A model for freight transport chain choice in Europe

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Abstract:

This paper describes the structure of the Transtools3 freight transport chain choice model for Europe and the data at the shipment level that were used in estimation, and presents the estimation results and resulting elasticities. It also discusses the structure of the overall freight model and how production-consumption matrices from a trade model are combined with the transport chain choice model in model application. In the estimation of the transport chain choice model on the available disaggregate data sources (the Swedish Commodity Flow Survey 2009 and the French ECHO survey) we tested several options for the specification of transport costs in the model and various nesting structures.

1. Introduction

The choice of mode in freight transport is usually modelled as a choice of a single main mode at the level of aggregate origin-destination (OD) flows (see for an overview: chapter 6 of Tavasszy and de Jong, 2014). The fact that a large part of freight transport uses transport chains consisting of several modes in a sequence that stretches from the production location to the place of consumption is often ignored. Furthermore, freight mode choice modelling often depends to a large extent on transport costs that are treated in a linear fashion. 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).

In this paper we present a model, called Transtools3, that differs from these conventions in the following ways:

- Instead of modelling main modes we model the choice among transport chains (sequences of modes, e.g. road-rail-road) at the level of flows between production and consumption (PC) locations. In freight transport modelling, an important distinction is between production-consumption (PC) matrices and origin-destination (OD) matrices. PC matrices contain flows of goods between production (P) zones and consumption (C) zones (being retail for final consumption; and further processing of goods for intermediate consumption). The transport between P and C can involve various transport legs (these are the OD flows), each with their own mode.
- The model is estimated on disaggregate data, which in this case refers to data at the level of individual shipments (simultaneous estimation based on the Swedish Commodity Flow Survey (CFS) 2009 and the French ECHO survey).
- Besides linear transport costs, we test various non-linear specifications of transport costs (logarithmic, combination of linear and logarithmic, piece-wise linear and non-linear spline functions). As far as we know, a systematic analysis of the cost specification at this spatial level has so far not been undertaken in freight transport analysis.

The Transtools3 model is a new forecasting model system for passenger and freight transport in Europe, developed by a consortium led by DTU from Denmark for DG MOVE of the European Commission[1]. It consists of three main blocks: the passenger transport models, the freight and logistics models (de Jong et al., 2015), and the network assignment models. This paper focuses on the central sub-model, i.e. the transport chain choice model, within the freight and logistics model. The transport chain choice model explains the choice between mode sequences between the location of production and the location of consumption. This model was estimated jointly based on two micro data sets with observations at the shipment level (CFS and ECHO). These data was then combined with level-of-service information resulting from assignment models applied to the relevant European networks. It is applied to the whole of Europe (after recalibration of the alternative-specific constants to match aggregate European data on the modal split).

A specific issue is the joint model estimation based on two different revealed preference (RP) data sets (ECHO and CFS 2009) with observations at the shipment level. To combine the two datasets we use the logit scaling approach (Bradley and Daly, 1997) that is commonly applied to combine stated

[1] The Transtools3 model is a successor of earlier models at the European scale, such as STREAMS, STEMM, SCENES, Transtools1 and 2. A more strategic model (not based on detailed networks) for Europe developed at about the same time as Transtools3 is Hightool.

preference (SP) and RP data in passenger transport analysis. However, as the CFS (with almost 3 million shipments) then might swamp the influence of ECHO (about 10,000 shipments) on the parameter estimation, it was decided to allow for a weighting between the two data sets. Therefore we weight the ECHO data so that CFS and ECHO have equal weight and compare the outcomes to an unweighted estimation.

Different models were estimated for three different freight load types (solid bulk, liquid bulk and general cargo/container). For each of these three load types we tested different specifications involving different sets of shipment characteristics, different cost function specifications (see above) and different nesting structures within the framework of nested logit models.

In Section 2 of this paper, the structure of the overall Transtools3 freight transport model and the position of the transport chain choice model within this framework are explained. The data used in estimation of the transport chain choice model are described in Section 3. Section 4 presents and discusses the estimation results and section 5 the cost and time elasticities derived from the estimated models. The implementation methodology is briefly explained in Section 6 and Section 7 contains the conclusions from this work.

2. The model structure

The structure of the overall freight transport model of Transtools3 is provided in Figure 1. In the upper right part of the model, future year PC matrices are calculated by means of a trade model (de Jong et al., 2016) that yields growth factors by zone pair (at the level of NUTS3 zones or subdivisions of these) and by NSTR-1 commodity types that are pivoted with respect to a base PC matrix. Estimation of the trade model was based on the gravity formulation using characteristics of the zones and their spatial separation and the transport resistance between them. The dependent variables for this model are the flows according to the PC matrix for 2010 as constructed in another project for the European Commission, ETISplus (ETISplus, 2014). Explanatory variables are partly derived from ETISplus and partly from publicly available sources (de Jong et al., 2016).

The transport chain choice model, which is the focus of this paper, is in the middle of the Figure (labelled 'stochastic logistic model for choice of chain type'). It takes the base year or future year PC matrix and then determines the split of the tonnes (by NSTR-1) for each cell over the available transport chains, also taking into account the influence of level-of-service variables such as transport cost. The latter are based on skims of the networks and unit values for time- and distance-based transport cost and transhipment cost by mode. On the basis of the outcomes of the transport chain choice model, OD matrices (by NSTR-1) are calculated. For these we also determine growth factors at cell level between base and future and pivot these on base OD matrices (by mode and NSTR-1). The OD matrices can be converted to vehicles and vessels and assigned to their respective networks (bottom part of Figure 1).

