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On structural inelasticity of modal substitution in freight transport

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ABSTRACT

At the European level there is an increasing focus on how freight transport can be moved from trucks on roads to more environmentally friendly modes such as rail and ship. A large proportion of the transport services between OD pairs, however, cannot be substituted since there is only one alternative available. The paper investigates the magnitude of this "structural inelasticity" of modal substitution in freight transport due to a sparser layout of rail and ship-based freight networks compared to road. In the analysis we use a recent Scandinavian freight demand model covering more than 800 zones. We find that the structural inelasticity is very significant – in particular for transportation over less than 500 km. Moreover, the inelasticity varies greatly with commodity groups and between OD pairs, and it depends strongly on the port and rail infrastructure. The results suggest that pure charging instruments (road pricing for trucks) in many regions will have limited mode substitution impacts. However, if combined with structural changes in terms of improved infrastructure for rail and ship, impacts may be greater.

1. Introduction

Recently there has been a lot of focus on sustainable freight transport and the European Commission (EC) has proposed an ambitious development plan for the European rail freight infrastructure in the TEN-T priority axes (European Commission, 2005). Parallel to this, road-charging schemes for trucks which are underway in many European countries will have an impact on the mode choice profile in the European freight sector. The difference between charging policies and infrastructure changes is that, although charging policies may cause overall changes to the modal pattern, these changes are essentially conditional on the actual layout of the freight transport infrastructure. It means that if road-charging is imposed in a region with undeveloped alternative rail and ship networks, mode choice effects are likely to be modest. In contrast, changes to the infrastructure will open up new corridors and strengthen competition in existing ones.

The paper gives special attention to the potential for modal substitution by analysing the "structural inelasticity" that result from the lack of physical networks in the freight transport market. Since the layout of the network for rail and ships is in many cases sparse, the vast majority of OD pairs are only serviced by a single mode, which is most often truck. This causes the mode substitution elasticity to be zero for these specific OD pairs and imposes a generally reduced sensitivity to cost and time attributes.

In a freight modelling context, the presence of "structural inelasticity" has consequences for the model design. If in a model, the zone structure is aggregated to a point where the underlying heterogeneity in the network is not correctly represented, it will result in model aggregation bias. The point is that whereas large zones are more likely to have several mode alternatives available, this is not necessarily the case for a subdivision of the zone system. As a result, a prediction based on an aggregate model will generally over-predict the number of rail and ship transports to- and from zone which are in reality only serviced by truck. On the other hand, there will be too few transports attached to zones which are in reality serviced by more mode choice alternatives. The problem is that although the model will be correct on average as a result of alternative specific constants, which will ensure that OD transport flows are replicated, we will observe significant aggregation bias at a sub-zone level. In a freight context this is a critical issue because of strong correlation between the commodity mix, transport modes, and the geography. In other words, a potential spatial bias will tend to be inherited in commodities as well as modes and as a result hereof, in the ton-km measurement.

A further problem of this aggregation bias is that it is common that elasticities from other studies and geographical areas are often transferred to new models and/or geographical areas (e.g. elasticities provided by reviews such as De Jong et al., 2004). These transfers of elasticities could then be erroneous if they are not reflecting the zone size and the structural inelasticities correctly.

The quantification of the inelasticity is complex because it requires a detailed zone system which can represent the spatial

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heterogeneity in the underlying freight networks for all modes involved plus a detailed division of commodity groups. If this is not the case and all modes can go everywhere, elasticities will tend to be significantly biased as discussed above. The present paper investigates structural inelasticity by applying a recent detailed Scandinavian freight demand model (Rich et al., 2009b). The model, which is formulated as a weighted discrete choice model, covers 832 zones and includes a detailed network description for road, rail and ship. The model also allows for combinations of modes in that combi-rail (road and rail) and combi-ship are included separately plus a division into thirteen parallel commodity groups. Whereas (Rich et al., 2009b) was concerned with a description of the model including data and estimation issues, the present paper focus on structural inelasticities and aggregation bias in the freight market.

1.1. Freight transport elasticities

Reviews of transport elasticities for freight transport demand are presented in Graham and Glaister (2004), Goodwin et al. (2004), Oum et al. (1990), and Abdelwahab (1998). The number of studies considered is rather limited, and the variation of elasticities reported in the reviews is quite large. This is due to methodological as well as geographical differences. Graham and Glaister (2004) reports an average price elasticity of demand close to −1. Another recent study by De Jong et al. (2004) reports price elasticities for trucks from −0.4 to −0.7 based on a European meta-model, whereas Maibach et al. (2008) recommends using truck elasticities around −0.3. Estimates of price elasticities for trucks derived in Rich et al. (2009b) are significantly lower with an average value of −0.13. However, there are sizeable differences between commodity groups, with a minimum of −0.035 and a maximum of −0.28.

