Selling Innovative Products in the Presence of Consumer Environmental Awareness

Research-in-Progress

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Abstract

Environmental sustainability has been a critical issue for both firms and governments. This issue has received increasing attention from both industry and academia. On one hand, firms are facing the pressure to offer green products, which could be designed aided by technologies such as Internet of Things and big data. On the other hand, firms face higher costs and prices when offering green products. Furthermore, firms are threatened by the uncertainty from consumers' heterogeneity in their awareness to environment. This article aims to investigate the optimal selling strategy from the perspectives of both firms and environment. The initial finding highlights the tension between firms and environment by showing that the firm's profit-maximizing selling strategy may not align with the best environmental outcome.

Keywords: *Green products, innovative products, environmental sustainability, optimal selling strategy, consumer environmental awareness*

Introduction

With economic growth, environmental sustainability has received much attention from both government and industry. Due to the pressure from the government and environment protection organizations, designing the green products, which consume less energy and generate less pollution emission, has been the key issue for many "brown" companies[1] in recent years. Additionally, consumers are increasingly paying more attention to the "green" attributes of products during their purchasing decision making. Fueled by new technologies, such as Internet of Things and big data, firms now have ability to design and manufacture products generating less environmental impact during daily use, which helps address consumer environmental concern. For example, Google's innovative product, Nest Learning Thermostat[2], can help consumer automatically adjust household's temperature to minimize energy use, which eventually shrinks carbon footprint. Because of the innovative and green design, Nest Learning Thermostat has won CES best of innovations award in eco-design and sustainable technology category[3]. Meanwhile, researchers have also emphasized that the role that information systems can play in energy saving and pollution emission reduction in product lifecycle (Malhotra et al. 2013; Melville 2010; Watson et al. 2010).

Although green products have received increasing attention, most firms are still unsure to totally transfer

[1] "Brown" companies refer to companies offer traditional products.
[2] https://nest.com/thermostats/
[3] For more detail information, please refer to https://nest.com/fr/press/nest-learning-thermostat-wins-ces-best-of-innovations-award-in-eco-design-and-sustainable-technology-category/

from selling traditional brown products to innovative green products due to the high cost. Besides, consumer's attitude towards innovative products varies, especially towards the "greenness" of the innovative product, which may further affect firm's incentive to provide innovative products. Moreover, although there exists education about green products from news and media, the consumers' awareness to environmental protection is still heterogeneous.

Therefore, firms simultaneously face the pressure and the uncertainty to design and offer green products. It is not immediately clear that what is the firm's best response to this issue. Motivated by this phenomenon, this research aims to investigate the profitability and environmental implications of selling innovative products, with the special consideration of consumers' environmental awareness. In particular, we propose three selling strategies for firms: (i) the traditional strategy, where firms only sell traditional brown products, (ii) the innovative strategy, where firms only sell innovative green products and (iii) the hybrid strategy, where firms sell both traditional products and innovative products. We build three models to analytically discuss the optimality of each selling strategy. By comparing the equilibrium outcomes of each strategy, we identify the condition under which the proposed strategy could be more profitable for firms and can be beneficial to the environment.

Our initial results suggest that the firm's profit-maximizing selling strategy may not align with the best environmental outcome. The result highlights the tension between profitability and environment performance. Our work contributes to the literature on sustainability and innovative product design by showing that designing a more innovative product does not necessarily contribute to a greener society as it stimulates a larger demand. Our results provide important insights for social planers that some approaches such as subsidy and tax should be taken into account when coordinating the profitability and environment performance.

Literature Review

Sustainable development in business has received increasing attention in both practice and academia. Pioneer work has been done in the field of information systems and operations management (Agrawal et al. 2018; Girotra and Netessine 2013; Seidel et al. 2013). The purpose of environmental sustainability is to improve the usage efficiency in energy and raw materials, as well as to decrease pollution emission by the innovation in technology and business models. The efforts made to improve environmental suitability includes green product design (Gui et al. 2018; Singhal and Singhal 2002), lean and green operations (King and Lenox 2001; Martínez-Jurado and Moyano-Fuentes 2014), business model innovation (Girotra and Netessine 2013).

Among the effort in firms' sustainability development, information technology is playing a critical role. Existing research has claimed that "Green IT" initiatives could help to improve firms' environmental performance (Elliot 2011). Melville (2010) proposes a conceptual framework that emphasizes the intersection of information systems, organizations and environmental sustainability. Besides, Watson et al. (2010) recognize the role of IT can play in reducing energy consumption and carbon emission. Based on their prior work, they propose a new subfield in information systems research: energy informatics.

