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Agent interactions and the response of supply chains to pricing and incentives

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ABSTRACT

The paper analyzes how the interactions among the freight agents influence the supply chain's response to public policy initiatives based on pricing and incentives. The fundamental tenet of this paper is that, because of the role played by agent interactions in supply chains, carrier centered approaches are likely to be less effective than comprehensive approaches that exploit the power relations between supply chain agents to achieve policy goals. The paper characterizes the typical roles and interactions between the agents involved in supply chains; provides an economic interpretation of these interactions; and conducts a comparative analysis of the (limited) real-life evidence pertaining to the behavioral impacts of pricing and incentives.

1. Introduction

One of the fundamental objectives of public sector intervention is to induce changes in the behavior of economic agents to increase economic welfare. The economic rationale for intervening in the functioning of markets – established by Pigou (1920) in his seminal treatise on welfare economics – provided the seed for the work of Walters (1961) and Vickrey (1963) on congestion pricing. Pigou's insight is conceptually simple: that the negative externalities produced by any economic activity could be reduced, and even eliminated, if the producers of those effects internalize the economic costs of the damage produced to the rest of society. The use of the so-called "Pigouvian tax" would alter the private optimal level of production, leading to the elimination of the externalities. Building on Pigou's insight, Walters (1961) concluded that in the case of road traffic, charging a congestion toll equal to the difference between the marginal cost to society and the private cost to the driver would lead to the optimal amount of road use. Embedded in Walters' formulation, and the many others that followed such as Vickrey (1963) and Beckmann (1967), is the assumption that the congestion toll reaches the decision maker with the power to decide if and how to change behavior. This assumption deserves further examination because it is far from general.

The behavioral research conducted on passenger car users response to pricing, based on both stated and revealed preference data, casts doubt on the ability of users to change time-of-travel (Yamamoto et al., 2000; Cain et al., 2001; Burris et al., 2004; Holguín-Veras et al., 2007b, 2014; Ozbay and Yanmaz-Tuzel, 2008; Holguin-Veras and Allen, 2013). This body of research suggests that the typical outcome is a switch to transit if suitable modal alternatives are available, leaving time of travel unchanged. This is particularly the case of compulsory trips, such as travel to work, which represent the bulk of trips in the peak hours. These constraints are significant. A survey conducted in New York City revealed that car drivers traveling to work have narrow arrival time windows that average 20.4 min (early arrival) and 12.3 min (late arrival) (Holguín-Veras et al., 2011a); significantly constraints the possibility of a time of travel change to avoid the toll. There is a substantial difference between discretionary and a compulsory trip. In the former, the driver controls how and when the activity takes place, while in the latter the driver does not. Generally, employers control the travel patterns of employees. Because of the asymmetric power relation, where the employer dictates work conditions, policies that target the employee are not guaranteed to change employer behavior. Most employees cannot induce employers to change work hours. This does not mean, however, that employers cannot be influenced. It only means that the policy signals work best if they are directly aimed at the employers. There is a growing body of research that suggests the potential of comprehensive demand management approaches that go beyond the pricing-only view. Holguín-Veras et al. (2014) used stated preference data to

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estimate discrete choice models and analyze the effectiveness of four different policies: (1) toll discounts, (2) changes in crossing times at the toll booths (of the kind produced by changing the allocation of the number of toll booths that accept cash-payments), (3) increases in arrival flexibility, and (4) toll discounts combined with changes in crossing times and increases in arrival time flexibility. The results clearly showed that the time of arrival constraints limit the ability of car users to change time of travel; and that the use of comprehensive policies significantly enhances the ability of users to change behavior. Moreover, the research conducted by Yushimito et al. (2013a, 2013b) – based on the urban freight case (Holguín-Veras et al., 2007a, 2008; Holguín-Veras, 2008, 2011) – recast the traditional congestion pricing problem as a bi-level mathematical program where employers set the work hours that creates the demand for travel in the peak periods. This body of research suggests that road pricing combined with incentives to induce employers to relax work hours are more effective than road pricing alone in influencing traffic patterns.

In freight transportation, these dynamics play out with increased intensity. The reason is that freight carrier operations do not operate in isolation as they are one of the links in supply chains. The chain metaphor is appropriate. In the same way that a link in a (real) steel chain cannot be moved without generating resistance from the rest of the chain, the ability of carriers to change behavior is constrained by the other participants in the supply chain. All participants must agree on a common operational strategy; otherwise the supply chain breaks down. The steel chain metaphor is not perfect though. While in the steel chain the links are equal, in supply chains the links are vastly different. They perform different functions and have different degrees of power over the other agents (links). Complicating the matter, these power relations vary from industry sector to industry sector, from supply chain to supply chain, and from company to company. There is tremendous heterogeneity. The asymmetry in power presents a challenge to transportation policy. For a policy to be effective in changing the behavior of the supply chain, it has to reach the right decision maker, which is the one that could induce the other participants to change behavior in the desired manner. It is not necessarily correct to assume that policies that target different agents in a supply chain could reach the same outcome. This could only happen if transitivity of power holds in the supply chain, which is not the case. In a context in which the agents have different degrees of power, the powerful influences the weak not the other way around. Power is asymmetric.

