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Environmental implications of transport contract choice - capacity investment and pricing under volume and capacity contracts

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ABSTRACT

Inspired by the observation that capacity contracts are used by some retailers to increase their transport provider's investments in green transport solutions, we investigate and compare a service provider's optimal investment, and its environmental implications under a volume and a capacity contract respectively. We solve the service provider's investment problem under the assumption that the retailer uses the service to replenish a warehouse with storable goods. We then show that a capacity contract leads to more green transports, but not necessarily a larger investment in green transport solutions. At the same time, the optimal solution involves heavy investment in inventory at the retailer. The investment in inventory is non-decreasing in the cost benefit of the green transports, which may have a significant negative environmental impact. The implication is that a capacity contract will lead to better environmental performance than a volume contract only when the green transports' cost benefit is within a given interval. Whether the capacity contract is the more profitable option for the service provider within this interval depends on inventory related costs and the relative environmental costs from transportation and inventory. Interestingly, owing to this, regulation that target the price of the conventional vehicles, such as a carbon tax, may lead to both an increase or a decrease in environmental performance.

1. Introduction

With the increased interest in environmental sustainability, many firms express a desire to reduce greenhouse gas (GHG) emissions also from outsourced transport operations. In the 2013 Carbon Disclosure Project (CDP) report, more than 30% of the firms report that they measure and work with improving emissions from outsourced distribution and transports (CDP, 2013). Manufacturer Unilever, for instance, claims that "a major objective at Unilever is to reduce our carbon footprint in the distribution of our products...we need logistics providers that are not only capable of moving and storing our goods in a service-driven, cost-effective and reliable way, but also with the smallest carbon footprint possible" (Ehrhart, 2010). Retailer H&M has a similar point of view: " we know that the biggest climate impacts along our value chain happen outside of our operations", adding that they therefore, "promote environmental consciousness at the transport companies we work with" (H&M, 2013).

The problem with emissions from outsourced operations (i.e. "Scope 3" emissions) is that another firm controls the decisions that ultimately determine the amount of emissions. In this paper we consider a retailer who has outsourced the replenishment of a warehouse to a transport service provider. While the retailer decides when and how much to replenish, it cannot directly decide on the composition of the fleet used to perform the replenishment – a key factor in determining the transport emissions from the system. This decision is made by the service provider. We assume the service provider chooses between two types of transport solutions: "green" transports; or "conventional" transports, and that the share of each type is adjusted at the beginning of the contract with the retailer. Green transports result in lower operating costs on scale through lower fuel consumption, reduced road tolls, or improved access in cities, but instead come with a higher upfront investment than conventional transports (see e.g. Wang, Ferguson, Hu, & Souza, 2013; Eng-Larsson, 2012). When demand is uncertain, these aspects imply that the risk for the service provider is higher for the green transports as it involves a higher fixed cost for an investment that may or may not be used. As a result, it is often financially optimal for the service provider to use only a very small

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share of green transports, despite retailers' efforts to "promote environmental consciousness".

In this paper we investigate how the service provider's decision on how much green transports to use depends on the contract with the retailer. We focus on two contracts often found on the transport market: *volume contracts;* and *capacity contracts* (see e.g. Lundin & Hedberg 2012; Mellin & Sorkina 2013). With a volume contract, the retailer orders and pays for transports as the need arises. With a capacity contract, the retailer pays for a fixed capacity level in each period independently of whether that capacity is used or not. Typically, this is combined with a flexible volume "on top of" this capacity, which is paid for only when used. What we have observed when working with firms on the transport market, is that several manufacturers and retailers have shifted to capacity contracts as a type of risk-sharing strategy to reduce the investment risk of the service provider, and thus increase the investment in green transports. For a retailer who has outsourced the replenishment of a warehouse to a service provider, shifting to capacity contracts has two effects. First, it reduces the uncertainty and volatility of the service provider's *revenue stream* over the duration of the contract. Second, it leads to a more stable *demand process* for the service provider, since it becomes beneficial for the retailer to pre-position inventory in times of low demand to be used in times of high demand. As such, a capacity contract, it is argued, reduces the service provider's risk of investing in green technology. But how does this reduction in risk impact the service provider's optimal investment in green technology? And what is the end effect on GHG emissions? This is what we seek to understand in this paper.

