Article:

Jensen, AF, Thorhauge, M, De Jong, G orcid.org/0000-0003-3405-6523 et al. (6 more authors) (2019) A disaggregate freight transport chain choice model for Europe. Transportation Research Part E: Logistics and Transportation Review, 121. pp. 43-62. ISSN 1366-5545

https://doi.org/10.1016/j.tre.2018.10.004

A disaggregate freight transport chain choice model for Europe

Anders Fjendbo Jensen[a,*]

Mikkel Thorhauge[a]

Gerard de Jong[b,c]

Jeppe Rich[a]

Thijs Dekker[b]

Daniel Johnson[b]

Manuel Ojeda Cabral[b]

John Bates[d]

Otto Anker Nielsen[a]

[a] Division of Transport Modeling, DTU Management Engineering , Technical University of Denmark, Bygningstorvet 116B, 2800 Kgs. Lyngby, Denmark

[b] Institute for Transport Studies, University of Leeds, 34-40 University Road, Leeds LS2 9JT, United Kingdom

[c] Significance b. v., Koninginnegracht 23, 2514 AB The Hague, The Netherlands

[d] John Bates Services, Picklers Hill 1, OW14 2BA Abingdon, United Kingdom

A disaggregate freight transport chain choice model for Europe

Key words: freight transport, mode choice, modal split, transport chains, Europe

Abstract:

This paper presents the estimation of a discrete freight transport chain choice model for Europe, which was developed for the European Union as part of the Transtools 3 project. The model describes nine different multi- and single mode chain alternatives of which three can be either container or non-containerised, and it segments freight into dry bulk, liquid bulk, containers and general cargo. The model was estimated on the basis of disaggregate data at the shipment level (Swedish CFS and French ECHO data). Several transport costs specifications and nesting structures were tested and elasticities compared with reference literature. It was found that freight models are characterised by heterogeneity, non-linearity in transport costs and hence Value of Times and non-constant rates of substitution. Not taking these elements into account will have consequences for the evaluation of transport policies using the freight transport model.

1. Introduction

1.1 Background and motivation

The choice of transport mode is a key decision in freight transport and has direct influence on goods flows, congestion and other derived external costs. Today, most long distance shipments are transported in chains (Guilbault, 2008), as it is hereby possible to utilise advantages of the particular modes or vehicles in the most productive manner (Konings et al., 2008). As a result, in freight modelling contexts, choice of mode must be seen in a transport chain choice perspective where transport chains from the production to the consumption location are formed by a multi-modal sequence of chain segments. Failing to acknowledge the multimodal nature of freight transport chains will lead to biased market shares and biased substitution effects across modes. With the increase in freight transport (Woodburn et al., 2008) there is an increasing need for accurate estimation of these movements and the underlying commodity flows (Chow et al., 2010; Huber, 2017). At the political level, the continuous increase in road transport calls for political action on how to promote intermodal transport and assess the potential of intermodal mode shifts (Tsamboulas et al., 2007). As a result, intermodal transport and transport chains are an important issue – both in practice and from a research perspective.

1.2 Literature review of previous freight modelling approaches

Two distinctions are commonly used in the literature for classifying mode choice freight models (De Jong, 2014a). Firstly, the distinction between different degrees of multimodality - possibly combined with type and size of shipments - and secondly the distinction between different levels of aggregation.

The first distinction is related to the detailing of the endogenous variable and how substitution is modelled in a multimodal chain model. Historically, several model structures have been proposed of which the most important are discussed below:

- Models that study the mode choice for each origin-destination (OD) relation separately without considering that this OD relation could be part of a larger, multi-modal transport chain.
- Transport chain choice models: These models address the multimodal nature of freight models by defining the choice set in terms of transport chains, e.g. direct road, direct rail or road-rail-road. These chains typically relate to PC (production and consumption) flows and the transport between origin of production (P) and place of consumption (C). Examples are the Norwegian, Swedish and Danish national freight transport models (Ben-Akiva and de Jong, 2013, Windisch et al. 2010). The only applied disaggregate chain choice model, at least for Europe, is Abate et al. (2018), which is only a prototype model for two commodities. Also, models that determine the shortest part (‘hyperpath’) through a multimodal network belong to this category (e.g. Beuthe et al., 2001).

Some of the models not only explain mode or transport chain choice, but other choices as well:

– Models of mode (or transport chain) and shipment size (e.g., McFadden et al., 1985; Abdelwahab, 1998): This is an extension of the mode choice models in that shipment size is modelled endogenously.
– Mode and supplier choice: These are models where a receiver of the goods chooses the supplier (or the supply zone). Such models are considered in Samimi et al. (2010) and Outwater et al. (2013).
– Mode and route choice: These models integrate the choice of route with choice of mode and are typically based on an aggregated multimodal network assignment design. Examples include the European SCENES model (SCENES consortium, 2001), the NODUS model in Belgium (Beuthe et al., 2001) and the Worldnet model (Newton, 2008).

The second distinction between different levels of aggregation is relevant for estimation as well as for application. In general, two approaches have been considered in the literature:

– Disaggregate mode choice or transport choice models (e.g. Arunotayanun, 2009; Feo-Valero et al., 2011) that explain the choice of mode or transport chain at the level of an individual shipment.
– Aggregate mode choice models that explain the split of the annual number of tonnes transported between each pair of zones (e.g. the NEAC model for Europe (NEA, 2000), the early versions of the Transtools model for Europe (Tetraplan, 2009) or the Dutch national freight transport model BasGoed (de Jong et al., 2011).

In estimation, the presence of micro (disaggregate) data enables a micro-econometric estimation of parameters (as in this paper), which in an efficient way utilises the variation in the underlying data as a basis for parameter estimation. The importance of this is underlined by the fact that goods are far from homogenous (de Jong et al., 2004; Liedtke, 2009; de Jong et al., 2013) and that potential aggregation is likely to imply efficiency loss as well as bias of the corresponding parameters.

In application, freight models are almost always aggregated as they are linked with aggregated trade-models and aggregate network assignment models, and the final outputs of a freight transport model are aggregate predictions, not forecasts for individual firms and shipments (Ben-Akiva and de Jong, 2013). Choices then represent prototypical chain choices and possibly prototypical shipments for given commodities and PC combinations. This is particularly important in a forecasting perspective where a completely disaggregated setup would require knowledge of the spatial distribution of firms and their commodity profiles as well as the distribution of the population and jobs in the future. The aggregated approach, however, poses the challenge that zones are often quite large, which leads to an over-estimation of the consolidation of flows and an unrealistic preference for large vehicles and vessels, since the volume of the zone-to-zone flows will often be so large that these vehicles and vessels will be optimal at the zonal pair level. This can be solved by introducing a synthetic firm-to-firm break down in which zone-to-zone flows are distributed across different firm prototypes that vary with size. This is the approach taken in the ADA (aggregate-disaggregate-aggregate) models in Norway, Sweden and Denmark (Ben-Akiva and de Jong, 2013). This approach so far has only been used at the national or regional (Flanders in Belgium) scale.

1.3 Contributions of the study

To our knowledge no prior studies have used the ADA approach for multimodal transport freight chain choices in large scale transport models. The objective of this paper is therefore to provide insight into the structure of transport chain choice and the estimation and application of chain choice in a large-scale European freight transport model utilizing the ADA-framework. More specifically, this paper provides three important contributions.

The first contribution of this study is the probabilistic modelling of chain choice across commodity groups. What distinguishes the presented model from the existing operating national ADA models is that these typically adopt a transport chain choice which is modelled as a deterministic choice that searches for the optimum by minimising the total logistics costs (see Ben-Akiva and de Jong, 2013; Abate et al., 2018). This is a common strategy when micro-data is not available for estimation, as it allows for a disaggregate model (and therefore some level of heterogeneity) within an overall aggregate model. However, the model presented in this paper introduces a stochastic model for the choice of chains. This enables a better estimation of substitution effects and a better trade-off between chain flows and transport costs. Abate et al. (2018) also did this in the Swedish freight transport model, but only applied it to two different commodities (chemical and metal products). This paper contains estimation and application results for all commodities. The model is estimated on the basis of disaggregate data and it is applied to all zone pairs in Europe. In the application, the choice of shipment size was made exogenous as it was not possible to handle combinations of Level-of-Service files for transport chain and shipment size. Therefore, in this particular respect the model presented here is actually simpler than the national ADA logistics models, although the parameters and the substitution across choice sets reflect the heterogeneity of the micro data.

The second contribution concerns the econometric estimation of these models. Not only do we apply two separate micro datasets in the model estimation to reflect as much heterogeneity as possible, we also explore functional form in a rather detailed way. Practically all freight mode choice models, including the ADA logistics models, use linear transport cost functions, and systematic research related to non-linear cost functions appears to be missing in the freight literature. In applied large-scale models for passenger transport, non-linear transport costs functions have been used quite frequently (e.g. Fox et al. 2009; Willigers and de Bok, 2009; Rich and Hansen, 2016). However, with a linear cost specification, cost elasticities become dependent on the scale of the cost attribute variable in a logit model specification. This is often not realistic and has led to the need for "damping specifications" as described in Daly (2010). In this paper, we test, besides linear transport costs, various non-linear specifications of transport costs.

As a third contribution, we present elasticities and VoT derived from the estimated models in order to show the importance of differentiating between freight types and with increasing transport costs.

1.4 Modelling approach

The model presented in this paper was estimated on the basis of disaggregate data. More specifically, it is based on a joint estimation over two micro datasets with observations at the shipment level, using a nested-logit model framework to 1) allow for differences in the substitution patterns across mode and chain combinations for the two datasets, and 2) capture scaling between the two datasets.

The two datasets used during model estimation were the Swedish *Commodity Flow Survey* (CFS) from 2009, and the French *Envoi – CHargeurs – Opérateurs* (ECHO) survey from 2004. These datasets are combined with Level-of-Service information resulting from the Transtools 3 assignment models[1]..

The remaining part of the paper is organised as follows. In Section 2 of this paper we present the two disaggregate datasets and the Level-of-Service data used in the model estimation. Section 3 describes the modelling process, the estimation results and elasticities on the estimation data for the transport chain model, whereas section 4 concludes the paper.

2 Methodology

The model was estimated on the basis of two disaggregate revealed preference datasets for European freight transport: The French, Envoi – CHargeurs – Opérateurs (ECHO), survey from 2004 and the Swedish, Commodity Flow Survey (CFS), from 2009. Both data sources contain observations at the level of individual shipments between firms (at the PC level), collected by interviewing shippers (and for ECHO also carriers). By combining both datasets into a joint estimation, we take advantage of heterogeneity from both sources; the smaller ECHO dataset with rather detailed information, and the very large CFS dataset with fewer details. More specifically, this enables estimation of specific parameters that only exist in one dataset, while at the same time we specify generic parameters across both datasets to obtain more robust parameters. The used datasets are the only available disaggregate datasets with observations on transport chains in Europe. Both datasets are unique in the sense that these are the only disaggregate datasets at a larger level covering European freight transport, and by combining them with LoS data from the TransTools 3 project (Jong et al, 2016) enabled estimating a discrete choice model for freight chain choices.

