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Effects of corporate social responsibility on food safety

You-Hua CHEN[1]*, Pu-Yan NIE[2], Yong-Cong YANG[3]

[1]*College of Economics & Management and Guangdong Center for Rural Economic Studies, South China Agricultural University, Guangzhou, China*
[2]*Guangdong University of Finance & Economics, Guangzhou, China*
[3]*Guangdong University of Foreign Studies, Guangzhou, China*

Corresponding author: chenyhua214@163.com

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Abstract: This paper develops the theory of corporate social responsibility (CSR) in the food industry. The effects of CSR on the food industry are captured. First, we argue that CSR reduces the profits of a CSR firm under monopoly. Second, under complete information, regulation does not improve social welfare. We find that both active price regulation and active quality regulation reduce a monopolist's profits, consumer surplus and social welfare. Finally, under incomplete information, the monopolist exaggerates quality as much as possible. With quality regulation, CSR reduces exaggerated quality in the food industry.

Keywords: food quality, game theory, quality regulation, social welfare

There have been numerous incidents related to food safety in China recently, including poisonous Jinhua ham in 2003, counterfeit baby formula in 2004, the Sudan red dye incident, and illicit cooking oil in 2012, according to online information[1]. Thus, food safety has attracted much attention from both the government and Chinese consumers in recent years. The results of the "China Food Safety Report 2015" showed that more than 227 000 food incidents in total or 62 incidents per day occurred in China from 2005 to 2014.

Many serious incidents surrounding food have also been reported from other countries. In 2011, poor-quality illegal alcohol in West Bengal resulted in an estimated 126 deaths. The alcohol may have contained ammonium nitrate and/or methanol (BBC News 2011). In 1955, a disodium phosphate additive was inadvertently contaminated with sodium arsenate in Japan. The incident became known as the "Morinaga dried milk poisoning". By 2002, there were an estimated 13 400 cases and over 100 deaths attributed to consumption of the milk powder (Dakeishi et al 2006). Incidents related to food security are reported almost every year from all over the world.

Therefore, food safety is a concern throughout the world, and a significant amount of literature regarding food security and food quality has appeared in recent years. There are many factors, such as global trade, socio-economic and technological development, urbanization and agricultural land use, that affect food safety (Tirado et al. 2010; Nie and Chen 2014; Assefa et al. 2015; Chen et al. 2015; Webb and Morancie 2015; Chen et al. 2017). For example, it is increasingly important for European consumers that livestock producers adopt more animal-friendly practices (Nocella et al. 2010). Tirado et al. (2010) argued that climate change has an important effect on food quality and reviewed the effects of climate change on food safety. Diagne et al. (2013) addressed the food security of the rice industry on different technological levels.

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[1]https://en.wikipedia.org/wiki/Food_safety_incidents_in_China

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Recently, in a natural experiment, Kong (2012) found that CSR has a significant effect on food quality and safety in the Chinese food industry. Chen and Nie (2016) developed a theory regarding CSR in the food industry under oligopoly and surprisingly argued that there exists a U-shaped relationship between CSR and a firm's profits. Moreover, Chen et al. (2016) addressed the effects of CSR on the food industry with respect to spill over and competition. Although CSR has been intensively analysed in areas of economics and management (Kitzmueller and Shimshack 2012) such as contracts (Baron 2008), financial performance (Orlitzky et al. 2003; Brammer and Millington 2008; Starks 2009), consumer behaviour (Mohr et al. 2001) and the market shares and profits of CSR firms (Kopel and Brand 2012), there is no theoretical literature about CSR in the food industry.

This paper aims to further describe the effects of CSR on the food industry in theory. Using a two-stage game model, this work highlights the effects of CSR on consumer demand, equilibrium quality and social welfare. Moreover, regulation in the food industry is also captured both under complete information and under incomplete information. We hope that this paper contributes to developing the theory regarding the effects of CSR on the food industry.

Because the food industry should take quantity and quality into account, we refer to Dixit (1979) and Sheshinski (1976) in formulating the model in this paper. In this paper, we employ the traditional CSR model, in which CSR firms maximize profits plus a weighted consumer surplus.

This paper reports two main findings. On the one hand, in terms of CSR theory, this paper shows that CSR reduces the monopolist's profits, which is different than for other market structures such as duopolies and oligopolies. To our best knowledge, this is the first work to describe the relationship between CSR and a firm's performance under a monopoly. To address quality, we introduce the Cobb-Douglas utility function into the quality competition of Dixit (1979).

