illegal profits, meaning the entire social cost is borne by consumers. In contrast, although the removal policy cannot change manufacturers' fraudulent behavior, it can improve overall market welfare through a wealth redistribution-like effect, making it more economically efficient than the destruction policy. Therefore, this paper ranks the three policies by their economic benefits as follows: imposing fines on unscrupulous manufacturers is most effective, mandatory removal of substandard products is second best, while mandatory destruction of substandard products is least effective.

It's worth noting that in this paper's model, connoisseurs lose their "connoisseur reward" advantage they had in the information asymmetric market after policy intervention. They can only purchase products in the low-quality market, resulting in a connoisseur adverse selection phenomenon.

4. Conclusions and Recommendations

This paper establishes an information asymmetric heterogeneous product market decision model to analyze potential social welfare changes and different policy intervention effects regarding consumers' common misperception of agricultural product quality.

Research results show that when consumers have misperceptions about product quality in the market, product suppliers have incentives to deceive. At this time, manufacturers will use prices lower than monopoly pricing to attract more consumers to purchase fake high-quality products. Product suppliers can profit from this, but ultimately consumer welfare and overall social welfare will decrease.

In the short term, consumers with low identification ability in the high-quality product market may suffer losses without realizing it, meaning there exists an illusion utility effect. In other words, when consumers have cognitive errors, due to the "ignorance is bliss" effect, there will appear to be a phenomenon where social welfare levels are higher than market equilibrium under complete information. However, this phenomenon is equivalent to condoning manufacturers deceiving consumers, which does not align with social justice, so the government should still intervene with policies.

Under no policy intervention, consumers with high identification ability have opportunities to enjoy connoisseur rewards. Therefore, for consumers, collecting relevant information or consulting experts before purchasing products is a better strategy.

Regarding the effectiveness of three policies - mandatory removal of substandard products, mandatory destruction of substandard products, and imposing fines on unscrupulous manufacturers - to deter manufacturer fraud: While the removal policy can increase overall market welfare, it cannot correct manufacturers' fraudulent behavior nor help deceived consumers. Although the destruction policy can improve product quality slightly, it causes social resource waste, and manufacturers still enjoy illegal profits, meaning the entire social cost is borne by consumers. Therefore, using fines to eliminate manufacturers' economic incentives for deception is the most effective policy. The three policies ranked by economic benefits are: fines on unscrupulous manufacturers is best, mandatory removal of substandard products second best, and mandatory destruction of substandard products worst.

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