The behavioral changes of the agents involved in a supply chain can be enacted at different levels. For instance, in response to changes in parking prices a freight carrier can unilaterally decide to use a battery-powered electric cart to make deliveries faster and spend less on parking fees. As long as the change is not detrimental to shippers or receivers, the use of the electric cart will not be opposed. A different situation is that of a receiver that decides to accept off-hour deliveries (OHD), between 7PM and 6AM, in exchange for a financial incentive. Since the receiver has a large influence on carrier operations, it is likely that the receiver's decision will translate into some of its vendors implementing OHD. A third example could be the case of shipper that reacts to a newly developed intermodal freight terminal, by increasing shipment sizes to use rail for the long-haul transport to a large metropolitan area. The shippers' decision is likely to lead to changes in carriers and receivers operations. These interconnections are ignored if the sole focus is on the carriers as the visible actors that produce the externalities. Such perspective overlooks the fact that freight traffic is the direct result of the receivers' demand for freight and the operational decisions made by shippers and receivers.

The main goal of this paper is to analyze how the interactions among the freight agents influence the supply chain's response to public policy initiatives based on pricing and incentives. The fundamental tenet of this paper is that, because of the role played by agent interactions in supply chains, carrier centered approaches are likely to be less effective than comprehensive approaches that exploit the power relations between supply chain agents to achieve policy goals. The paper characterizes the typical roles and interactions between the agents involved in supply chains; provides an economic interpretation of these interactions; and conducts a comparative analysis of the (limited) real-life evidence pertaining to the behavioral impacts of pricing and incentives.

Throughout the paper, the term *freight pricing* designates all forms of pricing that target the agents involved in freight. Since the paper's main focus is on policies that use pricing mechanisms to achieve a public goal; the use of pricing to achieve private sector goals, such as revenue maximization, are not considered. The paper has six main sections. The paper analyzes the interconnections between the agents involved in freight activity in Section 2; investigates the empirical evidence from the case studies in Sections 3 and 4; synthesizes the chief findings in Section 5; and provides concluding remarks in Section 6.

2. Freight agent interactions

The fundamental tenets of this paper are that: (1) to be effective, transportation policy has to be designed based on a solid understanding of the behavior of the target population, and particularly, on how that population would respond to the policy; and (2) understanding the behavioral response of the freight carriers to pricing and incentives requires careful study of the interactions among the various economic agents involved in supply chains. To this effect, this section describes the typical patterns of interaction and behavior among the key agents involved in supply chains. The focus is on the "typical", as multiple factors can influence the nature of the economic interconnections at the core of supply chain decision making, thus altering the "typical" behavior. The power relations among agents are one of these factors.

A multitude of agents are involved in supply chains: producers/manufacturers, shippers, freight forwarders, third party logistic providers, warehouse operators, carriers, and receivers. (These agents could be part of the same or a different company.) However, close examination reveals that the primary roles are played by those that supply, transport, and consume the supplies. Throughout the paper, the "supplier" is assumed to be a super-agent that conflates the roles of producers/manufacturers and shippers. The "carrier" represents the agents that take care of the transportation between shipping and receiving locations. The "receiver" is the actual recipient of the cargo, which could be an input to a subsequent economic process, or a final good to be sold to consumers. The rest of the agents (e.g., freight forwarders, third party logistic providers, warehouse operators), simply modify these primary functions and are ignored throughout the paper. It should be noted that modern supply chains are comprised of dozens, even hundreds, of these individual production-consumption segments that link suppliers, carriers, and receivers. In most cases, suppliers and receivers play a dual role as receivers of input materials, and suppliers of the product they manufacture or transform. Essentially, the freight carriers are a conduit between the suppliers of the cargo and the receivers that consume it (Holguín-Veras, 2011). In fulfilling their mission carriers produce the vehicular traffic required to transport the freight demand. In all cases, the carriers must meet the constraints set by both suppliers and receivers. Generally speaking, receivers have a lot to say about how and when activities in supply chains take place. For this fundamental reason, they must play a prominent role in enhancing sustainability of urban supply chains.

Fig. 1 shows a schematic of the typical decisions made by suppliers, carriers, and receivers. The figure shows that some

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