This makes the Transtools3 model structure largely consistent with the aggregate-disaggregate-aggregate (ADA) national freight models of Norway and Sweden (see de Jong and Ben-Akiva, 2007; Ben-Akiva and de Jong, 2013), the freight model developed for the Mobility Masterplan Flanders (de Jong et al., 2010b) and the Danish national freight model (Hansen, 2015).

The key characteristic that distinguishes these ADA models (and a handful of other transport models using different approaches; see for instance Tavasszy et al., 1998; Hunt et al., 2001; Jin et al., 2005; Liedtke, 2009; Friedrich, 2010; Roorda et al., 2010; Samimi et al., 2010) from conventional freight transport models is the inclusion of logistics choices, such as transport chain choice.

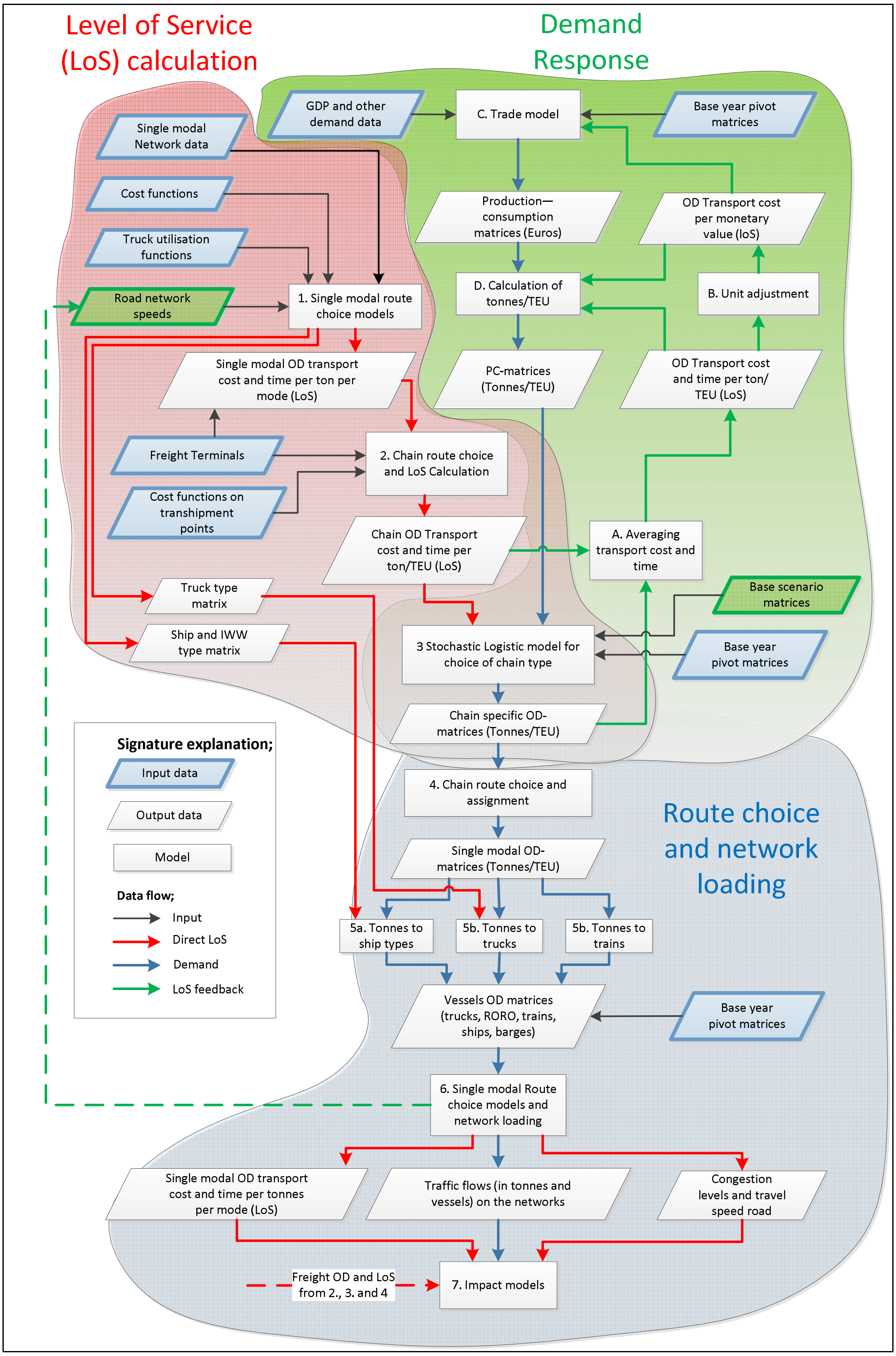

Figure 1. Overall structure of the Transtools3 freight transport model.

3. Data used

Mode choice in freight transport is in practice often modelled at the aggregate level. This is to a large extent due to the lack of disaggregate freight data. Our model is instead estimated on two (out of the very few) available disaggregate revealed preference data bases in European for freight transport: The French, Envoi – CHargeurs – Opérateurs (ECHO), survey of 2004 and the Swedish, Commodity Flow Survey (CFS), of 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).

