

# **Joint econometric models of freight transport chain and shipment size choice<sup>1</sup>**

Megersa Abate Inge Vierth

Swedish National Road and Transport Research Institute (VTI)

and

Gerard de Jong

Significance, ITS University of Leeds and, Center for Transport Studies, VTI/KTH

April, 2014

## **Abstract**

In freight transportation, decisions on the choice of transport mode (or chains of modes) and shipment size are closely linked. Building on this basic insight, in this paper we estimate and review various joint econometric models using the Swedish National Commodity Flow surveys. Robust parameter estimates from this exercise will be used to update the current deterministic Swedish national freight model system (the SAMGODS model) to a stochastic one.

## **I. Introduction**

The main feature of the current Swedish national freight model system (SAMGODS model) is incorporation of a logistic component in the traditional freight demand modeling framework. Logistical decisions of firms are incorporated in the modeling process based on the shipment size optimization theory. According to this theory, firms are assumed to minimize total annual logistics costs by trading-off inventory holding costs, order costs and transport costs. The logistics module of the SAMGODS model estimates frequency/shipment size choice and transport chain choice (i.e. transport mode choices and use of transshipment) based on a deterministic cost minimization model where firms are assumed to minimize annual total logistic cost.

---

<sup>1</sup> This report is funded by trafikverket through the “Stokastisk logistikmodul” project. This funding is both acknowledged and gratefully appreciated. We would like to thank Christian Overgård, Henrik Edwards and Jonas Westin for their constructive comments. Thanks also to seminar participants at the center for transport studies (CTS) and Trafikeverket in Stockholm for helpful suggestions and comments. The usual disclaimer applies.

Judged by international standards in freight transport modeling, the SAMGODS model is relatively modern. Its logistic module, however, lacks two main elements. First, it does not account for the main determinants of shipment size and transport chain choices other than cost, i.e. decisions are mainly based on cost considerations (and to some extent on factors such as access to road and rail and value densities).<sup>2</sup> Second, the model is deterministic and lacks a stochastic component. In order to improve the predictions of the model and allow richer policy analyses, logistical decisions should be modeled taking into account these two elements (Section II describes how we intend to carry out this). A full random utility logistic model which accounts for this was planned (SIKA, 2004), but has not yet been estimated on disaggregated data (de Jong and Ben-Akiva, 2007).

This project is a first step towards estimating a full random utility logistic model. Its main objective is to estimate robust econometric models that describe the determinants of transport mode chains and shipment size choices. We use the 2004/2005 Swedish Commodity Flow Survey (CFS) to estimate the choice models.<sup>3</sup> The main econometric work in this project involves modeling the interdependence between shipment size and transport chain choices using a joint (e.g. discrete-continuous or discrete-discrete) econometric model. Parameter estimates from this model will later be used for estimation of a full random utility logistic model. They could also be used to estimate transport time and cost elasticities to analyze policy outcomes.

The remaining part of this paper is organized as follows. Section II presents a brief overview of the logistic model component of the current SAMGODS model and outlines of how to implement stochastic logistic model. Section III presents joint econometric models for the estimation of transport chain and shipment size choices. Section IV describes the data and Section V presents main results. Finally, Section VI presents our main conclusions and suggestions for future works.

---

<sup>2</sup> Various haul, carrier, shipper and commodity characteristics have been shown to be important factors in determining these decisions (see for details, Abate and de Jong, 2013; Johnson and de Jong, 2011; Holguin-Veras 2002; Abdelwahab and Sargious, 1992; Inaba and Wallace, 1989; McFadden et al. 1986)

<sup>3</sup> The initial plan was to use the 2009 CFS. However, we had to use the earlier CFS because we could only obtain costs for 2004/2005 from the current SAMGODS.

## II. SAMGODS review

When the logistics model within the aggregate-disaggregate-aggregate (ADA) framework for Sweden (and Norway) was first conceived, the idea was that the logistics model would be estimated on data at the individual shipment level from the Swedish Commodity Flow Survey CFS (see: de Jong and Ben-Akiva, 2007, section 7).

Since the deterministic logistics module as such is complex and the estimation of disaggregate models would take a significant amount of time, a ‘preliminary’ or ‘prototype’ version of the logistics model was developed (see: de Jong and Ben-Akiva, 2007, section 8) in 2005/2006. This version did not require disaggregate estimation. Instead it relied on a cost minimisation per firm-to-firm (f2f) flow where for each f2f flow only one alternative (namely the one with the lowest total logistics cost) is chosen. This method therefore is a deterministic cost minimisation model, which is conceptually equivalent to the all-or-nothing assignment method often used for allocating traffic flows to a network. Because it uses different transport solutions for different firm sizes and shipment sizes, the all-or-nothing character of the deterministic model is reduced.

After the prototype had been developed, it has been improved in a number of rounds and also calibrated to aggregate data for a base year. Even though Sweden is one of the few countries in the world where disaggregate data on freight transport is available (in the form of the CFS), work on estimating disaggregate models was not commissioned until 2013, when the project started on a stochastic logistics module, that is reported in this report, and the logistics model within SAMGODS remained a deterministic model.<sup>4</sup> The logistics models within the ADA framework for Norway and Flanders are also deterministic models (Ben-Akiva and de Jong, 2013, section 4.6). The Danish national freight model, that is being developed at the moment and also follows the ADA setup, contains a module for the choice of mode to cross the Fehmarn Belt screenline that uses a random utility model estimated on disaggregate data (including stated preference SP surveys in the Fehmarn Belt corridor). Other transport chains however (e.g. within Denmark) are handled by a deterministic logistics model (Ben-Akiva and de Jong, 2013, section 4.6).

---

<sup>4</sup> Some estimation work involving models for shipment size and mode or transport chain on Swedish CFS data took place in the meantime at the University of Leeds (e.g. Johnson and de Jong, 2011) and as part of an internship at Significance of a student from the Delft University of Technology (Windisch et al., 2010), but also at Swedish Universities (Habibi, 2010; Liu, 2012).

There are however several arguments for going from the current deterministic to a random utility logistics model:

- 1) A deterministic model has a weak empirical foundation: the way transport agents behave in the model is not based on observed data, but on the assumption that they will choose the shipment size and transport chain that has minimum costs (and on data on transport networks, possible transshipment locations and expert knowledge on cost functions). Instead of observed behaviour, such a model represents normative behaviour: what would be the outcome if all freight transport agents behave fully according to standard economic theory (also see Tavasszy and de Jong, 2014, chapters 6 and 10)? The CFS can provide the main empirical data that is needed here (revealed preference data) for a basis in real life. So far, calibration of the logistics model has only been done at the level of very aggregate OD-level data,
- 2) This also implies that explanatory factors that are not part of the logistics costs are not included in the model. But the choice of transport chain also depends on factors such as reliability and flexibility of modes. Here the CFS only provides limited information. But at least it contains observed choice information, that is the result of all relevant factors together, which gives the possibility to estimate constants per transport chain alternative that give the average influence of factors such as reliability. To estimate separate coefficients for the effect of such factors one would need to collect additional data, presumably stated preference data and estimate a joint model on this data and the CFS (or transfer outcomes from stated preference models from other countries to Sweden, as in the planned transferability project on reliability in freight transport that aims to make use of results of the Norwegian and Dutch SP studies on the value of reliability (Krüger, N; Vierth, I; de Jong, G; Halse A; Killi, M, 2013). However, the task of including these other factors refers to further improvements of the SAMGODS, which will presumably take place after having moved from a deterministic to a (partly) probabilistic model. It is not necessary for a random utility model to include SP evidence; the data in the CFS is good enough for going from a deterministic cost minimisation logistics model to a random utility logistics model (for many of the commodity groups). Every commodity type where we can base the choice mechanism on observed data, as from the CFS, constitutes an improvement relative to the deterministic model. But we can improve the new random utility logistics model in a later phase with the results of (foreign or domestic) SP surveys. Another benefit

from these SP surveys is that that they can lead to better founded values of reliability for use in cost-benefit analysis.

