

## Research Article

# The Manufacturer Decision Analysis for Corporate Social Responsibility under Government Subsidy

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Charitable donation and energy-saving R&D are two common approaches to fulfill corporate social responsibility (CSR). A recent survey in China shows that most firms prefer donating to investing in energy-saving research and development. To understand firms' preference, we develop a game model to investigate the optimal CSR decisions and profit of the firm, which considers donation and energy-saving R&D approaches, respectively. Then, we analyze how the government subsidies for CSR, as well as the unit production cost and the R&D cost of energy-saving product, affect the firm's CSR decisions and the CSR rate of return. Finally, we study the triple bottom line approach, i.e., considering donation and energy-saving R&D approaches simultaneously, and investigate the interaction between the above two approaches. The results show the following. (1) Government subsidy is an important driver for the firm's CSR fulfillment and the triple bottom line approach is optimal if the government simultaneously provides two subsidies. (2) When the government subsidy for energy-saving product is moderate, the firm will choose the approach with high profit and high CSR rate of return. (3) The CSR rates of return of different approaches are also compared to reveal the efficiency of the CSR fulfillment and the firm may sometimes choose an approach with low CSR rate of return to pursue high profit. We identify why and when firms prefer charitable donation to energy-saving R&D approach and determine the threshold of the firm engaging CSR for the government to formulate CSR subsidy policies.

## 1. Introduction

With the social progress and economic development, companies are required to undertake more and more corporate social responsibility (CSR). To practice CSR, companies should be cautious of and responsible for the impact they may have on all aspects of society including economic, social, and environmental.

For manufacturing firms, CSR, especially the environmental part, can be achieved by energy-saving research and design (R&D), including designing new energy-saving products, improving the energy-saving level of existing products, and introducing new techniques to reduce the environmental pollution and raw material waste during the production process. For example, Tesla designs the pure electric vehicles, electrical manufacturing firms such as Panasonic put efforts into improving the energy-saving level

of air-conditioning, and food companies such as Friesland actively promote waste reduction in the production process [1].

Another common way to fulfill CSR is through charitable donation, which refers to donating products, such as medicines, medical supplies, clothing, food, and electrical products, to charity and other public welfare activities. From the perspective of firms, charitable donation not only improves firms' reputation and brand awareness, but also consumes inventory, reduces storage cost, and maintains retail scarcity levels [2–4].

Elkington [5] proposed the concept of the triple bottom line, which requires companies to perform CSR from three aspects: profit, people, and planet. The triple bottom line is increasingly popular and is subsequently incorporated into business practices [6, 7]. However, compared to energy-saving R&D, charitable donation is a more popular CSR

approach. According to *Observatory Report of CSR in China* [8], Chinese companies prefer charitable donation to energy-saving R&D and the fulfillment of the environmental CSR in China is generally inadequate. Although charitable donation can help people in the disaster-affected or undeveloped areas, it cannot, in most cases, make up for the destruction that firms may have caused to the environment. In contrast, charitable donation builds good image and reputation for companies, which in certain sense help companies disguise from the public and the supervision department, the absence of environmental awareness and protection. As Jack Ma, the founder of Alibaba, said at the 2018 XIN Public Welfare Conference, “Companies cannot make and sell poisonous fakes and pollute the environment, while donating to erase the immoral and irresponsible behavior [9].”

“Lucid waters and lush mountains are invaluable assets,” as proposed by the Chinese President Xi in the 19th National Congress of the Communist Party. In order to encourage the fulfillment of the environmental CSR, the government has carried out many measures and policies, such as subsidies for remanufactured products and tax cut for firms practicing carbon emissions reduction. Among those measures and policies, kinds of direct and indirect government subsidies play a major role. However, the practiced effect of subsidies is unsatisfactory.

Why firms prefer charitable donation to energy-saving R&D? How does the government subsidy affect firms’ CSR engagement? How should the government make advantage of subsidy to encourage firms to fulfill CSR? This paper will explore and answer these interesting questions.

In the literature, some works focus on the impact of energy-saving R&D on the manufacturing firm. On the one hand, energy-saving R&D attracts socially responsible consumers, which increases the profit of firms [10, 11]. On the other hand, the energy-saving R&D is a great burden for firms because of the high R&D cost [12]. Majority of these works consider the firm’s energy-saving decision-making and coordination in different supply chains. For example, Ghosh and Shah [13, 14] study the impact on the manufacturer’s CSR decision-making when its supplier invests in green efforts. Liu et al. [15] and Zhu and He [16] analyze how competition structures affect the economic performance of the green manufacturer. Li et al. [17] explore the energy-saving R&D and channel decision-making of the manufacturer in a dual-channel supply chain and find that the dual-channel supply chain makes the firm go greener in certain situations. Moreover, a few works focus on the impact of government subsidy on the energy-saving R&D decision-making. Firstly, government subsidy or tax exemption encourages firms to research and design the new energy-saving product. Zhang et al. [18] study the energy reuse and compare the quantity of the manufacturer, the repurchase price of the recycler, and the profits of them. Zhou et al. [19] and Li and Li [20] study the interaction between the subsidy regulation of government and the firm’s marketing regimes. They find that the subsidy type and market segmentation may result in different consequences of government subsidy. Secondly, the government restricts

firms’ environmental pollution behavior through law and regulations. Sheu [21] considers the impact of financial intervention by a government on the relative bargaining power of green supply chain members in negotiations. Tsireme et al. [22] study the importance of environmental legislation and find the market-based legislation is positive on the energy-saving R&D of the firm. Xie et al. [23] study the energy-saving decision-making of the firm based on the minimization of financial risk. And Xie [24] further analyzes the situation where the government sets a lower threshold for energy level.

However, none of the aforementioned studies considers the social impact of CSR. In recent years, increasing works focus on the decision-making of socially responsible firm. Two classical approaches are adopted to incorporate social aspect in the firm in extant literature. Some scholars have examined social dimension in the form of consumer surplus [25–29], while others incorporate the dimension as CSR efforts [7, 30–33]. All of them ignore the charitable donation practices of firms. In fact, charitable donation is an important approach to engaging in CSR, especially when the government provides donation subsidy. On the one hand, charitable donation approach directly increases the firm’s profit in business operation. Stecklow [3] finds donating products could reduce excess inventory. Lev et al. [34] demonstrate that charitable donation has a positive impact on sales growth based on an empirical research of America. Chu et al. [35] investigate the tax deduction for charitable donation and after-tax profits and find that consumers would like to pay a premium for charitable donation, which increases the firm’s profit. On the other hand, the charitable donation approach obtains tangible profits and intangible benefits from the government. They obtain tangible profits from government subsidy such as tax cuts [36, 37] and gain intangible benefits such as better relationship with the government and more advantages in the market competition [38, 39]. Arya and Mittendorf [4] study the consequences of charitable donation under the government incentives and examine such wider consequences for supply chains with donation subsidy. Furthermore, Zhang et al. [40] and Modak et al. [41] combine charitable donation with remanufacturing product and closed-loop supply chain, respectively. They find that donation indirectly increases the recovery and sales quantity of remanufactured products. In addition, none of the aforementioned studies focus on the triple bottom line approach, that is, considering the economic, environmental, and social dimensions simultaneously. Biswas et al. [42] explore the coordination of supply chain, when the firm engages in CSR by the triple bottom line approach. Raj et al. [43] study the firm consideration of greening and CSR approaches simultaneously. However, none of them discusses the charitable donation as a CSR practice.

Therefore, we focus on the firm’s CSR approaches under government subsidy, i.e., donation, energy-saving R&D, and triple bottom line approach. Our work contributes to the extant literature in three ways. First, our model considers charitable donation and energy-saving R&D approaches simultaneously, which is hardly reported in the existing

literature. Second, we investigate the interaction between donation and energy-saving R&D approaches and explain why many firms prefer charitable donation to energy-saving R&D approach. Third, we demonstrate the impact of government subsidies on the way the firm fulfill CSR. We find that (1) when the government subsidy is high, the firm always benefits regardless of which CSR approach is selected. The triple bottom line is optimal if the government simultaneously provide two subsidies. (2) The firm's CSR decision is not only related to the government subsidies, but also directly related to the unit production cost and the energy-saving R&D cost. (3) By comparing the CSR rate of return, it is found that the firm's optimal CSR decisions may not guarantee maximum CSR efficiency, which depend on the proportion of government subsidies, especially the energy-saving R&D subsidy.

