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Non-collaborative emission targets joining and quantity flow decisions in a Stackelberg setting

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ABSTRACT

This study considers a Stackelberg channel, where the leader determines the quantity flow along the channel. Both the leader and the follower have emission targets and the leader should respect those targets. In this setting, the leader and the follower can join their emission targets to lower costs while ensuring that the channel emissions do not exceed the cumulative target. The decisions for joining targets define a non-collaborative game between the leader and the follower. We characterize the equilibrium of this game. Furthermore, we analyze the effects of channel leadership. A manufacturer-retailer scenario is used to demonstrate the model.

1. Introduction

Many activities along supply chains such as production, transportation, logistics and warehousing operations, are major contributors to the greenhouse gas (GHG) emissions generated within manufacturing, retailing, and service industries. Considering the growing concerns on climate change, it is therefore crucial to increase the sustainability of the operations along supply chains (Plambeck, 2012). Recent review papers highlight the importance of sustainable supply chain management practices (see e.g., Corbett and Kleindorfer, 2001a; Corbett and Kleindorfer, 2001b; Srivastava, 2007; Linton et al., 2007; Tang and Zhou, 2012; Brandenburg et al., 2014; Jaehn, 2016). In this study, we consider a two-echelon supply chain with environmental considerations at each echelon.

Particularly, environmental regulations such as carbon trading, taxing, cap, and offsetting, have been legislated by many governments to incentivize companies to abate their emissions (see, e.g., CBO, 2008; Wara and Victor, 2008; Jaehn and Letmathe, 2010; Lin and Li, 2011; Kroes et al., 2012; Krass et al., 2013; Choi, 2013a,b; Wang et al., 2016a; Chen and Wang, 2016; Song et al., 2017 for discussion on these regulations). Nevertheless, such regulations are not the only motivation for companies to green their operations. Due to the increasing consumer awareness on the environment (see, e.g., Klassen and McLaughlin, 1996; Yenipazarli and Vakharia, 2015), a company's improved environmental performance gives a competitive advantage at the end customer market and help the company build a good reputation (Markley and Davis, 2007; Hopkins, 2010; Kim and Lyon, 2011; Bouchery et al., 2012). For instance, in a survey conducted by BearingPoint (Loebich et al., 2011), the majority of the 582 European companies interviewed noted that, rather than regulations, brand image and executive management were the main drivers for environmental improvement activities taken after 2010. In an another

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survey conducted with 2874 managers from 113 countries, Kiron et al. (2012) note that two-third of the respondents regarded sustainability as a critical factor for being competitive.

In addition to comply with the environmental regulations and/or address the consumers' pressures and gain competitive advantages at the market, the companies, which do not directly associate themselves with the end consumer market, are also urged to add sustainability into their agenda in order to respond to the requests of the other firms in the supply chain. Considering that a company's environmental performance is affected by the activities of the other parties along the chain (Caro et al., 2013; Touboulic et al., 2014; Plambeck and Taylor, 2016; Chen and Wang, 2016), buying firms request and account for the environmental performance of their suppliers (Jira and Toffel, 2013). For instance, Plambeck (2012) notes that Walmart, the biggest retail chain in the US, asks its suppliers to monitor their carbon footprints and set environmental goals (see, also, Brichall, 2010). In another study, Sarkar et al. (2016) demonstrate the effects of different agents on the emissions at each echelon of a three-echelon supply chain. Recent studies on green supplier selection also emphasize the importance of a supplier's environmental performance for buying firms (see, e.g., Handfield et al., 2002; Choi, 2013b; Kannan et al., 2014; Kumar et al., 2014; Dou et al., 2014; Govindan and Sivakumar, 2016; Konur et al., 2017, and recent reviews by Govindan et al. (2015) and Zimmer et al. (2016)).