On the other hand, this paper captures regulation in the food industry. We argue that regulation does not improve social welfare under complete information. Under incomplete information, rational regulation means that CSR reduces exaggerated quality. The policy implication is that it is not necessary to implement regulation under complete information, whereas consumers benefit from regulation under incomplete information. The research of Chan, Chen and He (2015) also showed that quality regulation may be harmful to industry competition.

This work is closely related to that of Chen and Nie (2016). The differences between this article and the one of Chen and Nie (2016) lies in two aspects: the first aspect is the different market structure. Chen and Nie (2016) addressed oligopoly and competition was highlighted, while this article focuses on monopoly and competition is neglected. In practice, there are significant differences in taste and quality in China and almost all firms strive towards a monopoly position[2].

The other differing aspect is that this article highlights governmental regulation while Chen and Nie (2016) captured the free competition of firms. Many countries and regions have launched laws to regulate food quality. Therefore, addressing the regulation of food quality it is of utmost importance.

MODEL

Here we establish the theoretical model for food quality with CSR under a monopoly. The quality of the product is denoted by x. The corresponding quantity is q along with price p.

Consumers. We denote the wealth of a representative consumer to be $\omega > 0$, "other commodities" to be y. The corresponding price is normalized to 1, so a quasi-linear utility function is employed:

$$U = (x - x^0)^{1-\beta} q^{\beta} + y \quad (1)$$

Where x^0 is the lowest quality required for food safety and $\beta \in (0,1)$ is a constant, which indicates the elasticity of the quantity of products. We note that function (1) is a type of Cobb-Douglas utility function for quality and quantity with constant returns to scale. From function (1), if the quality of food is lower than the level of food safety, the consumer's utility in consuming the corresponding food is negative. Moreover, the consumer is subject to budget constraints as follows:

$$pq + y = \omega \quad (2)$$

[2]There are eight main Chinese cuisines, including Anhui, Cantonese, Fujian, Hunan, Jiangsu, Shandong, Szechuan and Zhejiang cuisines. Different cuisines have different tastes. For example, Hunan and Szechuan cuisines have peppery tastes, whereas Jiangsu and Zhejiang cuisines have sweet tastes; Shandong and Fujian are salty, while Cantonese people prefer natural flavours. For more details see: http://en.wikipedia.org/wiki/Cuisine_of_China.

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Then, the inverse demand function based on function (1) and (2) is

$$p = \beta(\frac{x - x^0}{q})^{1-\beta} \quad (3)$$

And the corresponding consumer surplus (*CS*) is

$$CS = (1-\beta)(x - x^0)^{1-\beta} q^{\beta} + \omega \quad (4)$$

Monopolist. Here we model a monopolist in the food industry. This monopolist integrates corporate social responsibility (CSR) into its business operations. In other words, the monopolist maximizes profits plus a weighted consumer surplus and the objective function of the monopolist is

$$\Pi = \pi + \mu CS = (p - x^{\frac{1-\beta}{\beta^2}})q + \mu[\omega + (1-\beta)(x - x^0)^{1-\beta} q^{\beta}] \quad (5)$$

In function (5), the costs of food are $x^{\frac{1-\beta}{\beta^2}} q$. The cost function is convex in food quality and lineal in quantity. This is a special cost function, but it still does not lose of generality and it has the advantage of simplifying the calculation. μ ∈ (0,1) stands for the degree of CSR. μ = 0 signifies a profit-maximizing firm, and μ = 1 signifies a public firm. $\pi = (p - x^{\frac{1-\beta}{\beta^2}})q$ represents the profits of the monopolist. Similar to Kopel and Brand (2012), the CSR firm maximizes its objection function (5) with price and quality.

We also note that this paper addresses the monopoly situation because many types of food industry are characterised by monopoly positions. The time table of the monopolist is as follows: In the first stage, based on the objective function, the monopolist chooses quality and commits to the quality level of products to consumers. In the second stage, according to the quality level, the monopolist prices and supplies a certain quantity of the products and consumers determine the quantity to consume.