- 3) A well-known disadvantage of deterministic models (that also takes place in case of all-or-nothing traffic assignment) is that the impact of changes in scenario variables (e.g. oil prices) or policy variables (e.g. a new road, railway or terminal) can lead to an implausibly large response, so-called ‘overshooting’ or ‘flip-flop’ behaviour. This happens when the relevant part of the logistics costs function is rather flat, and a small change in logistics costs can lead to a shift to completely different optimum shipment size and transport chain. This phenomenon does not always happen, it is corrected to some degree by using very many different f2f flows in the model, which do not have to move in the same way. And if the optimal alternative has much lower logistics costs than the second-best alternative, the model behaviour could be very stable. But the possibility of flip-flop behaviour is present and it has been noted that the SAMGODS model in some cases behaves too shaky to make a proper comparison of a reference case and a project case for cost-benefit analysis. However, the Swedish shipper market is quite concentrated and single large shippers’ logistic decisions of single large shippers can influence the overall modal split.<sup>5</sup>

The issues 1 and 3 above can be solved by estimating disaggregate random utility models on the CFS data: the observed shipment level data will then form the empirical basis for the behavioural coefficients of the model. By their nature these are probabilistic models because they include a stochastic component to account for the influence of omitted factors. A deterministic model effectively assumes that the stochastic component can be ignored; in other words: that the researcher has full knowledge on all the drivers of behaviour and that there is no randomness in actual behaviour. As a result of adding the stochastic component in the random utility model, the response functions (now expressed in the form of probabilities) become smooth instead of lumped at 0 and 1 as in a deterministic model. The project on the stochastic logistics module that is reported in this report is doing exactly this disaggregate estimation. On issue 2: the CFS does not contain information to include the more soft factors that may also influence the choice of shipment size and transport chain, but since it contains the information on choices really made, one can estimate constants per transport chain

---

<sup>5</sup> For examples see i. e. (Vierth, 2012)

alternative that give the average influence of these factors (besides the influence of the stochastic component).

The disaggregate models that are tested in the stochastic logistics module project are estimated for various commodity categories separately, but not necessarily for all commodity groups that are in the current SAMGODS (the estimation project also does not include imports flows into Sweden, which are in the current SAMGODS).

This project is only an estimation project. To establish a version of SAMGODS that is based on random utility modelling, the following further steps are required:

- a. Extend coverage to all commodities (and directions); move from the extended NSTR classification to the NST 2007 classification for commodities

If the estimated models do not cover all commodities (and directions, such as missing imports), that should be covered in SAMGODS, one must determine which behavioural rules should be used for any missing commodities (e.g. by further estimation, by relating to a similar commodity for which a model was estimated or by keeping a deterministic model for these commodities). Determining these rules is not much work (a few person-days), unless further estimation would be involved, which could take a few additional months to cover all commodity groups that are required and can be taken from the CFS. A new model version of SAMGODS that will use a random utility formulation for some of the commodities, but deterministic costs minimisation for other commodities is feasible, since the commodities are independent in the model.

The next version of the SAMGODS model will be based on NST 2007 as commodity classification. This is very different from the NST/R classification that the CFS 2004-2005 uses (CFS 2009 uses NST 2007). To maximise the possible use of models that estimated on the CFS 2004-2005, it is best to concentrate on commodities that can be translated one-to-one from the CFS 2004-2005 to the new model that will be based on NST 2007 (or where the conversion is straightforward). Later we may have to estimate further models on CFS 2009 and future CFSs.

The move from the extended NSTR commodity classification to the NST 2007 classification has to be synchronised with the ongoing update of the zone-to-zone base matrices (production-warehouse-consumption matrices, PWC matrices). As for the actual matrices

(CFS 2001 and CFS 2004/5), the commodity flow survey (next CFS) is one of the main data sources for estimating the PWC matrices.

b. Determine the annual firm-to-firm flows

For the probabilistic model, the routines to generate firm-to-firm flows (from the zone-to-zone flows) can remain as they are. The new models will be applied at the level of these firm-to-firm flows, so as input for the logistics choices we will know the annual firm-to-firm demand  $Q$ , as well as transport time and cost for all available transport chain and shipment size alternatives

c. Determine the input for applying the utility functions

The utility functions that are estimated in this project are similar to the current total logistics costs formulations. An important difference is that some of the cost components and some of the parameters (e.g. order costs, implied discount rate on the inventories in transit and in the warehouse or a value of time; see de Jong and Ben-Akiva, 2007, section 4) have now been estimated instead of given an assumed value by logistic cost experts<sup>6</sup>. But for the application of the estimated utility functions we will still need transport distance and time for the available shipments size and transport chains combinations. In the current logistics model, this is done by the BuildChain routine within SAMGODS. The new BuildChain program can remain similar to the current version, but adapted to reflect a more limited amount of available chain types. In principle this (for an adapted BuildChain routine) work for an adapted BuildChain routine has already been carried out to provide input data for the estimation in this estimation project. However, this refers to 2004/2005. If one wants to apply the model for later years (including future years), new networks need to be made, new assumptions on the transshipment locations need to be made, new network skims need to be made to determine the optimal routes per transport chain and new assumptions need to be made on the magnitude of various components of the logistics cost functions.

d. Implementation of the utility functions and their coefficients to determine shipment size and transport chain choice probabilities

---

<sup>6</sup> In the current implementation of the logistics model in Samgods, the cost of deterioration and damage during transit and stockout costs are not included. The CFS does not contain information to include these components explicitly in the random utility functions either.

In the current logistics model, the routine where the choice of shipment size and transport chain is determined is called ChainChoi. This is the part of the model that needs to be re-programmed considerably when moving to a random utility model. In a random utility setting, ChainChoi needs to determine the expected shipment size and probabilities for each of the transport chain alternatives for each annual f2f flow in the model and then sum shipments and probabilities over f2f flows.

In equation form what the logistics model does is to determine the sequence (for each flow of commodity k from firm m to firm n):

$$\{q, l\} = \{q, (h_1, t_1), (h_2, t_2), \dots, (h_i, t_i), \dots, (h_{I_l})\} \quad (1)$$

Where q is the shipment size (the same over the whole transport chain, though it can be consolidated with other shipments), l is the transport chain, h is a mode used on a leg of the chain and t is the next transshipment location. The index I,  $i=1, \dots, I_l$  denotes a leg of a transport chain (chain l has  $I_l$  legs).

Since we do not observe the transshipment locations  $t_i$  in the CFS, we cannot include this choice in estimation. Therefore we keep the split between the determination of the optimal transshipment points and the choice of transport chain separate as in the current model. The determination of the optimal transshipment locations for each available chain type from the set of available locations will be done in BuildChain, as in the present model. The random utility model in the new ChainChoi program will refer to the problem:

$$\{q, l\} = \{q, (h_1 | t_1), (h_2 | t_2), \dots, (h_i | t_i), \dots, (h_{I_l})\} \quad (2)$$

The deterministic version of ChainChoi solved this problem by finding a single (least cost) transport chain and shipment size alternative for each annual flow of commodity k from m to n. The probabilistic model then replaces this for specific commodities. We will now calculate for the f2f flow a number of probabilities, one for every available alternative. For instance for an alternative j (say an alternative with shipment size (class)  $q_0$  and direct road transport as transport chain), the probability is:

$$P(\{q, l\} = j) = \exp(U_j) / \sum_{\{q, l\}} \exp(U_{\{q, l\}}) \quad (3)$$

The numerator is the exponentiated utility function of alternative j, whereas the denominator is the sum over all available alternatives  $\{q, l\}$  of their exponentiated utilities.



