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Sustainable supply chains under government intervention with a real-world case study: An evolutionary game theoretic approach

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A B S T R A C T

It is clear that the problem of global warming and greenhouse gas emissions is one of the most important and challenging issues in recent years. Governments have a key role in managing this crisis. They can influence the polluting activities of producers by enacting policies and applying incentives. In addition, government policies can also affect the production and competitive markets of industries. Applying too-strict policies can lead to significant reductions in producers' profit, and even complete business closure. For the first time, this paper models the contrast between government objectives and producers' targets, using a two-population evolutionary game theory approach under different scenarios. Three different scenarios are considered for government. In the first scenario, the government imposes taxes and subsidies to maximize its profit with an upper bound for total environmental impacts. In the second one the government chooses tariffs that minimize total environmental impacts by considering a lower bound for its profit. Finally in the third scenario, the government makes a trade-off between its profit and environmental objectives by a linear combination in an objective function. Using two-population evolutionary game theory approach, the performance of supply chains members under different government scenarios is modeled. Finally, the proposed sustainable model is applied to the Indian textile industry. The results show that government policy clearly affects producers' activity, competitive markets and emissions. Imposed tariffs are the most effective government approach to minimizing environmental impacts.

1. Introduction

Sustainability is defined in three dimensions: social, environmental, and economic. To achieve complete sustainability, processes must be sustainable in all three areas. Environmental sustainability is the most important principle. If it is not attained, then no matter how much effort is put into the other aspects, no resolution will occur, because social and economic factors exist within the environment (http://www.thwink.org/sustain/glossary/Sustainability.htm., 2014).

By increasing various industries throughout the world, using of fossil fuels and greenhouse gas emissions have been increased. Therefore, pollution and environmental protection have become highly significant global problems in recent century. Accordingly, governments have paid special attention to these issues and have tried different policies to encourage producers to produce with lower emissions, such as taxes on non-green activities and subsidies for green activities. For example, the Chinese government has increasingly focused on implementation of green supply chains: Local development and reform committees have encouraged enterprises to adopt the strategy of circular economy and cleaner production; some local economic committees have evaluated energy consumption by local heavy industrial enterprises; and local finance bureaus have initiated programs such as green public procurement (Zhu, 2004). These government environmental policies are mostly inconsistent with the profitability policies of producers. For example, taxes on non-green activities increase the cost of production, resulting in decreases in profit.

The tension between economic and environmental targets has led to managerial research to promote methodologies whose goal is to achieve profits and preserve the sustainability of the environment. Supply chain management is one of the important issues that has attracted a lot of scientific research. With the introduction of environmental issues and green/non-green activities in the context of supply chain management, new discussions began about green supply chain management (GSCM), which means integrating environmental protection attitudes in all supply chain activates, from supplying the raw materials and production stages to delivering stages and even after selling (Srivastava, 2007).

There has been a lot of research that uses game theory to study GSCM. Barari, Agarwal, Zhang, Mahanty, and Tiwari (2012) applied evolutionary game theory approach in the green supply chain management concept. They modeled competition of a population of

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retailers against a population of producers. Their numerical analysis showed that with the proposed evolutionary game theory approach, the evolutionary stable strategy of the game depends on greening cost and governmental tariffs. Zhang and Liu (2013) used game theory to study a three-level green supply chain where market demand correlates with product green degree. They developed four different game models: cooperative decision-making, a three-level leader–follower game, Stackelberg game I and Stackelberg game II. Then they compared the results of the models. Based on evolutionary game theory, Tian, Govindan, and Zhu (2014) extended a system dynamics model to guiding subsidy policies to promote the diffusion of GSCM in the Chinese automotive manufacturing industry. Evolutionary game theory was used to analyze the relationships of government, enterprises and consumers. Their study showed that subsidies for manufacturers are better than those for consumers to promote GSCM diffusion. Hafezalkotob (2015) developed a price competition model of two supply chains, one green and one regular, under the influence of government financial intervention. Each supply chain contains one producer and one retailer. They considered three different scenarios for the government involving the elements of the supply chain, producer and retailers, under two strategies and different decision-making structures, that is, the centralized or decentralized configuration. They analyzed the effects of government tariffs on the players' optimal strategies. Mahmoudi and Hafezalkotob (2015) modeled the monitoring and implementation problem between government and enterprises in a green supply chain using a bargaining game model. Their numerical analysis showed that GSCM implementation costs and benefits, as well as government subsidies and penalties, directly affect the strategies. Li, Zhu, Jiang, and Li (2016) studied a dual-channel supply chain where the producer makes green products for environmentally conscious consumers. Using a Stackelberg game model, they surveyed pricing and greening strategies for the supply chain members in the centralized and decentralized cases. Table 1 demonstrates that the proposed approach of the present paper covers new features in comparison with other existing models.

