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Active or passive? Sustainable manufacturing in the direct-channel green supply chain: A perspective of two types of green product designs



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ABSTRACT

This paper considers a supply chain in which a manufacturer produces and sells two types of green products in its direct channel under government interventions aiming to improve social welfare. There is a Stackelberg game between the two stakeholders. Our research derives the closed form solutions to the optimal tax, green degree and price for the products, and obtains the strategies for government and manufacturer under different environmental policies. By considering six scenarios, our models obtain the best choice from the comparison between the two cases in which the manufacturer determines its product green degree actively or accepts the green standard set by the government passively. Then, we conduct some sensitivity analyses and explore the scenario in which there is competition between green products and non-green products. The results of this research indicate that the government setting the product green standard and providing the manufacturer with a subsidy is significant.

1. Introduction

Due to the rapid consumption of natural resources and the intensification of the greenhouse effect, public awareness of greening has been continuously strengthened. The government is also paying increasing attention to the environmental issues, and is actively implementing policies to maximize the sustainability of industrial production (Xu et al., 2017). Therefore, more researchers are beginning to devote themselves to solving green supply chain management (GSCM) problems for enterprises. These researchers concentrate on the following topics: sustainable supply chain coordination, low-carbon logistics optimization, reverse supply chain operations, technology selection, product design and environmental regulations (Chen et al., 2012; Cullinane and Bergqvist, 2014; Huang et al., 2016; Laari et al., 2017; Sheu et al., 2005; Sheu and Chen, 2012; Zhang et al., 2014; Zhu and Sarkis, 2004). From this perspective, this paper studies both sustainable supply chain management and types of green product design considering government intervention under direct-channel supply chain settings.

For this study, the first case is in the automotive industry. For example, Chrysler is one of the biggest automobile manufacturers in U.S. To meet the emission reduction target proposed by the U.S. Congress, some emissions control devices were installed to make the vehicles greener (Chen et al., 2004). Thus, this emissions reduction cost largely relies on the emissions control system cost. It can be

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applied to the products immediately. Because it requires more parts in the vehicles and additional devices to install, they incur costs in manufacturing. Thus, they are variable manufacturing costs. [Zhu and He \(2017\)](#) called this type of product “marginal cost-intensive green products (MIGPs)”. However, automakers can also develop some emerging technologies that are able to increase fuel efficiency remarkably but need huge R&D investment to be realistically applied ([Council, 2002](#)). Thus, the major cost is the R&D cost replacing the manufacturing cost per product. For example, electric vehicle technology is well-known in these emerging technologies. For electric vehicles, the battery technologies need a lot of investment in R&D, which is mainly a fixed cost. In addition, the cost of infrastructure setup, such as charging facilities, is another fixed cost. [Zhu and He \(2017\)](#) called these products development-intensive green products (DIGPs). Because these two types of products have different cost structures, we want to analyze the sustainable manufacturing and the optimal governmental regulations for them. This will provide guidance to the manufacturers greening these two products, and to the governments making suitable policies.

We also study the case involving environmental regulation from the government. Under pressure from the environment, the government is getting involved in the production and supply chain of enterprises in various ways ([Xu et al., 2017](#)). These government interventions can be financial, such as an environmental tax or subsidy. They can also be political, such as setting a carbon cap for manufacturers. Some are mixed, e.g., carbon cap-and-trade policies ([Cachon, 2014](#); [Chai et al., 2018](#); [Fahimnia et al., 2015](#); [Gao et al., 2018](#); [Wang et al., 2017](#); [Xu et al., 2017](#)). Nevertheless, there are a growing number of governments in the world setting standards for green products. Only when the manufacturers satisfy these requirements can they obtain an eco-label from the governments for their products. The American Green Products Committee (AGPC), the European Union Eco-Labeling Board (EUEB) and the Certification and Accreditation Administration of the People’s Republic of China (CAAC) have already begun to implement this policy ([Prieto-Sandoval et al., 2016](#)). There have been similar measures to certify products when they meet certain requirements and standards, such as the China Compulsory Certification (CCC) and ISO certification. Green product certification is the labeling system for products. Some calculate pollution by units of measurement, and they advocate for maintaining the sustainability of production and reducing environmental hazards ([Horne, 2010](#); [Paull, 2009](#)). Receiving this type of label can increase the acceptance of the manufacturers’ products by more consumers with strong environmental awareness, and the products can receive a more favorable tax policy so that are more competitive in the market ([Chen et al., 2016](#)). In this way, many manufacturers would make the green degree of products just meet the standards set by the government. Because this allows them to get the above benefits. They don’t need to exceed the standard a lot because of huge green cost. Thus, manufacturers must passively try their best to get the eco-label when governments set the green degree standard for their products. There are numerous studies focusing on enterprises taking the initiative to improve their products green degree to attract consumers. In this situation, manufacturers can determine the green degree for their products by actively facing government interventions like taxes or subsidy caps and trade policies. We will discuss this situation carefully in the next section. As a result, few papers concentrate on the government eco-label case to obtain a decision framework between manufacturers and governments. We think it is needed to analyze the different impacts in these two situations.

Based on the above discussion, this paper intends to investigate the following managerial issues:

- What are the best price policies and environment regulation methods for the two different products?
- Should manufacturers be active or passive to determine the green degree for products?
- How can the green supply chain considering government intervention be effectively governed to increase both profit and sustainability?
- For governments, should they collect an environmental tax or offer a subsidy to manufacturers aiming to maximize the social welfare (SW)?
- Will green products dominate when competing with non-green products?

To find the answers, we use a Stackelberg game-theoretic method, and discuss the managerial implications based on the analytical results. This paper focuses on a direct-channel supply chain. There is a manufacturer producing green products and selling the products through its direct channel. This is because, in this paper, we mainly consider the processes and strategies for the government intervening decision and manufacturer producing and pricing decisions. To say the least, we can also see the retailer as the customer for the manufacturer, because we do not care about the retailer’s strategy. In addition, the government implements some interventions to improve SW.

This study’s contribution mainly contains the following points. Firstly, we consider the difference between MIGP and DIGP carefully. This was not be sufficiently discussed in the previous literature. Due to the difference in cost structures, our research analyzes the optimal strategic decisions for each of these two products so that it can further guide green product design research. Secondly, we discuss the different effects of different government intervention policies on manufacturers’ products. The difference in the decision makers in the product green degree changes the structure of the game in the supply chain. In this way, our research provides a great contribution to the GSCM literature, and it can help governments worldwide choose the optimal environmental policies. To our knowledge, these issues have not been sufficiently addressed for green supply chains. Thirdly, we provide some conclusions to help manufacturers manage their own green supply chain effectively. Some of these conclusions may be counter-intuitive. Generally speaking, people think that manufacturers setting the product green degree themselves will achieve the greatest profit. However, based on the analytical results, we find that is not always the case. This can help manufacturers make the optimal strategic decision between accepting environmental regulations of governments passively and setting the green degree for product actively. Finally, we prove that with the appropriate environmental policy, green products will have more competitive advantages than non-green products, and the non-green products will be gradually eliminated in the market.

The remainder of this paper consists of the following sections. [Section 2](#) reviews the previous literature. The models and solutions

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