3.1 Description of CFS 2009 and development of estimation data files

For CFS 2009 it was decided only to use outgoing commodity flows (the major part of the CFS), not the incoming flows. Some CFS commodity flows come 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, which does not fit in the model concept (see Ben-Akiva and de Jong, 2013). Then all commodity flows transported by air and (or) unknown modes of transport were dropped since these modes of transport are not part of the Transtools3 model. This provided us with 1,936,894 commodity flows that could potentially be used for estimating the transport chain decision. Preparing the data for analysis required coding the production zone (P), consumption zone (C) and (PC) pair for each commodity flow in units consistent with the eventual Transtools3 zonal structure.

All P's of the outgoing commodity flows in the CFS are within Sweden, for which the NUTS3 zonal code is stored by the variable 'Avg Lan' in CFS 2009. Most flows originate in the Västra Götalands län. The C zones within Sweden are stored by the variable 'Mlan', but these vary by national and international destination. A total of 1,485,231 national and 449,375 international commodity flows is maintained as 2,288 flows have an unknown consumption zone. Like the Ps, all the national Cs were in NUTS3 coding. The Cs for the international commodity flows turned out to be more complex as they were registered by means of their C city and country.[3] Different conversion approaches had to be applied and information sources consulted to convert these international Cs into the Transtools 3 zoning structure.

The CFS 2004/2005 has been used before to construct 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 construct 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 Transtools3 zonal structure.

[2] Commodity types ('Varukod') 12, 13, 16 and 44 were excluded from the dataset.
[3] In certain cases postal codes or local administrative units were used.

The first step of the conversion to Transtools3 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, respectively NO011 and NO012. 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 Transtools3 zonal structure operates at a higher spatial level for those C's. Therefore, it was decided to use the GIS structure of Transtools3 directly and create links between yet untransformed Samgods zones and the "far C's" in the Transtools3 zonal system. In the final steps NUTS3 coding was transformed into ETIS coding (which was used for several inputs to Transtools3 prepared by the ETISplus consortium) and subsequently into Transtools3 coding where population weights were applied when the zonal structure was split. After discarding for intra-zonal trips at the Transtools3 zoning structure level we are left with a final sample size of 1,614,660 flows.

As mentioned before, the aviation and unknown modes of transport are disregarded in the Transtools3 model. All transports using road only, were recoded into road chains. In estimation, some of the road shipments were re-classified as RORO 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 are all commodity flows making use of both rail and sea, including road trips along either part of the flow. Specific conversion tables for the *Chain* variable, but also other variables are available upon request.

Freight load type is constructed 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 NSTR1 classification as used by the Transtools3 model. The original variable 'Vikt' was used to construct the shipment size variables. *Values* in the original CFS dataset were recorded in 2009 SEK, which needed conversion into 2010 euros. To this end Statistics Sweden was consulted for the 2009-2010 CPI inflation index (1.013) and Eurostat for the Euro/ECU exchange rates in 2010 between the SEK and € (1 € = 9.5373 SEK). The values and weight variables are then used to derive a value per kg for each commodity flow.

3.2 Description of ECHO and development of estimation data files

The French ECHO survey was carried out by IFSTTAR (previously INRETS) and ISL in 2004. To obtain the ECHO database, a special application was required to the 'Comité du Secret' of INSEE, the French national statistical institute. Transtools3 applied for this and was granted access to the ECHO data for estimation work within the Transtools3 project.

The basis of the ECHO survey is interviews of almost 3,000 French shippers. They provided detailed information about their shipments in 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, ECHO therefore is much smaller in terms of shipments, but richer in terms of the information per shipment. ECHO contains five questionnaires: pre-interview, shipper, shipment, operator and journey leg. The data that we received includes 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.

Given the coding of the PC pairs at the NUTS3 level, the conversion into Transtools3 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 Transtools3 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 Transtools3 was applied and population weights were applied to facilitate zonal splitting.

Freight shipments in ECHO are recorded in legs. For our purposes the shipment level record details on commodity type (NSTR classification), volume (tonnes), consistency and value from the shipment file and information on mode and O-D from the journey leg file. These datasets were merged together using the shipment identifier.

From the data we identified 10,462 flows (=shipments) which were coded to provide variables representing tonnes, value density (euro per ton), freight load type, shipment chain type and commodity group.

NUTS3 codes were available for European origins and destinations, NUTS2 for other countries.

Of these flows, 121 were missing sufficient information about NUTS coding to convert to Transtools3 area codes. A further 1,358 observations were dropped as there was insufficient information about the transport leg modes. A further 6 flows were dropped because they did not originate in France, leaving 8,977 observations. Of these remaining flows, a further 6 were dropped as they didn't have freight load type information. Then a further 769 observations were dropped as they were in the same Transtool3 zone[4], leaving 8208 valid flows. 2915 observations recorded a zero for value density due to missing data on the reported shipment values. 1321 observations recorded a -999 (missing value) for frequency as no data was reported from the shippers.

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 with the CFS data.

3.3 Description of the level of service data

In Transtools3, European (and to some extent global) networks were constructed for road, rail, inland waterways, sea and roll on/roll off transport (also for air transport, but in the model these are only

[4] In the model within-zone transports will be assigned identical level-of-service and cannot be used in the estimation.

used for passengers), starting from networks delivered by the ETISplus project. These networks were then skimmed 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.