PRIMARY ANALYSIS

We first give the equilibrium by backward induction. In the second stage, the monopolist determines outputs. Because function (5) is concave in *q*, we have

$$\frac{\partial \Pi}{\partial q} = \beta^2 (x - x^0)^{1-\beta} q^{\beta-1} - x^{(1-\beta)/\beta^2} + \mu(1-\beta)\beta(x - x^0)^{1-\beta} q^{\beta-1} = 0 \quad (6)$$

$$\text{Or, } q = (x - x^0)\{\frac{x^{(1-\beta)/\beta^2}}{[\mu(1-\beta)+\beta]\beta}\}^{\frac{1}{\beta-1}} \quad (7)$$

Substituting equation (7) into function (5) we have

$$\Pi = (1-\beta)[\mu(1-\beta)+\beta](x - x^0)\{\frac{x^{(1-\beta)/\beta^2}}{[\mu(1-\beta)+\beta]\beta}\}^{\frac{\beta}{\beta-1}} + \mu\omega = (1-\beta)[\mu(1-\beta)+\beta]^{\frac{1}{1-\beta}}(x - x^0)\beta^{\frac{\beta}{1-\beta}} x^{-1/\beta} + \mu\omega \quad (8)$$

In the first step, we solve function (8) to obtain the optimal quality in equilibrium. According to the first-order optimal conditions of function (8), we have the following formulation:

$$x^* = x^0/(1-\beta),\ q^* = \frac{\beta}{1-\beta}(x^0)^{1-1/\beta^2}\{[\mu(1-\beta)+\beta]\beta\}^{\frac{1}{1-\beta}}(1-\beta)^{\frac{1}{\beta^2}} \quad (9)$$

We further note that function (8) is not globally concave for all *x* but is locally concave. Although function (8) is not globally concave, equation (9) is the unique solution to function (8) because the following formulations always hold: $\left.\frac{\partial \Pi}{\partial x}\right|_{x<x^*} > 0$ and $\left.\frac{\partial \Pi}{\partial x}\right|_{x>x^*} < 0$. The corresponding price (p^*), CSR firm profits (π^*), values of the objective function (Π^*), the consumer surplus (CS^*) and social welfare (*SW*) are represented as follows

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$$p^* = \frac{[x^0/(1-\beta)]^{(1-\beta)/\beta^2}}{[\mu(1-\beta)+\beta]},\ \pi^* = \hat{a}^{\frac{1}{1-\beta}}\beta(1-\mu)[\mu(1-\beta)+\beta]^{\frac{\beta}{1-\beta}}(x^0)^{1-\frac{1}{\beta}}(1-\beta)^{\frac{1}{\beta}} \tag{10}$$

$$\Pi^* = (x^0)^{1-1/\beta}(1-\beta)^{\frac{1}{\beta}}\beta^2\{[\mu(1-\beta)+\beta]\beta\}^{\frac{\beta}{1-\beta}}[(1-\mu)+\mu(\frac{\beta}{1-\beta})^{1-\frac{1}{\beta}}]+\mu\omega \tag{11}$$

$$\begin{aligned} CS^* &= (1-\beta)(x^0)^{1-\beta}\frac{\beta}{1-\beta}(x^0)^{\beta-1/\beta}\beta\{[\mu(1-\beta)+\beta]\beta\}^{\frac{\beta}{1-\beta}}(1-\beta)^{\frac{1}{\beta}}(\frac{\beta}{1-\beta})^{1-\beta}+\omega \\ &= (x^0)^{1-1/\beta}\beta^2\{[\mu(1-\beta)+\beta]\beta\}^{\frac{\beta}{1-\beta}}(1-\beta)^{\frac{1}{\beta}}(\frac{\beta}{1-\beta})^{1-\beta}+\omega \end{aligned} \tag{12}$$

$$\begin{aligned} SW^* &= \beta^{\frac{1}{1-\beta}}\beta(1-\mu)[\mu(1-\beta)+\beta]^{\frac{\beta}{1-\beta}}(x^0)^{1-\frac{1}{\beta}}(1-\beta)^{\frac{1}{\beta}}+(x^0)^{1-1/\beta}\beta^2\{[\mu(1-\beta)+\beta]\beta\}^{\frac{\beta}{1-\beta}}(1-\beta)^{\frac{1}{\beta}}(\frac{\beta}{1-\beta})^{1-\beta}+\omega \\ &= (x^0)^{1-1/\beta}(1-\beta)^{\frac{1}{\beta}}\beta^2\{[\mu(1-\beta)+\beta]\beta\}^{\frac{\beta}{1-\beta}}[(1-\mu)+(\frac{\beta}{1-\beta})^{1-\frac{1}{\beta}}]+\omega \end{aligned} \tag{13}$$

For (10)–(13), we have the relationships $\frac{\partial p^*}{\partial \mu}<0$, $\frac{\partial \pi^*}{\partial \mu}<0$, $\frac{\partial q^*}{\partial \mu}>0$, $\frac{\partial CS^*}{\partial \mu}>0$, $\frac{\partial \Pi^*}{\partial \mu}>0$ and $\frac{\partial SW^*}{\partial \mu}>0$, which are summarized in the following:

Proposition 1. Both price and profits decrease with CSR, whereas the consumer surplus, the value of the CSR firm and social welfare increase with CSR.