There are several reasons for the lower elasticities including geographical differences[1] and the use of cost dampening functional forms as discussed in Rich et al. (2009b). However, an additional problem is that many studies used in meta-models are essentially concerned with intercity freight (Picard and Gaudry, 1998; Winston, 1979) or small-scale SP studies (Norojono and Young, 2003; Shinghal and Fowkes, 2002; Nam, 1997), which cannot be compared with full-scale freight models due to the problem outlined in this paper. The impact of local geographical conditions seems to be supported by Cardebring and Lundin (2007) and Forss and Ramstead (2007), who find elasticities based on the Swedish STAN model much in line with our findings. The two main problems identified in the literature and addressed here are the local geographical conditions – the “structural inelasticities” – and, related to this, the geographical zone size within which the elasticities are measured.

Analysis of the specific issue of “structural inelasticity” we are concerned with in this paper has not to our knowledge been given any attention in the literature. Beuthe et al. (2001) presented a study for Belgium in which they applied a detailed network for several parallel modes and reported elasticities for 10 commodity groups. Their study showed elasticities close to unity and in this respect compares well with many of the American studies included in Graham and Glaister (2004). However, there is no indication in Beuthe et al. (2001) of the zone structure (the number and geographical size of zones) and only aggregated costs are analysed. Moreover, the elasticity matrix was not based on a discrete choice model and thus not necessarily consistent with random utility. It is not completely clear how substitution effects are addressed in a cost-minimization approach and how statistical dependencies (e.g. in the mode-choice) are dealt with.[2] Due to this it may be difficult to compare the elasticities from the two approaches.

The issue of “structural instability” is also closely related to freight distances. If distances between origin and destination zones are short, the fraction of OD pairs with only one mode alternative will be relatively large, whereas for long distances, more modes will be competing in bundled networks (Kreutzberger, 2008). In this sense, the “structural inelasticity” may be seen as a reflection of the “last-mile” problem, where trucks are always used for the last mile. The problem arises since this use of trucks on the last mile often leads to the use of truck also on longer distances where alternatives exist. It is therefore important to distinguish between ton and ton-km. A measure in ton does not take into account that the distance (the last mile) is rather short and the inelasticity effects measured in tons may be very considerable, whereas a corresponding measurement in ton-km is likely to be more moderate.

1.2. The outline of the paper

In Section 2, we consider data and network layout. Section 3 gives a very brief model description. In Section 4 we present simulation results. Section 5 includes a discussion and finally we offer our conclusions in Section 6.

2. Data and model

The model operates on OD matrices that describe transported tonnes between 832 zone pairs, for 13 commodity groups, and 5 modes covering truck, combi-rail, combi-ship, rail, and ship. The overall mode choice share measured in ton and in ton-km is shown in Table 1 below.

Table 1
Aggregate modal split across all zones and commodity groups.

	Truck (%)	Combi-rail (%)	Combi-ship (%)	Rail (%)	Ship (%)
Ton	41.34	0.61	7.77	1.44	48.84
Ton-km	14.06	0.34	7.95	2.28	75.38

The dominant modes are road and ship including intermodal truck-ship (*Combi-Ship*). Rail and ship modes represent larger shares when we consider ton-km since these modes are typically used on longer distances and also for commodities that can be shipped in bulk loads and are characterised by very large quantities at the same time.

The term “structural inelasticity” as applied in this paper may rather be referred to as “revealed structural inelasticity” since the inelasticity basically reflects the ton formation in the OD matrix rather than the specific network availability although these two are strongly related. In other words, if there is a “zero ton entry” in the OD matrix for a particular mode, then we assume that the corresponding OD pair is inelastic to changes. In a marginal (elasticity) perspective this is true, however, it is not the same as to say that goods cannot be transported on this OD pair.[3] The strength of this from a methodological perspective is that the structural inelasticity is less sensitive to the specific network layout and the way level-of-service variables are calculated, and more sensitive to what has been revealed about actual freight logistics in the matrices A lot of work has been put into the work of construct-

[1] A discussion of the large structural differences between the US and the European freight markets with focus on rail can be found in Vassallo and Fagan (2007).

[2] Statistical dependency in Rich et al. (2009b) was managed in a nested-logit framework, which tends to lower the elasticities in the choice of mode.

[3] For instance, it would always be possible to reload goods from truck to rail or ship and bring the combined rail or ship alternative into the choice alternatives. However, this would be a “de facto” alternative more than a real alternative.