The rest of the paper is organized as follows. Section 2 describes the basic assumptions and the models. Section 3 analyzes the equilibrium and the theoretical results, which are verified numerically in Section 4. Finally, Section 5 summarizes this paper and the directions of future research.

## 2. Assumptions and Models

Consider a monopoly manufacturer produces certain products and sells those products directly to consumers. There are two approaches to fulfill CSR, i.e., the charitable donation CSR approach by making a donation to charity (donation approach for short) and the energy-saving R&D CSR approach by investing the R&D of energy-saving product (energy-saving R&D approach for short). The government provides subsidy for both approaches; for example, the corporate income tax breaks for the donation approach and the subsidy for new energy production and remanufactured product for the energy-saving approach.

If the manufacturer chooses the energy-saving R&D approach, consumers would like to pay a premium for the energy-saving product. It is assumed that the market (reverse) demand function is shown as follows [14]:

$$p(q) = a - q + b\theta, \quad (1)$$

where  $a$  is the demand intercept,  $b$  is the linear coefficient of energy-saving level on demand, which refers the consumers' awareness of environment,  $\theta$  is the energy-saving level of the product,  $q$  is the quantity of sales, and  $p(q)$ , which is a function of  $q$ , is the unit retail price. The production cost is  $cq^2/2$ , which is governed by the uneconomic scale and the energy-saving R&D cost is  $k\theta^2/2$ , where  $c$  and  $k$  are the cost coefficients of production and energy-saving R&D, respectively [33]. The total government subsidy of energy-saving product is  $r\theta q$ , where  $r$  ( $r \geq 0$ ) is the subsidy level. To sum up, the profit when the manufacturer chooses the energy-saving R&D approach, which is denoted as  $\Pi_E$ , can be written as

$$\begin{aligned} \Pi_E &= p(q)q - \frac{1}{2}cq^2 - \frac{1}{2}k\theta^2 + r\theta q \\ &= (a - q + b\theta)q - \frac{1}{2}cq^2 - \frac{1}{2}k\theta^2 + r\theta q. \end{aligned} \quad (2)$$

If the manufacturer chooses the donation approach, it can opt to set aside  $d$  (the product donation quantity to charity). It is assumed that the products are donated directly to nonprofit organizations or groups in need and have no effect on the market sales and retail price [13, 44]. The market (reverse) demand function is  $p(q) = a - q$ . The total production quantity includes the sales volume and the quantity of products donated to charity; thus, the total production cost is  $c(q + d)^2/2$ , similarly as the case with energy-saving R&D approach. Following Arya and Mittendorf [4], the government subsidy is tied to the retail price, i.e., subsidy equals  $s[p(q)]d$ , where  $s \geq 0$  is the coefficient (This assumption is reasonable in reality. Taking the Chinese government as an example, on one hand, the Chinese government provides tax-free incentives for charitable donation and deduct taxes based on the value added of donated goods (according to the *People's Republic of China Public Welfare Donation Law*), which is indirect subsidy for companies. On the other hand, when a major disaster occurs, the government will directly subsidize the firm based on the value of donated good. To sum up, the government's subsidy effect on the firm is actually a direct subsidy related to the added value of donated goods.). Moreover, according to the literature and the reality, charitable donation helps firms to gain the intangible benefit from the government and society, which is also known as the "warm glow" [45]. The "warm glow" is assumed to be proportional to the value of the donation and is given by  $\omega[p(q)]d$ , where  $\omega \geq 0$  denotes the coefficient. To sum up, the profit when the manufacturer chooses the donation approach, which is denoted as  $\Pi_D$ , can be written as

$$\begin{aligned} \Pi_D &= p(q)q - \frac{1}{2}c(q + d)^2 + s[p(q)]d + \omega[p(q)]d \\ &= (a - q)q - \frac{1}{2}c(q + d)^2 + s(a - q)d + \omega(a - q)d. \end{aligned} \quad (3)$$

Finally, if the manufacturer chooses the triple bottom line approach, i.e., both the environment and the donation approach, the profit can be written as

$$\begin{aligned} \Pi_T &= (a - q + b\theta)q - \frac{1}{2}c(d + q)^2 + (s + \omega)(a - q + b\theta)d \\ &\quad - \frac{1}{2}k\theta^2 + r\theta q. \end{aligned} \quad (4)$$

### 3. Model Analysis

In this section, we solve the models and analyze the equilibrium solutions for the above CSR approaches, respectively (all proofs are provided in Appendix).

**3.1. Energy-Saving R&D Approach.** When the firm chooses the energy-saving R&D approach, it needs to decide the energy-saving level  $\theta$  ( $\theta > 0$ ) and the quantity  $q$  of sales. Assume that the firm makes decisions to maximize profit; that is,

$$\text{Max } \Pi_E = (a - q + b\theta)q - \frac{1}{2}cq^2 + r\theta q - \frac{1}{2}k\theta^2. \quad (5)$$

From equation (5), the equilibrium solution can be obtained as shown in Lemma 1.

**Lemma 1.** *In the energy-saving R&D model, the equilibrium solution exists when conditions (1)  $b^2/(2+c) < k \leq b^2(2+c)$  and  $r < \sqrt{(2+c)k} - b$  and (2)  $k > b^2(2+c)$  and  $r < (\sqrt{b^2+4(1+c)k} - b)/2$  are satisfied. The quantity  $q^*$  of sales and the energy-saving level  $\theta^*$  are as follows:*

$$\begin{aligned} q^* &= \frac{ak}{(2+c)k - (b+r)^2}, \\ \theta^* &= \frac{a(b+r)}{(2+c)k - (b+r)^2}. \end{aligned} \quad (6)$$

Conditions (1) and (2) in Lemma 2 indicate that when the energy-saving R&D cost  $k$  is high, the range of the government energy-saving subsidy  $r$  is relatively large. In contrast, when  $k$  is low, the range of  $r$  is relatively small.

From Lemma 1, we can get Proposition 1 and Proposition 2.

**Proposition 1.** *When the firm chooses the energy-saving R&D approach,*

- (1) *the energy-saving level  $\theta^*$  increases with the government energy-saving subsidy  $r$ , that is,  $\partial\theta^*/\partial r > 0$ ;*
- (2) *the energy-saving level  $\theta^*$  increases with the consumers' environmental awareness  $b$ , that is,  $\partial\theta^*/\partial b > 0$ ;*
- (3) *the energy-saving level  $\theta^*$  decreases with the increased energy-saving R&D cost  $k$ , that is,  $\partial\theta^*/\partial k < 0$ ;*
- (4) *the energy-saving level  $\theta^*$  decreases with the increased unit production cost  $c$ , that is,  $\partial\theta^*/\partial c < 0$ .*

Proposition 1 shows that when the firm chooses the energy-saving R&D approach, as the government energy-saving subsidy  $r$  increases, it can not only improve the energy-saving level  $\theta^*$ , but also benefit the firm directly because of the total government subsidy  $r\theta q$ . It is an important reason why the firm can engage in CSR by the energy-saving R&D approach.

In reality, the Chinese government provides energy-saving subsidies to encourage companies to carry out energy-saving R&D, but it is much less effective than neighboring countries such as Japan. According to the *Report of Environmental White*

*Paper* [46], the Japanese environmental efficiency in 2014 increased by 2.31 times compared with 2000, and the energy consumption decreased by 2.7%. However, the Chinese energy consumption has increased year by year, from 1.45 billion tons in 2000 to 3.20 billion tons in 2018, and shows a trend of continual growth in the next 10 years. There are two reasons: on the one hand, public environmental awareness is low ( $b$  is low). Hence, the consumers may pay higher prices for energy-saving product than common products and the firm does not have enough incentive to fulfill CSR when the energy-saving subsidy is low. On the other hand, the energy-saving R&D cost  $k$  is high, which requires the government to pay high subsidy to encourage the firm's CSR engagement.

In addition, only when the values of  $k$ ,  $b$ , and  $r$  meet the condition such that  $k > (b+r)^2/(2+c)$ , will the firm be willing to fulfill CSR. The condition shows that (1) too high subsidy ( $r$ ) may discourage the firm from investing the energy-saving R&D, and (2) when the technology reaches the peak, the energy-saving level  $\theta$  will not increase with the increase of  $r$ . Therefore, the government should take the energy-saving R&D cost, unit production cost, and the consumers' environmental awareness into account when making the energy-saving subsidy.