Remarks: We find it interesting that CSR reduces the profits of a CSR firm under a monopoly. CSR stimulates a CSR firm's outputs such that the outputs exceed the monopolization level under profit maximization. Therefore, CSR correspondingly reduces the monopolist's profits.

We also note that this conclusion is contrary to that reported for multiple firms (Chen and Nie (2016) argued that increasing CSR first improves then reduces the profits of CSR firms). This Proposition captures the effects of CSR on a firm's profits under monopoly. Moreover, under complete information, CSR has no effects on the quality of food. In general, therefore, the monopolist is not willing to engage in CSR because CSR reduces its profits.

We now turn our attention to social welfare optimality. In this case, social welfare is maximized. Similarly, by backward induction, we have the following expressions in equilibrium

$$x^{*,sw} = x^0/(1-\beta),\ q^{*,sw} = \frac{\beta}{1-\beta}(x^0)^{1-1/\beta^2}(1-\beta)^{\frac{1}{\beta^2}} \tag{14}$$

$$p^{*,sw} = [x^0/(1-\beta)]^{(1-\beta)/\beta},\ \pi^{*,sw} = 0 \tag{15}$$

$$\Pi^{*,sw} = \mu(x^0)^{1-1/\beta}\beta^2\beta^{\frac{\beta}{1-\beta}}(1-\beta)^{\frac{1}{\beta}}(\frac{\beta}{1-\beta})^{1-\beta}+\mu\omega \tag{16}$$

$$CS^{*,sw} = (x^0)^{1-1/\beta}\beta^2\beta^{\frac{\beta}{1-\beta}}(1-\beta)^{\frac{1}{\beta}}(\frac{\beta}{1-\beta})^{1-\beta}+\omega \tag{17}$$

$$SW^{*,sw} = (x^0)^{1-1/\beta}\beta^2\beta^{\frac{\beta}{1-\beta}}(1-\beta)^{\frac{1}{\beta}}(\frac{\beta}{1-\beta})^{1-\beta}+\omega \tag{18}$$

Comparing equations (14)–(18) with (9)–(13), we obtain the following conclusions: Both the price and profits are higher than the optimal level, whereas the consumer surplus, the value of the CSR firm and social welfare are lower than those under social welfare maximization, which can also be induced by Proposition 1 directly.

Because the CSR monopolist's outputs are lower than what is socially optimal, it is interesting and logical to analyse the effects of governmental regulation.

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REGULATION UNDER COMPLETE INFORMATION

This section addresses both price and quality regulation under complete information. The effects of regulation on consumer surplus and social welfare are captured.

Price regulation

Here, we address the effects of price regulation. A price restriction is introduced as $p \le p^r$, where $p^r > 0$ is the price restriction value. If $p^r \le p^*$, this price regulation has no effects on equilibriums. Here, we only address the case with $p^r < p^*$. In this case, the optimal price is $p^{*,r1} = p^r$. With the same backward induction approach as in Primary analysis, we have the corresponding optimal solution:

$$x^{*,r1} = \{p^r[\mu(1-\beta)+\beta]\}^{\frac{\beta^2}{1-\beta}},\ q^{*,r1} = \{\{p^r[\mu(1-\beta)+\beta]\}^{\frac{\beta^2}{1-\beta}} - x^0\}(\frac{p^r}{\beta})^{\frac{1}{\beta-1}} \tag{20}$$

$$p^{*,r1} = p^r,\ \pi^{*,r1} = p^r(1-\mu)(1-\beta)\{\{p^r[\mu(1-\beta)+\beta]\}^{\frac{\beta^2}{1-\beta}} - x^0\}(\frac{p^r}{\beta})^{\frac{1}{\beta-1}} \tag{21}$$