For each of the two data sources a matching set of Level-of-Service matrices has been prepared for all chain types (see in Section 4). These chain types also distinguish between dry bulk, liquid bulk, general cargo and containers. Thus, the Level-of-Service information is available in four tables for CFS and four tables for ECHO. Each Level-of-Service table contains the information (for each chain) on: the Transtools3 zone pair (to match the Level-of-Service data with the individual PC flows from CFS and ECHO), distance, total travel cost (all modes used and all transshipments) per ton and transport time by mode (road, rail, sea, inland waterways and RORO).

4. Estimation

4.1 Model specification

The model is estimated as a standard multinomial and nested logit model, where the choice alternatives are not the individual modes, but transport chains:

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
6. Rail – non-container
7. Inland waterways (IWW)
8. Rail and IWW
9. Sea
10. Rail and sea
11. IWW and sea
12. Rail and IWW and sea

These 12 alternatives consist of 9 chain types of which 3 can be either container or non-containerised general cargo. The choice whether to use a container or not in a transport chain therefore is also (endogenously) included in the model. Note that road transport can 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 transshipment 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

A separate chain choice model is estimated for each of the three freight load types. Model 1 (dry bulk) and model 2 (liquid bulk) have a total of 9 alternatives (the alternatives 2, 4, 6-12 from the list above). For model 3 it is assumed that general cargo is only relevant for road, rail and RORO alternatives, thus it is assumed that non-bulk goods transported via sea or IWW are transported in containers. Hence model 3 has a total of 12 alternatives (nine for containers, and three for general cargo, as in the list above). This means that for this freight load type it is assumed that 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 CFS/ECHO, and therefore cannot be included in the model estimation. Table 1 below shows the number of times each alternative is available and is chosen for each data set and freight load type. Furthermore, in order to allow the CFS and ECHO data to be equally weighted the French ECHO data is up-scaled. Based on the table below the ECHO data is up-scaled by 17,053/1,063, 75,052/144 and 1,512,004/6,605 for model 1, 2, and 3 respectively. The total number of observations used in estimation from CFS is 1,604,109 and 7,812 from ECHO. The reduction from 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 alternative available.

Alternatives			**CFS**			**Echo**		
Chain	**AlternativeID**	**ChainID**	**Model 1**	**Model 2**	**Model 3**	**Model 1**	**Model 2**	**Model 3**
Road – container	1	1	-	-	14,200 (1,509,718)	889 (1,049)	77 (144)	227 (6,345)
Road – non-container	2	1	16,440 (17,045)	74,636 (75,052)	1237,099 (1,512,002)			5,819 (6,345)
RORO – container	3	5	-	-	966 (1,512,004)	-	-	-
RORO – non-container	4	5	225 (17,048)	136 (75,052)	31,422 (1,512,004)	10 (1,049)	1 (144)	-
Rail – container	5	2	-	-	425 (1,512,004)	-	-	10 (6,345)
Rail – non-container	6	2	166 (17,048)	106 (75,052)	26823 (1,512,004)	100 (1,049)	58 (144)	176 (6,345)
IWW	7	3	-	-	-	25 (1,049)	4 (144)	-
Rail and IWW	8	6	-	-	-	-	-	-
Sea	9	4	220 (17,053)	174 (75,052)	201,043 (1,512,004)	35 (1,063)	4 (144)	350 (6,605)
Rail and sea	10	7	2 (205)	0 (447)	26 (1,642)	-	-	1 (6,605)
IWW and sea	11	8	-	-	-	4 (120)	-	22 (1,039)
Rail and IWW and sea	12	9	-	-	-	-	-	-
"Valid" observations			**17,053**	**75,052**	**1,512,004**	**1,063**	**144**	**6,605**

Table 1. Number of times an alternative has been chosen in the estimation data (availability count in brackets).

The general estimation procedure used for all three models is as follows. For each model we first searched for the best MNL specification for each single dataset (CFS and ECHO), i.e. 3x2 MNL models. To do this we investigated for which NSTR-1 commodity types 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 some tests whether the same parameter should be used for all alternatives. 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 specification 1 and 2 for freight load type 3 in Table 2).

With this general specification, we then tested five different specifications for transport cost:

1. Linear (lin)
2. Logarithmic (ln)
3. Combination of linear and logarithmic (lin+ln)
4. Spline
5. Nonlinear spline

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 ton) and each element $Price_{S<x>}$. Below we present the utility specifications for the spline and the non-linear spline.

(1)
$$\begin{aligned} Price_{S1} &= min(Price, 25) \\ Price_{S2} &= max(0, min(Price - 25,25)) \\ Price_{S3} &= max(0, min(Price - 50,25)) \\ Price_{S4} &= max(0, min(Price - 75,25)) \\ Price_{S5} &= max(0, Price - 100) \end{aligned}$$

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

(2)
$$F(price) = \begin{cases} \ln(\text{Price})^3 & if\ \ 0 < \text{Price} <= \text{c}_1 \\ \theta_2 \ln(\text{Price})^2 + \gamma_2 & if\ \ \text{c}_1 < \text{Price} < \text{c}_2 \\ \theta_3 \ln(\text{Price}) + \gamma_3 & if\ \ \text{Price} >= \text{c}_2 \\ 0\ otherwise & \end{cases}$$

Where $\text{c}_1 = 100/3$, $\text{c}_2 = 2 * 100/3$, 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 (2016).