2.1 Description of CFS 2009 data

For CFS 2009 it was decided to use only outgoing shipments (the major part of the CFS), not the incoming shipments. Some CFS shipments are available directly from register sources on forest, dairy and sugar products. These flows have been excluded[2] from the dataset as they are OD flows (instead of PC) and are unfit for the model concept (see Ben-Akiva and de Jong, 2013). Moreover, all commodity flows transported by air and (or) unknown modes of transport were dropped. After data cleaning, 1,614,660 flows were available for estimation. A detailed description of the zone data conversion strategy is offered in Appendix A.

All transports using road only were recoded into road chains. In estimation, some of the road shipments were re-classified as Roll-On-Roll-Off ferries (RORO)[3] based on whether the generalised transport cost was lower for RORO than road. Rail chains are chains using rail only, or any combination of rail and road in any order. Similarly, sea chains are chains using sea only, or any combination of sea and road in any order. Finally, rail and sea represent shipments that make use of

[1] The TT3 model has been developed by a consortium led by the Technical University of Denmark (DTU) for DG MOVE of the European Commission, see Jong et al (2006 & 2017)

[2] Commodity types ('Varukod') 12, 13, 16 and 44 were excluded from the dataset.

[3] A RORO ship can carry vehicles, i.e. a truck or trailer is driven on-board and off the ship on its own wheels or using a platform vehicle.

both rail and sea, possibly also including road trips as part of the chain. Specific conversion tables for the *Chain* variable, but also other variables, are available upon request.

2.2 Description of ECHO data

The French ECHO survey was carried out by IFSTTAR[4] (previously INRETS) in 2004. To obtain access to the ECHO database, a special application was required by the 'Comité du Secret' of INSEE, the French national statistical institute.

The basis of the ECHO survey is interviews of almost 3,000 French shippers. They provided detailed information about their shipments during a period of one to three months prior to the interview. The unique feature of ECHO is that the researchers subsequently interviewed 27,000 receivers, transport operators and logistic service providers, starting from the information provided by the shippers on the parties involved in the transport of their shipments. This enabled the researchers to reconstitute the full transport chain (PC level) for around 10,000 shipments.

Compared to the CFS dataset, the ECHO dataset is much smaller in terms of number of shipments, but richer in terms of information per shipment. ECHO contains five questionnaires: pre-interview, shipper, shipment, operator and journey leg (segment of the transport chain). The data that we received include attributes of the firms involved, locations of production, consumption and transhipment (NUTS3 level), annual flow, weight, volume, commodity type and modes used in the transport chain.

For our purposes, the shipment level includes details on commodity type (NST/R classification), volume (tonnes), consistency and value from the shipment file and information on mode and OD from the journey leg file. These datasets were merged together using the shipment identifier. After data cleaning, 8,208 valid shipments were left for estimation.

2.3 Description of the Level-of-Service data

European (and to some extent global) freight networks were constructed for road, rail, inland waterways, sea and RORO transport (Jong et al., 2016). Initially the networks were based on the ETISplus project (ETISplus, 2014). These networks were then applied to derive Level-of-Service information for estimating the transport chain choice models on CFS and ECHO, both for the chosen and the unchosen alternatives (Nielsen, etal., 2015).

For each of the two data sources a matching set of Level-of-Service matrices was prepared for all chain types. These chain types also distinguish between dry bulk, liquid bulk, general cargo and containers. Thus, the Level-of-Service information was available in four tables for CFS and four tables for ECHO. Each Level-of-Service table contains information for each chain. In particular, the specific zone pair (to match the Level-of-Service data with the individual PC flows from CFS and ECHO), distance, total travel cost for all modes and all transhipments per tonne and transport time by mode (road, rail, sea, inland waterways and RORO), Jong et al. (2016)

Because of the coarseness of the railway network, railway transport is indeed concentrated mainly in a limited number of corridors. If road access and egress transport to and from the rail terminals is not accounted for, rail is likely to be too attractive and used from many points to many points, even if

[4] French institute of science and technology for transport, spatial planning, development and networks

these points are far away from the railway corridors (Jourguin et al. 2014). We estimate the effect of road access and egress costs and transfer cost to and from rail. In particular, in the estimation and application of our models for transport chain choice, access to rail is defined as a 0/1 dummy variable that is equal to 1 if the origin or destination zone has a terminal for the mode(s) studied, and 0 otherwise. This variable is derived directly from the level-of-service matrices.

3 Model formulation

The mode chain choice is modelled as a standard nested logit (NL) model, where choice alternatives are represented by transport chains. The nested logit model is formulated in a hierarchical conditional structure, where the utility for alternative i belonging to nest q is formulated as:

$$U_{i,q}^{D} = V_i + V_{i|q} + \varepsilon_i + \varepsilon_{i|q}, \forall i, q \qquad (1)$$

Where V_i and $V_{i|q}$ represent the deterministic component and ε_i and $\varepsilon_{i|q}$ are the random terms, which are assumed to be identical and independently extreme value distributed.

The deterministic utility of a mode is defined from a number of relevant attributes X describing each shipment (i.e. shipment value and cargo specification), transport cost, transport time and geographical information about available terminals at origin or destination of the shipment.

$$V_i = \theta^D w^D \sum_k \beta_k \cdot X_k \qquad (2)$$

Where θ^D is a scale parameter adjusting the utility of the two separate datasets D to the same scale (size of parameters) whereas w^d represents a weighting of the two datasets.

The probability that a mode is chosen is then the joint probability of choosing the nest P_q and the conditional probability $P_{i,q}$ of choosing the alternative i given that this alternative belongs to nest q,

$$P_{i,q} = P_q \cdot P_{i|q} = \frac{\exp(V_q + I_q)}{\sum_q \exp(V_q + I_q)} \cdot \frac{\exp(V_{i|q})}{\sum_i \exp(V_{i|q})} \qquad (3)$$

where $I_q = \mu_q log \sum_i \exp(\frac{V_{i|q}}{\mu_q})$ and μ_q is the logsum parameter used to measure the degree of independence among the unobserved proportion of the utility for alternatives within the nest. The parameters of the model were estimated in Alogit using maximum likelihood estimation. In particular, the log-likelihood function to be maximised is:

$$LL = \sum_{n=1}^{N} \sum_{j=1}^{J} d_{ni} \ln(P_{i,q}), \qquad (4)$$

where LL is the Log-likelihood function, N is the number of observations, J is the number of alternatives, d_{ni} is 1 if the alternative i was chosen and 0 otherwise.

More specifically, the following 12 chain alternatives were modelled:

1. Road direct (includes road-ferry combinations) – container
2. Road direct (includes road-ferry combinations) – non-container
3. Road with roll on/roll off (RORO) – container
4. Road with RORO – non-container

5. Rail – container (this also includes chains such as road-rail, rail-road and road-rail-road)
6. Rail – non-container (this also includes chains such as road-rail, rail-road and road-rail-road)
7. Inland waterways (IWW) (this also includes chains such as road-IWW, IWW-road and road-IWW-road)
8. Rail and IWW (this also includes chains like rail-IWW-road)
9. Sea (this also includes chains like road-sea, sea-road and road-sea-road)
10. Rail and sea (this also includes chains like rail-sea-road or sea-rail-road)
11. IWW and sea (this also includes chains like sea-IWW-road or IWW-sea-road)
12. Rail and IWW and sea (this also includes chains like road-rail-sea-IWW)

These 12 alternatives consist of 9 chain types of which 3 can be either container or non-containerised general cargo. Due to this, the choice of using a container or not is modelled endogenously. Note that road transport can (but does not have to) be part of all transport chains and therefore alternative 1 and 2 are road-only alternatives.

For all transport chains, we have coded European (multi-modal) transport networks that are then used to determine which of these chains will be available for a specific zone pair and what the transport distance, cost and time are for each chain. The transhipment points used to go from one mode in the transport chain to another are determined in the network assignment. This assignment also determines vehicle and vessel type used within each mode, and hence (minimum) transport costs per chain. The transport chain choice model then handles the competition between the resulting transport chains.

Cargo transport is classified in three freight load types (FLT):

1. Dry bulk
2. Liquid bulk
3. Containers and general cargo

Within each freight consistency type, the freight is furthermore divided into 10 commodity types using the NSTR-1 classification shown in Table 1.

Table 1: Frequencies of observations withing each dataset and FLT group classified on NST/R segments

	ECHO			CFS		
NST/R	FLT 1	FLT 2	FLT 3	FLT 1	FLT 2	FLT 3
0: Agricultural products and live animals	141	0	289	12,267	4,811	219,367
1: Foodstuffs and animal fodder	239	0	1,153	303	1,110	67,943
2: Solid mineral fuels	0	0	0	4	0	260
3: Petroleum products	0	56	65	0	68,129	2,745
4: Ores and metal waste	28	0	19	39	0	11
5: Metal products	105	0	238	160	2	50,434
6: Crude and manufactured minerals, building materials	64	0	200	2,535	102	11,219
7:Fertilisers	10	0	38	2	0	87
8: Chemicals	41	88	694	111	835	7,714
9: Machinery, transport equipment, manufactured and misc. articles	435	0	3,909	1,632	63	1,152,224

Total	1,063	144	6,605	17,053	75,052	1,512,004

A separate transport chain choice model is estimated for each of the three FLTs. Model 1 (dry bulk) and model 2 (liquid bulk) have a total of nine alternatives (the alternatives 2, 4, 6-12). For model 3 it is assumed that general cargo is only relevant for road, rail and RORO alternatives which means that non-bulk goods transported via sea or IWW are assumed to be transported in containers. Hence model 3 has a total of twelve alternatives (nine for containers and three for general cargo, as in the list above). This means that for the model formulation of this FLT, the choice is not only the chain type itself, but also whether or not the goods should be transported in a container or as general cargo.

Note that some chain types are not used at all in the CFS data or the ECHO data or in neither of these, and can therefore not be included in the model estimation. This includes the chain with Rail and Inland Waterways and the chain with Rail, Inland Waterways and Sea. The total number of observations used in estimation from CFS is 1,604,109 and 7,812 from ECHO. The reduction as compared to the earlier numbers (1,614,660 and 8,208) is due to discarding observations for which we had no Level-of-Service for the chosen alternative or where there was only a single transport chain available. In order to allow the CFS and ECHO data to be equally weighted, the French ECHO data is up-scaled. This is done to avoid that the details of the ECHO data are swamped due to the much greater sample size of the CFS data. Thus, the ECHO data is up-scaled within each FLT by 17,053/1,063, 75,052/144 and 1,512,004/6,605 for models 1, 2, and 3, respectively. It should be noted that according to theory, consistent estimates for the model coefficients can be obtained from non-representative samples (Manski and McFadden, 1981). This applies to sample selectivity in terms of the exogenous variables and even for samples that are choice-based (selective on the endogenous variable). Following this, the estimation of multinomial logit models with a full set of alternative-specific constants provides consistent estimates for all model coefficients except the alternative-specific constants. We use this theoretical insight to estimate parameters, which combined with recalibrated constants and matrix pivoting render a consistent representation of preferences.