$$\Pi^{*,r1} = (1-\beta)\{\{p^r[\mu(1-\beta)+\beta]\}^{\frac{\beta^2}{1-\beta}} - x^0\}(\frac{p^r}{\beta})^{\frac{\beta}{\beta-1}}[\mu+(1-\mu)\beta] + \mu\omega \tag{22}$$

$$CS^{*,r1} = (1-\beta)\{\{p^r[\mu(1-\beta)+\beta]\}^{\frac{\beta^2}{1-\beta}} - x^0\}(\frac{p^r}{\beta})^{\frac{\beta}{\beta-1}} + \omega \tag{23}$$

$$SW^{*,r1} = (1-\beta)\{\{p^r[\mu(1-\beta)+\beta]\}^{\frac{\beta^2}{1-\beta}} - x^0\}(\frac{p^r}{\beta})^{\frac{\beta}{\beta-1}}[1+(1-\mu)\beta] + \omega \tag{24}$$

Obviously, $p^r < p^*$ yields $x^{*,r1} < x^*$ and equations (20)–(24) indicate

$\frac{\partial \pi^{*,r1}}{\partial p^r} = (1-\mu)(1-\beta)\beta(p^r)^{-1}\{-(p^r)^{-\beta}[\mu(1-\beta)+\beta]^{\frac{\beta^2}{1-\beta}} + \frac{1}{1-\beta}(p^r)^{\frac{\beta}{\beta-1}}x^0\}(\frac{1}{\beta})^{\frac{1}{\beta-1}} > 0$. This inequality holds because

$x^{*,r1} < x^* = \frac{x^0}{1-\beta}$

Similarly, we have $\frac{\partial CS^{*,r1}}{\partial p^r} > 0$ and $\frac{\partial SW^{*,r1}}{\partial p^r} > 0$. Comparing equations (20)–(24) with equations (10)–(18), and from $\frac{\partial \pi^{*,r1}}{\partial p^r} > 0$, $\frac{\partial CS^{*,r1}}{\partial p^r} > 0$ and $\frac{\partial SW^{*,r1}}{\partial p^r} > 0$, we immediately have the following Proposition.

Proposition 2. Under $p \le p^r < p^*$, we have $x^{*,r1} < x^*$, $q^{*,r1} < q^*$, $\pi^{*,r1} < \pi^*$, $CS^{*,r1} < CS^*$ and $SW^{*,r1} < SW^*$.

Remarks: Under complete information and price regulation, firm lowers quality to reduce costs. Therefore, price regulation lowers the quality of food. Because price regulation improves the quantity of products but lowers the quality of food, efficient price regulation reduces the monopolist's profits, consumer surplus and social welfare.

This proposition supports the theory arguing against price regulation, and the policy implication is that food price regulation is not a good choice for society. To maintain the consumer surplus and social welfare, we suggest price regulation $p \le p^r$ satisfying $p^r \ge p^*$. This type of price regulation is inactive.

Quality regulation

Here we address the effects of the government's quality regulation. A quality restriction is introduced as $x \ge x^r$, where $x^r > 0$ is the quality restriction value. Similarly, here we consider $x^r > x^*$. Using a similar approach as in Section Primary analysis, we have

$$x^{*,r2} = x^r,\ q^{*,r2} = (x^r - x^0)(x^r)^{-1/\beta^2}[\mu(1-\beta)+\beta]^{\frac{1}{1-\beta}}\beta^{\frac{1}{1-\beta}} \tag{25}$$

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$$p^{*,r2} = \frac{(x^r)^{(1-\beta)/\beta^2}}{[\mu(1-\beta)+\beta]},\ \pi^{*,r2} = (x^r)^{-1/\beta}[\mu(1-\beta)+\beta]^{\frac{\beta}{1-\beta}}(1-\mu)(1-\beta)(x^r - x^0)\beta^{\frac{1}{1-\beta}} \tag{26}$$

$$\Pi^{*,r2} = (1-\beta)(x^r - x^0)(x^r)^{-1/\beta}[\mu(1-\beta)+\beta]^{\frac{\beta}{1-\beta}}\beta^{\frac{\beta}{1-\beta}}[\beta(1-\mu)+\mu] + \mu\omega \tag{27}$$

$$CS^{*,r2} = (1-\beta)(x^r - x^0)(x^r)^{-1/\beta}[\mu(1-\beta)+\beta]^{\frac{\beta}{1-\beta}}\beta^{\frac{\beta}{1-\beta}} + \omega \tag{28}$$

$$SW^{*,r2} = (1-\beta)(x^r - x^0)(x^r)^{-1/\beta}[\mu(1-\beta)+\beta]^{\frac{\beta}{1-\beta}}\beta^{\frac{\beta}{1-\beta}}[\beta(1-\mu)+1] + \omega \tag{29}$$