### Proposition 2

- (1) *When the energy-saving R&D cost  $k$  is low, i.e.,  $b^2/(2+c) < k \leq b^2(2+c)$ , the retail price  $p$  increases with the government energy-saving subsidy  $r$ , that is,  $\partial p(q^*(r))/\partial r > 0$ .*
- (2) *When the energy-saving R&D cost  $k$  is high, i.e.,  $k > b^2(2+c)$ , there are two cases:*

*If  $0 < r \leq (k - \sqrt{k(-b^2(2+c)+k)})/b - b$ , the retail price  $p$  increases with the government energy-saving subsidy  $r$ , that is,  $\partial p(q^*(r))/\partial r > 0$ .*

*If  $(k - \sqrt{k(-b^2(2+c)+k)})/b - b < r \leq (\sqrt{b^2+4(1+c)k} - b)/2$ , the retail price  $p$  decreases with the increased government energy-saving subsidy  $r$ , that is,  $\partial p(q^*(r))/\partial r < 0$ .*

Proposition 2 shows that if the energy-saving R&D cost  $k$  is low, the retail price  $p$  increases with the government energy-saving subsidy  $r$ . This is because when  $k$  is low, the equilibrium solution of the energy-saving level  $\theta^*$  is high. Therefore, consumers will pay a premium for the high energy-saving  $\theta^*$  and the firm benefits from energy-saving R&D approach. However, if  $k$  is high,  $p$  first increases and then decreases with the value of  $r$ . This is because when  $k$  is high, the firm tends to choose the low  $\theta$  and the premium that consumers are willing to provide is low. If  $r$  is low, consumers will pay a premium to the firm for the energy-saving product. If  $r$  is high enough, the government subsidy not only encourages the firm's energy-saving R&D, but also benefits consumers.

**3.2. Donation Approach.** When the firm chooses the donation approach, it needs to decide the quantity  $q$  of sales and the donation quantity  $d$ . Assume that the firm makes decisions to maximize profit, that is,

$$\text{Max } \Pi_D = (a - q)q - \frac{1}{2}c(q + d)^2 + s(a - q)d + \omega(a - q)d. \quad (7)$$

According to equation (7), it is easy to get the equilibrium solution as shown in Lemma 2.

**Lemma 2.** *When choosing the donation approach, the equilibrium quantity  $q^{**}$  of sales and donation  $d^{**}$  are as follows:*

If  $0 \leq s < \bar{s}$ , then  $d^{**} = 0$  and  $q^{**} = a/(2 + c)$ .

For  $\bar{s} \leq s \leq \bar{s}$ ,  $d^{**} = \hat{d}$ ,  $q^{**} = \hat{q}$ ,

where

$$\begin{aligned} \bar{s} &= \frac{c}{1 + c} - \omega, \bar{s} = \frac{1}{2}(\sqrt{c(4 + c)} - c - 2\omega), \\ \hat{q} &= \frac{a(c(s + \omega - 1) + (s + \omega)^2)}{2c(s + \omega - 1) + (s + \omega)^2}, \hat{d} = \frac{a(s + \omega + c(s + \omega - 1))}{2c(s + \omega - 1) - (s + \omega)^2}. \end{aligned} \quad (8)$$

Lemma 2 shows that if the government donation subsidy  $s$  is low ( $0 \leq s < \bar{s}$ ), the firm will not engage in CSR by donation approach, that is,  $d = 0$ . If  $s$  is high enough ( $\bar{s} \leq s \leq \bar{s}$ ), the firm will engage in CSR by the donation approach. However, if  $s$  is too high ( $s > \bar{s}$ ), the market clearing quantity  $q^{**}$  of sales is less than 0. To ensure the operation of the market, we assume that  $s$  does not exceed  $\bar{s}$ , i.e., satisfies  $s \leq \bar{s}$ , in the remainder of this paper.

From Lemma 2, we can get Proposition 3 and Proposition 4.

**Proposition 3.** *In the donation approach,*

- (1) *The firm will engage in CSR by the donation approach if and only if the government donation subsidy  $s$  is high enough, that is,  $\bar{s} \leq s \leq \bar{s}$*
- (2) *When the firm chooses the donation approach, i.e.,  $\bar{s} \leq s \leq \bar{s}$ :*
  - ① *the donation quantity  $d^{**}$  increases with the government donation subsidy  $s$ , that is,  $\partial d^{**}/\partial s > 0$ .*
  - ② *the donation quantity  $d^{**}$  increases with the “warm glow” effect  $\omega$ , that is,  $\partial d^{**}/\partial \omega > 0$ .*
  - ③ *the donation quantity  $d^{**}$  decreases with the increased unit production cost  $c$ , that is,  $\partial d^{**}/\partial c < 0$ .*

According to Proposition 3, when the government donation subsidy  $s$  is high enough, the firm chooses to engage in CSR by the donation approach. The equilibrium donation quantity  $d^{**}$  is determined by three parameters, i.e., the government donation subsidy  $s$ , the “warm glow” effect  $\omega$ , and the unit production cost  $c$ . To be specific, as  $s$  increases, the firm tends to increase donation quantity  $d^{**}$ , which is consistent with the reality. For example, the Chinese government passed the *Amendment of the Corporate Income Tax Law (Draft)* in 2017 providing subsidies to encourage companies to make charitable

donation [47]. According to the China Charity List published by the *Public Welfare Times* (2017), the number of Chinese companies doing charities increased from 414 in 2016 to 721 in 2017 and the total value of donation increased from ¥7.115 billion to ¥12.079 billion. This example justifies that the increase of  $s$  indeed promotes firms to engage in CSR by charitable donation. As for the other two parameters, as the intangible benefits from donation approach,  $d^{**}$  increases if  $\omega$  increases, while  $d^{**}$  decreases if  $c$  increases. These results are intuitive, because the increase of  $\omega$  leads to an increase in the benefits of donation and the increase of  $c$  raises the total cost of donation.

**Proposition 4.** *When the firm chooses the donation approach, i.e.,  $\bar{s} \leq s \leq \bar{s}$ ,*

- (1) *consumers pay a premium for the firm, that is,  $p(q^{**}(s)) > p(q(\bar{s}))$ .*
- (2) *the premium increases with the government donation subsidy  $s$ , that is,  $\partial[p(q^{**}(s)) - p(q(\bar{s}))]/\partial s > 0$ .*

Proposition 4 shows that the retail price  $p$  is higher when the firm chooses the donation approach than when it does not engage in CSR. This occurs as a result of the firm obtaining more profits with the higher government donation subsidy  $s$ . That is to say, the higher  $s$ , the more amount of government donation subsidy (i.e.,  $s[p(q)]d$ ). The firm may deliberately raise the retail price to pursue higher subsidy and more profit. It demonstrates that the CSR behavior of the firm is undertaken by consumers. In addition, consumers are willing to pay for the donation approach because the firm improves the brand image and the consumer brand loyalty by engaging in CSR. For example, Red Wong Lo Kat, a Chinese beverage giant selling herbal tea, has improved the corporate image and reputation through high-value charitable donation and has increased the profit by 130% simultaneously. Moreover, the consumers' premium increases with  $s$ .

**3.3. Comparative Analysis of the Donation and the Energy-Saving R&D Approach.** According to Propositions 1–4, if the government subsidy is high enough, the firm will engage in CSR by either energy-saving approach or donation approach. Two immediate questions are as follows: given two CSR approaches at the same time, which CSR approach is more beneficial for the firm in terms of profit? And which approach is more efficient for the firm in terms of rate of return? To answer the two questions, we compare the firm's profit and the rate of return with two CSR approaches as shown in Proposition 5 and Proposition 6.

**Proposition 5.** *When the firm faces two CSR approaches, the donation approach and the energy-saving R&D approach, there are two cases:*

- (1) *If and only if the energy-saving R&D cost  $k$  is high (i.e.,  $k > (b^2(2 + c) + \sqrt{b^4c(4 + c)})/2$  and the government energy-saving subsidy  $r$  is low but the donation subsidy  $s$  is high, i.e.,  $0 < r \leq \sqrt{[k(c(s + \omega - 1) + s + \omega)^2]/[c(s + \omega - 1)^2]} - b$  and  $[\sqrt{b^2ck} + c(k + ck - b^2)]/[(1 + c)^2k - b^2c]$*

- $-\omega < s \leq \bar{s}$ , then  $\Pi_D > \Pi_E$ , implying that the firm chooses the donation approach.
- (2) Otherwise,  $\Pi_D < \Pi_E$ , implying that the firm chooses the energy-saving R&D approach.

Proposition 5 indicates that the government should pay attention to the impact of different subsidy levels on CSR and make appropriate policies. Furthermore, we have the following two observations from Proposition 5.