3.1 Model specification

The aim of the estimation process was to reach a joint specification with parameters general to both datasets and parameters specific to either CFS or ECHO, in order to utilize both the size of the CFS data and the great detail of the ECHO data. The joint CFS-ECHO model estimation was conducted using the logit scaling approach (Bradley and Daly, 1997), which is a well-known method in econometrics when combining different datasets in a joint estimation. Theoretically, two different datasets can be seen as separate nests in the nested logit framework, where the nest parameter is used to estimate the scale difference across the datasets. This means that the unobserved variance is allowed to differ between datasets.

Thus, the alternatives of the different datasets were treated just as different choice alternatives in a nested logit setting, where each observation was only available in one specific dataset, but where some of the coefficients for different datasets may be the same while others are not. It was chosen to fix the scale-parameter for ECHO to 1 and estimate the scale parameter for CFS.

The general estimation procedure used for all three models is as follows. For each model, we first searched for the best Multinomial Logit (MNL) specification for each combination of the three FLT models and two sets of data, i.e. six models in total. To do this, we investigated for which NST/R-1 (Standard European goods classification for transport) it was possible to estimate commodity-specific dummy parameters (i.e. an interaction between the alternative and the commodity type). In the initial model estimations, we included all possible commodity type dummies whether they were significant or not. For transport time we used a linear specification, but made tests as to whether the same parameter should be used for all alternatives or not.

Based on these tests, across all models, we decided to include a separate time parameter for all sea-based alternatives, i.e. all alternatives including Sea, IWW or RORO. In model 3, we furthermore included a separate transport time parameter for general cargo alternatives, except RORO general cargo, which we decided to keep with the other sailing alternatives (see the estimation results for specifications 1 and 2 for FLT 3 in Appendix B).

With this general specification, we then tested five different specifications for transport cost; Linear, Logarithmic, Combination of linear and logarithmic, Spline and Nonlinear spline. The models cover a wide range of distances of freight transport (in length as well as cost/time). One might therefore expect that a simple linear MNL might yield at too stochastic behaviour in choices between alternatives for short shipments as compared to the mean cost of these trips and too deterministic behaviour for choices between long shipments, which would also alter the elasticities when running the model for policy scenarios. One might expect some cost damping effect with distance (measured in cost), which can be revealed by significant logarithmic terms or the spline functions. The spline-functions - on the other hand - might also reveal increasing cost sensitiveness (although one would not expect this). This is why we specified and tested different cost functions (shown later in table 2).

The spline specification is (piece-wise) linear and divided into 5 segments on the basis of transport cost, here represented as the "Price" variable (in Euro per tonne) and each element $Price_{S<x>}$. Below in (5) and (6) we present the utility specifications for the piece-wise linear spline and the non-linear spline.

For the piece-wise linear spline we use:

$$\begin{aligned} Price_{S1} &= min(Price, 25) \\ Price_{S2} &= max(0, min(Price - 25, 25)) \\ Price_{S3} &= max(0, min(Price - 50, 25)) \\ Price_{S4} &= max(0, min(Price - 75, 25)) \\ Price_{S5} &= max(0, Price - 100) \end{aligned} \qquad (5)$$

The non-linear spline function $F(price)$ is calculated as follows:

$$F(price) = \begin{cases} ln(Price)^3 & if\ 0 < Price <= c_1 \\ \theta_2 ln(Price)^2 + \gamma_2 & if\ c_1 < Price < c_2 \\ \theta_3 ln(Price) + \gamma_3 & if\ Price >= c_2 \\ 0\ otherwise & \end{cases} \quad (6)$$

Where $c_1 = 100/3$, $c_2 = 2 \times 100/3$, and $\theta_2 = \frac{3}{2}\ln(c_1)$, $\theta_3 = 3\ln(c_1)\ln(c_2)$, $\gamma_2 = -0.5(\ln(c_1))^3$ and $\gamma_3 = -0.5\ln(c_1)[3(\ln(c_2))^2 + (\ln(c_1))^2]$. The derivation of these spline-parameters, to ensure connectivity and continuity of the cost curve, can be found in Rich (2018).

The best of these model specifications was then expanded with dummies for high value goods and dummies for direct access to water, sea and rail. Then the models were reduced so that only significant parameters were left in the final MNL specification.

For each of the six MNL specifications, several structures for nesting the transport chains were tested. The best Nested Logit (NL) specification within each combination was then used in the joint CFS-ECHO models.

The initial tests for CFS and ECHO resulted in the same specification for transport costs within each FLT model. More specifically, for Model 1 (Dry Bulk), a combined linear and logarithmic specification was the best for both CFS and ECHO. For Model 2 (Liquid Bulk), a linear spline specification was the best, whereas for Model 3 (containers and general cargo), a logarithmic specification was the best. This means that for all commodities we find that the standard linear transport cost specification that has been used in almost all freight transport models in practice so far is outperformed by other specifications of transport costs. This potentially has important consequences when using the model to simulate policies, especially policies that involve changes in transport costs, such as tolls.

Apart from using a nesting structure to combine multiple datasets, we also tested various nesting structures to analyse whether some combinations of choice alternatives have a greater degree of substitution than other alternatives:

1. Nests for all alternatives that include other modes than road transport versus road only nests
2. Nests for alternatives that include rail transport versus alternatives that do not
3. Nests for alternatives that include sea transport versus alternatives that do not
4. Nests for alternatives that include the same number of OD legs versus alternatives that do not
5. Nests for container alternatives versus non-containerised general cargo alternatives (only for FLT 3).

The choice of nesting structure was based on the log-likelihood value and whether the nesting parameter was within the allowed range (between 0 a 1) to be consistent with the random utility maximization paradigm. The best NL model for FLT 1 (dry bulk) contains rail and non-rail nests, as depicted in Figure 1. This nesting structure accounts for the effect that non-rail alternatives are more likely to exchange market share with each other than with rail-alternatives.

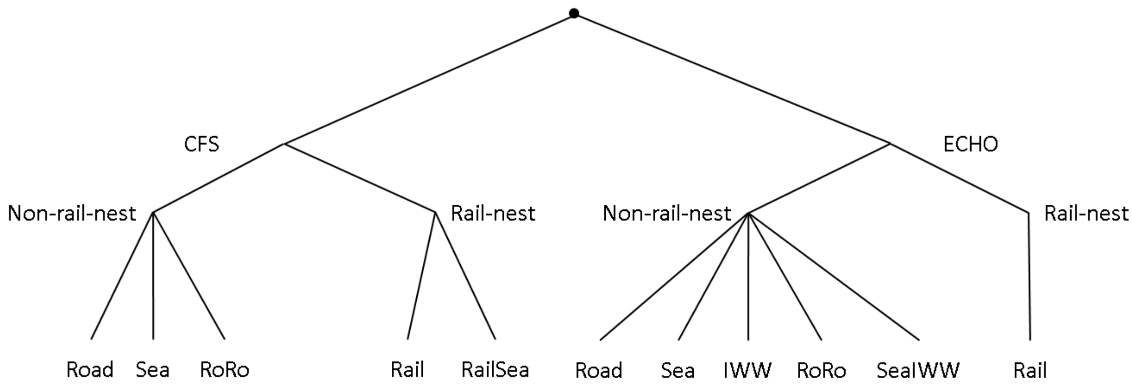

Figure 1: Nest structure in the final estimated model for FLT=1 (dry bulk).

Similarly to Model 1, the best nested logit model for liquid bulk contains rail and non-rail nests (see Figure 2).

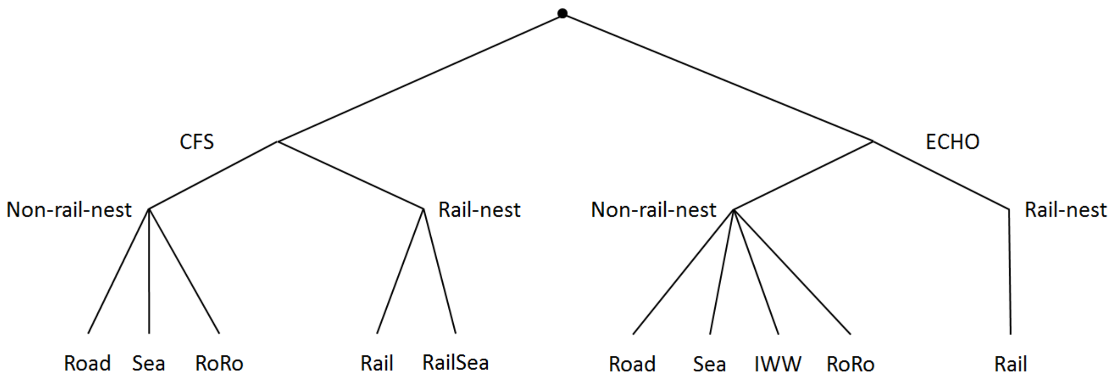

Figure 2: Nest structure in the final estimated model for FLT=2 (liquid bulk).

Model 3 is estimated as a nested logit with specific nests for container and general cargo, as depicted in Figure 3. This nesting structure was superior and captures the correlation among alternatives with the same type of cargo (general cargo or container).

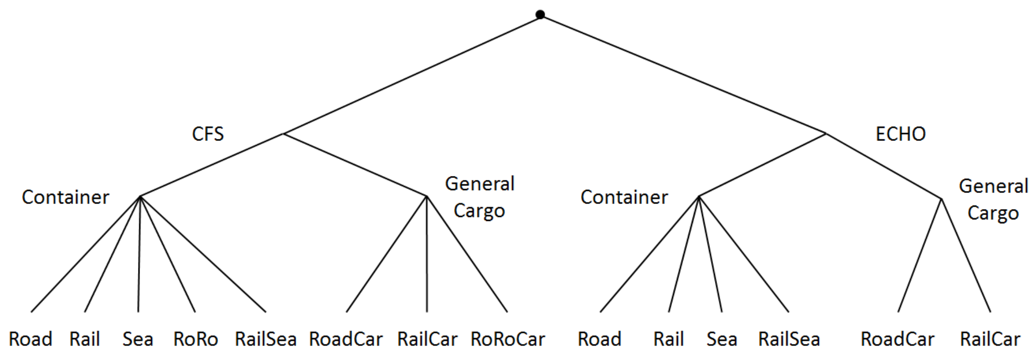

Figure 3: Nest structure in the final estimated model for FLT=3 (containers and general cargo).

4 Estimation results, implied elasticities and values of time

4.1 Estimation outcomes for transport chain choice

The models were estimated using Alogit (Alogit Software & Analysis Ltd, 2007). The high-value density (HvD) dummies are 1 if the value per kg for a shipment is greater than a given threshold value, and zero otherwise. The threshold values are 0.14, 0.45 and 19.35€/kg for models 1, 2, and 3, respectively. Note, however, that the HvD dummy was tested for all 3 models, but is only retained in model 3. Direct access dummies (only estimated on ECHO data and related parameters are therefore only found in table 5) are dummy variables which indicate whether the origin or destination zone has direct access to a hub for a given mode. These dummies are considered for rail, sea and IWW. Finally, the NST/R dummies measure systematic heterogeneity among shipments based on the cargo classification used in the data. In this study the NST/R-1 classification is used as presented in table 1).[5]. The NST/R dummies are 1 if a shipment is within a given NST/R category, and zero otherwise.