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.

Table 2 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 was chosen. Furthermore, the process resulted in the choice for a logarithmic transport cost specification (specification 3). Note that the linear spline specification obtains a better LL, but as some of the parameters for the spline intervals becomes positive, this specification was discarded. The lin+ln specification also get a loglikelihood 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.

	Specification 1		Specification 2		Specification 3		Specification 4		Specificationl 5		Specification 6		Specification 7	
Desciption 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 NSTR 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 NSTR 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 NSTR 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 NSTR 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 NSTR 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 NSTR 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 NSTR 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 NSTR 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 NSTR 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 NSTR 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 NSTR 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 NSTR 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 NSTR 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 NSTR 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 NSTR 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 NSTR 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 NSTR 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 NSTR 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 NSTR 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 NSTR 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 NSTR 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 NSTR 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 NSTR 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

Table 2. Specification tests for CFS data and FLT = 3

For each of the six (combinations of three FLT and two sets of data) 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 for Model 1, 2 and 3. Furthermore, in the model estimation only "valid" observations were included.

The joint CFS-ECHO model estimation is conducted using the logit scaling approach (Bradley and Daly, 1997). It was chosen to fix the scale-parameter for ECHO to 1 and estimate the scale parameter for CFS. This was chosen because ECHO is the main data source for the implementation at a later stage. The initial tests for CFS and ECHO resulted in the same specification for transport costs within each FLT model. More specifically, for Model 1, a lin+ln specification was superior for both CFS and ECHO. Similarly, for Model 2 a linear spline specification was superior, whereas for Model 3 a logarithmic specification was superior.

Models that give ECHO an equal weight as CFS did not lead to large changes in the coefficient values compared to unweighted estimation. The results that we present in this paper refer to the weighted estimation.

We tested various nesting structures:

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. Nest for alternatives that include the same number of OD legs versus alternatives that do not
5. Nest for container alternatives versus non-containerised general cargo alternatives (only for freight load type 3).

The choice of nesting structure is based on whether the nesting parameter is in the allowed range (between 0 a 1) to be consistent with the random utility maximization paradigm, and on the loglikelihood value. The best NL model for freight load type 1 (solid bulk) contains rail and non-rail nests, as depicted in Figure 2. This nesting structure accounts for the effect that rail alternatives are more likely to exchange market share with each other than with other alternatives.

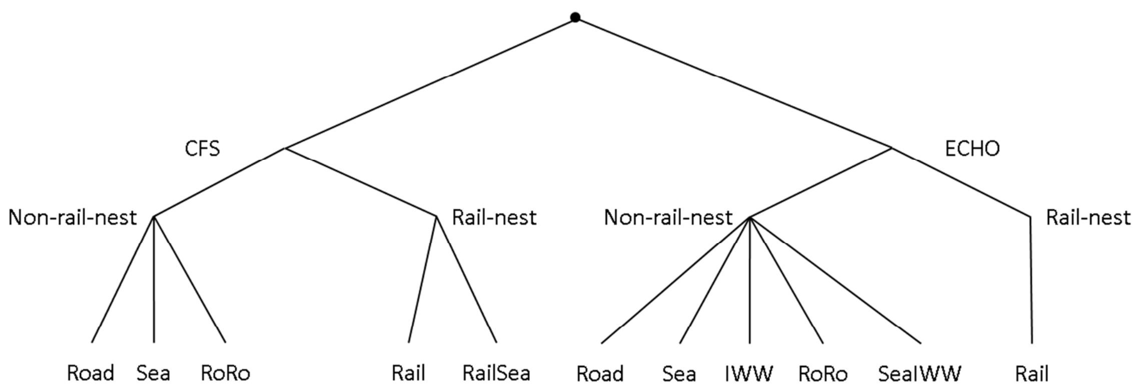

Figure 2. Nest structure in the final estimated model for FLT=1.

The final utility specifications for Model 2 use a spline function for transport cost.

Similarly to Model 1, the best nested logit model for liquid bulk contains rail and non-rail nests (see Figure 3).

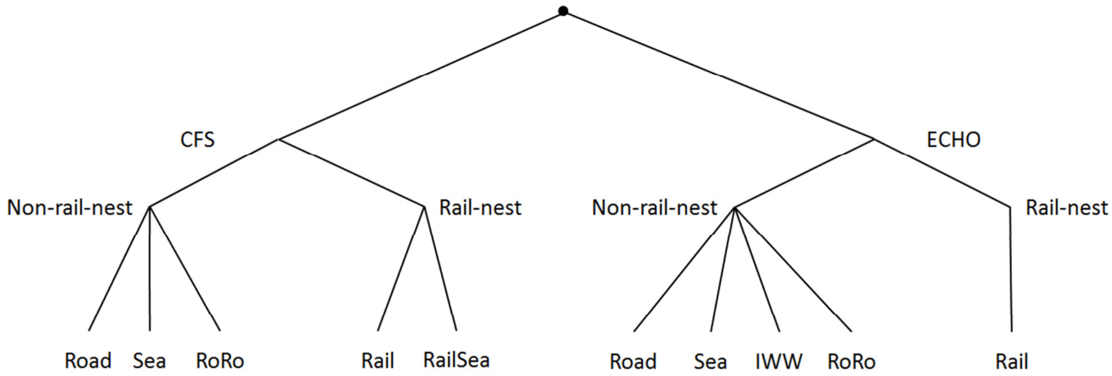

Figure 3. Nest structure in the final estimated model for FLT=2.