These probabilities can be summed at the level of the origins and the destinations of the individual legs (e.g. from the sender  $m$  to the first transshipment location) over all f2f flows (and weighted by the volume of the annual flows) and by commodity type to get the OD matrices (as in the Swedish national passenger transport model SAMPERS, where application also involves summing probabilities). In calculating the transport costs, consolidation can be handled in the usual way, except that the volume using a certain mode between two transshipment points from a previous iteration now will also be based on a summation of probabilities. What becomes more difficult is to get a vehicle load factor at the level of the f2f flow (since we only have a probability per transport chain), but vehicle load factors per OD and commodity are possible. The Linear Programming model to take rail capacity restrictions into account can also still be used, though one will need to test how effective increasing the cost for certain rail alternatives will be in the new setup.

In terms of its dimensions, this will probably mean a simplification of SAMGODS, since the number of different models estimated for different commodity groups will be smaller than the number of commodities in the present SAMGODS (35). Also the number of transport chain alternatives in the estimated models will be smaller than in the current SAMGODS (67), as will be the number of vehicle/vessel types (35), mainly because of a lack of more detailed information in the CFS. If the Transport Administration should wish to include more transport chains or vehicle/vessel types than could be included in model estimation on the CFS, this could be made possible by combining the estimated random utility models with deterministic models for the allocation to finer categories given the outcomes of the former models. It will still be possible to use the 35 commodity-specific values for the cost parameters (inventory costs, order costs, ...), but groups of commodities will share the same cost coefficient in the utility functions. So it will still be possible that the model is operated on 35 separate commodities, but not all commodities will have their own set of model coefficients.

e. Testing and validating the implemented model

Finally, a test and validation of the resulting OD flows by mode against observed aggregate data for a (new) base year is recommended, since a model estimated on one data set (CFS flows) will not necessarily match with other data, such as traffic counts.

### III. Econometric Framework

Econometric studies of freight mode/vehicle choice are based on the key insight that mode/vehicle choice entails simultaneous decisions on how much to ship (see for example, Abate and de Jong, 2013; Johnson and de Jong, 2011; Holguin-Veras 2002; Abdelwahab and Sargious, 1992; Inaba and Wallace, 1989; McFadden et al. 1986). This simultaneity in decisions requires the use of joint econometric techniques such as discrete-continuous models.<sup>7</sup> In addition to recognizing this simultaneous decision process, these studies show that various haul, carrier, and commodity characteristics affect the decisions on the optimal shipment size choice and the choice of transport mode.<sup>8</sup>

McFadden et al. (1985) and Abdelwahab and Sargious (1992) provide the most complete formulation of the firm's simultaneous choice of mode and shipment size. However, the applicability of their models is rather limited when decision makers have to choose from more than two mode alternatives. Holguin-Veras (2002) and Johnson and de Jong (2011) used an indirect approach to address the simultaneity problem. They model the discrete choice component (vehicle class choice in Holguin-Veras and mode choice in Johnson and de Jong) as the structural equation of interest, replacing actual shipment with prediction from a shipment size auxiliary regression. This approach is an interesting one when the main focus is the vehicle/mode choice because it is possible to apply advanced discrete choice models that overcome the independence of irrelevant alternatives (IIA) problem that most selection models suffer from. But, unlike McFadden et al. (1985), this approach does not allow for testing for simultaneity bias.

Due to the above technical complexities, mode choice in freight transport is usually studied in isolation (or in combination with network assignment, as multi-modal assignment). However, as pointed out by Johnson and de Jong and (2011, pp: 1) mode and shipment size are closely linked decisions. Large shipment sizes usually coincide with higher market shares for non-road transport, whereas there is a high correlation between road transport and small shipment sizes. In search of robust parameter estimates, in this project we formulate and review three disaggregate models specified as: an independent mode choice model (which is the most

---

<sup>7</sup> An alternative sometimes is discrete-discrete (by classifying shipment sizes to a number of size classes), as in Johnson and de Jong and (2011) and Windisch et al. (2010), using Swedish CFSs of 2001 and 2004/05, respectively.

<sup>8</sup> While we only consider the weight of shipment size as an endogenous variable, we note that shipment volume (in m<sup>3</sup>) is also an important factor which shippers consider jointly with mode choice decisions. We cannot model shipment volume because the CFS does not contain this information.

common formulation), a joint model with discrete mode and discrete shipment size choice and a joint model with discrete mode and continuous shipment size choice. The models are specified as follows:

1. An independent mode choice model

$$U_{11} = \beta_1 X_1 + \varepsilon_1 \quad (4)$$

2. A joint model with discrete mode and discrete shipment size choice

$$U_{12} = \beta_2 X_2 + \phi_2 G_2 + \varepsilon_2 \quad (5)$$

3. A joint model with discrete mode and continuous shipment size choice

$$U_{13} = \beta_3 X_3 + \phi_3 G_3 + \varepsilon_3 \quad (6.1)$$

$$SS_{13} = \beta_3 G_3 + \varepsilon_{32} \quad (6.2)$$

Where:

- $U_{11}$  and  $U_{13}$  are the utilities derived from mode 1 in model 1, 2 and 3 respectively
- $U_{12}$  is the utility derived from a discrete combination of mode and shipment size
- $X_1$ ,  $X_2$  and  $X_3$  are vectors of independent variables explaining mode choice
- $G_2$  and  $G_3$  are vectors of independent variables explaining shipment size choice
- $\beta_1, \beta_2, \beta_3, \phi_2, \phi_3$  are vectors of parameters to be estimated
- $SS_{13}$  is shipment size
- $\varepsilon_1, \varepsilon_2$  and  $\varepsilon_{32}$  are error terms

Equation 1 is a simple multinomial choice model formulation that only considers mode choice decisions of firms. The probability of choosing a given mode of transport is a negative function of transport cost and transport time, the two most common explanatory variables in  $X_1$ . Although its formulation allows for application of advanced discrete choice models, a formulation such as Equation 4 disregards the influence of shipment size choice decisions. Equation 5 is a more advanced formulation that accounts for shipment sizes. Here  $U_{12}$  is the utility derived from the choice of a discrete combination of mode and shipment size choice. In addition to explanatory variables that affect mode choice ( $X_2$ ), it controls for additional set of explanatory variables that affect shipment size choice decisions ( $G_2$ ).

Earlier works (De Jong (2007); Windisch (2009) on the Swedish CFSs estimated both mode and shipment size as discrete choices, but clearly shipment size is a continuous variable.<sup>9</sup> Johnson and De Jong (2011) correctly noted that both assuming independence between mode and shipment size choice and discretising the continuous information on shipment size may be interpreted as forms of specification error. Model 3 overcomes this basic problem by estimating a joint discrete-continuous model of mode-shipment size model. Equation 6.1 is the discrete mode choice model and Equation 6.2 is a continuous part for shipment size.

Note that the two error terms,  $\varepsilon_3$  and  $\varepsilon_{32}$ , are correlated because of the possibility that the transport planner makes a choice between transport chains and at the same time decides how much to load on the chosen transport modes. We note that decisions on the optimal shipment size and mode are generated from the same optimization problem, which implies that the error terms are likely to be correlated. Ignoring this correlation would lead to a specification bias. For this reason, we need to model mode choice and shipment size choice using a discrete-continuous model. Accordingly, we rely on a basic econometric model developed by Dubin and McFadden (1984) to address this bias in the context of a polychotomous-continuous choice. A multinomial logit model (MNL) of mode choice is estimated in the first step (Equation 6.1) followed by estimation of the shipment size equation (6.2) given the mode choice decision (see Abate and de Jong, 2014, for details of how to apply Dubin and McFadden's model in freight transport demand modeling context).

#### **IV. Data**

The main data source for this project is the 2004/5 Swedish Commodity Flow Survey (CFS). The data has 2,986,259 records. Each record is a shipment to/from a company in Sweden, with information on origin, destination, modes, weight and value of the shipment, sector of the sending firm, commodity type, access to rail tracks and quays, etc.<sup>10</sup> From this we selected a file of around 2,897,010 outgoing shipments (domestic transport and export, no import) for which we have complete information on all the endogenous and exogenous variables.