Specification of cost functions

In table 2, a comparison of log-likelihood for the different model estimations is presented In order to select the best model for each segment, we looked at the Log-Likelihood, the signs of the parameters and used Likelihood-Ratio tests. The specifications preferred within each combination of data and FLT are marked in bold. It is seen that across the two datasets, lin+log is preferred for FLT = 1, linear spline is preferred for FLT = 2 and log is preferred for FLT = 3.

Table 2: Comparison of Log-likelihood across single estimations on each combination of data and freight load type. The chosen specification for the final joint models is marked in bold. FLT1=Dry Bulk, FLT2=Liquid Bulk, FLT3= containers and general cargo

DATA	FLT	#obs	Specification				
			Lin	Log	Lin + Log	Lin spline	Non-lin spline
CFS	1	17053	-1646	-1594	**-1587**	-1572	-1593
CFS	2	75052	-1458	-1607	-1458	**-1420**	-1498
CFS	3	1512004	-665374	**-662472**	-662466	-643801	-662835
ECHO	1	1063	-467.4	-446.1	**-442.3**	-451.4	-449.8
ECHO	2	144	-114.3	-115.9	-114.0	**-111.1**	-113.7
ECHO	3	6605	-2282.6	**-2171.3**	-2154.2	-2190.8	-2242.1

The specific choice of the “best” model was not straight forward. First of all it was desired that the models based on CFS and ECHO had the same specification for each freight category (FLT class). Secondly it was desired that signs of parameters was logical and significant.

CFS FLT1 had a slightly better fit for the Lin spline function, however, the parameter for price >100 Euro had a wrong sign, and the ECHO data showed a much better fit for the Lin+log specification. This specification was therefore also chosen for the CFS specification.

FLT2 was significantly better with the Lin Spline function than the other specifications for both CFS and ECHO data. The second best function was the lin+log, however, almost identical with the pure Lin function in log.likelihood, which also was confirmed by insignificant parameters for the log

[5] For more information regarding the NSTR cargo classification see: http://ec.europa.eu/eurostat/ramon.

parameter. Since the lin spline function partially supported the assumption of some cost damping effect, this was chosen, even though the function was not concave (see discussion in the following).

FLT3 had the best fit with the linear spline, however, with both CFS and ECHO some of the signs were illogical. The lin+log specifications were marginally better than the lin specification, however, with insignificant linear parameters almost equal to zero. The pure log specifications was therefore selected for both datasets.

The following Tables 3-5 describe the estimated model parameters for the preferred models for each of the three FLTs for the simultaneous model on both datasets. In general, the parameters are highly significant and have intuitive signs. More specifically, if we focus on the time and cost parameters we see that all the parameters are negative, which is correct, and that all are highly significant (at least at t = 16.6). All of the applied cost functions are connected and monotonously decreasing in time and cost. The lin+log and the log specification are furthermore differentiable whereas the linear spline is not. As a result, the lin+log and log functions facilitates cost damping in the sense that there is a marginal declining sensitivity to cost (or time).

This is not the case for the linear spline. Although the parameters of the function parameters are all well identified and the function is strict monotone, its curvature is non-smooth and resemble an s-shaped form. We acknowledge that for certain forecasting scenarios a simpler more robust function is preferable. There can be several arguments why the cost-parameters in Table 3 increase and decrease for certain intervals. It could be related to start-up costs for shorter trips or due to differences in the mode and commodity composition for longer trips, i.e. that certain commodity types are dominating within a certain cost interval. However, even though data shows this s-shaped cost function parameters one might choose to replace these in an applied model in order to obtain a concave function by replacing the parameters in the 50-75 and 75-100 Euro interval with the parameter in the 25-50 Euro interval (which would secure a concave function with the least possible change of parameters).

Figure 4 shows the cost-functions as function of costs. As seen dry bulk and liquid bulk are much more cost-sensitive over long distances than general cargo. This could also be expected, since it is usually lower value goods where the transport cost has a higher share of the overall cost than general cargo. The “S-shaped” cost function of liquid seems less “dramatic” when visualized as overall costs (figure 4) than the parameters in table 3 indicates, which is because these values only have effect on the marginal increase in cost within the 50-75 and 75-100 Euro intervals.

Other choice parameters

Model 3 indicates that container transport is less attractive for high value goods, which seems plausible given that high value goods are often transported in rather small batches as general cargo (e.g. in crates, boxes, pallets). Furthermore, Road, Sea and RORO are preferred for high value goods compared to the other alternatives (road transport is usually much faster than rail or inland waterway transport, whereas sea and RORO transport are also used for high value goods when there is no good land connection).

For the direct access dummies we see that these are all positive, and highly significant (at least at t=2.85). This indicates that an alternative is more likely to be selected if either the origin or destination zone has direct access to that mode (i.e. rail, sea or IWW), which makes sense, since a feeder road transport by truck can be avoided.

For the NST/R dummies we see a negative relation between RORO and NST/R 9 (Machinery, Transport equipment, Manufactured and Miscellaneous articles) whereas for both Rail and Sea there are positive relations with NST/R 5 (Metal Products), NST/R 6 (Crude and manufactured minerals, building materials) and NST/R 8 (Chemicals).

Finally, we note that the nesting parameter, which is inversely related to the degree of substitution within the nest relative to that across nests, takes a value between 0 and 1, as required for global consistency with random utility maximization, and is highly significant when tested against 1.

Table 3: Parameters estimated jointly across both datasets for the final joint models.

Description	Model 1; Dry Bulk		Model 2; Liquid Bulk		Model 3; Containers and general cargo	
	Value	T-Test	Value	T-Test	Value	T-Test
Parameters estimated jointly across datasets						
Alternative specific parameters						
ASC, Road (non-container)					5.382	211.927
ASC, RORO (non-container)			-1.160	-11.929		
ASC, Rail (container)					-2.827	-64.463
ASC, Rail (non-container)	-3.956	-14.752	-2.779	-14.193	8.732	185.098
ASC, Sea	-5.041	-45.424	0.102	1.478	-0.844	-79.170
Time and cost parameters						
Log(Cost)	-2.076	-24.601			-1.199	-155.011
Cost (Euro)	-0.055	-20.155				
Linear spline for Cost 0-25 Euro			-0.114	-55.338		
Linear spline for Cost 25-50 Euro			-0.087	-31.217		
Linear spline for Cost 50-75 Euro			-0.041	-16.630		
Linear spline for Cost 75-100 Euro			-0.195	-35.528		
Linear spline for Cost >100 Euro			-0.078	-21.63		
Time (1/1000 min)	-0.491	-7.133	-1.481	-20.119		
Time, containers (1/1000 min)					-1.172	-79.815
Time, general cargo (1/1000 min)					-3.166	-263.525
Time, sea/IWW/RORO (1/1000 min)	-0.209	-14.706	-1.148	-48.902	-0.157	-114.065
NST/R commodity type parameters						
NST/R 9 dummy, RORO (non-container)	-1.212	-10.859				
NST/R 5 dummy, Rail (non-container)	2.283	14.971			1.682	133.986
NST/R 6 dummy, Rail (non-container)	0.829	5.083				
NST/R 8 dummy, Rail (non-container)	2.095	11.488			0.699	47.196
NST/R 5 dummy, Sea					0.182	9.298
NST/R 6 dummy, Sea					0.119	2.892
NST/R 8 dummy, Sea					1.034	65.908
Other chain specific parameters						
HvD-dummy, Container					-1.772	-107.981
HvD-dummy, Road					1.160	109.743
HvD-dummy, Sea					2.540	128.402
HvD-dummy, RORO					0.845	55.517

Nesting and scale parameters (t-test against 1[6])						
Scale parameter, CFS	1.142	5.78	2.102	33.71	1.238	96.24
Scale parameter, ECHO	1	-	1	-	1	-
Nesting parameter	0.72	8.52	0.517	33.69	0.815	53.5

Table 4: Parameters estimated on the CFS dataset for the final joint models.

Description	Model 1; Dry Bulk		Model 2; Liquid Bulk		Model 3; Containers and general cargo	
	Value	T-Test	Value	T-Test	Value	T-Test
Parameters estimated on CFS dataset						
Alternative specific parameters						
ASC, RORO (container)					-3.286	-21.716
ASC, RORO (non-container)	-0.620	-6.438			1.225	33.907
ASC, Rail and sea	-8.896	-7.961			-1.040	-5.651
NST/R commodity type parameters						
NST/R 5 dummy, RORO (container)					-0.838	-2.917
NST/R 9 dummy, RORO (container)					1.930	12.598
NST/R 1 dummy, RORO (non-container)			2.184	12.772	0.169	3.808
NST/R 2 dummy, RORO (non-container)	1.819	1.710				
NST/R 3 dummy, RORO (non-container)			0.231	2.112	1.227	19.552
NST/R 5 dummy, RORO (non-container)	0.128	0.588			-0.605	-14.881
NST/R 6 dummy, RORO (non-container)	-2.107	-3.275			1.300	29.408
NST/R 8 dummy, RORO (non-container)					-0.191	-2.697
NST/R 9 dummy, RORO (non-container)					0.257	8.520
NST/R 2 dummy, Rail (container)					8.068	58.340
NST/R 5 dummy, Rail (container)					1.263	9.109
NST/R 6 dummy, Rail (container)					1.959	9.677
NST/R 8 dummy, Rail (container)					1.738	5.615
NST/R 1 dummy, Rail (non-container)			0.67	2.008		
NST/R 4 dummy, Rail (non-container)	5.225	9.160				
NST/R 5 dummy, Rail (non-container)			5.339	3.965		
NST/R 8 dummy, Rail (non-container)			3.131	18.931		
NST/R 9 dummy, Rail (non-container)	-4.135	-3.364			1.266	115.326
NST/R 1 dummy, Sea			-2.853	-9.729		
NST/R 3 dummy, Sea			-1.637	-20.625		
NST/R 6 dummy, Sea	1.188	5.729				
NST/R 8 dummy, Sea	1.105	3.825	-0.859	-7.322		
NST/R 9 dummy, Sea	-2.797	-5.855	-2.800	-3.837	2.026	198.556
NST/R 5 dummy, Rail and sea					-1.672	-4.092
NST/R 5 dummy, Rail and sea					-1.672	-4.092

Table 5: Parameters estimated on the ECHO dataset for the final joint models.

Description	Model 1; Dry Bulk		Model 2; Liquid Bulk		Model 3; Containers and general cargo	
	Value	T-Test	Value	T-Test	Value	T-Test
Parameters estimated on ECHO dataset						
Alternative specific parameters						
ASC, IWW	-4.335	-33.723	0.352	5.814		
ASC, IWW and sea	-10.550	-29.081			-2.826	-159.069
NST/R commodity type parameters						
NST/R 1 dummy, Road (non-container)					1.589	77.198

[6] For the scaling and nesting parameters, it is tested whether the value is significantly different from 1 instead of zero. If the scale parameter is 1, the scale across the two datasets is the same and the parameter is not needed. If the nest parameter is 1, then the model is not different from a (non-nested) MNL model.