With equation (26), $x^r > x^* = x^0/(1-\beta)$ indicates

$\frac{\partial \pi^{*,r2}}{\partial x^r} = [\mu(1-\beta)+\beta]^{\frac{\beta}{1-\beta}}(1-\mu)(1-\beta)\beta^{\frac{1}{1-\beta}}\frac{1}{\beta}x^0(x^r)^{-1/\beta-1}[x^0-(1-\beta)x^r] < 0$. Similarly, we have $\frac{\partial CS^{*,r2}}{\partial x^r} < 0$ and $\frac{\partial SW^{*,r2}}{\partial x^r} < 0$. Comparing equations (25)–(29) with equations (10)–(18), by $\frac{\partial \pi^{*,r2}}{\partial x^r} < 0$, $\frac{\partial CS^{*,r2}}{\partial x^r} < 0$ and $\frac{\partial SW^{*,r2}}{\partial x^r} < 0$, we immediately have Proposition 3 as following.

Proposition 3. Under quality regulation $x \geq x^r$ satisfying $x^r > x^*$, we have $p^{*,r2} > p^*$, $q^{*,r2} > q^*$, $\pi^{*,r2} > \pi^*$, $CS^{*,r2} > CS^*$ and $SW^{*,r2} > SW$.

Remarks: Quality regulation improves the price of food and lowers the quantity of outputs. Because quality regulation improves the price of products and lowers the outputs of food, active quality regulation reduces the monopolist's profits, consumer surplus and social welfare. This proposition supports the theory arguing against quality regulation, and the policy implication is that food quality regulation is not a good choice for society under complete information, which is consistent with Wang et al. (2015).

In summary, under complete information, both price regulation and quality regulation are not good for the consumer surplus and social welfare. Moreover, regulation cannot reach the socially optimal solution under complete information. Regulations distort the quality or price for food markets, which is consistent with the interesting conclusions of Anderson et al. (2013).

Because regulations distort markets, the policy implication of the above conclusions is that regulations are not necessary under complete information.

It is impossible for a single regulation to reach social optimality. If two types of regulations are simultaneously adopted, from functions (14) and (15), social optimality can be achieved if regulation simultaneously satisfies the conditions $x^{*,sw} = x^0/(1-\beta)$ and $p^{*,sw} = [x^0/(1-\beta)]^{(1-\beta)/\beta}$.

EXAGGERATED QUALITY UNDER INCOMPLETE INFORMATION

Here, we consider the situation in which the monopolist owns private information on the quality of food. We assume that consumers have no ability to judge the exact quality of food. We modify the model in Section Model as follows. In the first stage, the monopolist commits to the quality of food x^c and actually produces food with quality $x^c - \tau\Delta$, where the constant $\tau\Delta$ means the quality gap, in which $\Delta \geq 0$ is determined by the properties of food. If the firm declares the quality of this food to be x^c, consumers can judge this exaggerated commitment when the quality of this food is lower than $x^c - \Delta$, with the firm choosing a quality of $x^c - \tau\Delta$, where $\tau \in [0,1]$. This is a two-stage game. In the first stage, the monopolist commits to the quality of the food as x^c and determines $\tau \in [0,1]$ with the actual quality $x^c - \tau\Delta$. In the second stage, the producer considers the demand and provides the quantity of food. In this case,

$$p = \beta\left(\frac{x^c - x^0}{q}\right)^{1-\beta} \tag{30}$$

$$\Pi = \pi + \mu CS = \left[\beta\left(\frac{x^c - x^0}{q}\right)^{1-\beta} - (x^c - \tau\Delta)^{\frac{1-\beta}{\beta^2}}\right]q + \mu[\omega + (1-\beta)(x^c - \tau\Delta - x^0)^{1-\beta}q^\beta] \tag{31}$$