Although the CFS data is extensive, it does not contain information on important variables such as transport costs and transport time. Given the importance of these variables in

---

<sup>9</sup> Windisch's and de Jong's models are based on the Swedish 2004/2005 and 2001 CFSs, respectively.

<sup>10</sup> In the CFS a shipment is defined as a unique delivery of goods with the same commodity code to/from the local unit or to/from a particular recipient/supplier (SIKA, 2004).

mode/shipment size choice analysis, the logistic module of the SAMGODS model was used to generate transport cost and time variables for each shipment in the CFS based on a number of the transport mode chain and shipment size combinations (see below for definition of these combinations).<sup>11</sup> These variables were generated both for the chosen mode-shipment alternatives in the CFS and for potential non-chosen alternatives tailored to each shipper based on the transport network of the origin and destination of their shipment.

The CFS classifies transport mode chains to chains inside Sweden and chains outside Sweden. Table 1 presents the distribution of transport chains inside Sweden (the number of times each option is chosen). Trucking accounts for the overwhelming majority of the shipments (95.79%) followed by chains which involve waterborne transport modes (a ship vessel and ferry).<sup>12</sup> The high share of trucking is also evident in its percentage share in weight and value of the whole shipments. Table 2 presents similar distributions for international shipments. As seen vessel transport accounts for the highest share for international shipments in terms of share in total frequency, shipment weight and value.

---

<sup>11</sup> This task was undertaken by Jaap Baak from Significance. The cost functions used for choice set generation are outlined in de Jong et al (2010).

<sup>12</sup> We defined transport chain alternatives based on their frequency in the CFS. Transportation chains that occurred with a frequency of 96 or higher were considered as possible choice options.

**Table 1: Domestic Transport chains for outgoing shipments- as stated in the 2004/05 CFS**

Chain	Frequency	% share of shipment frequency	% share of shipment weight (KG)	% share of shipment value (SEK)
Truck	2,767,569	95.79	91.93	77.56
Truck-Truck	413	0.01	0.0003	0.04
Rail	4,797	0.17	1.25	1.87
Truck-Rail	6,380	0.05	0.05	0.26
Truck-Rail-Truck	148	0.01	0.001	0.01
Rail-Vessel	5,759	0.20	1.38	0.86
Ferry	154	0.01	0.004	0.02
Truck-Ferry	13,375	0.47	0.2	1.37
Ferry-Truck	461	0.02	0.0002	0.01
Truck-Ferry-Truck	436	0.02	0.0034	0.07
Vessel	42,990	1.50	1.77	3.0
Truck-Vessel	4,718	0.16	0.2	1.05
Truck-Vessel-Truck	88	0.00	0.001	0.017
Air	7,537	0.26	0.002	0.21
Truck-Air	5,440	0.19	0.01	0.74
Air-Truck	182	0.01	0.0	0.01
Truck-Air-Truck	1,935	0.07	0.0001	0.2
Truck-Rail-Air	6,885	0.24	0.0	0.0
Missing	7826	0.29	3.11	6.9
Total	2,877,093	99.5	99.9	94.2

**Table 2: International Transport chains for outgoing shipments- inside and outside Sweden as stated in the 2004/05 CFS**

Chain	Frequency	% share of shipment frequency	% share of shipment weight (KG)	% share of shipment value (SEK)
Truck	90,851	48.33	3.19	11.81
Truck-Truck	171	0.10	0.005	0.12
Rail	910	0.53	0.93	1.37
Truck-Rail	54	0.03	0.03	0.03
Truck-Rail-Truck	19	0.01	0.01	0.02
Rail-Truck	582	0.34	0.47	0.56
Rail-Vessel	33	0.02	0.05	0.02
Truck-Rail-Ferry	203	0.12	0.06	0.04
Ferry	342	0.20	0.36	0.67
Truck-Ferry	1,659	0.97	0.24	0.71
Ferry-Truck	32,701	19.18	5.15	13.75
Ferry-Rail	118	0.07	0.25	0.55
Ferry-Rail-Truck	116	0.07	0.07	0.12
Truck-Ferry-Truck	1,069	0.63	0.14	0.38
Vessel	25,303	13.46	64.07	46.52
Truck-Vessel	790	0.46	0.15	0.40
Vessel-Truck	13.46	1.94	2.16	3.44
Truck-Vessel-Truck	92	0.05	0.02	0.06
Vessel-Rail	563	0.30	17.99	2.77
Air	6,825	3.92	0.12	1.41
Truck-Air	1,059	0.59	0.003	0.51
Air-Truck	8,620	4.59	0.11	3.82
Truck-Air-Truck	3,078	1.64	0.004	1.34
Total	175023	97.6	95.6	90.4

To see the distribution of shipment sizes we classified the continuous weight variable in the CFS into 16 categories as shown in Table 3. A quarter of the total shipments fall in the first category (0-50 kg). This prevalence of small shipments reflects the dominance of trucking which is usually preferred for its flexibility and reliability. Categories 10 and 11, ranging from 35 to 45 tonnes, account for 23.71%. These are also well within a full truck load range, again showing the dominant role of trucking.

**Table 3: Weight Categories inside and outside Sweden as stated in the 2004/05 CFS**

Category	From (kg)	To (kg)	Freq.	%
1	0	50	703,939	24.36
2	51	200	153,222	5.3
3	201	800	160,420	5.55
4	801	3000	157,891	5.46
5	3001	7500	136,884	4.74
6	7501	12500	127,583	4.42
7	12501	20000	161,688	5.6
8	20001	30000	210,919	7.3
9	30001	35000	207,622	7.19
10	35001	40000	344,695	11.93
11	40001	45000	340,498	11.78
12	45001	100000	153,857	5.32
13	100001	200000	10,835	0.37
14	200001	400000	7,238	0.25
15	400001	800000	6,417	0.22
16	800001	-	5,641	0.2
Total			2,889,349	100

Table 4 presents the commodity groups in the whole (both incoming and outgoing shipments) 2004/5 CFS. Four commodity groups (Timber, Foodstuff and animal fodder, Machineries, Leather and Textile, Live animals) constitute about 80% of the total shipments. It is important to note here that the 2004/05 CFS comes from two sources. The first is a sample survey for mining, manufacturing and the wholesale sectors. The second source is a register based survey for forest and logging products, sugar beets cultivation, and dairy products (this a reason why timber accounts for half (49.7%) of the whole CFS).<sup>13</sup> The table also reports average value and weight per shipment for each commodity group.

<sup>13</sup> The register data for timber flows are not door-to-door flows (PWC-flows) but do only comprise OD-links for road. For the time being Trafikanalys is carrying out a pre-study with the goal to include the whole transport chains for timber ( Henrik Pettersson, Trafikanalys 2014-02-27).

**Table 4: Share of different commodity groups in the CFS 2004/5 (both outgoing and incoming shipments)**

Commodity Code	Definition	No. of Shipments	% share		
			shipments	weight	value
1	Cereals	40,929	1.4	3.30	2
2	Potatoes, other vegetables, fresh or frozen, fresh fruit	89,644	3	2.7	0.9
3	Live animals	128,139	4.3	0.5	2.7
4	Sugar beet	3,930	0.1	0	0.1
9	Textiles, manmade fibers, other raw animal and vegetable materials	29,908	1	0	0.5
10	Foodstuff and animal fodder	314,915	10.6	0.5	5.1
11	Oil Seeds and oleaginous fruits and fats	9,710	0.3	1	1.8
12	Solid minerals	514	0	0.2	0.1
13	Crude Petroleum	118	0,0	7.9	10.6
14	Petroleum products	63,784	2.1	16.8	33.7
15	Iron ore, iron and steel waste and blast-furnace dust	420	0	2.1	0.7
16	Non famous ores and waste	763	0	0.2	0.6
17	Metal products	40,596	1.4	0.3	1.5
18	Cement, lime, manufactured building materials	37,023	1.2	0.5	0.6
21	Natural and chemical fertilizers	245	0	0	0
22	Coal chemicals	1,751	0.1	0	1.5
23	Chemicals other than coal chemicals and tar	61,801	2.1	0.4	3.2
24	Paper pulp and waste paper	1,092	0	0.2	0.3
25	Transport Equipment and parts thereof	60,266	2	0.1	6.9
26	Manufactures of metals	56,497	1.9	0.2	3.2
27	Glass, glassware, ceramic products	12,035	0.4	0	0.5
29	Leather textile, clothing, paperboard etc.	193,595	6.5	0.2	2.7
32	Machinery, apparatus, engines (assembled and unassembled), and parts thereof	253,619	8.5	0.1	6.5
33	Paper, paperboard, and manufactures thereof	70,623	2.4	0.6	2.5
34	Wrapping Material	1,409	0	0.1	0.2
5/31	Timber	1,484,605	49.7	60.3	9.8
6/7	Wood (chips, wood waste, sliced, peeled, squared or sawed)	23,342	0.8	1.6	1.3
19/20	Earth, and gravel, other crude and manufactured minerals	3,305	0.1	0.4	0.1
		2,984,578	100	100	100