NST/R 6 dummy, Road (non-container)					1.509	31.587
NST/R 0 dummy, Rail (non-container)	2.349	15.889				
NST/R 1 dummy, Rail (non-container)	1.240	9.809			2.072	86.357
NST/R 6 dummy, Rail (non-container)					2.077	38.594
NST/R 7 dummy, Rail (non-container)	2.556	8.313				
NST/R 1 dummy, Sea					1.336	58.046
NST/R 3 dummy, Sea					1.434	28.774
NST/R 1 dummy, IWW and sea	3.814	8.728				
Other chain specific parameters						
Direct access, Rail (container)					2.528	52.489
Direct access, Rail (non-container)	2.847	17.628	6.023	32.227	1.049	110.259
Direct access, IWW	3.195	24.213				

Table 6: Model summary

Model summary	Model 1; Dry Bulk	Model 2; Liquid Bulk	Model 3; Containers and general cargo
Final value of Likelihood	-8,464	-53,966	-1,172,636
Likelihood with Constants only	-13,814	-73,169	-1,689,193
Likelihood with Zero Coefficients	-51,231	-224,935	-5,450,457
"Rho-Squared" w.r.t. Constants	0.39	0.23	0.31
"Rho-Squared" w.r.t. Zero	0.83	0.75	0.78
#parameters	30	23	46
#observations Total	18,116	75,196	1,518,609
#observations CFS	17,053	75,052	1,512,004
#observations ECHO	1,063	144	6,605

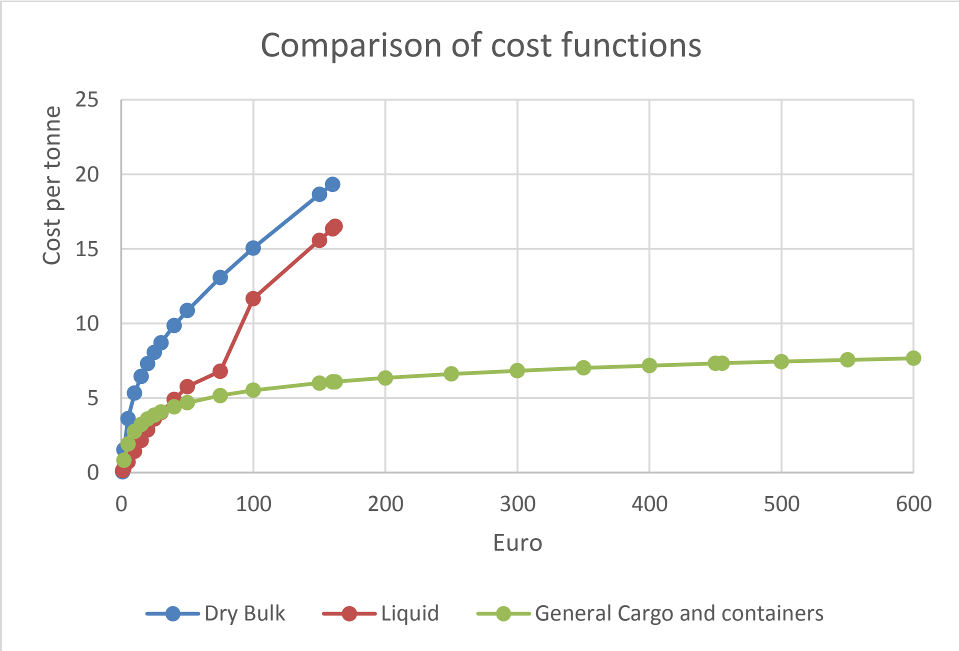

Figure 4 Estimated cost functions for the 3 freight category types (curves are only shown for interval which are supported by data, except for containers which have values up to 3848 Euro [7])

4.2 Elasticities

In order to validate the estimated models, elasticities were computed for each of the three final joint CFS-ECHO models and compared to reference elasticities from the literature. The sensitivity tests were based on the estimation dataset but applied to different input data, e.g. the simulation of a 10% increase in time or cost for a given alternative. Changes in variables for each specific mode (i.e. changes in the rail mode that affect several chain alternatives that include rail as a mode) as well as changes in variables for each chain alternative (i.e. changes are only applied to each chain individually, e.g. rail-sea) have been tested. These changes were then compared to the market shares of a neutral base scenario in order to reveal elasticities.

The calculated elasticities are shown in Table 7. The first two elasticity columns present the impact of cost and time changes of a specific transport chain (e.g. 'rail only' or 'rail and sea') on the transport chain alternatives. The third column illustrates the effect of changing the transport time of a specific mode (e.g. rail, which appears in several transport chains) on the transport chains. Elasticities of the non-road modes are usually larger than those of road. A few elasticities are quite high, but these are usually concerned with chains for which the market share is negligible. For road transport, the highest elasticities are found for containerised goods, where rail (and sometimes inland waterways) can be a tough competitor.

[7] General cargo have values up to 455 Euro, whereas containers have values up to 3848 Euros,

Table 7: Elasticities for the estimated models. The model presents how many % mode share change is found in mode j as a result of a 1% change in travel cost or travel time of mode i.

		Elasticities: Change in market shares		
		Travel Cost	Travel Time	Travel Time
i	j	Chain Specific	Chain Specific	Mode Specific
Model 1 (Dry bulk)				
Road	Road	-0.21	-0.01	-0.01
Rail	Rail	-1.90	-0.49	-0.02
Rail	RailSea			-0.01
IWW	IWW	-2.12	-0.80	-0.56
Sea	Sea	-1.15	-0.67	-0.35
Sea	RailSea			-0.67
Sea	IWWSea			-0.15
RORO	RORO	-3.59	-0.37	-0.27
RailSea	RailSea	-2.48	-2.65	
IWWSea	IWWSea	-1.23	-2.5	
IWW	IWWSea			-0.14
Model 2 (Liquid bulk)				
Road	Road	-0.23	-0.05	-0.01
Rail	Rail	-0.94	-0.59	-0.03
Rail	RailSea			-0.08
IWW	IWW	-1.43	-2.32	-0.91
Sea	Sea	-1.34	-3.25	-1.66
Sea	Railsea			-2.06
RORO	RORO	-2.20	-0.99	-0.72
RailSea	Railsea	-1.98	-5.07	
Model 3 (General cargo and containers)				
Road Container	Road Container	-0.43	-0.98	
Road General Cargo	Road General Cargo	-0.17	-0.11	
Road	Road General Cargo			-0.13
Rail Container	Rail Container	-1.36	-1.04	
Rail General Cargo	Rail General Cargo	-5.68	-1.10	
Rail	Rail Container			-0.09
Rail	Rail General Cargo			-0.38
Rail	RailSea			-0.02
RORO Container	RORO Container	-0.38	-1.31	
RORO General Cargo	RORO General Cargo	-0.40	-1.11	
RORO	RORO Container			-0.22
RORO	RORO General Cargo			-0.29
Sea	Sea	-0.46	-0.59	-0.23
Sea	Railsea			-0.08
RailSea	Railsea	-1.22	-0.48	
IWWSea	IWWSea	-3.14	-0.99	
IWW	IWWSea			-0.29

The elasticities in Table 7 were given in terms of the impact on the market shares of the shipments. The elasticities in Table 8 reflect reference elasticities from the international literature, typically measured as tonnes or tonne-kilometres (tkm) elasticities. Tonne elasticities are likely to be lower on average (in absolute values) compared to shipment elasticities. This is because many heavy products have a low modal substitution rate. Elasticities for tkm, on the other hand, are usually higher. This is because these elasticities are a combination of mode and mileage effects in contrast to tonne elasticities that only reflect mode substitution. It is also worth noting that long-haul transports are usually more sensitive with respect to transport costs and that elasticities in general reflect baseline market shares, which could be rather different across countries and continents. A strict direct comparison between elasticities therefore needs to be carried out with some caution.

Table 8: Cost elasticities of the number of tkm for all commodities (unless otherwise indicated) for mode choice found in the literature.

Source and country/mode	road	rail	IWW
NODUS model (EXPEDITE Consortium, 2002), Belgium			-0.76
Rich et al. (2009), effect on tonnes, Denmark/Sweden	-0.09 to -0.29	-0.10 to -0.40	
VTI and Significance (2010), international review		(-0.8 to -1.6)	
De Jong et al. (2010a), international review	-0.4 (-0.2 to -1.2)		
De Jong et al. (2011), Netherlands	-0.5	-0.87	-0.28
Abate et al. (2018), effect on tonnes, metal products, Sweden	-0.04 to -0.49	-0.02 to -0.12	
Abate et al. (2018), effect on tonnes, chemical products, Sweden	-0.12 to -0.52	-0.29 to -0.56	

On the basis of the review of elasticities it is concluded that the revealed costs elasticities of the TT3 model across modes are generally plausible and in line with the international literature.

4.3 Values of transport time

The average VoTs for each category are presented in Table 9. In the table we have furthermore segmented between land-based and sea-based transport as we estimated separate time parameters for these. Furthermore, Figure 5 shows how the cost-functions may be transferred to Value of Time (VoT) as function of cost (which is easy to calculate since it is the ratio between the time and cost parameters in the MNL as long as the parameters do not include taste heterogeneity). Note that the figure use a logarithmic scale due to the large difference between VoT of the 3 categories. As can be seen in Figure 5, the dry bulk has a much lower VoT than the other goods, which is expected due to the low value density of dry bulk. Liquid bulk has higher and a quite constant VoT as a function of cost, with a small (illogical) deviation around the 50-75-100 Euro interval as previously discussed. Containers and especially General Cargo have a higher and increasing VoT for most of the cost range as compared to the two other categories[8]. This might be expected because of the higher value density of general cargo and a higher degree of fast delivery requirements in this category.

Table 9: Value of transport time in Euro/Tonnes/h

	FLT1: Dry bulk	FLT2: Liquid Bulk	FLT3: General Cargo	FLT4: Container
Land-based modes	0.12 - 0.18	0.61 - 0.76	0.55 - 0.61	0.16 - 0.19
Water-based modes	0.06 - 0.11	0.33 - 0.57	0.03	0.02 - 0.03

[8] Note that containers and general cargo have different cost functions since they have different time parameters.