As such, many companies set (voluntary) environmental targets to improve their sustainability (as noted by Hoffman (2005), their strategic reasons for voluntary emission reduction can vary and Kolk and Pinske (2004) mention three main approaches for setting emission reduction/stabilization targets). Carbon Disclosure Project (CDP) reports in CDP (2011) that, out of 404 respondents of a survey conducted amongst the Global 500 companies, 74% of the respondents imparted emission reduction targets (see also Hoen et al., 2014). For instance, Gouldson and Sullivan (2013) list the environmental goals, as of April 2012, of seven major UK supermarkets (Asda, Co-Operative, Marks and Spencer, Morrisons, Sainsbury's, Tesco, Waitrose). Other examples can be found in CDP (2015). Furthermore, a recent report published by CDP documents that 34%, 54%, 51%, and 49% of the surveyed 1532 US, 1108 EU, 238 China, and 1127 other suppliers, respectively, have emissions reduction targets (CDP, 2016). Based on the foregoing discussion, this study considers that the agents at the different echelons of the channel aim to keep their emissions below a certain level, which we refer to as an emission target.

In particular, we model a two-echelon supply chain as a Stackelberg game with a leader at the upper echelon and a follower at the lower echelon. Such channel settings, i.e., a leader-follower channel, where the leader determines the quantity flow between the leader and follower, are observed in many practical cases. For instance, in a supplier-retailer channel practicing vendor-managed-inventory (see, e.g., Cetinkaya and Lee, 2000; Mishra and Raghunathan, 2004), the supplier holds the channel power and leads: the supplier determines the shipment amount and frequency to the retailer, which would define the retailer's inventory. Another case is a manufacturer-retailer channel, where the manufacturer produces and ships the retailer's order (see, e.g., Dong et al., 2016; Toptal and Cetinkaya, 2017); thus, the retailer leads the channel (such as in the case of joint economic lot sizing or buyer-vendor problems, see, e.g., Glock, 2012 for a review). Later, in Section 2, we discuss the similarities and differences of the channel of interest in this study with the models investigated in the literature.

Here, we model the leader's and the follower's costs and emissions as generic functions of the quantity flow set by the leader. We assume that each agent has an emission target such that their individual emission levels should not exceed this target. As noted above, this target can be self-imposed or defined by regulations (e.g., in case of a carbon cap policy). For instance, given a company aims to achieve 20% reduction from its current emissions, its emissions should not exceed 80% of the current emissions. The references cited above define many examples for such environmental goals (further discussion can be found in Reid and Toffel, 2009; Short and Toffel, 2010). Our modeling approach is therefore similar to the ones used for formulating carbon emission constraints (or the carbon cap regulation) in many inventory control and transportation problems (see, e.g., Benjaafar et al., 2013; Chen et al., 2013; Absi et al., 2013; Konur, 2014; Konur and Schaefer, 2014, 2016; Schaefer and Konur, 2014; Toptal et al., 2014; Hoen et al., 2014; Chen and Hao, 2015; Helmrich et al., 2015; Absi et al., 2016).

As the leader's decision on the quantity flow between him/herself and the follower will directly affect the costs and emissions of both agents, the leader should assure that the follower's emission target is respected as well as his/her own emission target (otherwise, it might be assumed that the follower will not do business with the leader). As noted by Klassen and Vachon (2003), joint actions taken among different parties along a supply chain can promote the environmental performance of the channel. Furthermore, Benjaafar et al. (2013) note that firms within the same supply chain can achieve more economic emission reduction by cooperation. Here, the environmental targets are already defined but we consider joint emission targeting as an opportunity to achieve cost savings for both the leader and the follower while maintaining the channel wide environmental targets. Nevertheless, a centralized decision maker is not defined for such a joint emission targeting decisions in this study; we assume that the leader and the follower are independent decision makers, i.e., we consider a decentralized channel (unlike Benjaafar et al., 2013). Furthermore, it is assumed that these agents do not collaborate with each other in order to share savings (a similar non-collaborative decision making in a two-echelon supply chain with environmental considerations has been recently analyzed by Yenipazarli, 2017).

In particular, joining the leader's and the follower's emission targets can create opportunities for the channel as well as the individual agents since this will alter the leader's decision on the quantity flow. Specifically, when emission targets are joined, one can assume that the leader determines the quantity flow while assuring that the total emissions along the channel do not exceed the cumulative emission target, which might be accepted as achieving the environmental goals for the channel as well as the agents involved (see, also Benjaafar et al., 2013). While the leader, as the agent who holds the power to determine the quantity flow, will enjoy joint emission targeting (as this will give the leader a relaxed feasible strategy set);