Since the main objective of this project is finding the best estimation techniques and robust parameter estimates from the joint modeling of transport mode chain and shipment size choice decisions, we focus in this paper two commodity groups, from the CFS, metal products and chemical products and conduct an in-depth analysis. In Section V, we also review results from previous studies which used the Swedish CFS to have an idea of the robustness of parameter estimates when some of these techniques are applied on all commodity groups in the CFS.



At this stage of the project, it is more instructive to analyze selected commodities rather than all commodities identified in the CFS for a number of reasons. First and for most, as shown in Table 1, trucking is the most dominant transport chain. In fact for ten commodity groups (namely, groups 1, 2, 3, 4, 10, 12, 13, 14, 21 and 31) the share of trucking is more than 98%. Clearly, there is little to learn about the determinants of mode choice decision of shippers when there is such an overwhelming dominance of one mode of transport. For the remaining 16 commodity groups (including metal products and chemical products, analyzed in depth here), there is relatively less dominance of trucking. In future studies, one has to look at these groups of commodities to get more insights into the mode/shipment size decisions.

The second reason for looking at selected commodities is the change of commodity classification from NSTR to NST 2007. The chosen commodity groups should ideally be easily comparable in the two classification systems to ease transferability of parameter estimates between different CFSs. Third, due to problems with the recorded transport chains in the CFS data and transport network, generating transport cost data inputs has proved to be problematic. In addition to metal products and chemical products, we tried to include other commodity groups from the sub-group of 16 commodities where trucking is less dominant. However, we haven't managed to replicate the transport chains in the CFS in a reasonable manner in the cost estimation exercise. In future studies, the remaining commodities should be closely investigated. Finally, narrowing the number commodity groups is also necessary to ease the implementation of advanced modeling techniques (applying some discrete choice models on about 2.9 million observations is rather daunting, if not impossible).

We applied two estimation techniques, namely discrete-discrete (Eq. 5) and discrete-continuous (Eq. 6.1 and Eq. 6.2) using observations from the metal products commodity group. As for chemical products commodity groups, we applied only the discrete-continuous models. For the discrete mode and discrete shipment size model, we classified the continuous weight variable from the CFS into 16 categories (similar to Table 3 above). Table 5A shows distribution of transport chains for metal products. Five main transport chains namely: Truck (93.58%), Rail (4.13%), Truck-Rail-Truck (0.10%) Truck-Ferry-Truck (1.77%) and Truck-Vessel-Truck (0.42%) were recorded in the CFS. The most common shipment size category for metal products is category 1 (0-50 kg), similar to the general pattern in the whole CFS data.

**Table 5A: Domestic Transport chains for outgoing shipments- Metal Products**

Chain	Frequency	% share of shipment frequency	% share of shipment weight (KG)	% share of shipment value (SEK)
Truck	36,822	94.06	22.86	48.4
Rail	1,784	4.56	9.16	23.67
Vessel	127	0.32	63.64	16.41
Truck-Rail	59	0.15	0.91	2.23
Truck-Ferry	182	0.46	0.81	2.41
Truck-Vessel	15	0.04	0.55	0.69
Truck-Air	7	0.02	0.00	0.75
Rail-Truck	5	0.01	0.16	0.36
Rail-Ferry	1	0.00	0.00	0.00
Truck-Ferry-Truck	26	0.07	0.29	0.78
Truck-Vessel-Truck	2	0.01	0.05	0.08
Missing	86	0.21	1.34	3
	39,116			
Total		100	100	100

**Table 5B: Domestic Transport chains for outgoing shipments- Chemical Products – Modeled**

Chain	Frequency	% share of shipment frequency	% share of shipment weight (KG)	% share of shipment value (SEK)
Truck	30,576	81.22	46.73	63.37
Truck-Rail-Truck	35	0.09	0.87	0.15
Truck-Ferry-Truck	5,551	14.74	23.74	20.79
Truck-Vessel-Truck	1,486	3.95	28.66	15.69
Total	37648	100	100	100

Table 5B shows the distribution of transport chains for chemical products. Note that all transport chain alternatives start and end with trucking. Mode choice entries in the CFS where rail, ferry and vessel are stated as the only used mode needed to be updated. This is because often in reality, for shippers of such products trucks are used in the first and final leg of a transport chain. Furthermore, judged by the location shippers and the transport network available to them, trucking is needed both at the first and last leg to access other modes of transport. Finally, in order to estimate transport cost and time variables for chosen and non-chosen alternatives, adding trucking at either end was also necessary.<sup>14</sup>

<sup>14</sup> This is a rather pragmatic solution. In future studies, the validity of such an assumption should be closely investigated on commodity by commodity basis. Future design and collection of the CFS can address some of these problems by asking the right set of questions which solicit all the transport modes used for a shipment.

Descriptive statistics are given in Table 6 for the whole CFS, metal products and chemical products. As seen for 2% of the total shipments in the CFS, senders had access to rail at origin and 0.4 % of them had access to quay at origin. The equivalent figures for metal products (chemical products) are 57 (0.03) % and 0.5 (0.03) %, respectively. It appears that average shipment values are somewhat comparable, whereas average shipment weights of metal products and chemical products are much less than their whole CFS equivalent. Furthermore, on per shipment basis, to ship an average metal product (chemical product) shipment, it costs SEK 3,684(6,783) and takes 3.5 (10.37) hours. The average shipment distances are 256 km and 616 km, respectively.

**Table 6: Descriptive statistics**

	Mean		
	All Commodities	Metal products <sup>1</sup>	Chemical Products
Rail Access (%)	2	57	0.03
Quay Access (%)	0.4	0.5	0.03
Shipment Weight (KG)	26,011	6,556	4,023
Shipment Value (SEK)	37,122	31,943	42,907
Value Density <sup>2</sup> (SEK/KG)	1,231	24	288
Transport Costs (SEK)		3,684	6,783
Transport Time (hours)		3.5	10.37
Transport Distance		256	616
No. of Observations	2,897,175	34,627	37,648

<sup>1</sup> Metal products include pig iron, crude steel, iron alloys, rolled steel, beams, wired rods, steel plates, strip sheets and non-ferrous metal.

<sup>2</sup> Note that the mean of the value density variable is not calculated by dividing the mean values of shipment value and weight for the whole sample. It is calculated for as the mean of the value density for each shipment in the CFS. The two values could be close to each other if both variables are greater than or equal to one. For some observations, however, the weight and value variables are recorded as having values less than one in the CFS, which explains the divergence between the two statistics.

### **Econometric Results**

This section presents results from the econometric specifications outlined in Section III. Since our main objective in this paper is finding robust parameter estimates of transport chain and shipment size choice models, we present results both from previous studies which used the Swedish CFS and from those obtained during the course of this project.