Following this stream of literature, this study focuses on environmental awareness (Chitra 2007; Ginsberg and Bloom 2004; Liu et al. 2012). With the consumer environmental awareness increases, "green consumer" are becoming an important determinant factor in firm's business model (Collins et al. 2007). Hartmann and Apaolaza-Ibáñez (2012) also propose and empirically verified a similar statement that consumer environmental awareness has a significant effect on consumer's purchase intention. Some studies try to incorporate consumer environmental awareness into their analytical models via the utility model to investigate its effect on consumer choice and product demand (Ghosh et al. 2018; Zhang et al. 2015; Zhu and He 2017). All these studies emphasize the importance of environmental awareness from the consumer-side perspective. Following the same spirit of prior work, this article focuses on the consumer attitude towards pollution emission.

Among efforts to address consumer's environmental concern, many firms are propelled to design green products (Bi et al. 2017; Dangelico and Pujari 2010; Yalabik and Fairchild 2011). Yenipazarli and Vakharia (2015) pay attention to the benefits and hazards faced by an incumbent firm currently selling only the "brown" products, when introducing a new green product. Yenipazarli and Vakharia (2017)

explore the firm's green products strategy choice by considering three different consumer segments which varies in consumers' level in environmental awareness. Chen (2001) analyze the firm's strategic decisions regarding the quantity of green products introduced and their prices and qualities. Murali et al. (2018) investigate the effect of ecolabels and mandatory environmental regulation on green product development among competing firms. Gui et al. (2018) analyze the effect of Extended Producer Responsibility (EPR) legislation on firm's incentive to design green products.

Although sharing similar interests, this article proposes three selling strategies for firms and aims to identify the optimal selling strategy as well as its associated circumstance. Specifically, we scrutinize the environmental performance of each selling strategy. Our initial results advance our understanding in the tension between the profitability and environment.

Model Setup

One profit-maximizing monopoly firm manufactures two types of products: (1) traditional product (hereafter referred to as *product T*) and (2) innovative product (hereafter referred to as *product G*). The cost of product T (or G) is c_T (or c_G). The energy consumption and pollution emission from using product T is e_T. It is assumed that the pollution emission from using product G is lower than product T: $e_T - e$, where e measures the energy-saving and emission-reduction because of the innovative design. The functional value of two products is the same, i.e., v for both product T and product G[4]. We ignore the R&D cost and development cost of product G for firms, since these are sunk cost which would has less impact on firms' selling strategies. The firm could sell product T and G in three selling strategies: two pure strategies and one mixed strategy. More specifically, the firm could only sell product T, termed as the traditional strategy in this article, or the firm could only sell product G, termed as the innovative strategy. Finally, the firm could sell both product T and G simultaneously, termed as the hybrid strategy.

Consumers

Consumers are heterogeneous in terms of their preference θ, which follows a uniform distribution $\theta \sim U[0, \bar{\theta}]$. This preference could be understood as consumers' environmental awareness or sensitivity to pollution emission, with higher θ consumers paying more attention to environmental protection. Without loss of generality, the whole consumer population is normalized to one. When buying product T, the utility for consumer with θ is given by $U_T = v - \theta e_T - p_T$. When buying product G, consumers' utility can be written as $U_G = v - \theta(e_T - e) - p_G$, where p_T and p_G are the prices for product T and G, respectively.

The terms θe_T for product T and $\theta(e_T - e)$ for product G could be understood as the disutility for consumers due to the pollution emission. Thus, consumers with higher θ would tend to value products with lower emission. Once prices are set, consumers would buy the product generating higher utilities. The firm could realize the demand D_T for product T and the demand D_G for product G.

Firms' Problem

The firm's objective is to choose an optimal selling strategy to maximize its profit. The firm compares its profits in three selling strategies. We formulate the firm's profit functions in each selling strategy as follows: (1) traditional strategy, $\pi_T = (p_T - c_T)D_T$; (2) innovative strategy, $\pi_G = (p_G - c_G)D_G$; (3) hybrid strategy, $\pi_H = (p_{HT} - c_G)D_{HT} + (p_{HG} - c_T)D_{HG}$, where the subscript H refers to the hybrid strategy.