First of all, when the government provides two CSR subsidies simultaneously, the firm's CSR decision is determined by the donation subsidy  $s$ , the energy-saving R&D subsidy  $r$ , and the energy-saving R&D cost  $k$ . When  $k$  is too low  $k < (b^2(2+c) + \sqrt{b^4c(4+c)})/2$ , the firm tends to choose the energy-saving R&D approach, regardless of the values of  $s$  and  $r$ . And when  $k$  is high enough  $k > (b^2(2+c) + \sqrt{b^4c(4+c)})/2$ , the firm's CSR decision depends on the values of  $s$  and  $r$ . Specifically, if  $r$  is high enough (i.e.,  $r > \sqrt{k(c(s+\omega-1) + s + \omega)^2/c(s+\omega-1)^2 - b}$ ), the firm tends to adopt the energy-saving R&D approach, regardless of the value of  $s$ . However, when  $r$  is low (i.e.,  $0 < r \leq \sqrt{k(c(s+\omega-1) + s + \omega)^2/c(s+\omega-1)^2 - b}$ ), the decisions depend on the value of  $s$ . The firm tends to choose the energy-saving R&D approach if  $s$  is low (i.e.,  $\bar{s} \leq s \leq [\sqrt{b^2ck} + c(k+ck-b^2)]/[(1+c)^2k - b^2c] - \omega$ ), and otherwise (i.e.,  $[\sqrt{b^2ck} + c(k+ck-b^2)]/[(1+c)^2k - b^2c] - \omega < s \leq \bar{s}$ ) the donation approach.

This observation may explain the preference of Chinese companies for the charitable donation approach comparing to the energy-saving R&D approach [8]. This may be because that the R&D activity is always expensive and risky (i.e.,  $k$  is high) and the Chinese government provides the relatively high donation subsidy level  $s$  and the relatively low energy-saving R&D subsidy level  $r$ . In fact, many special subsidy policies in China provide the tax deduction in full amount, which is much higher than that in the United States and almost reaches the highest level all around the world. Meanwhile, the energy-saving R&D subsidy by the Chinese government is inadequate. Taking eco-friendly cars as an example, the tax reduction rate of buying new-energy vehicles in Japan is as high as 100% [48], while the counter in China is only 25% in 2017.

Secondly, Proposition 5 shows the decision-making of the firm is related to four factors: the unit production cost  $c$ , the energy-saving R&D cost  $k$ , the "warm glow"  $\omega$ , and the consumers' environmental awareness of environment  $b$ . When  $c$  or  $b$  increases, the threshold of the energy-saving R&D subsidy, i.e.,  $\sqrt{k(c(s+\omega-1) + s + \omega)^2/c(s+\omega-1)^2}$

$-b$ , will decrease and the firm will tend to choose the energy-saving R&D approach. When  $k$  or  $\omega$  increases, this threshold will increase, and the firm will tend to choose the donation approach. The preference of Chinese firms for the donation approach may partially come from the fact that the environmental awareness of Chinese consumers is low and the energy-saving R&D cost is too high.

Next, we analyze and compare the CSR rate of return of two CSR approaches. According to the definition of labor rate of return [49], we define the CSR rate of return as follows.

**Definition 1.** The CSR rates of return of the donation approach and the energy-saving R&D approach are  $(\Delta\Pi_D/\Delta C_D)$  and  $(\Delta\Pi_E/\Delta C_E)$ , respectively.

In the definition,  $\Delta\Pi_D$  and  $\Delta\Pi_E$  denote the CSR return (the extra profit from the government and society) of two approaches, respectively, that is,

$$\begin{aligned}\Delta\Pi_D &= \Pi_D - \Pi_0, \\ \Delta\Pi_E &= \Pi_E - \Pi_0,\end{aligned}\tag{9}$$

where  $\Pi_0$  denotes the firm's profit without CSR and  $\Pi_D$  and  $\Pi_E$  represent the profit of firm choosing the donation approach and the energy-saving R&D approach, respectively.  $\Delta C_D$  and  $\Delta C_E$  represent the CSR cost (the extra cost of the firm) when choosing two CSR approaches respectively, that is,

$$\begin{aligned}\Delta C_D &= \frac{1}{2}c(q+d)^2 - \frac{1}{2}cq_0^2, \\ \Delta C_E &= \frac{1}{2}cq^2 + \frac{1}{2}k\theta^2 - \frac{1}{2}cq_0^2,\end{aligned}\tag{10}$$

where  $q_0$  denotes the optimal quantity of sales when the firm does not engage in CSR.

**Proposition 6.** When the firm faces two CSR approaches, the donation approach and the energy-saving R&D approach, there are two cases:

- (1) If  $0 < r < f(s)$ , the CSR rate of return of the energy-saving R&D approach is higher than the donation approach, i.e.,  $\Delta\Pi_E/\Delta C_E > \Delta\Pi_D/\Delta C_D$ .
- (2) If  $f(s) < r < \sqrt{(2+c)k} - b$ , the CSR rate of return of the donation approach is higher than the energy-saving R&D approach, i.e.,  $\Delta\Pi_D/\Delta C_D > \Delta\Pi_E/\Delta C_E$ , where

$$f(s) = \sqrt{\frac{k(3c^3(s+\omega-1)^2 + (s+\omega)^3 + c(s+\omega)^2(4s+4\omega-3) + c^2(s+\omega-1)((s+\omega)(5+2s+2\omega)-4)}{c(s+\omega-1)^2(c+s+\omega)}} - b.\tag{11}$$

From Proposition 6, we find that the firm's CSR rate of return is affected by the government energy-saving subsidy  $r$ . If  $r$  is low, the CSR rate of return of the energy-saving R&D approach is higher than that of the donation approach. However, if  $r$  is high, the CSR rate of return of the energy-saving R&D approach is lower than that of the donation approach. It is because that the CSR rate of return is the ratio of the firm's extra profit to the extra cost when engaging in CSR. When  $r$  is low, the firm mainly obtains extra profit from the consumers' premium. However, the consumers' premium is restricted by the energy-saving R&D cost  $k$ . Therefore, the firm needs trade-off between the CSR cost  $\Delta C$  and CSR return  $\Delta\Pi$  and chooses the low energy-saving level  $\theta$  and optimal quantity  $q$  of sales. In contrast, when  $r$  is high, the firm will choose high  $\theta$  and corresponding  $q$ , so as to obtain higher profit from the government, meanwhile ignoring the fact that CSR rate of return of the energy-saving R&D approach is low. In other words, the firm may choose the energy-saving R&D approach with low CSR rate of return to pursue high profits.

In addition, the government donation subsidy  $s$  affects the CSR rate of return by the threshold of  $r$ , i.e.,  $f(s)$ . If  $s$  is low,  $df(s)/ds$  is less than 0, while if  $s$  is high,  $df(s)/ds$  is greater than 0, implying that the range of  $r$  in the second

statement of Proposition 6 shrinks with the increased value of  $s$ . That is to say, as the value of  $s$  increases, the CSR rate of return of the donation approach is less likely to go beyond that of the energy-saving R&D approach.

To conclude, Proposition 6 indicates that the government should carefully trade off the CSR rate of return of the two approaches to ensure the CSR efficiency.