Model 3 is estimated as a nested logit with specific nests for container and general cargo, as depicted in Figure 4. This nesting structure was superior, and captures the correlation among alternatives with the same type of cargo (general cargo or container).

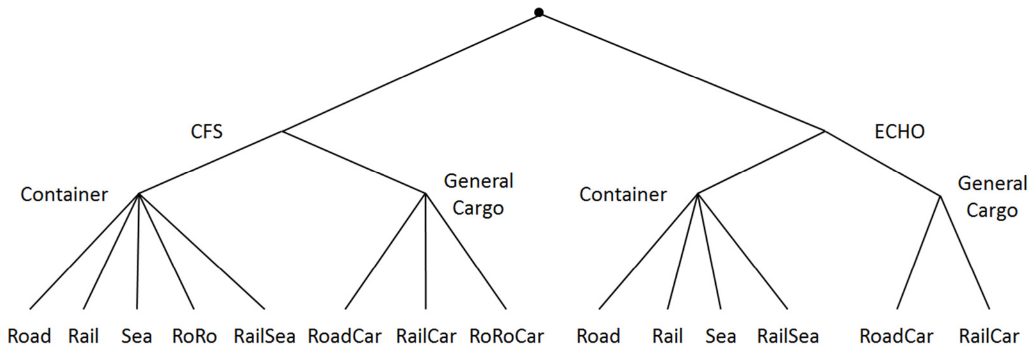

Figure 4. Nest structure in the final estimated model for FLT=3.

4.2 Final estimation results

The following Table 3-6 describes the estimated model parameters for the preferred models for each of the three freight load types. The models are 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, $19.35 Euro/kg$ for model 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 are dummy variables which indicate whether a zone has direct access to a given mode. As road is assumed to always be accessible within a zone, dummies are considered for rail, sea and IWW. More specifically, the direct access dummies are 1 if either the origin or destination zone has direct access to rail, sea, or IWW respectively. Finally, the NSTR-dummies measures systematic heterogeneity among shipments based on the cargo classification used in the data. In this study the NSTR-1 classification is used. The 10 categories are: 0) Agricultural products and live animals, 1) Foodstuffs and animal fodder, 2) Solid mineral fuels, 3) Petroleum products, 4) Ores and metal waste, 5) Metal products, 6) Crude and manufactured mineral, building materials, 7) Fertilisers, 8) Chemicals, 9) Machinery, transport equipment, manufactured and miscellaneous articles[5]. The NSTR-dummies are 1 if a shipment is within a given NSTR category, and zero otherwise. In general the parameters are highly significant and have correct and 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 p=0.001). The model indicates that container transport is less attractive for high value goods, which seems plausible. Furthermore, Road, Sea and RORO are preferred for high value goods compared to the other alternatives.

For the direct access dummies we see that these are all positive, and highly significant (at least at p=0.001). This indicates that an alternative is more likely to be selected if either the origin or destination zone has direct access to that mode (that being rail, sea or IWW), which makes sense.

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

Description	Model 1		Model 2		Model 3	
	Value	T-Test	Value	T-Test	Value	T-Test
Parameters estimated jointly across dataset						
Alternative specific parameters						
ASC, Road (non-container)					5.382	211.927
ASC, RORO (non-container)			-1.16	-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	-79.17
Time and cost parameters						
Log(Cost)	-2.076	-24.601			-1.199	-155.011
Cost	-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	-16.63		
Linear spline for Cost 75-100 Euro			-0.195	-35.528		
Linear spline for Cost >100 Euro			-0.078	-21.63		
Time	-0.491	-7.133	-1.481	-20.119	-1.172	-79.815
Time, general cargo					-3.166	-263.525
Time, sea/IWW/RORO	-0.209	-14.706	-1.148	-48.902	-0.157	-114.065
NSTR commodity type parameters						
NSTR 9 dummy, RORO (non-container)	-1.212	-10.859				

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

NSTR 5 dummy, Rail (non-container)	2.283	14.971			1.682	133.986
NSTR 6 dummy, Rail (non-container)	0.829	5.083				
NSTR 8 dummy, Rail (non-container)	2.095	11.488			0.699	47.196
NSTR 5 dummy, Sea					0.182	9.298
NSTR 6 dummy, Sea					0.119	2.892
NSTR 8 dummy, Sea					1.034	65.908
Other chain specific parameters						
HvD-dummy, Container					-1.772	-107.981
HvD-dummy, Road					1.16	109.743
HvD-dummy, Sea					2.54	128.402
HvD-dummy, RORO					0.845	55.517
Nesting and scale parameters (t-test against 1)						
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 3: Parameter estimates for the preferred chain choice models. Parameters estimated jointly across both dataset.

