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A logit model for shipment size choice with latent classes – Empirical findings for Germany

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ABSTRACT

Decisions on shipment size in freight transport are often seen to represent a whole set of logistics decisions made by shippers and recipients. Also, shipment sizes have a large impact on transport mode choice. Therefore, they are an important aspect in the modeling of freight transport demand, as they allow to display the reactions of various stakeholders on policy measures. In this article, a model for the discrete choice of shipment sizes is applied to interregional road freight transport. Preferences of actors are reflected by a total logistics cost expression. Furthermore, a Latent Class Analysis approach is applied to identify groups of transport cases with similar logistics requirements. The classification reduces significantly heterogeneity in behavior. Reactions of actors on external influences such as policy measures could be predicted more accurately.

1. Motivation

The globally growing relevance of freight transport increases the importance of adequately assessing policy measures for predicting the changes in freight transport demand resulting from external influences. As the logistics activities of involved actors determine to a great extent the characteristics of freight transport, the use of behaviorally sensitive freight transport models based on rational decisions and covering the main dimensions of logistical behavior are becoming more and more necessary.

Generally, the consideration of logistic choices in the context of freight transport is accompanied by a huge variety and diversity of involved actors (shippers, carriers, receiver, operators, etc.) and an enormous diversity of transported commodities. As a consequence, each company's logistics operations are differently organized and very detailed on the level of single actors, so that they cannot be inserted into comprehensive freight transport models directly. Instead, simplifications and generalizations have to be found which still allow causes and effects to be traced, and which also preserve the variability in logistics behavior in the model.

A usual practice of finding such simplifications is to model single logistics decisions on a high level of aggregation. One of these proxy decisions is the choice of shipment sizes, which covers the central aspects of the actor's logistical calculus and to some extent explains the behavioral heterogeneity of the actors. In general, the shipment can be seen as one of the simplest links between commodity flows formed from economic interactions on the transport demand side and the vehicle movements that take place on the various transport routes. On the one hand, the size and other properties of the shipments determine the arrangement of the trade relationships between shippers and receivers from which the demand for freight

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transport results. On the other hand, the requests of the potential customers and the restrictions placed by the transport system are influencing the offers of the transport companies competing on the transport markets. Because of the shipment's occurrence on all stages of decision, the finding of a shipment size that fulfills the requirements of all involved parties can serve as a model at a high aggregation level of the underlying logistics considerations.

Summarizing the previous aspects, two questions arise in developing a shipment size choice model for large-scale freight transport model systems:

(1) Which influences have to be considered as crucial for the explanation of logistical actors' behavior, and how can they be incorporated in an operational transport model?
(2) How can the omnipresent heterogeneity of actors and decision situations be addressed in a manageable yet realistic way?

The purpose of this paper is to suggest answers to these two questions. We propose a discrete shipment choice model based on a total logistics cost formulation, as it turned out that decisions are oriented on given vehicle and bundle sizes. Additionally, technology-related or market-related influencing factors on transport cost functions, such as the number of transshipments or the characteristics of the goods, support a certain categorical character (Combes et al., 2016). This orientation results in shipment sizes that fall into a limited number of categories. Moreover, a limited set of size categories from which to choose seems to be more manageable when it comes to integration of the shipment size component in a comprehensive freight transport model.

Discrete choice models are usually estimated from samples that cover a wide range of responses and thus decision situations. Consequently, the estimated model instances reflect the behavior of the sample population as a whole and cannot account for the variability of actor reactions on external influences. A way to alleviate this is to distinguish segments of freight transport demand that exhibit similar behavior. In this case study, we use a novel approach in the context of shipment size choice that segments transport cases according to logistics aspects by means of a latent class model, which in combination with a rational framework of total logistics cost minimization improves the explanatory power of the shipment size choice behavior.

For model estimation a dataset was used which was gathered at the beginning of 2013 within the scope of the research project "Development of a model for the calculation of freight traffic modal shifting to derive consistent evaluation approaches for German federal infrastructure planning (BVWP)" (BVU – Beratergruppe Verkehr + Umwelt, TNS Infratest (2014)). The data contains in total an amount of 926 transport cases gained from 474 interviews with shippers and receivers. The model in this article has to be restricted to road transports as there are not enough observations for modes other than truck available (23 by rail, 9 by inland waterway, 13 by intermodal rail and 5 by intermodal inland waterway). Nevertheless, the estimated model provides possible links for the comprehensive integration of the mode choice.

This article is organized as follows: Section 2 contains a brief review of the literature dealing with shipment size choice models and the formation of homogeneous groups. Section 3 covers the conceptual framework, which consists of the theoretical background of shipment size choice, the development of a discretized total logistics cost model, and the essentials of determining latent classes. The source data and descriptive analysis take center stage in Section 4, whereas Section 5 presents the estimation results. Finally a summary and an outlook on possible directions for further research will be given in Section 6.

2. Literature review

Most freight transport models assume that the goods to be transported between shippers and recipients do not result from one-off businesses. It is rather assumed that the shipment will be part of a long-established business relationship. From such relationships, a total flow of goods per period results, which has to be split up into several shipments. Two cost components determine the optimal partition. For every order placed at a transport company, a fixed amount has to be payed, regardless of the quantity that is shipped. On the other hand, a small number of large shipments will cause high inventory holding costs. A simple mathematical expression for this tradeoff is given by the Economic Order Quantity (EOQ) model (Harris, 1913). In the context of freight transport, Baumol and Vinod (1970) developed a total logistics cost approach for the determination of shipment sizes. Hall (1985) considered the influence of given vehicle sizes when taking the lower envelope of the transport cost functions of various transport modes as one of the decision criteria. By doing so, the inherently discrete choice of a transport mode was combined with the choice of a (continuous) shipment size. A further reason for this joint consideration is that shipment sizes depend on total logistics cost, which, in turn, are heavily influenced by the physical provision of transport. Thus, most subsequent shipment size models did not consider shipment size choice as an isolated factor, but rather combined it with the choices of mode, carrier or transport chain. However, Holguin-Veras (2002) pointed out that such combined choices are often not taken by the same decision maker, although they are in many cases seen as belonging together.

In large-scale freight transport model systems, econometric models based on the total logistics cost as the actor's rational choice criterion for the determination of shipment sizes prevail. Within the group of these models, there are basically three different ways in which the problem has been addressed:

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