**3.4. Triple Bottom Line Approach.** When the firm chooses the triple bottom line approach, i.e., both the energy-saving R&D and donation approach, it needs to decide the energy-saving level  $\theta$  ( $\theta > 0$ ), the quantity  $q$  of sales, and the donation  $d$ . Assume that the firm makes decisions to maximize profit, that is,

$$\begin{aligned} \text{Max } \Pi_T = & (a - q + b\theta)q - \frac{1}{2}c(d + q)^2 \\ & + (s + \omega)(a - q + b\theta)d - \frac{1}{2}k\theta^2 + r\theta q. \end{aligned} \quad (12)$$

If the government subsidies meet the following conditions:

$$\begin{aligned} \frac{c}{1+c} - \omega < s < -c + \sqrt{c(2+c)} - \omega \\ k > \text{Max} \left\{ \frac{r(b+r)(s+\omega)}{c(-1+s+\omega)+s+\omega}, \frac{-c(b+r)^2+2bc(b+r)(s+\omega)+b(-bc+2r)(s+\omega)^2}{2c(-1+s+\omega)+(s+\omega)^2} \right\}, \end{aligned} \quad (13)$$

the equilibrium quantity  $\hat{q}$  of sales, the donation  $\hat{d}$ , and the energy-saving level  $\hat{\theta}$  are as follows:

$$\begin{aligned} \hat{q} &= \frac{a(ck(-1+s+\omega)+(k-br)(s+\omega)^2)}{b^2c(-1+s+\omega)^2+k(s+\omega)^2+c(r^2+2k(-1+s+\omega))-2br(c(-1+s+\omega)+(s+\omega)^2)}, \\ \hat{d} &= \frac{a(-ck(-1+s+\omega)-(k-r(b+r))(s+\omega))}{b^2c(-1+s+\omega)^2+k(s+\omega)^2+c(r^2+2k(-1+s+\omega))-2br(c(-1+s+\omega)+(s+\omega)^2)}, \\ \hat{\theta} &= \frac{a(bc(-1+s+\omega)^2-r(c(-1+s+\omega)+(s+\omega)^2))}{b^2c(-1+s+\omega)^2+k(s+\omega)^2+c(r^2+2k(-1+s+\omega))-2br(c(-1+s+\omega)+(s+\omega)^2)}. \end{aligned} \quad (14)$$

Therefore, when the firm chooses the triple bottom line approach, the optimal profit is

$$\widehat{\Pi}_T = (a - \hat{q} + b\hat{\theta})\hat{q} - \frac{1}{2}c(\hat{d} + \hat{q})^2 + (s + \omega)(a - \hat{q} + b\hat{\theta})\hat{d} - \frac{1}{2}k\hat{\theta}^2 + r\hat{\theta}\hat{q}. \quad (15)$$

We use some numerical experiments to investigate the firm's consequence of the triple bottom line approach in

Section 4, since the above equilibrium and the conditions are too complicated to analyze.

#### 4. Numerical Analysis of the Triple Bottom Line Approach

Further, we discuss the firm's consequence of the triple bottom line approach. We first analyze the impact of two government subsidies, i.e., the donation subsidy  $s$  and the energy-saving subsidy  $r$ , on the quantity  $q$  of sales, the donation  $d$ , the retail price  $p$ , and the marginal profit changes. Then, we compare the firm's profit by choosing the energy-saving R&D, the donation, and the triple bottom line approach, respectively. In the end, we compare the three different CSR of rate of return.

**4.1. The Impact of Government Subsidy on the Firm's Decision.** Firstly, we analyze the impact of two government subsidies, i.e., the donation subsidy  $s$  and the energy-saving subsidy  $r$ , on the firm's decision, including quantity  $q$  of sales, donation  $d$ , retail price  $p$ , and marginal profit changes, when the firm chooses the triple bottom line approach. Assume that  $a = 1$ ,  $c = 0.2$ ,  $b = 0.1$ ,  $\omega = 0.1$ , and  $k = 1$ . The results are shown in Figures 1–3.

Figure 1 shows the impact of the donation subsidy  $s$  and the energy-saving subsidy  $r$  on the quantity  $q$  of sales and the donation  $d$ , where the dark blue surface represents the quantity  $q$  of sales and light blue surface represents donation  $d$ . As shown in Figure 1,  $q$  is decreasing and  $d$  is increasing in  $s$ , while  $q$  is increasing and  $d$  is decreasing in  $r$ . Figure 2 depicts the impact of  $s$  and  $r$  on the energy-saving level  $\theta$ . According to Figure 2,  $\theta$  is slowly decreasing in  $s$ , but quickly increasing in  $r$ . We find that the results are similar to the simple CSR approaches (Proposition 1–3).

Figures 3(a) and 3(b) describe the marginal profit changes with  $s$  and  $r$ , respectively. According to Figure 3,  $s$  is negatively related to the energy-saving R&D approach of the firm and  $r$  is negatively related to the firm's donation. This shows that when the firm can consider two CSR approaches at the same time, it always tends to take the approach which has high government subsidy and appropriately reduce the other approach. That is to say, the two CSR approaches are complementary. It is exactly the significance of our study focusing on a single approach. Therefore, the government should consider the cross-effects of the two subsidies and reduce the inhibitory effect.

**4.2. The Sensitivity Analysis of the Triple Bottom Line Approach.** We analyze the sensitivity of the triple bottom line approach. Assume that  $a = 1$ ,  $b = 0.1$ ,  $\omega = 0.1$ ,  $k = 1$ ,  $s = 0.1$ , and  $r = 0.1$ . The impact of the unit production cost  $c$  on the firm's profit is shown in Figure 4.

In Figure 4, the firm can obtain more profit by engaging in CSR regardless of the unit production cost  $c$ . And when the firm can consider the triple bottom line approach, i.e., two CSR approaches at the same time, it always gets more profit. However, the firm's profit with the donation approach  $\Pi_D$  has a greater effect on  $c$  than the energy-saving R&D approach  $\Pi_E$ . When  $c$  is small ( $c < 0.167$ ),  $\Pi_D$  is greater than  $\Pi_E$ . And when  $c$  is smaller, the difference is greater between two profits. On the contrary, when  $c$  is large

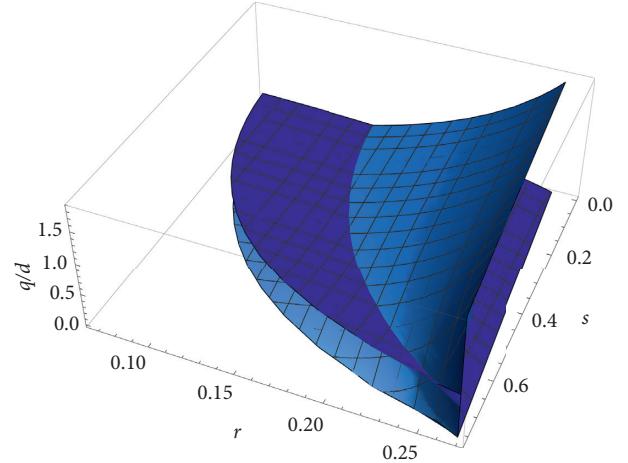


FIGURE 1: The impact of two government subsidies ( $s$  and  $r$ ) on the quantity  $q$  of sales and the donation  $d$ .