Description	**Model 1**		**Model 2**		**Model 3**	
	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)	-0.62	-6.438			1.225	33.907
ASC, Rail and sea	-8.896	-7.961			-1.04	-5.651
NSTR commodity type parameters						
NSTR 5 dummy, RORO (container)					-0.838	-2.917
NSTR 9 dummy, RORO (container)					1.93	12.598
NSTR 1 dummy, RORO (non-container)			2.184	12.772	0.169	3.808
NSTR 2 dummy, RORO (non-container)	1.819	1.71				
NSTR 3 dummy, RORO (non-container)			0.231	2.112	1.227	19.552
NSTR 5 dummy, RORO (non-container)	0.128	0.588			-0.605	-14.881
NSTR 6 dummy, RORO (non-container)	-2.107	-3.275			1.3	29.408
NSTR 8 dummy, RORO (non-container)					-0.191	-2.697
NSTR 9 dummy, RORO (non-container)					0.257	8.52
NSTR 2 dummy, Rail (container)					8.068	58.34
NSTR 5 dummy, Rail (container)					1.263	9.109
NSTR 6 dummy, Rail (container)					1.959	9.677
NSTR 8 dummy, Rail (container)					1.738	5.615
NSTR 1 dummy, Rail (non-container)			0.67	2.008		
NSTR 4 dummy, Rail (non-container)	5.225	9.16				
NSTR 5 dummy, Rail (non-container)			5.339	3.965		
NSTR 8 dummy, Rail (non-container)			3.131	18.931		
NSTR 9 dummy, Rail (non-container)	-4.135	-3.364			1.266	115.326

Description	Model 1 Value	Model 1 T-Test	Model 2 Value	Model 2 T-Test	Model 3 Value	Model 3 T-Test
NSTR 1 dummy, Sea			-2.853	-9.729		
NSTR 3 dummy, Sea			-1.637	-20.625		
NSTR 6 dummy, Sea	1.188	5.729				
NSTR 8 dummy, Sea	1.105	3.825	-0.859	-7.322		
NSTR 9 dummy, Sea	-2.797	-5.855	-2.8	-3.837	2.026	198.556
NSTR 5 dummy, Rail and sea					-1.672	-4.092
NSTR 5 dummy, Rail and sea					-1.672	-4.092

Table 4. Parameter estimates for the preferred chain choice models. Parameters estimated on the CFS dataset.

Description	Model 1		Model 2		Model 3	
	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	-10.55	-29.081			-2.826	-159.069
NSTR commodity type parameters						
NSTR 1 dummy, Road (non-container)					1.589	77.198
NSTR 6 dummy, Road (non-container)					1.509	31.587
NSTR 0 dummy, Rail (non-container)	2.349	15.889				
NSTR 1 dummy, Rail (non-container)	1.24	9.809			2.072	86.357
NSTR 6 dummy, Rail (non-container)					2.077	38.594
NSTR 7 dummy, Rail (non-container)	2.556	8.313				
NSTR 1 dummy, Sea					1.336	58.046
NSTR 3 dummy, Sea					1.434	28.774
NSTR 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 5. Parameter estimates for the preferred chain choice models. Parameters estimated on the ECHO dataset.

Model summary	Model1	Model2	Model3
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

Table 6. Model summary.

5. Elasticities

It is important to validate the model parameters in the estimation phase as these reflect the preferences of individuals. In order to validate the estimated models for the Transtools3 logistics model, elasticities are computed for each of the three final joint CFS-ECHO models. This is done using the estimation data set for simulation in Alogit. More specifically, this was done by simulating a 10% increase in time or cost for an alternative. Note, that the final elasticities from the implemented Transtools3 model could be somewhat different. We have tested both changes in variables for each specific mode (i.e. changes for the rail mode that affect several chain alternatives that include rail as a mode) and changes in variables for each chain alternative (i.e. changes are only applied for each chain individually, e.g. rail-sea) and comparing the market shares for that scenario with a base scenario (without the 10% increase). Note that with the used data, the mode specific calculations can only be conducted for changes in transport time. The elasticities are then computed by comparing the market shares (in terms of the number of shipments) between the base and the scenario. Please find the calculated direct elasticities in Tables 7 to 9.

In Tables 7 to 9 the first two elasticity columns give the impact of a cost or time change of a specific transport chain (e.g. 'rail only' or 'rail and sea') on the transport chain alternatives. The third column gives the effect of changing the time of a specific mode (e.g. rail, which appears in several transport chains) on the transport chains. In these tables we see that (in absolute values), the direct elasticities of the non-road modes are usually larger than those for road. Also the impact of making a specific chain slower on that chain itself is more pronounced that the impact on that chain of making a mode within that chain slower (because other chain alternatives with the altered mode also become less attractive). A few elasticities are quite strong, but this usually concerns chains with small market shares. For road transport, the highest elasticities are for containerised goods.

	Elasticities: Change in market shares		
	Travel Cost Chain Specific	Travel Time Chain Specific	Travel Time Mode Specific
Road on Road	-0.21	-0.01	-0.01
Rail on Rail	-1.9	-0.49	-0.02
Rail on RailSea			-0.01
IWW on IWW	-2.12	-0.8	-0.56
Sea on Sea	-1.15	-0.67	-0.35
Sea on RailSea			-0.67
Sea on IWWSea			-0.15
RORO on RORO	-3.59	-0.37	-0.27
RailSea on RailSea	-2.48	-2.65	
IWWSea on IWWSea	-1.23	-2.5	
IWW on IWWSea			-0.14

Table 7. Direct elasticities for Model 1 (dry bulk).

