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The impacts of technology evolution on market structure for green products

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ABSTRACT

This paper studies how two technologies, Zero-Sum and Synergy, impact the market structure strategy for green products. We develop mathematical models to determine the optimal price, traditional quality, and environmental quality in order to maximize profit. We also perform sensitivity analysis to derive conditions under which a firm tends to adopt the Market Segmentation strategy rather than the Mass Marketing strategy. Our results indicate that to increase total green quality, investing in technology improvement to enable Synergy is more effective than introducing more products. Finally, we investigate the effects of government regulations on the selection of these two marketing strategies and two technologies.

1. Introduction

Due to the importance of environmental issues, governments are beginning to make laws and regulations to protect the environment. For example, the Restriction of Hazardous Substances (RoHS) of the European Union restricts the use of six toxic materials in the manufacture of all electronic and electrical equipment. Meanwhile, consumers are paying more attention as to whether corporations are environmentally friendly. They are increasingly willing to purchase eco-friendly or so called green products even though these products are often more expensive. Since protecting the environment has emerged as one of the hottest global trends, it is important for firms to understand how to design and manage green products.

In recent years, we observe that many companies have evolved from Zero-Sum technology to Synergy technology. In Zero-Sum, it costs more to maintain the same level of environmental quality when trying to enhance traditional quality. A typical example of Zero-Sum technology can be found in the automobile industry. The fuel efficiency (i.e., environmental quality) generally deteriorates in order to increase the engine horsepower (i.e., traditional quality). As a result, additional investments are required to overcome the deficiency in environmental quality. In Synergy, the cost of maintaining the same level of environmental quality is less when the firm enhances traditional quality because the investments employed to improve traditional quality also improve environmental quality.

Fig. 1 uses an LCD example to illustrate the evolution from Zero-Sum to Synergy technology. The conventional LCD uses a backlight as the light source and we see the images after the light goes through color filters. This type of technology is known as the *transmissive mode*. In this mode, the power consumption will be higher when increasing the brightness of the monitor. A company recently developed a new technology called the *transflective mode* in which a half-mirror is added.

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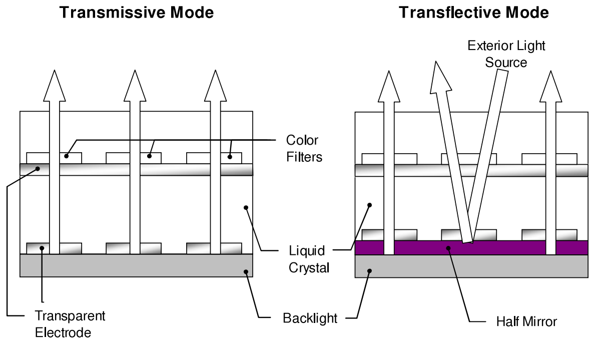

Fig. 1. An example of synergy technology.

The half-mirror reflects the external light to create a second light source. Hence, the brightness is increased but the power consumption of the backlight is decreased due to the availability of the second light source. In other words, the investments to increase traditional quality (brightness of the monitor) also contribute to the enhancement of the environmental quality (reduction of power consumption). Therefore, the cost of maintaining the same level of environmental quality is less when the firm employs Synergy technology.

Based on the above observations, we believe it is essential to study how technology evolution impacts green product strategies. To the best of our knowledge, this paper is the first to study how two technologies, Zero-Sum and Synergy, impact green product strategies. Mathematical models are developed to determine the optimal price, traditional quality, and environmental quality to maximize profit. We examine under what conditions the company tends to adopt a Market Segmentation strategy (two products are offered to two different market segments) and under what conditions the firm tends to adopt a Mass Marketing strategy (only one product is offered to both segments). Furthermore, we discuss how government regulations impact the results and how technologies interact with government regulations.

The rest of the paper is organized as follows. Relevant literature is reviewed in Section 2. The proposed problems are defined in Section 3. We develop mathematical models for the problems and obtain optimal solutions in Section 4. Results and managerial insights are discussed in Section 5. Finally, the paper is concluded with a summary and several future research directions in Section 6.

2. Literature review

Abundant research has been performed to help corporations to become more environmentally friendly through process re-engineering such as reuse, remanufacturing, recycling, and collaboration. Guide and Van Wassenhove [1] build a framework for analyzing the profitability of reuse activities. Debo et al. [2] address several managerial issues faced by a manufacturer who considers making a remanufacturable product. They find that high production costs of the single-use product, low remanufacturing costs, and low incremental costs to make a single-use product remanufacturable are the major drivers for remanufacturing. Ferguson and Toktay [3] examine the effect of competition on recovery strategies. They identify conditions under which the manufacturer would choose remanufacturing or a preemptive collection strategy. Using a survey of North American manufacturers, Vachon and Klassen [4] study the impact of environmental collaboration in the supply chain on manufacturing and environmental performance. They conclude that environmental collaboration with suppliers is mainly linked to superior delivery and flexibility; while collaboration with customers is mostly linked to better quality performance. In our paper, we focus on market segmentation; specifically, how a firm determines its optimal market segmentation strategy. We also discuss the impact of our decision on the environment.

There are a number of articles addressing the product design issue. Chen [5] discusses how a firm sets its traditional quality and environmental quality when these qualities are in direct conflict. Kouvelis and Mukhopadhyay [6] develop a model to study the design quality and pricing policy a firm should follow for a durable product over its product life cycle. Kim and Chhajed [7] discuss the product design problem where the monopolist produces products with multiple quality-type attributes. They find that offering a single product for both segments is never optimal when the order of preference for attributes differs. Chung and Wee [8] investigate the impact of green product design, new technology evolution and remanufacturing on the production-inventory policy, and develop an integrated deteriorating inventory model with green-component lifecycle value design and remanufacturing. Chung et al. [9] propose a multi-echelon inventory system with manufacturing capability and develop a closed-loop supply chain inventory model to maximize the joint profits of various parties in the supply chain. Their study shows a significant increase in the joint profit when the integrated policy is adopted. Yang et al. [10] extend the study of Chung et al. [9] by considering deteriorating inventory and multi-manufacturing and multi-remanufacturing cycles and draw a similar conclusion as given in [9]. In our paper, we analyze how a firm determines the traditional and environmental qualities, based on the firm's adopted technology and market segmentation strategy.

Government regulations often play an important role in influencing a firm's decision regarding environmental protection. Many scholars discus how government influences a firm's behavior through tax subsidy [11–13]. Chen [5] develops a