Table 7 presents results from two Multinomial Logit (MNL) models based on discrete-discrete model (Equation 5) using the 2004/5 CFS.<sup>15</sup> Results under Model 1 are from Windisch (2009) for all commodity groups but limited to outgoing shipments inside Sweden. Those under Model 1 are from the current project and are only for metal products (outgoing shipments inside and outside Sweden). As expected, in both models transport cost has negative effect on the utility of a choice alternative, implying that higher delivery costs make a choice alternative less attractive. The magnitude the cost parameter estimate is higher by a factor of 10 under Model 1 than Model 2. This is probably due to the higher number of observations used in Model 1. However, in both models the effect of cost is rather too low.<sup>16</sup>

**Table 7: Multinomial logit model of discrete shipment size and transport chain choice**

Variable	Model 1 (all commodities)		Model 2 (metal products)	
	Relevant Alternative	Coefficient estimates	Relevant Alternative	Coefficient estimates
Cost	All chains	-0.0011***	All chains	-0.0001***
Transport time (in hours) times value of goods (in SEK)			Truck	-1.98e-7***
Proxy to Rail/Quay Value Density	Rail, Ferry, Vessel	0.729***	Rail	
Value Density 1	Weight Cat 1- 5	-5.79***	All modes: smallest 2 shipment sizes	0.122***
Value Density 2	Weight Cat 6- 9	4.49***		
Value Density 3	Weight Cat 1	0.961***		
Time of Year (Summer)		1.02***		
Rail			Constant	-3.46***
Ferry			Constant	-4.13***
Vessel			Constant	-5.76***
Truck			Fixed	
Observations	2,225,150		33,868	
Final LL value	-1,601,661		-77,652.81	
Rho <sup>2</sup> (0)	0.737			
Rho <sup>2</sup> (C)	0.314		0.384	

Significance is marked as: \*\*\* p<0.01, \*\* p<0.05, \* p<0.1. Source: Model 2 own estimation and Model 1 Windisch (2009)

Under Model 2 the variable for inventory costs during truck transport (transport time times value of the shipment) has the right (negative) sign, and is highly significant. This variable

<sup>15</sup> Note that for consistent estimation of standard discrete choice models (such as MNL) it is not necessary to re-weight the observations (e.g. using the CFS weighting factors). On an exogenously selected sample, as it is the case with the CFS, consistent estimates will be obtained.

<sup>16</sup> A more meaningful comparison of results from different discrete choice models is comparison of elasticities. The final part of this Section presents this comparison.

captures time costs related to the capital cost of the inventory in transit and maybe also to deterioration and safety stock considerations. For truck transport this turns out to be statistically significant, but the point estimates are rather too low. We expect to find a more meaningful effect if one applies the same model on more commodity groups.

For Model 1 we see that the dummy variables for rail and quay proximity have significant positive parameters. These dummy variables were only included in the utility functions of choice alternatives where the mode rail and/or vessel were used as first or second mode in the chosen transportation chain. The interpretation of the parameter values is that shippers located in the proximity of rail and/or quay docking facilities are more likely to choose chains that start with a ‘rail’ or ‘vessel’ leg (or use these modes on the second leg of the chain).<sup>17</sup>

In both models we see a significant positive effect for the value density variable. This implies that high value densities correlate with smaller shipment sizes, which might also imply frequent shipments. For Model 2 the transportation chain specific constants all show a negative sign implying that all transportation chains are less attractive compared to the ‘truck’ chain. This is expected given that the reference chain type, chain type 1 (‘Truck’), is usually chosen for its flexibility and ease of access. While the results reported on Table 7 are plausible, they come from a model where shipment size is treated as a discrete variable, but clearly shipment size is a continuous variable.<sup>18</sup> What follows presents results from theoretically sound models in which shipment size is treated as a continuous model.

Table 8 presents the best model results from Johnson and de Jong (2011) who use the 2001 Swedish CFS. Their modeling approach is a variant of Equation 6.1 and is based on the work of Holguin-Veras (2002). The mean cost and time coefficient have a significant negative effect. Furthermore the results show significant and substantial unobserved heterogeneity in the cost coefficients and the air time coefficient. Johnson and de Jong (2011) report that between 5 and 10% of these costs and time coefficients values get a positive sign. The effect V1, which measures the absolute difference between the average and observed shipment for a given mode  $l$  and the estimated shipment size, is negative. The implication of this result is that at its average observed shipment size, the capacity of a mode and a shipment match very well.

---

<sup>17</sup> Based on these results Windisch (2009) argues that changes in infrastructure that improve shippers’ access to rail and waterway networks might have a significant effect on decision making that would result in less road freight transport.

<sup>18</sup> As a sensitivity analysis we split the data to domestic and international and applied a mixed MNL model. Results from there exercise are presented in Table A1 in appendix 2.

When the shipment deviates more from this average (either smaller or larger), the probability of choosing that mode for this shipment will decrease as implied by the negative sign.

**Table 8. Mixed multinomial logit model including estimated shipment size at instrumental variable**

Variable	Relevant alternatives	Coefficient	t-ratio	Distribution (standard deviation)	t-ratio
Road constant	Road	3.169	126.6		
Rail constant	Rail	-1.107	-21.1		
Water constant	Water	-1.385	-22.6		
Company is in biggest size class (sector-dependent)	Rail	.279	8.1		
Commodity type is metal products	Rail	-.471	-9.3		
Commodity type is chemical products	Rail	-.0338	-.6		
Absolute difference between estimated and average observed shipment size $V_1$	All	-.240	-63.0		
Transport cost in SEK/shipment	Road, rail, water, air	-.0000240	-35.2	-.0000142	-54.5
Transport time in hours (*10)	Road	-.00745	-32.2	.0000918	.5
Transport time in hours (*10)	Rail	-.00317	-17.1	.000132	.5
Transport time in hours (*10)	Air	-.328	-20.4	.167	19.2
Number of observations: 744860					
Final log likelihood value: -124835.5142					
Pseudo rho-squared w.r.t. zero: .8791					
Pseudo rho-squared w.r.t. constants: .0529					

Source: Johnson and de Jong (2011) Table 7.

To get insights into what determines shipment size decisions of shippers we estimated Equation 6.2 for all commodity groups, metal products, and chemical products. Table 9 presents results from this exercise where the dependent variable is the log of shipment size. Most of the explanatory variables have expected signs and are statistically significant. As seen from estimates for the value density variable, high value goods are shipped in smaller

quantities. The interpretation is that high value products are shipped in smaller quantities which is usually the case in reality.

For metals products and chemical products shipments destined to distance places are shipped in larger quantities as implied by the significant and positive effect of the distance variable coefficients. Shippers who have access to rail or quay at origin ship larger quantities (except chemical product shippers with access to quay at origin). In all the three cases, shipments are larger if they are destined outside Sweden. We found opposite effects for time of year indicator (summer), negative for all commodity and positive for the two commodity groups. Finally, shippers who have larger number of total shipments per reported period tend to ship in smaller quantities. This result is interesting and reveals the tradeoff shippers make between inventory holding and shipment frequency.

**Table 9: Independent Shipment Size model**

	All Commodities	Metal Products	Chemical Products
<b>VARIABLES</b>			
Log. Value Density	-0.90***	-1.70***	-1.15***
Log. Distance		0.21***	0.08***
Access to Rail at Origin	0.79***	0.22***	0.92***
Access to Quay at Origin	0.20***	0.44	-0.64***
International Shipment	0.96***	1.44***	0.68***
Log. Total Shipments	-0.44***	-0.94***	-0.31***
Summer	-0.01**	1.06***	0.11***
Commodity Class	Included		
Constant	8.08***	13.17***	10.24***
Observations	2,897,128	34,627	37,648
R-squared	0.57	0.21	0.55

Significance is marked as: \*\*\* p<0.01, \*\* p<0.05, \* p<0.1. Source: Own estimation

While the results on Table 9 reveal interesting findings on the main determinants of shipment size, the specification they are based on doesn't take into account the transport mode chain choice problems of shippers. Tables 10 and 11 present a conditional (i.e. conditional on or accounting for transport mode chain choice) shipment quantity models for metal products and chemical products, respectively. The models were estimated using the Dubin-McFadden model that jointly estimates Equations 6.1 and 6.2.<sup>19</sup> The estimation procedure involves two steps (but estimation is done simultaneously) where in the first step the selection probabilities are estimated using Equation 6.1. The second step consists of using the estimates from the first step to construct the selectivity correction terms which will be appended to Equation 6.2.