	Elasticities: Change in market shares		
	Travel Cost Chain Specific	Travel Time Chain Specific	Travel Time Mode Specific
Road on Road	-0.23	-0.05	-0.01
Rail on Rail	-0.94	-0.59	-0.03
Rail on RailSea			-0.08
IWW on IWW	-1.43	-2.32	-0.91
Sea on Sea	-1.34	-3.25	-1.66
Sea on RailSea			-2.06
RORO on RORO	-2.20	-0.99	-0.72
RailSea on RailSea	-1.98	-5.07	

Table 8. Direct elasticities for Model 2 (liquid bulk).	**Elasticities: Change in market shares**		
	Travel Cost Chain Specific	Travel Time Chain Specific	Travel Time Mode Specific
Road Container on Road Container	-0.43	-0.98	
Road General Cargo on Road General Cargo	-0.17	-0.11	
Road on Road Container			0.45
Road on Road General Cargo			-0.13
Rail Container on Rail Container	-1.36	-1.04	
Rail General Cargo on Rail General Cargo	-5.68	-1.10	
Rail on Rail Container			-0.09
Rail on Rail General Cargo			-0.38
Rail on RailSea			-0.02
RORO Container on RORO Container	-0.38	-1.31	
RORO General Cargo on RORO General Cargo	-0.40	-1.11	
RORO on RORO Container			-0.22
RORO on RORO General Cargo			-0.29
Sea on Sea	-0.46	-0.59	-0.23
Sea on RailSea			-0.08
Sea on IWWSea			0.02
RailSea on RailSea	-1.22	-0.48	
IWWSea on IWWSea	-3.14	-0.99	
IWW on IWWSea			-0.29

Table 9. Direct elasticities for Model 3 (general cargo and containers).

The Transtools3 elasticities in Tables 7 to 9 were given in terms of the impact on the market shares of the shipments. The elasticities in Table 10 from the international literature are for impacts on tonnes or tonne-kilometres (tkm). Tonne elasticities are probably on average lower (in absolute values) than shipment-elasticities (because many heavy products have rather low modal substitution rates), whereas tkm elasticites are usually higher (because longer distances, which also have higher sensitivities, count heavier in the tkm). Taking all of this into account, we conclude that the

Transtools3 direct costs elasticities of the modes are generally plausible and in line with those from the international 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. (2016), effect on tonnes, metal products, Sweden	-0.04 to -0.49	-0.02 to -0.12	
Abate et al. (2016), effect on tonnes, chemical products, Sweden	-0.12 to -0.52	-0.29 to -0.56	

Table 10. Cost elasticities of the number of tkm for all commodities (unless otherwise indicated) for mode choice from the literature.

6. Implementation

The output of the first model step, the trade model (after pivoting), consists of aggregate (zone-to-zone) PC matrices for the future, whereas the transport chain choice model was estimated as a disaggregate model. However, the estimated logit models do not depend on shipment size (nor does the level-of-service) and include only on a limited number of dummy-type characteristics of the shipment (commodity type, direct rail access and high value-density).

We considered conducting the application of the transport chain model on a prototypical sample of shipments. However, given the limited dependency on shipment characteristics, it is computationally much more efficient to apply the model at the level of the number of tonnes per aggregate PC flow.

For this reason, we chose to apply the transport chain models to the aggregate number of tonnes per NSTR-1 category from the trade model. Commodity type at the NSTR-1 level is already given in the outputs of the trade model. Direct rail access for a zone is determined from the networks used. Whether or not the goods have a high value density is determined using a table of value density by NSTR-1, based (mainly) on the ECHO data.

After having programmed the transport chain choice model, the alternative-specific constants were recalibrated to reflect the observed aggregate mode shares in Europe for the base year (as in the EU Energy and Transport in Figures Statistical Pocketbook for 2010, European Commission (2010)).

The legs of the chain by mode and commodity are summed over the PC relations to produce aggregate OD matrices by mode and commodity type (in tonnes), which are then (after pivoting) used as input to the network assignment.

7. Conclusions

This paper described the data used and the structure of the Transtools3 transport chain choice model for Europe and presented the estimation results for various specifications. It also discussed the structure of the overall freight model and how PC matrices from the trade model are combined with the disaggregate transport chain choice model in model application.

In the estimation of the transport chain choice model on the available disaggregate data sources (the Swedish Commodity Flow Survey 2009 and the French ECHO survey) we 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. We tested several options for the specification of transport costs in the model. A linear plus logarithmic cost specification works best for solid 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. We also tested various nesting structures and found that for bulk goods, transport chain alternatives that include rail transport have a higher degree of mutual substitution than with other chain alternatives. For general cargo and container goods, the best nesting structure we obtained was with a general cargo nest and a container nest.

The transport chain choice model could be improved in a number of aspects. This includes modelling shipment size choice jointly with transport chain choice (but this puts very heavy demands on the network model that produces inputs) and allowing for unobserved heterogeneity in transport chain choice. Also the model, could be re-estimated when new data would become available (there will be a CFS 2016, maybe a new ECHO and other European countries could also start collecting this type of data).

Acknowledgment

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