Environmental Impact

We investigate the "greenness" of each selling strategy by measuring the environmental impact. Following previous literature (Bi et al. 2017), we measure the greenness using total pollution emission,

[4] Although the innovative product is specially designed, its basic function utility is close to that of the traditional product. The main difference between the traditional product and innovative product is that the innovative product is energy-saving and emission-reduction oriented.

which equals to the pollution emission per product multiplied by the product demand. Thus, the environmental impact of each business model can be written as follows: (1) traditional strategy, $E_T = e_T D_T$; (2) innovative strategy, $E_G = (e_T - e)D_G$; and (3) hybrid strategy, $E_H = e_T D_{HT} + (e_T - e)D_{HG}$.

Sequence of Events

The sequence of our model proceeds in the following three stages: (1) *firm's selling strategy choice decision*: the firm chooses the selling strategy leading to the highest profit as the optimal strategy; (2) *firm's pricing decision*: the firm sets the price in the selling strategy that it chooses in stage (1); (3) *consumer's purchasing decision*: consumers buy the product leading to higher utility.

Results and Analysis

We solve the proposed model using the backward induction approach. We first analyze two pure strategies and then the hybrid strategy.

Traditional Strategy

Under the tradition strategy, consumers would buy product T if $v - \theta e_T - p_T > 0$, leading to consumers with $\theta < \frac{v-p_T}{e_T}$ would buy the traditional product. Throughout the paper, we assume that $\bar{\theta}$ is large enough that the firm cannot fully serve the whole market, that is $\frac{v-p_T}{e_T} < \bar{\theta}$. When $\frac{v-p_T}{e_T} \geq \bar{\theta}$, all consumers would buy the traditional product. The purpose of setting the condition $0 < \frac{v-p_T}{e_T} < \bar{\theta}$ is to ensure that we mainly consider the internal case instead of corner case.

The demand of the traditional product is $d_T = \frac{v-p_T}{\bar{\theta}e_T}$. The firm's profit is $\pi_T = (p_T - c_T)\frac{v-p_T}{\bar{\theta}e_T}$. We can derive the following:

Lemma 1 (Traditional Strategy): *Under the traditional strategy, the equilibrium for firms are:* $p_T^* = \frac{v+c_T}{2}$, $d_T^* = \frac{v-c_T}{2\bar{\theta}e_T}$, $\pi_T^* = \frac{(v-c_T)^2}{4\bar{\theta}e_T}$. *The environmental impact is* $E_T^* = \frac{v-c_T}{2\bar{\theta}}$.

Lemma 1 illustrates that the consumer demand decreases with the amount of pollution emission (measured by e_T) and the overall consumers' environmental awareness (measured by $\bar{\theta}$). Also, due to the lower demand, the firm's profit decreases, which hurts the firm. However, when overall consumers' environmental awareness is higher, the environmental impact will be lower, which benefits the environment. The result has an important implication: cultivating consumers' environmental awareness can help reduce the negative environmental impact. Nonetheless, such approach may not be preferred by firm who aims to maximize profit.

Innovative Strategy

Under this model, consumers would buy the innovative product if $v - \theta(e_T - e) - p_G > 0$, leading to consumers with $\theta < \frac{v-p_G}{e_T-e}$ would buy the innovative product. Therefore, the demand of the innovative product is $d_G = \frac{v-p_G}{\bar{\theta}(e_T-e)}$. The firm's profit is given by $\pi_G = (p_G - c_G)\frac{v-p_G}{\bar{\theta}(e_T-e)}$.

Lemma 2 (Innovative Strategy): *Under the innovative strategy, the equilibrium for firms are:* $p_G^* = \frac{v+c_G}{2}$, $d_G^* = \frac{v-c_G}{2\bar{\theta}(e_T-e)}$, $\pi_G^* = \frac{(v-c_G)^2}{4\bar{\theta}(e_T-e)}$. *The environmental impact is* $E_G^* = \frac{v-c_G}{2\bar{\theta}}$.

Lemma 2 shows that the higher parameter *e* increases the consumer demand and the firm's profit. This result implies that if the firm can design an innovative product that reduce a larger portion of the pollution emission, the firm can attract more consumers and realize a higher profit. Surprisingly, with respect to the environmental impact, we find that the reduction of pollution emission has no effect on the total environmental impact. One may expect that the total environmental impact would decrease with *e,* since the innovative product now generates a lower pollution emission. However, as *e* increases,

the total demand increases as well. The benefit of reduction in pollution emission per product is exactly offset by the increase in the demand.