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According to function (31), the actual quality of food is $x^c - \tau\Delta$, while consumers think that the quality of the food is x^c. Therefore, the marginal cost is $(x^c - \tau\Delta)^{\frac{1-\beta}{\beta^2}}$. The price is determined by function (30), and the consumer surplus is $\omega + (1-\beta)(x^c - \tau\Delta - x^0)^{1-\beta}q^\beta$. By backward induction, we have

$$\frac{\partial \Pi}{\partial q} = \beta^2 (x^c - x^0)^{1-\beta} q^{\beta-1} - (x^c - \tau\Delta)^{(1-\beta)/\beta^2} + \mu(1-\beta)\beta(x^c - \tau\Delta - x^0)^{1-\beta} q^{\beta-1} = 0$$

$$q = [\frac{(x^c - \tau\Delta)^{(1-\beta)/\beta^2}}{\beta^2 (x^c - x^0)^{1-\beta} + \mu(1-\beta)\beta(x^c - \tau\Delta - x^0)^{1-\beta}}]^{\frac{1}{\beta-1}} \tag{32}$$

The objective function is rewritten as follows:

$$\Pi = (1-\beta)[\beta(x^c - x^0)^{1-\beta} + \mu(1-\beta)(x^c - \tau\Delta - x^0)^{1-\beta}] \; [\frac{(x^c - \tau\Delta)^{(1-\beta)/\beta^2}}{\beta^2 (x^c - x^0)^{1-\beta} + \mu(1-\beta)\beta(x^c - \tau\Delta - x^0)^{1-\beta}}]^{\frac{\beta}{\beta-1}} + \mu\omega$$

$$= (1-\beta)[\beta(x^c - x^0)^{1-\beta} + \mu(1-\beta)(x^c - \tau\Delta - x^0)^{1-\beta}]^{\frac{1}{1-\beta}} (x^c - \tau\Delta)^{-1/\beta} \beta^{\frac{\beta}{1-\beta}} + \mu\omega \tag{33}$$

In the first stage, the monopolist gives the quality and the parameter $\tau \in [0,1]$ to maximize the above objective function. The first optimal conditions are

$$\frac{\partial \Pi}{\partial x^c} = \beta^{\frac{\beta}{1-\beta}} (1-\beta)[\beta(x^c - x^0)^{1-\beta} + \mu(1-\beta)(x^c - \tau\Delta - x^0)^{1-\beta}]^{\frac{1}{1-\beta}-1} (x^c - \tau\Delta)^{-1/\beta-1}$$
$$\{(x^c - \tau\Delta)[\beta(x^c - x^0)^{-\beta} + \mu(1-\beta)(x^c - \tau\Delta - x^0)^{-\beta}] - \frac{1}{\beta}[\beta(x^c - x^0)^{1-\beta} + \mu(1-\beta)(x^c - \tau\Delta - x^0)^{1-\beta}]\} \tag{34}$$

$$\frac{\partial \Pi}{\partial \tau} = \beta^{\frac{\beta}{1-\beta}} (1-\beta)[\beta(x^c - x^0)^{1-\beta} + \mu(1-\beta)(x^c - \tau\Delta - x^0)^{1-\beta}]^{\frac{1}{1-\beta}-1} (x^c - \tau\Delta)^{-1/\beta-1}\Delta$$
$$\{-(x^c - \tau\Delta)\mu(1-\beta)(x^c - \tau\Delta - x^0)^{-\beta} + \frac{1}{\beta}[\beta(x^c - x^0)^{1-\beta} + \mu(1-\beta)(x^c - \tau\Delta - x^0)^{1-\beta}]\} \tag{35}$$

We denote the equilibrium as $x^{*,c}$ with τ^* such that $\left.\frac{\partial \Pi}{\partial x^c}\right|_{x^c = x^{*,c}} = 0$. We also note that given τ, $x^{*,c}$ is the unique equilibrium because $\left.\frac{\partial \Pi}{\partial x^c}\right|_{x^c < x^{*,c}} > 0$ and $\left.\frac{\partial \Pi}{\partial x^c}\right|_{x^c > x^{*,c}} < 0$. We further note that $\tau^* = 1$ because $\left.\frac{\partial \Pi}{\partial x^c}\right|_{x^c = x^{*,c}} = 0$ indicates $\left.\frac{\partial \Pi}{\partial \tau}\right|_{x^c = x^{*,c}} > 0$.

In summary, we have the following conclusion.

Proposition 4. Under incomplete information, regardless of CSR, the monopolist exaggerates the quality of its food as much as possible.

Remarks: Under incomplete information, because consumers cannot judge the quality of food, firms attempt to exaggerate the quality as much as possible to improve both profits and demand. In this way, a firm's profits are improved.