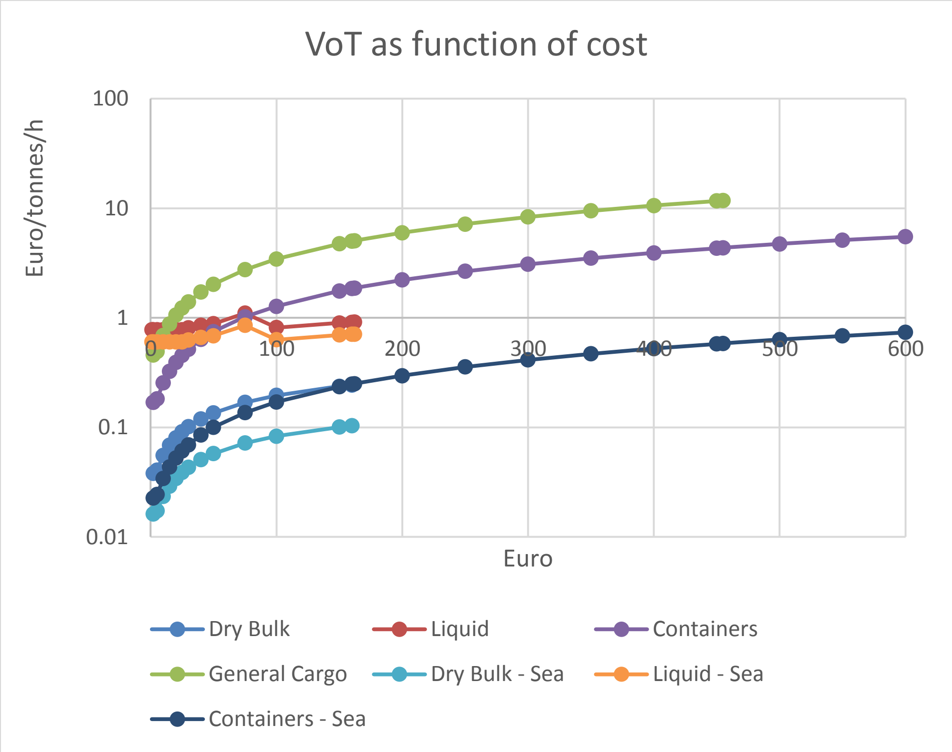

Figure 5 VoT as function of cost for all non-sea alternatives[9] (curves are only shown for intervals which are supported by data, except for containers which have values up to 3848 Euro)

Since the time-dependent costs (e.g. staff, vehicles) were already included in the transport costs, the time coefficient that we estimated refers to the time value of the cargo. Therefore the values of time that we obtain from this new study should be compared to values of transport time that refer to the cargo component not the transport cost component of the value of time (see de Jong et al, 2014 for a discussion on this distinction). In the table below we carry out this comparison.

[9] Where all sea/IWW/RORO alternatives would scale to a lower VoT cf. Table 2, which is logical since one would assume a selection process where less time-sensitive goods are using sea transport, whereas more time-sensitive goods are using road or rail.

Table 10: The cargo component in the value of transport time (VTT) in goods transport (in 2010 Euro per tonne per hour) found in the literature

Publication	Country	Data	Method	VTT
Fowkes (2006, 2015)	UK	SP (LASP interview)	Manual method and weighted regression	0.45 for all goods
				0.18 for coal
				0.05 for metals
				0.05 for aggregates
				0.54 for oil and chemicals
				1.76 for automotive
				0.14 for other bulks
				0.90 for container
				1.35 for finished goods
				9.00 for express goods
De Jong (2008)	Various Scandinavian studies up to 2001	SP	MNL	Road: 0-1 Rail: 0 - 0.1
Danielis et al. (2005)	Italy	SP	Ordered probit	Road: 1
IRE and RAPP Trans (2005), Maggi and Rudel (2008)	Switzerland	SP	MNL	Road: 1.5
Beuthe and Bouffioux (2008)	Belgium	SP	MNL (on ranking data)	Rail: 0.2
Rich et al. (2009)	Denmark/Swe den	RP	Aggregate weighted logit	0.08 (bulk) – 5.13 (general cargo), average 1.53
Kurri et al. (2000)	Finland	SP	MNL	Rail: 0.1
Fries et al. (2010)	Switzerland	SP	Mixed logit	Road 0.5
Halse et al. (2010)	Norway	SP	MNL and mixed logit	Road: 1
De Jong et al. (2011)	Netherlands	RP (mode choice)	Aggregate logit	All modes: Bulk goods: 0.1 – 0.4 General cargo/container: 0.7
Johnson and de Jong (2011)	Sweden	RP (mode and shipment size choice)	MNL and mixed logit	Road: 2.5 Rail: 0.1
Significance et al. (2013)	Netherlands	SP	MNL	Road: 0.5 Rail: 0.3
CGSP (2013)	France	SP	MNL	0.01 for freight with low added value (< 6000 euro/t): e.g. bulk/aggregates
				0.20 for ordinary freight (6000-35000 euro/t): e.g. other rail, sea and river transport
				0.60 for freight with high added value (> 35000 euro/t): e.g. combined, parcels, refrigerated, roro
BVU and TNS Infratest (2014)	Germany	SP	MNL	All commodities: 0.02 – 1.5 (median: 0.7)

Main source: Jong, G.C. de (2014b) – adapted and extended for this paper.

Looking at the VoTs in our model in Table 9, it is seen that our mean VoTs in Euro/Tonne/hr are well inside the range for the cargo component VoT in the international literature presented in Table 10. However, because of our non-linear specification, we have increasing unit VoT with increasing costs (Figure 5). This is in line with results often found in passenger transport. In fact, higher unit VoTs with increasing distance, are now also used in project appraisal in the UK (Batley et al., 2017). We consistently find higher values for land-based modes than for sea based. Finally, the unit values are highest for liquid bulk and general cargo. This pattern is reasonably consistent with Fowkes (2006, 2015) and de Jong et al. (2011).

5 Conclusions

This paper describes the structure of a transport chain choice model for Europe and presents estimation results for a range of model specifications.

The transport chain choice model was estimated jointly based on two disaggregate data sources, the Swedish Commodity Flow Survey (CFS) from 2009 and the French Envoi – CHargeurs – Opérateurs (ECHO) survey from 2004. It was found that transport chain choice depends on transport cost, transport time, value density of the goods, direct access to rail and waterways and commodity type. In a long-term strategic transport model, it is necessary to discuss how the direct access dummies might change over time.

A combined linear and logarithmic transport cost specification works best for dry bulk products, whereas a linear spline cost function works best for liquid bulk and a logarithmic cost works best for container goods and general cargo. This highlights that cost damping in the form of marginally decreasing sensitivity to cost is likely to be found in freight models and needs to be accounted for. It also highlights that different commodity combinations are likely to differ in that respect.

In addition, various nesting structures were tested, and it was found that for bulk goods, transport chain alternatives that include rail transport have a higher degree of mutual substitution than by other chain alternatives. For general cargo and container goods, the best nesting structure is represented by a general cargo nest and a container nest.

These findings indeed underline that freight models, contrary to the freight models that are often used in practice, are characterised by heterogeneity, non-linearity and rates of substitution which cannot be assumed constant. If these elements are not taken into account this is likely to have consequences for the evaluation of a wide range of transport policies.

Further it was found that VoT differed largely between freight types and with increasing transport costs, indicating the importance of differentiating between these elements. Finally the results indicate differences in the mode preferences across freight categories.

Acknowledgment

The presented logit models were developed as part of the Transtools 3 (TT3) project by a consortium led by the Technical University of Denmark (DTU) for DG MOVE of the European Commission.

We would like to thank Jaap Baak from Significance for helping with the conversion of CFS data into international C's in the CFS 2009. We would like to thank Inger Beate Hovi from TØI for providing the necessary keys for improving the usability of CFS 2009 data for Norway and Sweden. This directly allowed us to transform the city names into NUTS3 zones. Finally, the authors gratefully acknowledge the support of the grant agreement 266182 within the European Commission's Seventh Framework Programme for developing the Transtools 3 Model.

References

Abate, M., I. Vierth, R. Karlsson, G.C. de Jong and J. Baak (2018) A disaggregate stochastic freight transport model for Sweden, *Transportation*, doi:10.1007/s11116-018-9856-9.

Abdelwahab, W.M. (1998) Elasticities of mode choice probabilities and market elasticities of demand: evidence from a simultaneous mode choice/shipment-size choice freight transport model, *Transportation Research E*, 34, 257-266.

Arunotayanun, K. (2009) Modelling freight supplier behaviour and response, PhD thesis, Centre for Transport Studies, Imperial College London.

Alogit Software & Analysis Ltd (2007) Alogit version 4.2, Alogit, London.

Batley, R., Bates, J., Bliemer, M., Börjesson, M., Bourdon, J., Cabral, M. O., … Worsley, T. (2017). New appraisal values of travel time saving and reliability in Great Britain. Transportation, 1–39

Ben-Akiva, M.E. and G.C. de Jong (2013) The aggregate-disaggregate-aggregate (ADA) freight model system, in *Freight Transport Modelling* (Eds.: M.E. Ben-Akiva, H. Meersman and E. van de Voorde), Emerald.

Beuthe, M.B.J., J.-F. Geerts, and C. Koul a Ndjang Ha (2001) Freight transport demand elasticities: a geographic multimodal transportation network analysis, *Transportation Reseach E,* 37, 253-266.

Beuthe, M.B.J. and Ch. Bouffioux (2008) Analysing qualitative attributes of freight transport from stated orders of preference experiment, *Journal of Transport Economics and Policy*, Vol. 42, Part 1, 105-128.

Bradley, M.A. and A.J. Daly (1997) Estimation of logit choice models using mixed stated-preference and revealed-preference information, in: *Understanding Travel Behaviour in an Era of Change* (Eds.: P. Stopher and M. Lee-Gosselin), Pergamon.

BVU and TNS Infratest (2014) Entwicklung eines Modells zur Berechnung von modalen Verlagerungen im Güterverkehr für die Ableitung konsistenter Bewertungsansätze für die Bundesverkehrswegeplanung, Vorläufiger Endbericht, BVU/TNS Infratest, Freiburg/München.

CGSP (2013) Cost-benefit assessment of public investments, report of the mission chaired by Emile Quinet, summary and recommendations, www.strategie.gouv.fr.

Daly, A. (2010) Cost damping in travel demand models. Technical report, Rand Europe, URL: http://www.rand.org/pubs/technical_reports/TR717.html

Chow, J.Y.J., Yang, C.H.Y., Regan, A.C., 2010. State-of-the art of freight forecast modeling: lessons learned and the road ahead. Transportation 37(6), 1011–1030

Danielis, R., E. Marcucci and L. Rotaris (2005) Logistics managers' stated preferences for freight service attributes, *Transportation Research, Part E*, Vol. 41, 201-215.

ETISplus (2014) D8 ETISplus Final Report, Panteia/NEA: Sean Newton, ISIS: Riccardo Enei, TRT:Claudia de Stasio, KIT: Eckhard Szimba, NTU: Michael Stie Laugesen, TIS: Daniela Carvalho, NTUA: Athanassios Ballis, ITC: Kristiana Chakarova, ETISplus, Zoetermeer.

EXPEDITE Consortium (2002) EXPEDITE Deliverable 7: main outcomes of the national model runs for freight transport, EXPEDITE Consortium, RAND Europe, Den Haag.

Feo-Valero, M., L. Garcia-Menendez, L. Saez-Carramolino and S. Furio-Prunonosa (2011) The importance of the inland leg of containerised maritime shipments: an analysis of modal choice determinants in Spain, *Transportation Research E*, 47-4, 446-460.

Fowkes, A.S. (2006) The design and interpretation of freight stated preference experiments seeking to elicit behavioural valuations of journey attributes, ITS, University of Leeds.

Fowkes, A.S. (2015) Improving the understanding of the concept of the 'reliability ratio' for freight, informed by re-interpretation of past studies, paper presented at IATBR 2015, Windsor.