On the basis of the abovementioned results, we can compare the firm's profit and environmental performance between two pure models. The result is summarized as follows.

Proposition 1 (Traditional Strategy vs. Innovative Strategy):

(i) The pollution emission is higher under the traditional strategy than under the innovative strategy, i.e., $E_T^* > E_G^*$.

(ii) The profit is higher under the traditional strategy than under the innovative strategy when $\frac{e}{e_T} > 1 - (\frac{v-c_G}{v-c_T})^2$ *, otherwise, the profit is higher under the innovative strategy, i.e.,* $\begin{cases} \pi_T^* > \pi_G^*, \ if \ \ \frac{e}{e_T} > 1 - (\frac{v-c_G}{v-c_T})^2 \\ \pi_T^* \le \pi_G^*, \ if \ \ \frac{e}{e_T} < 1 - (\frac{v-c_G}{v-c_T})^2 \end{cases}$.

Note that $\frac{e}{e_T}$ can be understood as the pollution reduction rate. Proposition 1(i) shows that selling innovative products is always more beneficial to the environment than selling traditional products. However, from the firm's perspective, only when pollution reduction rate is higher than a threshold value (i.e., $1 - (\frac{v-c_G}{v-c_T})^2$), the innovative strategy is more profitable for firms. Otherwise, the traditional strategy is the better strategy. This implies that, to ensure the innovative strategy is better for the firm, there exists a threshold value for the pollution reduction rate of the innovative products. Moreover, the threshold value decreases as c_T but increases as c_G. The decrease (increase) in the threshold value means that the firm will be more (less) likely to choose the innovative strategy. Thus, we conclude that the higher cost of tradition product and the lower cost of green product, the more likely the firm chooses the innovative strategy.

We now analyze the equilibrium outcome under the hybrid strategy where the firm sells both the traditional product and the innovative product.

The Hybrid Strategy

Consumers buy the traditional product should satisfy (i) $v - \theta e_T - p_{HT} > 0$, leading to $\theta < \frac{v-p_{HT}}{e_T}$ and (ii) $v - \theta e_T - p_{HT} > v - \theta(e_T - e) - p_{HG}$, leading to $\theta < \frac{p_{HG}-p_{HT}}{e}$. Thus, consumers with $\theta < \frac{v-p_{HT}}{e_T}$ would buy the traditional product if $\frac{v-p_{HT}}{e_T} < \frac{p_{HG}-p_{HT}}{e}$, otherwise, consumers with $\theta < \frac{p_{HG}-p_{HT}}{e}$ would buy the traditional product. Consumers buying the innovative product should satisfy (i) $v - \theta(e_T - e) - p_{HG} > 0$, leading to $\theta < \frac{v-p_{HG}}{e_T-e}$ and (ii) $v - \theta e_T - p_{HT} < v - \theta(e_T - e) - p_{HG}$, leading to $\theta > \frac{p_{HG}-p_{HT}}{e}$.

To ensure there exist consumers buying the innovative product, it is assumed that $\frac{p_{HG}-p_{HT}}{e} < \frac{v-p_{HG}}{e_T-e}$. Otherwise, no consumers would buy the innovative product. Thus, consumers with $\frac{p_{HG}-p_{HT}}{e} < \theta < \frac{v-p_{HG}}{e_T-e}$ would buy the innovative product. The assumption $\frac{p_{HG}-p_{HT}}{e} < \frac{v-p_{HG}}{e_T-e}$ would lead to $\frac{p_{HG}-p_{HT}}{e} < \frac{v-p_{HT}}{e_T}$. Therefore, consumers with $\theta < \frac{p_{HG}-p_{HT}}{e}$ would buy the traditional product, consumers with $\frac{p_{HG}-p_{HT}}{e} < \theta < \frac{v-p_{HG}}{e_T-e}$ would buy the innovative product.