To the best of the authors' knowledge, there have been no studies in the context of GSCM that consider responses of competitive supply chains to government green policies using two-population evolutionary game models. Due to this gap in the literature, the main contributions of our research are twofold. First, using two-population evolutionary game model for the first time in addressing GSCM in which the government act as the leading player to investigate the impacts of green legislation and financial interventions on supply chain members' activity and obtaining pricing strategies. Bi-level programing and an evolutionary game model are used to survey this game. Second, considering Indian textile industry as real-world case study, sustainable performance of supply chains under different government scenarios during the time is studied. The results have been analyzed. By identifying the effective factors, short/long term policies have been suggested to the government as strategies.

In this article, we particularly use the mathematical game theory model to address the following research questions: (1) How can governments affect competition of supply chains by using taxes and subsidies as financial instruments, such that green purposes can be achieved? (2) Under government interventions, what are the evolutionary responses of the supply chain members and which strategy is used by the majority? (3) How do different government scenarios and policies influence the environmental effects of supply chain members' activities and competition? (4) What is the optimal price in each scenario and strategy?

This paper is organized as follows: A list of symbols is presented in Section 2. Section 3 presents the formulation of the problem. A real-world case study of the Indian textile industry is discussed in Section 4. Finally, concluding remarks and some directions for future research are provided in Section 5.

2. List of symbols

The subscript "*g*" is used throughout to denote green producers and "*ng*" denotes non-green producers; "*r*" is for retailer and "*p*" for producer. Moreover, symbols and notations used through the paper are shown below:

C^g	The greening cost, $C^g \geqslant 0$
S	The considered subside by the government for each producer, $S \geqslant 0$
T	The considered tax by the government for each producer, $T \geqslant 0$
CB	The market baseline for product, $CB \geqslant 0$
α	The price elasticity of demand, $\alpha \geqslant 0$
β	The marketing expenditure elasticity of demand $\beta \geqslant 0$
GNR	Government net revenue

Table 1
A comparison between previous studies and the current study.

Reference	GSCM	SCs	Government intervention	Considering government profit	Evolutionary game theory	Different scenarios	Pricing
Mitra and Webster (2008)	√	√	√				√
Sheu and Chen (2012)	√		√				√
Sheu (2011)	√		√				
Nagurney and Yu (2012)	√						√
Tsireme, Nikolaou, Georgantzis, and Tsagarakis (2012)	√		√				
Zhao, Neighbour, Han, McGuire, and Deutz (2012)	√		√				
Barari et al. (2012)	√	√	√		√		
Zhang and Liu (2013)	√	√					√
Mahmoudi, Hafezalkotob, and Makui (2014)			√	√			√
Tian et al. (2014)	√	√	√		√		
Zhang, Wang, and Ren (2014)	√						√
Hafezalkotob (2015)	√		√	√		√	√
Mahmoudi and Hafezalkotob (2015)	√		√	√			
Du, Ma, Fu, Zhu, and Zhang (2015)		√	√				
Li et al. (2016)	√	√					√
Jafari, Hejazi, and Rasti-Barzoki (2017)	√					√	√
Ülkü and Hsuan (2017)	√						√
Hafezalkotob and Mahmoudi (2017)			√	√	√	√	√
Madani and Rasti-Barzoki (2017)	√		√	√			√
Current study	√	√	√	√	√	√	√