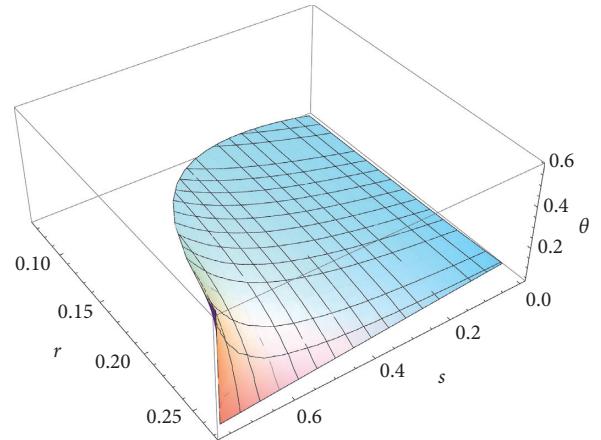
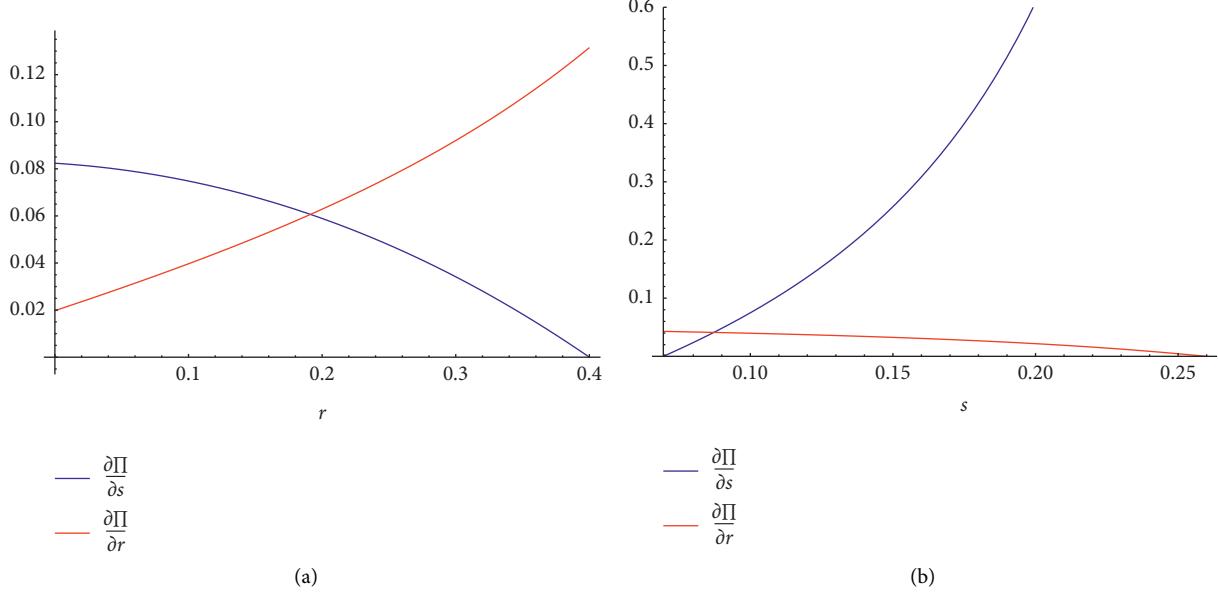
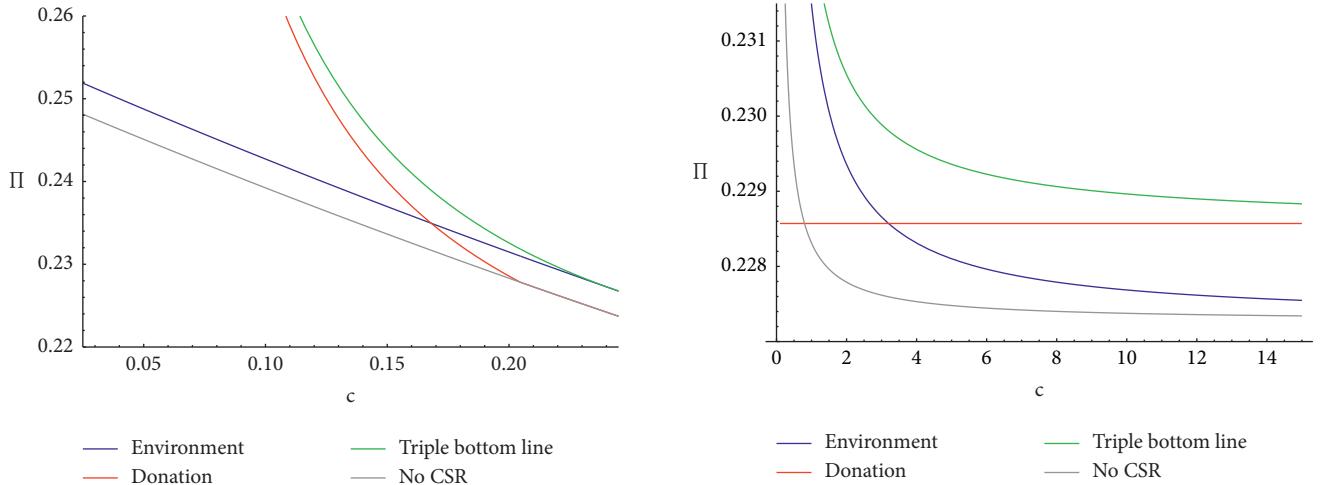


FIGURE 2: The impact of two government subsidies ( $s$  and  $r$ ) on the energy-saving level  $\theta$ .

( $c > 0.167$ ), the firm prefers energy-saving CSR approach due to  $\Pi_D < \Pi_E$ . It means the firm increases the donation quantities rather than the R&D investment when the unit production cost  $c$  is small, even if the government provides both subsidies.

Taking Midea, a leader among Chinese manufacturers, as an example, the operating income of Midea Group was ¥221.1 billion in 2017 and the total production cost was only ¥16.2 billion (except for raw material procurement). Meanwhile, the retail quantity of electrical appliances exceeds 400 million units. We presume Midea has a small unit production cost  $c$ , which is located on the left side of Figure 4. This is an important reason why Chinese firms prefer the donation approach. In reality, Midea has donated more than ¥600 million to charity and won the Most Caring Donation Corporation Award from the Ministry of Civil Affairs in 2014. This proves the government donation subsidy is a more effective way to encourage companies to fulfill CSR than the energy-saving subsidy in China.

To conclude, affected by the unit production cost, the Chinese government makes great efforts to encourage firms

FIGURE 3: The effect of subsidies on the firms' marginal profit. (a)  $s = 0.1$ . (b)  $r = 0.1$ .FIGURE 4: The impact of the unit production cost  $c$  on the firm's profit.

investing in the energy-saving R&D, but firms still prefer the donation approach. This conclusion suggests the government should improve the government subsidies of the energy-saving R&D and achieve the development of human, economic, and planet.

Next, we investigate the impact of the energy-saving R&D cost  $k$  on the firm's profit, as shown in Figure 5. Similarly, assume that  $a = 1$ ,  $b = 0.1$ ,  $\omega = 0.1$ ,  $c = 0.2$ ,  $s = 0.1$ , and  $r = 0.1$ .

From Figure 5, the firm that chooses to fulfill CSR is always better than that does not, i.e.,  $\Pi_D > \Pi_0$ ,  $\Pi_E > \Pi_0$ , and  $\Pi_T > \Pi_0$ , and the triple bottom line approach is optimal. If the energy-saving R&D cost  $k$  is low ( $k < 3.2$ ), the firm's profit with energy-saving approach  $\Pi_E$  is greater than donation approach  $\Pi_D$ . As  $k$  increases,  $\Pi_E$  decreases and  $\Pi_D$  keeps constant. It means the firm tends to decrease the R&D investment, when the energy-saving R&D cost is too large.

FIGURE 5: The impact of the energy-saving R&D cost  $k$  on the firm's profit.

From the development of Chinese manufacturing industry, the capability of R&D and the efficiency are low and the intellectual property protection is incomplete. That is to say,  $k$  is located on the right side of Figure 5. This is an important reason why Chinese firms prefer the donation approach. In addition, the incentive of government subsidy decreases rapidly with the increased energy-saving R&D cost. In conclusion, the government ought to make more another kind of subsidies or incentives to reduce R&D cost, such as creating platform of industry-university-research cooperation and subsidizing R&D laboratories of firms.

**4.3. Comparing the CSR Rate of Return of Different CSR Approaches.** Finally, we compare the CSR rate of return of different CSR approaches in Figure 6. Assume that  $a = 1$ ,  $b = 0.1$ ,  $\omega = 0.1$ , and  $c = 0.2$ . In Area I,

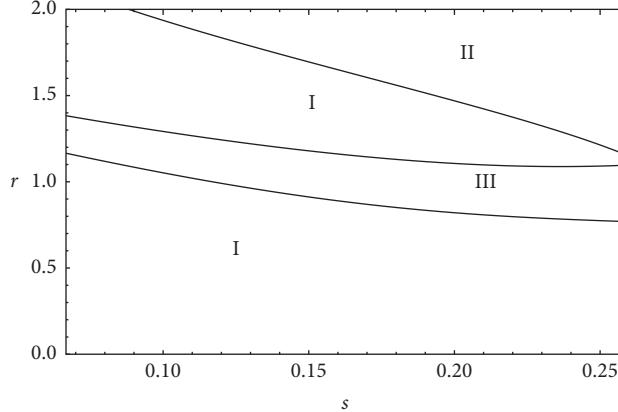


FIGURE 6: The CSR rate of return of different CSR approaches.

$\Delta\Pi_E/\Delta C_E > \Delta\Pi_D/\Delta C_D$  and  $\Delta\Pi_E/\Delta C_E > \Delta\Pi_T/\Delta C_T$ . In Area II,  $\Delta\Pi_D/\Delta C_D > \Delta\Pi_E/\Delta C_E$  and  $\Delta\Pi_T/\Delta C_T > \Delta\Pi_E/\Delta C_E$ . In Area III,  $\Delta\Pi_T/\Delta C_T > \Delta\Pi_E/\Delta C_E$  and  $\Delta\Pi_T/\Delta C_T > \Delta\Pi_D/\Delta C_D$ .

Figure 6 presents the results of the CSR rate of return comparison of different CSR approaches. From Figure 6(a), first at all, when the energy-saving subsidy  $r$  is quite low, the CSR rate of return of the energy-saving R&D approach is relatively larger regardless of the level of the donation subsidy  $s$  (Area I). Next, when  $r$  is moderate, the CSR rate of return of the triple bottom line approach is higher (Area III). Finally, if  $r$  is large enough, there are two cases: if and only if both  $s$  and  $r$  are large, the CSR rate of return of the donation approach is larger (Area II); otherwise, the energy-saving R&D approach is larger (Area I). In addition, Figure 6 implies that the CSR rate of return of the triple bottom line approach is not optimal in most cases (Area I and Area II), though this CSR approach allows the firm to obtain the maximum profit. Therefore, the government should take CSR efficiency (CSR rate of return) into account and comprehensively design subsidy ratio to encourage the firm to fulfill CSR efficiently with high CSR rate of return.