The demand of traditional product is $d_{HT} = \frac{p_{HG}-p_{HT}}{\bar{\theta}e}$. The demand of innovative product is $d_{HG} = \frac{v-p_{HG}}{\bar{\theta}(e_T-e)} - \frac{p_{HG}-p_{HT}}{\bar{\theta}e}$. The profit function is $\pi_H = (p_{HT} - c_T)\frac{p_{HG}-p_{HT}}{\bar{\theta}e} + (p_{HG} - c_G)\left(\frac{v-p_{HG}}{\bar{\theta}(e_T-e)} - \frac{p_{HG}-p_{HT}}{\bar{\theta}e}\right)$. Thus, the equilibrium outcomes can be derived as:

Lemma 3 (Hybrid Strategy): *Under the hybrid strategy, the equilibria for firms are* $\begin{cases} p_{HT}^* = \frac{v+c_T}{2} \\ p_{HG}^* = \frac{v+c_G}{2} \end{cases}$, $\begin{cases} d_{HT}^* = \frac{c_G - c_T}{2\bar{\theta}e} \\ d_{HG}^* = \frac{v-c_G}{2\bar{\theta}(e_T-e)} - \frac{c_G-c_T}{2\bar{\theta}e} \end{cases}$, $\pi_H^* = \frac{(c_G-c_T)^2}{4\bar{\theta}e} + \frac{(v-c_G)^2}{4\bar{\theta}(e_T-e)}$. *The environmental impact is* $E_H^* = \frac{v-c_T}{2\bar{\theta}}$.

The higher v and the lower c_T, the higher profit for the firm, the higher pollution emission in the hybrid strategy. The profit would first decrease (i.e., $\frac{\partial \pi_H^*}{\partial c_G} < 0$ when $c_G < \frac{e_T-e}{e_T}c_T + \frac{e}{e_T}v$) then increase (i.e., $\frac{\partial \pi_H^*}{\partial c_G} > 0$ when $c_G > \frac{e_T-e}{e_T}c_T + \frac{e}{e_T}v$) with c_G. This result show that c_G and c_T have very different effects on the firm's profit. This could be understood as follows. The firm's marginal profits from selling product T and G are $\frac{v-c_T}{2}$ and $\frac{v-c_G}{2}$, respectively. Obviously, for each product, the firm earns more from selling per unit product T. As c_T decreases, the demand of product T increases, while the total demand (the demand of product T plus the demand of product G) is constant ($\frac{v-c_G}{2\bar{\theta}(e_T-e)}$); thus, the relatively high demand of product T would lead to the higher profit for the firm.

In contrast, the impact from c_G is more complicated. As c_G increases, the total demand $\frac{v-c_G}{2\bar{\theta}(e_T-e)}$ is not constant but decreases, which may lead to lower potential profit. This could be defined as the *demand shrinkage effect*. The increase in c_G would also lead to the higher demand of product T, which may lead to the higher potential profit. This could be defined as the *marginal profit enhancement effect*. Overall, the effect of c_G on the firm's profit depends on the above two effects. When c_G is sufficient high, the latter effect dominates the former effect and the firm's profit would increase with c_G. Otherwise, the firm's profit would decrease with c_G. The implication of this finding is that it is the best for firms if the c_G is medium valued, neither too low nor too high.

Proposition 2 (Optimal Selling Strategy):

(i) The firm's profit is the highest under the hybrid model;
(ii) The environmental impact is the lowest under the innovative model.

From the firm's perspective, Proposition 2 highlights the benefits of selling both traditional and innovative products. Consumers with high environmental awareness would prefer the innovative product, while those with relatively low environmental awareness would prefer the traditional product. By adopting the hybrid strategy, the firm can easily satisfy the needs of consumers with different preferences and obtain a greater profit than using pure strategies.

However, the firm's optimal strategy may not align with the best environmental outcome. We find the innovative strategy leads to the lowest pollution emission. The result implies the tension between the profitability and environmental performance.

Conclusion and Future Research

The initial results have highlighted the importance of investigating the consumers' awareness in environment in this research. Our analysis shows that consumers' environmental awareness, production cost, and pollution reduction rate of the innovative products are the key parameters and have important effects on firm's optimal selling strategy as well as the associated environmental impact. We find the firm's profit-maximizing selling strategy may not align with the best environmental outcome. This work contributes to the existing literature on sustainability and innovative product design by incorporating consumer environmental awareness.

In the future, we would consider the optimality of each selling strategy in a more general model setting, with the consideration of the market competition. Besides, we plan to investigate consumers' awareness to environment in detail by considering its relation to other issues, such as the two-way influence among consumers. Finally, from the perspective of social planers, how to make a policy to coordinate the firm's

profit and environmental impact to maximize the social welfare is also one of our future directions. We hope to provide some insights to contribute to an environmentally sustainable society.

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