Literature Review. In the supply chain literature, volume and capacity contracts have been studied in both one-period settings (e.g. Cachon and Lariviere, 2001; Erkoc and Wu, 2005; Tomlin, 2003 and references therein) and multi-period settings without inventory (Akşin, de Véricourt, & Karaesmen, 2008). For instance, Akşin et al. (2008) analyze the same contracts as we do in the context of call center outsourcing. The major difference between these settings, however, is that in the transport service context, the buyer (i.e. the retailer) keeps an inventory which is affected by the contract parameters. This complicates the problem, since the service provider needs to consider how pricing affects the ordering pattern, which depends on downstream operations changes. Our first contribution is to extend this literature by considering a multi-period setting, where inventory can be kept between periods. In our model, a volume contract or a capacity contract (or a combination of the two) is implemented before the start of the first period. From the first period on, in each period, the retailer observes demand and places a replenishment order which is transported to the warehouse by the service provider. One of few papers that also considers a multi-period problem with inventory is Serel, Dada, and Moskowitz (2001). Serel et al. build on the inventory model of Henig, Gerchak, Ernst, and Pyke (1997), who derive the *retailer's* optimal inventory policy in a system where reserved capacity can be combined with a spot-market to replenish a storable good with stochastic demand. Given the buyer's response in Henig et al. (1997), Serel et al. (2001) determine the optimal pricing policy for the *service provider* numerically. We propose a slightly different approach to study the multi-period problem. To study the general system with both reserved capacity and variable capacity, we first address the simpler system with only reserved capacity. For this, we use tools from the literature on periodic review capacitated production-inventory systems (see e.g. Alp & Tan, 2008; Angelus & Porteus, 2002), which we embed in a Stackelberg contracting model. By proceeding in this way, we can extend previous work to compare contracts, and conduct sensitivity analyses to understand the impact of e.g. carbon taxes. We then relax this assumption, and show through a number of numerical examples that the key results seem to extend to the general problem with both reserved and variable capacity.

Our second contribution is in characterizing the players' optimal decisions, and identifying some interesting structural properties. In our analysis, we derive closed form expressions for the retailer's inventory problem which is then used to solve the service provider's investment problem under the different contracts. We illustrate how the investment in green transport capacity, under capacity contracts, is non-monotonic in a retailer's capacity reservation. We show that this also implies that with capacity contracts, a carbon tax may, in fact, lead to *less* green capacity and a higher expected environmental footprint. This is of particular interest, since carbon taxes has gained traction in business media and among regulators (see e.g. Hargreaves, 2010). In fact, some of the sustainability policies of firms like Unilever and H&M are motivated by an expectation of higher future tax pressure. As discussed by Krass, Nedorezov, and Ovchinnikov (2013), carbon taxation is an indirect tool, through which regulators try to provide incentives for firms and people to make the "right" technology choice. However, what we see is that this is not necessarily the case: if a regulator decides to make conventional vehicles more expensive to operate, it will not create incentives for investments in green vehicles, it will only make transports more expensive. This finding is similar to the finding of Krass et al. (2013), although the underlying mechanism is slightly different. Here, the investment is non-monotonic because an increase in the cost of the conventional technology makes it optimal for the service provider to increase the price of the greener service. This reduces the retailer's optimal capacity reservation which, under certain circumstances, reduces the service provider's optimal green transport capacity investment as well.

Our third contribution is in conducting a numerical comparison between the volume and capacity contracts, to understand when it is feasible and environmentally preferable to use each of the contracts. We show that the share of green transports is larger with a capacity contract. Also, in line with previous research in the capacity management literature (e.g. Jin & Wu, 2007), the capacity contract typically leads to a larger investment in green capacity. However, a capacity contract also leads to more inventory at the retailer. This creates an environmental trade-off. According to a report from WEF (2009), warehousing accounts for roughly 10% of all logistics-related emissions. McKinnon, Browne, and Whiteing (2012) argue that warehousing accounts for 2–3% of the world's total energy related emissions. Consequently, the increase in inventory leads to an increase in Scope 1 and/or Scope 2 emissions that, in extreme cases, may even offset the reduction in transport related Scope 3 emissions. In the numerical study we show when this is the case. Through this analysis, we hope to add to the growing discussion about the effects of operations decision-making on environmental performance (see e.g. Berling and Eng-Larsson, 2016; Bouchery, 2017; Brandenburg, Govindan, Sarkis, and Seuring, 2014; Demir, Bektaş, and Laporte, 2014 and Dekker, Bloemhof, & Mallidis, 2012). Previous research on green versus conventional vehicles by e.g. Wang et al. (2013) and Kleindorfer, Neboian, Roset, and Spinler (2012) consider a centralized decision-maker but, as shown by Mellin and Sorkina (2013), Jaafar and Rafiq (2005) and Hong, Chin, and Liu (2004), most transports are outsourced and controlled by different service providers. In this research we aim to show how this decentralized nature of transport operations is important in determining the environmental impact from a supply chain.

The remainder of the paper is organized as follows. Our multi-period model is described in greater detail Section 2. In Section 3, we characterize the players' optimal decisions under a volume contract and a capacity contract, and describe the capacity-and-volume contract. Section 4 provides a sensitivity analysis to see