**4.4. Managerial Insights.** Based on the above propositions and numerical examples, we suggest the managerial insights as follows:

Firstly, for the government, it is necessary to design appropriate CSR subsidies and suitably increase CSR subsidy, especially increase the government energy-saving subsidy so as to effectively encourage firms to fulfill CSR. In China, the *12th Five-Year Plan for Energy Conservation and Emission Reduction* and other plans show the determination of the Chinese government to encourage firms to produce energy-saving product. However, it is still difficult to completely implement subsidy policy on energy-saving products due to the unclear subsidy intensity and scope. Therefore, the Chinese government should expand the beneficiaries, increase the amount of subsidy, and ensure the production and sales of energy-saving products. In addition, appropriate subsidies given to the charitable donation is necessary. It may affirm the firm's feedback to the society and ensure the social welfare undertakings flourish. Moreover, in order to encourage firms to fulfill CSR more

efficiently, the government should not only design the appropriate subsidy level of charitable donation and energy-saving, but also try to reduce the R&D cost of energy-saving products, such as creating platform of industry-university-research cooperation and subsidizing R&D laboratories of firms.

Secondly, firms should actively cooperate with upstream and downstream firms in the supply chain to cut down the R&D cost and production cost of energy-saving products to decrease the CSR participation threshold. Then, firms should be fully marketing, highlight their positive image of CSR, and expand the “warm light effect” to increase their extra income from consumers. In addition, firms should actively respond to the government's CSR subsidy policy and increase the investment of CSR. On the one hand, firms could obtain corresponding benefits from government subsidy. On the other hand, they may take responsibility for environmental protection and energy saving at the same time.

## 5. Conclusion

Corporate social responsibility (CSR) embraces a wide range of responsibilities including economy, environment, and society. The charitable donation and the energy-saving R&D are two important approaches for firms to fulfill the CSR. In this paper, we study the impact of the CSR approaches, including the donation, the energy-saving R&D, and the triple bottom line approach, on the firm's profit. Then, we analyze the influence factors and the CSR rate of return. Finally, we compare the firm's profit and the CSR rate of return. The conclusions are shown as follows:

- (1) Government subsidy is an important reason for the firm engaging in CSR. For donation approach, the government donation subsidy is a decisive factor that determines whether the firm engages in CSR. When the government donation subsidy is low, the firm has no incentive to donate. When the government donation subsidy is high, the firm could benefit from the donation approach. For energy-saving approach, however, the firm would engage in CSR if the government provides energy-saving subsidy.

- (2) Government donation subsidy has three effects on the firm. Firstly, it transfers products from retail sales to donation and resources from consumers to society. Secondly, it increases the retail price and brings a premium to the firm. Finally, it increases the energy-saving level of product and provides more social welfare to consumers.
- (3) Unlike the study of Ghosh and Shah [14], who studied the impact on only one government subsidy to the firm, we study the firm's CSR under the two subsidy policies and compare the CSR rate of return. When the government subsidy is high, the firm always benefits regardless of which CSR approach is selected. The triple bottom line is optimal if the government simultaneously provides two subsidies. However, only when the government energy-saving subsidy is moderate, the firm has high profit and high CSR rate of return in energy-saving R&D approach. Therefore, the government should design appropriate subsidy, so that the firm can engage in CSR with high CSR rate of return and achieve coordinative development of economy, environment, and society.
- (4) There are some factors that influence the CSR approach except for government subsidy, such as the energy-saving R&D cost and the consumers' awareness of environment found out by Zhu and Sarkis [50] and the unit production cost. Specifically, the reason why the firms prefer donation is that the unit production cost is low. And another important reason is that the energy-saving R&D cost limits the firm's investment for the environmental technology.

This research can be further extended in several directions. First, we consider the CSR decision-making of a monopoly manufacturer, while many manufacturers are competitive in real life. Future research could consider the case with multiple manufacturers in market to assess the extent to which our policy insights extend. Second, the decisions of production activities and CSR practices are often long-term. For future research, further studies might investigate the long-term profits of firms obtained by the donation approach. Third, further studies might consider the different motivations of firms engaging in CSR, such as altruism and social feedback behaviors.

## Appendix

### Proofs

*Proof of Lemma 1.* The firm chooses quantity  $q$  of sales and the energy-saving level  $\theta$  to maximize:

$$\text{Max } \Pi_H = (a - q + b\theta)q - \frac{1}{2}cq^2 + r\theta q - \frac{1}{2}k\theta^2. \quad (\text{A.1})$$

Letting  $\partial\Pi_H/\partial q = 0$  and  $\partial\Pi_H/\partial\theta = 0$  yields

$$\hat{q} = \frac{ak}{(2+c)k - (b+r)^2}, \hat{\theta} = \frac{a(b+r)}{(2+c)k - (b+r)^2}. \quad (\text{A.2})$$

According to the Hessian matrix, the following conditions are satisfied:

$$\begin{cases} \frac{\partial^2 \Pi_H}{\partial q^2} = -2 - c < 0, \\ \frac{\partial^2 \Pi_H}{\partial \theta^2} = -k < 0, \\ \left(\frac{\partial^2 \Pi_H}{\partial q^2}\right)\left(\frac{\partial^2 \Pi_H}{\partial \theta^2}\right) - \left(\frac{\partial^2 \Pi_H}{\partial q \partial \theta}\right)^2 = (2+c)k - (b+r)^2 > 0, \end{cases} \quad (\text{A.3})$$

that is,

$$k > \frac{(b+r)^2}{2+c}. \quad (\text{A.4})$$

For the market operation, the price of sale  $p$  is greater than 0, so

$$p = \frac{a(-(1+c)k + r(b+r))}{-(2+c)k + (b+r)^2} > 0. \quad (\text{A.5})$$

From the above, there are two ranges of equilibrium solutions:

- (1)  $b^2/(2+c) < k \leq b^2(2+c)$  and  $r < \sqrt{(2+c)k} - b$
- (2)  $k > b^2(2+c)$  and  $r < (\sqrt{b^2 + 4(1+c)k} - b)/2$   $\square$

*Proof of Proposition 1.* From equation (A.2),

$$\begin{aligned} \frac{\partial \hat{\theta}}{\partial r} &= \frac{a((2+c)k + (b+r)^2)}{(-(2+c)k + (b+r)^2)^2} > 0, \\ \frac{\partial \hat{\theta}}{\partial b} &= \frac{a((2+c)k + (b+r)^2)}{(-(2+c)k + (b+r)^2)^2} > 0, \\ \frac{\partial \hat{\theta}}{\partial k} &= \frac{a(2+c)(b+r)}{(-(2+c)k + (b+r)^2)^2} < 0, \\ \frac{\partial \hat{\theta}}{\partial c} &= \frac{ak(b+r)}{(-(2+c)k + (b+r)^2)^2} < 0. \end{aligned} \quad (\text{A.6})$$

$\square$

*Proof of Proposition 2.*

For  $b^2/(2+c) < k \leq b^2(2+c)$ ,

$$\frac{\partial p(q(\hat{r}))}{\partial r} = \frac{a(b^3 + 2b^2r - 2kr + b(ck + r^2))}{(-(2+c)k + (b+r)^2)^2} > 0. \quad (\text{A.7})$$

For  $k > b^2(2+c)$ , if  $r = 0$ , then

$$\frac{\partial p(q(\hat{r}))}{\partial r} = \frac{a(b^3 + bck)}{(b^2 - (2+c)k)^2} > 0. \quad (\text{A.8})$$

If  $r = (\sqrt{b^2 + 4(1+c)k} - b)/2$ , then

$$\frac{\partial p(q(\hat{r}))}{\partial r} = \frac{2a(b^3 + 4b(1+c)k + b^2\sqrt{b^2 + 4(1+c)k} - 2k\sqrt{b^2 + 4(1+c)k})}{(b^2 - 2k + b\sqrt{b^2 + 4(1+c)k})^2} < 0. \quad (\text{A.9})$$

Therefore, there is  $r^* \in (0, (\sqrt{b^2 + 4(1+c)k} - b)/2)$ , so that  $\partial p(q(\hat{r}))/\partial r = 0$ .