**Table 10: Conditional shipment quantity model using the Dubin-McFadden Method – Metal Products**

	Truck	Rail	Truck-Rail-Truck	Truck-Ferry-Truck	Truck-Vessel-Truck
Log. Value Density	-1.86***	-0.56**	-0.67	-0.86***	-0.26
Log. Distance	0.05	0.72**	-2.80	-0.44	-0.83
Log. Total Shipments	-0.61***	-0.25***	0.25	0.12	.61
International Shipment	0.59***	-0.04	-0.27	-0.42	-3.05***
Select_Truck (T)		1.88*	3.14	2.41**	1.80
Select_Rail	-3.7***		1.98	-4.62**	-0.51
Select_T-Rail-T	12.37***	4.36**		3.23**	3.05
Select_T-Ferry-T	-4.51***	-1.49**	-3.29		-4.22
Select_T-Vessel-T	-4.07**	-0.51	-2.14	-0.76	
Summer	Included	Included	Included	Included	Included
Cargo Type	Included	Included	Included	Included	Included
Firm-Size	Included	Included	Included	Included	Included
Constant	10.36***	6.86**	30.07	16.5***	19.24**
No. Observations	32,348	1,478	43	600	158

Significance is marked as: \*\*\* p<0.01, \*\* p<0.05, \* p<0.1. Source: Own estimation

<sup>19</sup> The STATA 'selmlog' command developed by Bourguignon et al. (2007) was used to estimate the two D/C models.



**Table 11: Conditional shipment quantity model using the Dubin-McFadden Method – Chemical Products**

	Truck	Truck-Rail-Truck	Truck-Ferry-Truck	Truck-Vessel-Truck
Log. Value Density	-0.96***	-0.005	-1.57***	-0.37
Log. Distance	0.05***	-0.11	-0.50**	0.01
Log. Total Shipments	-0.32***	0.02	-0.76***	-.08**
International Shipment	-0.04**	-0.09	1.04***	-1.43***
Select_Truck (T)		0.40	1.89***	1.09***
Select_T-Rail-T	-8.36***		0.32	-0.24**
Select_T-Ferry-T	-0.45	-0.64		-0.81***
Select_T-Vessel-T	8.92***	0.34	-2.34***	
Summer	Included	Included	Included	Included
Cargo Type	Included	Included	Included	Included
Firm-Size	Included	Included	Included	Included
Constant	10.53***	12.07	21.79***	19.18***
No. Observations	30,576	35	5,551	1,486

Significance is marked as: \*\*\* p<0.01, \*\* p<0.05, \* p<0.1. Source: Own estimation

As seen in Table 10 and Table 11, accounting for transport mode chain selection gives different results to the ones in Table 9 (independent shipment size models). For metal products, although value density has the right negative effect on shipment size for all chains, it is only significant in the “Truck”, “Rail” and “Truck-Ferry-Truck” chains. The effect of distance becomes mixed as well and it is only significant for “Rail” chain. Similar differences are observed for chemical products as well. These differences are explained by the fact we now account for mode chain choice decision of shippers. The selectivity corrections terms (Select\_Truck etc) appear to be significant for most chains, implying that the joint estimation procedure is appropriate.

Table 12 reports the marginal effects from the coefficients of the selection models used for the discrete continuous models presented in Tables 10 and 11.<sup>20</sup> The estimates indicate the proportional change in the probability of choosing the transport chains for a proportional change in cost and time. Since these are proportional changes, they can be interpreted as elasticities. For metal products, if cost increases (i.e. for all chains) by 10% the demand for Truck and Truck-Rail-Truck chains decreases (relative to the other options) by 6% and 0.1%,

<sup>20</sup> The MNL model results on which these marginal impacts are based on are not reported, but can be accessed from the authors up on request. Table A2 in appendix 2 reports elasticity comparison for three models (similar to ones presented in this report) conducted by Johnson and de Jong (2011) using the 2001 CFS.

respectively. Whereas the demand for Rail, Truck-Ferry-Truck and Truck-Vessel-Truck increases (relative to the other options) by, 5%, 1% and 0.02%, respectively. The remaining results are interpreted likewise.

**Table 12: Average Marginal Effects**

Chains	Metal Products		Chemical Products	
	Cost	Time	Cost	Time
Truck	-0.06	0.01	-0.24	0.02
Rail	0.05	-0.03		
Truck- Rail- Truck	-0.001	0.003	0.002	-0.001
Truck- Ferry- Truck	0.01	0.01	0.27	-0.08
Truck-Vessel- Truck	0.0002	0.01	-0.02	0.08

## V. Conclusions and suggestions for future work

Building on the basic insight that decisions on freight transport mode and on shipment size are inter-dependent, in this paper we have reviewed and estimated several econometric models. We have also outlined how results from this exercise could be used as input for updating the Swedish national freight model system (SAMGODS) from its current deterministic version to a stochastic one. The 2004/5 Swedish National Commodity Flow Survey was used to estimate various models specifications at the level of individual shipments. These models simultaneously explain mode and shipment size, where shipment size can either be a discrete or a continuous variable. We have identified that variables such as cost, time, having access to rail or quay at origin and distance are important determinants of shipper's mode and shipment size choices.

A model where continuous shipment sizes have been converted into discrete categories leads to a model that has different behavioural responses than the model with continuous shipment size. The latter specification can be seen as the preferred model because it takes account of the endogenous nature of shipment size and uses the shipment size data as they come from the survey. However, applying this model on large dataset such as the CFS using standard

software could be challenging. Therefore, in practical applications; a model with two discrete choices might be preferable (see Johnson and de Jong, 2011 for more explanation).

Future modelling exercises can extend the models presented here in three important ways. First, there are several individual shipments records in the CFS which were sent by the same shippers. None of the models reviewed and applied here take into account this panel nature of the data. It is, therefore, important to apply models that control for individual (fixed) effects to improve model predictions.

Second, the discrete-continuous models presented here take shipment size as the main variable of interest and are based on selection models estimated by MNL models. While these models are advanced and theoretically sound, practical applications can be problematic. An alternative approach is the discrete-continuous model suggested by Holguin-veras' (2002) (and applied by Johnson and de Jong, (2011) on the 2001 CFS, see Table 8). This approach is an interesting one when the main focus is mode choice because it is possible to apply advanced discrete choice models that overcome the independence of irrelevant alternatives (IIA) problem that most selection models suffer from. This approach could be applied on the 2005 CFS, should there be any need of detailed mode choice analysis in the future.

Third, more commodity groups (from the 16 sub-groups identified as having potential for change in mode choice) should be studied using the econometric models analysed and suggested here. As much as possible, it is important to take into account the logistic structure of shippers of these commodities and the transport network available to them. Generating cost and time variables for CFS shippers has proved to be challenging, mainly due to pitfalls in the CFS (see appendix 1). These challenges aside, in this project we have generated inputs that could be used for future research and the development of the national freight model of Sweden.

As a general recommendation for future studies, it is important to make use of existing data sources for scientific and practical modelling purposes. Sweden is one of the very few countries in the world which have a detailed micro level commodity flow surveys. So far, only the 2001 and 2004/05 Swedish CFSs have been used for scientific studies. To our knowledge, the 2009 CFS is yet to be used for scientific purposes. As highlighted in this paper, empirical studies based on the CFS analyse important modelling approaches which could be used as a platform to improve the prediction of national models such as the SAMGODS. It is therefore, important to exploit existing data sources and encourage independent empirical

modelling efforts. Doing so improves national modelling efforts as well as the scientific literature at large.