Fox, J., A. Daly and B. Patruni (2009) Improving the treatment of cost in large scale models , paper presented at the European Transport Conference, Noordwijkerhout.

Fries, N., G.C. de Jong, Z. Patterson and U. Weidmann (2010) Shipper willingness to pay to increase environmental performance in freight transportation, *Transportation Research Record,* No 2168, 33-42.

Guilbault, M., (2008). ENQUETE ECHO - Envois - Chargeurs - Opérations de transport. Résultats de reference.

Halse, A.H., H. Samstad, M. Killi, S. Flügel and F. Ramjerdi (2010) Valuation of freight transport time and reliability (in Norwegian), TØI report 1083/2010, Oslo.

Huber, S. (2017). Transport chain choice modelling in freight transport demand models, Open Science Journal Vol 2(4).

IRE Università della Svizzera Italiana, Istituto di Ricerche Economiche and Rapp Trans AG (2005) Evaluation of quality attributes in freight transport, Research project ASTRA 2002/011 upon request of the Swiss Federal Roads Office, Berne.

Johnson, D. and G.C. de Jong (2011) Shippers' response to transport cost and time and model specification in freight mode and shipment size choice, paper presented at the second *International Choice Modelling Conference*, Leeds.

Jong, G.C. de (2014a) Mode choice models, in: Tavasszy, L. and G.C. de Jong (Eds.) *Modelling freight transport,* Elsevier Insights Series, Elsevier.

Jong, G.C. de (2014b) Freight service valuation and elasticities, in: Tavasszy, L. and G.C. de Jong (Eds.) *Modelling freight transport,* Elsevier Insights Series, Elsevier.

Jong, G.C. de, H.F. Gunn and W. Walker (2004) National and international freight transport models: overview and ideas for further development, *Transport Reviews*, 24-1, 103-124.

Jong, G.C. de (2008) Value of freight travel-time savings, revised and extended chapter in D.A. Hensher and K.J. Button (Eds.): *Handbook of Transport Modelling*, Handbooks in Transport, Volume 1, Elsevier, Oxford/Amsterdam.

Jong, G.C. de, A. Schroten, H. van Essen, M. Otten and P. Bucci (2010a) The price sensitivity of road freight transport – a review of elasticities, in *Applied Transport Economics, A Management and Policy Perspective* (Eds.: E. van de Voorde and Th. Vanelslander), De Boeck, Antwerpen, 2010.

Jong, G.C. de, A. Burgess, L. Tavasszy, R. Versteegh, M. de Bok and N. Schmorak (2011) Distribution and modal split models for freight transport in The Netherlands, Paper presented at the European Transport Conference 2011, Glasgow. http://etcproceedings.org.

Jong, G.C. de, I. Vierth, L. Tavasszy and M. Ben-Akiva (2013) Recent developments in national and international freight transport models within Europe, *Transportation*, Vol. 40-2, 347-371.

Jong, G.C. de, M. Kouwenhoven, J. Bates, P. Koster, E. Verhoef. L. Tavasszy and P. Warffemius (2014) New SP-values of time and reliability for freight transport in the Netherlands, *Transportation Research E*, 64, p. 71-87.

Jong, G.C. de, O.A. Nielsen, A.F. Jensen, M. Thorhauge, M. Henriques, R. Tanner, D. Johnson, T. Dekker, V. Sowa, I. Vierth, J. Bates and J. Rich (2016) Deliverable 7.2 - Final report on the freight and logistics model. Seventh Framework Programme theme [SST.2010.1.3-1.], MOVE/FP7/266182/TRANSTOOLS 3. DTU Transport.

Jong, G.C. de, R. Tanner, J. Rich, M. Thorhauge, O. Anker Nielsen and J. Bates (2017) Modelling production-consumption flows of goods in Europe: the trade model within Transtools 3, *Journal of Shipping and Trade,* 2:5.

Jourguin, B., Tavasszy, L., Duan, L. (2014), On the generalized cost - demand elasticity of intermodal container transport, *European Journal of Transport and Infrastructure Research,* 14-4, 362-374.

Konings, R., Priemus, H., Nijkmap, P. (2008) The Future of Intermodal Freight Transport – Operations, Design and Policy. Edward Elgar Publishing, Cheltenham.

Kurri, J., A. Sirkiä and J. Mikola (2000) Value of time in freight transport. *Transportation Research Record*, 1725, 26-30.

Liedtke, G. (2009) Principles of micro-behavior commodity transport modeling, *Transportation Research E,* 795-809.

Manski, C.F. and D.L. McFadden (1981) Structural Analysis of Discrete Data and Econometric Applications, The MIT Press, Cambridge.

McFadden, D.L., C. Winston and A. Boersch-Supan (1985) Joint estimation of freight transportation decisions under nonrandom sampling, in E.F. Daughety (Ed.): *Analytical Studies in Transport Economics,* Cambridge University Press, Cambridge.

NEA (2000) European transport forecasts 2020, Summary freight transport, report for the European Commission, NEA, Rijswijk.

Newton, S. (2008) Worldnet: Applying transport modelling techniques to long distance freight flows, Paper presented at the *European Transport Conference*, Noordwijkerhout, The Netherlands.

Nielsen, O.A., Rich, J and Pedersen, T.R. (2015) Deliverable 5.2 – Data Description. Seventh Framework Programme theme [SST.2010.1.3-1.], MOVE/FP7/266182/TRANSTOOLS 3. DTU Transport.

Outwater, M., C. Smith, K. Wies and J. Chen (2013) Tour based and supply chain modeling for freight: Integrated demoNST/Ration in Chicago, Transportation Letters, April 2013, DOI: 10.1179/1942786713Z.0000000009.

Rich, J. and Hansen, C.O. (2016) The Danish National Passenger Model – Model specification and results. *European Journal of Transport and Infrastructure Research*. 16(4): 573:599.

Rich, J. (2018) Spline function classes suitable for transport demand models, *Econometrics and Statistics Part A*, February 2018. https://doi.org/10.1016/j.ecosta.2018.02.002.

Rich, J., R.M. Holmblad and C.O. Hansen (2009) A weighted logit freight model choice model, *Transportation Research E,* 45, 1006-1019.

Samimi, A., K. Mohammadian and K. Kawamura (2010) Freight Demand Microsimulation in the U.S. World Conference on Transport Research (WCTR): Lisbon.

SCENES consortium (2001) SCENES transport forecasting model: calibration and forecast scenario results, deliverable 7 to EU DGTREN; SCENES Consortium, Cambridge.

Significance, VU University, John Bates Services, TNO, NEA, TNS NIPO and PanelClix (2013) Values of time and reliability in passenger and freight transport in The Netherlands, Report for the Ministry of Infrastructure and the Environment, Significance, The Hague.

Tetraplan (2009) TENCONNECT, Copenhagen: Tetraplan A/S.

Tsamboulas, D., Vrenken, H., Lekka, A.M., (2007) Assessment of a transport policy potential for intermodal mode shift on a European scale. Transportation Research Part A 41 (2007) 715–733

Vierth, I., N. Lord and J. McDaniel (2009) Representation of the Swedish transport and logistics system (Logistics Model Version 2.00), VTI, Stockholm.

VTI and Significance (2010) Review of the international literature on price elasticities of freight transport by rail, report for Banverket, VTI, Stockholm.

Willigers, J. and M. de Bok (2009) Updating and extending the disaggregate choice models in the Dutch National Model, paper presented at the European Transport Conference, Noordwijkerhout.

Windisch, E., de Jong, G.C and van Nes, R. (2010) A disaggregate freight transport model of transport chain choice and shipment size choice. Paper presented at *ETC 2010*, Glasgow

Woodburn, A., Allen, J., Browne, M., Leonardi, J. (2008) The impact of globalisation on international road and rail freight transport activity – Past trends and future perspectives. OECD/ITF Global Forum on Sustainable Development: Transport and Environment in a Globalising World. Guadalajara, Mexico.

Appendix A: Technical data preparation of CFS and Echo data

CFS data

The CFS 2004/2005 dataset has been used before to coNST/Ruct a stochastic version of the Swedish national freight model Samgods based on so-called Samgods zones (see Vierth et al., 2009). An executable file made available by Significance and VTI enabled us, after minor modifications, to convert (58.6%) of the international C's in the CFS 2009 into Samgods zones. Norway has also used the CFS 2009 data to coNST/Ruct a freight model based on Swedish and Norwegian trade data. The necessary conversion keys were provided by TØI Oslo to assist us in improving the coverage of the Norwegian sample. The conversion directly allowed us to transform the city names into NUTS3 zones. EUROSTAT provides key statistics on NUTS3 zones, including conversion tables to match Local Administrative Units (LAU) and postcodes into NUTS3 zones. In total, 367,776 (81.8%) international commodity flows were matched using the different procedures. This left a total of 1,853,007 national and international C's coded either in Samgods or NUTS3 zones, which needed to be converted into the Transtools 3 zone structure.

The first step of the conversion into Transtools 3 zones was to recode all the international flows currently coded in the Samgods structure into the NUTS3 structure. The Samgods zones in Norway, Finland and Denmark are already at the NUTS3 level (90.3% of the international flows). Conversions into the NUTS3 format are therefore straightforward except for the Oslo-Akershus zone. For this particular Samgods zone two NUTS3 zones exist, NO011 and NO012, respectively. We randomly assigned each flow to one of the two NUTS3 zones where the assignment probability depends on the relative population in both zones. For the next set of countries (moving away from Sweden), such as the UK, Netherlands, Germany, the Samgods zones only correspond to the NUTS1 level. For these C's we used the NUTS3 level for the capital/prime city within each NUTS1 zone. NUTS3 coding is not available for the Samgods C's outside of Europe. Also the Transtools 3 zonal structure operates at a higher spatial level for those C's. Therefore, it was decided to use the GIS structure of Transtools 3 directly and create links between yet untransformed Samgods zones and the "far C's" in the Transtools 3 zonal system. In the final steps NUTS3 coding was transformed into ETIS coding (which was used for several inputs to Transtools 3 prepared by the ETISplus consortium) and subsequently into Transtools 3 coding where population weights were applied when the zonal structure was split.

It was decided to use only outgoing shipments (the major part of the CFS), not the incoming shipments. Some CFS shipments are available directly from register sources on forest, dairy and sugar products. These flows have been excluded[10] from the dataset as they are OD flows (instead of PC) and are unfit for the model concept (see Ben-Akiva and de Jong, 2013). Moreover, all shipments transported by air and (or) unknown modes of transport were dropped since these modes are not part of the Transtools 3 (TT3) model. The data was prepared for analysis by coding the production zone (P), consumption zone (C) and (PC) pair for each shipment in units consistent with the TT3 zonal structure. All P's of the outgoing shipments in the CFS are within Sweden, for which the NUTS3 zonal code is stored by the variable 'Avg Lan' in CFS 2009. Most shipments originate in the Västra Götalands län in the western part of Sweden. The C zones within Sweden are stored by the variable 'Mlan', but these vary by national and international destinations. A total of 1,485,231 national and

[10] Commodity types ('Varukod') 12, 13, 16 and 44 were excluded from the dataset.