Let  $\frac{\partial p(q(\hat{r}))}{\partial r} = 0$ , and  $r^* = k/b - b - \sqrt{k(-2 - c + k/b^2)}$ .  $\square$

*Proof of Lemma 2.* The firm chooses quantity  $q$  of sales and donation  $d$  to maximize:

$$\text{Max } \Pi_D = (a - q)q - \frac{1}{2}c(q + d)^2 + s(a - q)d + \omega(a - q)d. \quad (\text{A.10})$$

Letting  $\partial \Pi_D / \partial q = 0$  and  $\partial \Pi_D / \partial d = 0$  yields

$$\hat{q} = \frac{a(c(s + \omega - 1) + (s + \omega)^2)}{2c(s + \omega - 1) + (s + \omega)^2}, \quad \hat{d} = \frac{a(s + \omega + c(s + \omega - 1))}{2c(s + \omega - 1) - (s + \omega)^2}. \quad (\text{A.11})$$

According to the Hessian matrix, the following conditions are satisfied:

$$\begin{cases} \frac{\partial^2 \Pi_D}{\partial q^2} = -2 - c < 0, \\ \frac{\partial^2 \Pi_D}{\partial d^2} = -c < 0, \\ \left(\frac{\partial^2 \Pi_D}{\partial q^2}\right)\left(\frac{\partial^2 \Pi_D}{\partial d^2}\right) - \left(\frac{\partial^2 \Pi_D}{\partial q \partial d}\right)^2 = c(2 + c) - (c + s + \omega)^2 > 0, \end{cases} \quad (\text{A.12})$$

that is,

$$s < \sqrt{c(2 + c)} - c - \omega. \quad (\text{A.13})$$

In addition, in reality, the quantity  $q$  of sales and donation  $d$  are both greater than or equal to 0, so

$$0 < s < -\frac{c}{2} + \frac{1}{2}\sqrt{4c + c^2} - \omega, \quad (\text{A.14})$$

$$\frac{c}{1 + c} - \omega < s < -c + \sqrt{2c + c^2} - \omega. \quad (\text{A.15})$$

According to (A.13)-(A.15),

$$\frac{c}{1 + c} - \omega < s < \frac{1}{2}(\sqrt{c(4 + c)} - c - 2\omega). \quad (\text{A.16})$$

Moreover, if  $s < c/(1 + c) - \omega$ ,  $d = 0$ . From the above,

$$d = \begin{cases} 0, & \text{for } 0 \leq s < \hat{s}, \\ \hat{d}, & \text{for } \hat{s} \leq s \leq \bar{s}, \end{cases} \quad (\text{A.17})$$

$$q = \begin{cases} \frac{a}{2 + c}, & \text{for } 0 \leq s < \hat{s}, \\ \hat{q}, & \text{for } \hat{s} \leq s \leq \bar{s}, \end{cases} \quad (\text{A.18})$$

where  $\bar{s} = (\sqrt{c(4 + c)} - c - 2\omega)/2$  and  $\hat{s} = c/(1 + c) - \omega$ .  $\square$

*Proof of Proposition 3.* From equation (A.17), if  $0 \leq s < \hat{s}$ , then  $d = 0$ . That is to say,  $d > 0$  if and only is  $s > \hat{s}$ .

For  $s > \hat{s}$ ,

$$\frac{\partial d}{\partial s} = \frac{a((s + \omega)^2 + c(2 + (s + \omega - 2)(s + \omega)))}{(2c(s + \omega - 1) + (s + \omega)^2)^2} > 0, \quad (\text{A.19})$$

$$\frac{\partial d}{\partial \omega} = \frac{a((s + \omega)^2 + c(2 + (s + \omega - 2)(s + \omega)))}{(2c(s + \omega - 1) + (s + \omega)^2)^2} > 0, \quad (\text{A.20})$$

$$\frac{\partial d}{\partial c} = \frac{a(s + \omega - 2)(s + \omega - 1)(s + \omega)}{(2c(s + \omega - 1) + (s + \omega)^2)^2} < 0. \quad (\text{A.21})$$

$\square$

*Proof of Proposition 4.* From equation (A.18), for  $0 \leq s < \hat{s}$ ,

$$p(q(s)) - p(q(\hat{s})) = \frac{ac(s + \omega - 1)}{2c(s + \omega - 1) + (s + \omega)^2} - \frac{a(1 + c)}{2 + c} > 0. \quad (\text{A.22})$$

$\square$

From (A.19),

$$\frac{\partial [p(q(s)) - p(q(\hat{s}))]}{\partial s} = -\frac{ac(s + \omega - 2)(s + \omega)}{(2c(s + \omega - 1) + (s + \omega)^2)^2} > 0. \quad (\text{A.23})$$

*Proof of Proposition 5.* Comparing the profits of the two approaches, there is

$$\Pi_D - \Pi_H = \frac{1}{2}a^2 \left( \frac{k}{-(2 + c)k + (b + r)^2} - \frac{c(s + \omega - 1)^2}{2c(s + \omega - 1) + (s + \omega)^2} \right). \quad (\text{A.24})$$

Case (1). For  $b^2/(2 + c) < k \leq (b^2(2 + c) + \sqrt{b^4c(4 + c)})/2$ ,

$$\Pi_D - \Pi_H < 0, \quad (\text{A.25})$$

*Case (2).* For  $b^2/(2+c) < k \leq (b^2(2+c) + \sqrt{b^4c(4+c)})/2$ , if and only if  $(-b^2c + c(1+c)k + b\sqrt{ck})/(-b^2c + (1+c)^2k) - \omega < s < (-c + \sqrt{c(4+c)})/2 - \omega$  and  $\sqrt{k(c(s+\omega-1)+(s+\omega))^2/c(s+\omega-1)^2} > b+r$ ,

$$\Pi_D - \Pi_H > 0. \quad (\text{A.26})$$

*Case (3).* For  $k > b^2(2+c)$ , if and only if  $(-b^2c + c(1+c)k + b\sqrt{ck})/(-b^2c + (1+c)^2k) - \omega < s < (-c + \sqrt{c(4+c)})/2 - \omega$  and  $\sqrt{k(c(s+\omega-1)+(s+\omega))^2/c(s+\omega-1)^2} > b+r$ ,

$$\Pi_D - \Pi_H > 0. \quad (\text{A.27})$$

Therefore, (1) for  $k > (b^2(2+c) + \sqrt{b^4c(4+c)})/2$  and  $(-b^2c + c(1+c)k + b\sqrt{ck})/(-b^2c + (1+c)^2k) - \omega < s < (-c + \sqrt{c(4+c)})/2 - \omega$  and  $\sqrt{k(c(s+\omega-1)+(s+\omega))^2/c(s+\omega-1)^2} > b+r$ ,  $\Pi_D - \Pi_H > 0$ . (2) Otherwise,  $\Pi_D - \Pi_H < 0$ .  $\square$

*Proof of Proposition 6.* Consider

$$\begin{aligned}\Delta\Pi_D &= \Pi_D - \Pi_0, \\ \Delta\Pi_H &= \Pi_H - \Pi_0.\end{aligned} \quad (\text{A.28})$$

We obtain

$$\begin{aligned}\frac{\Delta\Pi_D}{\Delta C_D} &= -\frac{(2+c)(c(-1+s+\omega)+s+\omega)(2c(-1+s+\omega)+(s+\omega)^2)}{c(-2+s+\omega)((s+\omega)(-2+3(s+\omega))+c(-2+s+\omega+(s+\omega)^2))}, \\ \frac{\Delta\Pi_H}{\Delta C_H} &= -\frac{(2+c)(-(2+c)k+(b+r)^2)}{4k+c((8+3c)k-(b+r)^2)}.\end{aligned} \quad (\text{A.29})$$

$$\Delta\Pi_H/\Delta C_H > \Delta\Pi_D/\Delta C_D, \quad (\text{A.31})$$

Therefore, for  $f(s) < r < \sqrt{(2+c)k} - b$ ,

$$\Delta\Pi_D/\Delta C_D > \Delta\Pi_H/\Delta C_H, \quad (\text{A.30})$$

for  $0 < r < f(s)$ ,

where  $f(s) = \sqrt{k(3c^3(s+\omega-1)^2 + (s+\omega)^3 + c(s+\omega)^2(4s+4\omega-3) + c^2(s+\omega-1)((s+\omega)(5+2s+2\omega)-4))/c(s+\omega-1)^2(c+s+\omega)} - b$ .  $\square$

## Data Availability

The data used to support the findings of this study are included within the article.

## Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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