Here, we address quality regulation under incomplete information. Assume that quality regulation $(x^{c,r})$ satisfies the conditions $\left.\frac{\partial \Pi}{\partial x^c}\right|_{x^c = x^{c,r}, \tau=1} > 0$ and $\left.\frac{\partial \Pi}{\partial \tau}\right|_{x^c = x^{c,r}, \tau=1} < 0$. In this case, the price regulation is active. The optimal exaggerating quality is determined by $\left.\frac{\partial \Pi}{\partial \tau}\right|_{x^c = x^{c,r}} = 0.$ We denote the solution as $\tau^{*,r}$. We then have the following conclusion:

Proposition 5. If the quality regulation $(x^{c,r})$ satisfies $\left.\frac{\partial \Pi}{\partial x^c}\right|_{x^c = x^{c,r}, \tau=1} > 0$ and $\left.\frac{\partial \Pi}{\partial \tau}\right|_{x^c = x^{c,r}, \tau=1} < 0$, the optimal degree to which the monopolist exaggerates the quality decreases with CSR.

Proof. Under and $\left.\frac{\partial \Pi}{\partial \tau}\right|_{x^c = x^{c,r}, \tau=1} < 0$, the optimal degree to which the monopolist exaggerates quality satisfies $\left.\frac{\partial \Pi}{\partial \tau}\right|_{x^c = x^{c,r}} = 0.$ According to function (35), we have

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$$\frac{1}{\beta}[\beta(x^{c,r}-x^0)^{1-\beta}+\mu(1-\beta)(x^{c,r}-\tau\Delta-x^0)^{1-\beta}]-(x^{c,r}-\tau\Delta)\mu(1-\beta)(x^{c,r}-\tau\Delta-x^0)^{-\beta}=0 \quad (36)$$

We denote the solution to function (36) as τ^{*r}. From the implicit function theorem, we have $\frac{\partial\tau^{*,r}}{\partial\mu}<0$. Therefore, the optimal degree to which the monopolist exaggerated quality decreases with CSR.

The conclusion is achieved, and the proof is complete.

Remarks: We note that $\left.\frac{\partial\Pi}{\partial x^c}\right|_{x^c=x^{c,r},\tau=1}>0$ and $\left.\frac{\partial\Pi}{\partial\tau}\right|_{x^c=x^{c,r},\tau=1}<0$ indicate that $\tau^{*,r}\in[0,1]$. Under certain conditions, we argue that the monopolist's CSR reduces the degree of quality exaggeration, which is consistent with the conclusions of Kong (2012). We reach Kong's empirical conclusions (2012) in theory.

Under incomplete information, CSR induces an avoidance of quality exaggeration. Therefore, under incomplete information, governments should encourage CSR to avoid quality exaggeration. The policy implication is support for CSR under incomplete information.

CONCLUSION

This paper develops the theory of CSR in the food industry. On the one hand, we capture the effects of CSR under a monopoly and argue that CSR reduces the profits of the monopolist. On the other hand, we address regulation. This article shows that both price regulation and quality regulation reduce the monopolist's profits, consumer surplus and social welfare. Under incomplete information, we find that firms attempt to exaggerate quality as much as possible. Under certain quality regulation, CSR reduces the degree of exaggerated quality.

Under complete information, the active price quality yields lower quality products and reduces the monopolist's profits, consumer surplus and social welfare. Active quality regulation yields a quality higher than what is socially optimal and reduces the monopolist's profits, consumer surplus and social welfare. Under incomplete information, because a CSR firm considers the consumer surplus and SR, CSR reduces the degree of exaggerated quality. The policy implication is that regulations should not be implemented under complete information, whereas regulation is quite necessary under incomplete information.

Our study has both theoretical and empirical implications. In practice, noting the serious food safety problems throughout the world, especially in developing countries such as China and Brazil, governments are always advised to implement regulation policies, but this study indicates that regulation is not a good option in the food industry, because price regulation reduces the quality of food while quality regulation reduces a firm's profits. Instead of regulation, the government should make efforts to understand the operation of food firms. To our best knowledge, our study is the first to develop a theoretical analysis of CSR in the food industry.

Empirical data (Kong 2012) support our results. Under incomplete information, this paper does not consider price regulation because it seems difficult to handle price regulation for the above model. However, this issue is a topic that we will address in further research. Another factor that merits consideration is consumer willingness to pay for quality. This is also an important variable in food quality regulation.

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