449,375 international shipments is applicable for estimation as a minor number of observations had to be excluded due to unknown consumption zone. Like the P's, all the national C's were in NUTS3 coding. The C's for the international shipments turned out to be more complex as they were registered by means of their C city and country.[11] Different conversion approaches had to be applied and information sources consulted to convert these international C's into the TT3 zoning structure. After discarding intra-zonal trips[12] at the TT3 zone level, a sample of 1,614,660 shipments were available for estimation.

Freight load type (FLT) is coNST/Ructed on the basis of the original variable 'Lasttyp'. The final variable contains four categories: Dry Bulk; Liquid Bulk; General Cargo and Containers. The original *commodity type* classification, represented by the variable 'Varukod' in the CFS database, needed to be transformed into the standard European classification of goods for transport (NST/R) as used by the TT3 model. The original variable 'Vikt' was used to coNST/Ruct the shipment size variables. Finally, the "value" variable was converted to the base year 2010 and measured in Euros. The values and weight variables are then used to derive a value per kg for each shipment.

Echo data

Given the coding of the PC pairs at the NUTS3 level, the conversion into Transtools 3 zones was easier than for the CFS dataset. First, all the NUTS3 zonal codes were transformed into ETIS coding (which was used for several inputs to Transtools 3 prepared by the ETISplus consortium). For this to work the NUTS3 2010 zoning structure was made backwards compatible with the NUTS3 2003 structure for which a conversion key to the ETIS zoning structure was available. In the final step, the conversion key from ETISplus to Transtools 3 was applied and population weights were applied to facilitate zonal splitting.

From the data we identified 10,462 shipments which were coded to provide variables representing tonnes, value density (euro per ton), FLT, shipment chain type and commodity group. NUTS3 codes were available for European origins and destinations, NUTS2 for other countries.

Of these shipments, 121 had insufficient information about NUTS coding to convert them into TT3 area codes. A further 1,358 observations were dropped as there was insufficient information about the transport leg modes. A further 6 observations were dropped because they did not originate in France, leaving at total of 8,977 observations. Of these remaining shipments, 6 additional obs were dropped as they had no FLT information. Then a further 769 intra-zonal observations were dropped, leaving 8,208 valid shipments for estimation. As with the CFS, RORO was classified based on whether the generalised transport cost was lower for RORO compared to road. Chains were classified in the same way as described above for the CFS data.

[11] In certain cases postal codes or local administrative units were used.

[12] In the model within-zone transports will be assigned identical Level-of-Service and cannot be used in the estimation.

Appendix B: Example of model estimation process for CFS data, FLT 3:

Table B1 below shows this process for the model estimated on the CFS data for FLT = 3 as an example. A specification with a specific time parameter for sea alternatives and a specific time parameter for general cargo alternatives were chosen. Furthermore, the process resulted in the choice of a logarithmic transport cost specification (specification 3). Note that the linear spline specification obtains a better log-likelihood, but as some of the parameters for the spline intervals become positive, this specification was discarded. The combined linear and logarithmic specification also gets a log-likelihood value that is just significantly better than for ln, but it was not selected because the linear cost coefficient is very small and positive.

In the final adjustments of the specification, several specifications for the inclusion of the high value dummy were tested (e.g. specification 7). In the final model, a negative parameter for the interaction between high value and container transport (with general cargo as reference) was obtained and positive parameters were obtained for the interaction between road and high value, sea and high value and roro and high value.

Table B1: Specification tests for CFS data and FLT = 3

	Specification 1		Specification 2		Specification 3		Specification 4		Specificationl 5		Specification 6		Specification 7	
Description time	Generic		Alt. Specific		Alt. Specific		Alt. Specific		Alt. Specific		Alt. Specific		Alt. Specific	
Description cost	Linear		Linear		Ln		Lin + Ln		Linear spline		Non-linear spline		Ln	
Number of observations	1512004		1512004		1512004		1512004		1512004		1512004		1512004	
Log likelihood	-712033		-665374		-662472		-662466		-643801		-662835		-648366	
	Value	Ttest	Value	Ttest	Value	Ttest	Value	Ttest	Value	Ttest	Value	Ttest	Value	Ttest
Log(Price)					-0.64	-95.37	-0.66	-75.27					-0.65	-96.98
Linear price [Euro]	-0.06	-498.21	-0.01	-59.68			0.00	3.50						
Time parameter * 1000 [min]	-0.26	-113.18	-2.84	-113.74	-2.32	-94.43	-2.32	-94.08	-3.16	-125.13	-2.47	-96.87	-1.94	-85.12
General cargo specific time parameter * 1000 [min]			-4.36	-308.23	-4.29	-361.49	-4.31	-314.07	-5.50	-287.25	-4.07	- 302.29	-4.32	-362.63
Sea specific time parameter * 1000 [min			-0.22	-97.74	-0.19	-88.55	-0.19	-81.54	-0.13	-58.61	-0.21	-96.58	-0.19	-88.19
Non linear price parameter											-0.02	-92.84		
ASC Road general cargo	5.70	641.45	5.30	387.53	5.72	402.93	5.73	395.64	5.47	378.24	5.55	392.98	5.23	383.01
ASC RORO container	-2.71	-14.55	-5.45	-29.16	-4.89	-26.19	-4.90	-26.20	-6.56	-32.61	-4.91	-26.28	-5.28	-28.24
ASC RORO general cargo	2.94	91.15	-0.69	-17.35	-0.24	-5.94	-0.27	-6.48	-1.92	-52.37	-0.12	-3.00	-0.67	-16.83
ASC Rail container	-3.43	-50.68	-2.04	-29.29	-2.20	-31.54	-2.20	-31.57	-1.76	-25.17	-2.17	-31.06	-2.22	-33.38
ASC Rail general cargo	-0.23	-3.13	7.84	97.56	8.30	106.09	8.37	104.11	10.44	121.93	7.61	96.02	7.88	110.82
ASC Sea	-0.39	-10.82	-1.22	-32.90	-1.08	-30.06	-1.08	-30.06	-1.30	-37.79	-1.11	-30.59	-1.54	-51.11
ASC Rail+Sea	-0.31	-1.36	-1.34	-5.91	-1.24	-5.53	-1.25	-5.55	-1.55	-6.93	-1.20	-5.30	-1.58	-7.00
Linear spline for price 0-25 Euro									-0.04	-72.82				
Linear spline for price 25-50 Euro									0.03	56.98				
Linear spline for price 50-75 Euro									0.01	21.95				
Linear spline for price 75-100 Euro									-0.05	-88.63				
Linear spline for price > 100 Euro									0.07	185.82				
Dummy for RORO container and NST/R 5	-0.32	-0.91	-1.45	-4.07	-1.33	-3.76	-1.33	-3.75	-0.61	-1.65	-1.28	-3.59	-1.25	-3.51
Dummy for RORO container and NST/R 9	1.29	6.82	1.54	8.12	1.42	7.51	1.42	7.51	1.84	9.10	1.40	7.42	2.41	12.75
Dummy for RORO general cargo and NST/R 1	0.49	10.07	0.39	7.36	0.35	6.38	0.35	6.44	0.16	3.10	0.33	6.13	0.36	6.74
Dummy for RORO general cargo and NST/R 3	2.35	34.25	1.83	24.20	1.79	23.47	1.79	23.50	1.77	23.46	1.77	23.45	1.76	23.19
Dummy for RORO general cargo and NST/R 5	1.34	33.11	-0.57	-11.46	-0.65	-12.85	-0.66	-12.96	-0.07	-1.56	-0.58	-11.57	-0.59	-11.81
Dummy for RORO general cargo and NST/R 6	2.24	49.19	1.79	32.76	1.73	31.23	1.74	31.24	1.67	31.04	1.72	31.43	1.70	31.01
Dummy for RORO general cargo and NST/R 8	1.32	17.54	0.48	5.67	0.29	3.36	0.29	3.28	0.47	5.84	0.32	3.72	0.30	3.53
Dummy for RORO general cargo and NST/R 9	0.74	24.28	0.61	17.41	0.54	15.00	0.55	15.10	0.39	11.61	0.53	14.84	0.72	19.76
Dummy for Rail container and NST/R 1	0.76	3.32	0.62	2.71	0.69	3.01	0.69	3.02	0.62	2.70	0.65	2.86		
Dummy for Rail container and NST/R 2	8.57	58.69	8.56	59.28	8.60	59.08	8.60	59.09	8.82	60.76	8.55	58.92	7.93	53.67
Dummy for Rail container and NST/R 5	1.28	7.25	1.29	7.36	1.23	6.99	1.23	6.97	1.34	7.63	1.29	7.37	0.36	2.04
Dummy for Rail container and NST/R 6	1.90	7.52	2.00	7.92	1.99	7.89	1.99	7.89	1.98	7.86	2.00	7.93	1.07	4.27
Dummy for Rail container and NST/R 8	1.61	4.18	1.59	4.15	1.57	4.08	1.57	4.07	1.60	4.16	1.58	4.12	0.79	2.06
Dummy for Rail general cargo and NST/R 1	-0.25	-1.48	-0.31	-1.86	-0.35	-2.13	-0.36	-2.14	-0.42	-2.54	-0.34	-2.06		
Dummy for Rail general cargo and NST/R 5	5.03	67.15	4.97	66.37	4.85	64.65	4.84	64.59	4.78	63.70	4.91	65.56	5.00	73.98
Dummy for Rail general cargo and NST/R 8	2.44	17.60	2.41	17.35	2.28	16.40	2.27	16.37	2.23	16.06	2.34	16.85	2.44	18.08
Dummy for Rail general cargo and NST/R 9	3.22	43.59	3.19	43.12	3.06	41.44	3.06	41.38	2.98	40.34	3.12	42.26	3.83	57.53
Dummy for Sea and NST/R 1	0.17	2.88	0.16	2.86	-0.01	-0.14	-0.01	-0.26	-0.14	-2.54	0.02	0.31		
Dummy for Sea and NST/R 5	0.36	7.40	-0.48	-9.52	-0.36	-7.45	-0.36	-7.48	-0.13	-2.85	-0.35	-7.21	-0.31	-7.04
Dummy for Sea and NST/R 6	-0.96	-9.57	-0.20	-2.16	-0.40	-4.32	-0.40	-4.35	-0.39	-4.28	-0.37	-4.00	-0.43	-4.76
Dummy for Sea and NST/R 8	2.23	37.82	1.95	31.52	1.85	30.91	1.85	30.87	1.86	31.82	1.86	30.89	1.87	32.90
Dummy for Sea and NST/R 9	2.94	85.19	2.85	84.05	2.61	79.42	2.60	79.04	2.48	79.19	2.65	79.99	2.76	102.58
Dummy for Rail+Sea and NST/R 5	-1.98	-3.93	-2.71	-5.40	-2.41	-4.79	-2.40	-4.78	-1.59	-3.18	-2.34	-4.65	-2.44	-4.85
Dummy for HVD and Container													-2.47	-88.80
Dummy for HVD and Road mode													1.60	105.06
Dummy for HVD and Sea mode													3.72	116.24
Dummy for HVD and Roro mode													1.21	60.03