In addition to helping macro level modelling efforts, the CFSs could also be used to study micro level freight demand modelling problems and answer important questions regarding freight movement and infrastructure needs. For instance, using the CFS one can answer questions such: does the length of a highway affect the value and weight of trade between regions in Sweden? And does it also affect sectoral specialization of regions in high value/weight sectors? Analyses of the above questions and estimation of the magnitude of these effects provide an important new insight into the way transportation infrastructure affects trade and the organization of economic activity. Better transportation encourages trade in general, and in particular, encourages the production and trade of things that are hard to move. In addition to their academic interest, these estimates help to inform policy makers as they make infrastructure policy. In particular, one can assess the relevant cost-benefit trade-offs involved in the construction of new roads or railways.

## References

- Abate, M. and de Jong, G.C., 2014: The optimal shipment size and truck size choice- the allocation of trucks across hauls. *Transportation Research Part A*, 59(1) 262–277
- Ben-Akiva, M.E. and de Jong, G.C. 2013: The aggregate-disaggregate-aggregate (ADA) freight model system. in: M.E. Ben-Akiva, Meersman, H. and van de Voorde, E., eds. *Freight Transport Modelling*, Emerald.
- Bourguignon, F., Fournier, M., Gurgand, M., 2007. Selection bias corrections based on the multinomial logit model: Monte Carlo comparisons. *Journal of Economic Surveys* 21 (1), 174–205.
- de Jong, G.C. and Ben-Akiva, M., 2007: A micro-simulation model of shipment size and transport chain choice. *Transportation Research Part B* 41(9), 950–965 (2007)
- de Jong, G., Ben-Akiva, M., Baak, J., 2010 : Method Report—Logistics Model in the Swedish National Freight Model System (Version 2). Significance, The Hague.
- Dubin, J.A. and McFadden, D.L., 1984: An Econometric Analysis of Residential Electric Appliance Holdings and Consumption. *Econometrica*, 52 (2), pp.345--362.
- Habibi, S. , 2010: A Discrete Choice Model of Transport chain and Shipment size on Swedish Commodity Flow Survey, Stockholm: Kungliga Tekniska högskolan, Department of Transport and Logistics.
- Holguín-Veras, J., 2002: Revealed Preference Analysis of Commercial Vehicle Choice Process. *Journal of Transportation Engineering*, 128 (4), 336--346.
- Inaba, F.S. & Wallace, N.E., 1989: Spatial price competition and the demand for freight transportation. *The Review of Economics and Statistics*, 71 (4), 614--625.
- Johnson, D. and de Jong, G.C., 2011: Shippers' response to transport cost and time and model specification in freight mode and shipment size choice. Proceedings of the 2<sup>nd</sup> International Choice Modeling Conference ICMC 2011, University of Leeds, United Kingdom, 4 - 6 July.
- Liu, X., 2012: Estimating value of time savings for freight transport: a simultaneous decision model of transport mode choice and shipment size. Örebro University Business School, Department of Economics.
- Krüger, N; Vierth, I; de Jong, G; Halse A; Killi, M, Value of Freight Time Variability Reductions, VTI-Notat N39-2013 (<http://www.vti.se/sv/publikationer/vardet-av-minskad-variabilitet-i-transporttid-for-godstransporter--resultat-framtagen-i-en-pilotstudie-pa-uppdrag-av-trafikverket/>)
- McFadden, D., Winston, C., and Boersch-Supan, A., 1986: Joint estimation of freight transportation decisions under non-random sampling. In: A. Daugherty, ed. *Analytical studies in transport economics*. Cambridge University Press, 137--157.
- SIKA (2003) Commodity Flow Survey 2001, Method report, SIKA Report 2003:4, SIKA, Stockholm.
- SIKA ,2004: The Swedish National Freight Model: A critical review and an outline of the way ahead, Samplan 2004:1, SIKA, Stockholm
- Tavasszy, L. and de Jong, G.C., 2014: *Modelling freight transport*. Elsevier Insights Series, Elsevier.

Windisch, E., 2009: A disaggregate freight transport model of transport chain and shipment size choice on the Swedish Commodity Flow Survey 2004/05. MSc Thesis, Delft University of Technology.

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

## *Appendix 1*

### **Suggestion for future collection of CFS**

1. It appears that many respondents of the CFS misinterpreted the transportation mode/chains used for shipments, e.g. they did not state the first and/or last legs of transportation chains properly. An explanation for this assumption could be that respondents were e.g. not aware of the importance of the first leg in the transportation chain (maybe because the first transportation in the leg of the whole chain was carried out by the sending unit itself and no designated third party was involved). Also possible is that respondents did not have knowledge of all (ending) legs of the transportation chain until the shipment would reach its destination. Questions related to mode could be divided into two: 1) main mode and 2) detailed transport chain.
2. For some entries access to rail or quay facilities stated in the CFS could not be verified by the network information obtained by Swedish freight model. These could be due to deficiencies in the information of the Swedish model or in the formulation of questions in the CFS. Respondents of CFS could mistakenly state that they have access to these facilities in their vicinity, while in fact they don't have direct rail or quay access from their own production facility or premises. So it is important to clarify questions relating to these in the next CFS.
3. The quality of the information concerning the weight and value of shipments is sufficient for the purposes in this project. However, we noticed that for few observations these variables are recorded as having values less than one. While a shipment that weighs less than 1 kilogram is conceivable, there seems to be a problem with shipment values (on per shipment basis) with less than 1 krona values. It is important to clearly indicate how these two variables are supposed to be measured and recorded in the CFS. Furthermore, information about the annual amount of shipments/goods sent and received by a shipper would be useful.
4. The CFS could be much more informative if question relating to what actual choice set was available for decision makers, and what choice alternatives were actually considered by the decision maker. This would allow defining choice sets more accurately and lead to richer transport mode choice analysis. The main information we want to solicit here is the size of transport alternatives decision makers had when choosing a give mode/chain of transport. Having this information helps modelers to have actual choice sets than, for example to figure out potential choice sets indirectly from network data that might lead to errors. One way to know this is asking the number of freight vehicles shippers have (i.e. fleet size). Another way to sort of get similar information is to ask shippers the second best alternative (i.e. other than the chosen mode/chain alternative) they considered for their shipment.
5. Related to number 4 above it would be really informative if additional firm characteristics such as the fleet size and other freight transportation activities are included. For instance, questions could be who under took the actual freight transportation, i.e. was it done in house (own-account shipping) or by a for-hire carrier?
6. Very welcome pieces of information from the CFS would be the transshipment locations and the volume of the annual flows of the commodity transported.
7. Over the years, the volume (in meter cube) of shipments has become an important factor for mode choice decisions. Future CFSs could be made more informative directly asking the density of a shipment or at least by asking shippers to classify shipments as high or low density.

**APPENDIX 2**

**Table A1: Mixed Multinomial Logit model of discrete shipment size and transport chain choice – Metal Products**

Variable	Relevant Alternative	Coefficient estimates		
		All	Domestic	International
Cost	All chains	-8.11e6***	-0.000141***	-2.99e5***
Cost ( <i>standard deviation</i> )	All chains	2.56e9	-6.25e5***	-1.79e5**
Transport time (in hours) times value of goods (in SEK)	Truck	-6.23e8***	-2.27e8***	-2.45e7***
Access to Rail Value Density	Rail, All modes: smallest 2 shipment sizes	-1.26e11	-3.24e9	1.97***
Rail	Constant	-3.43e11	-1.12e8	-2.04***
Ferry	Constant	-2.71e11	-8.41e9	0.147
Vessel	Constant	-1.49e8	-1.93e8	-2.88***
Truck	Fixed			
Observations		33,868	32,896	972
Final LL value		-123,675.54	-104,041.61	-3,114.56
Rho2		0.047	0.175	0.166

Significance is marked as: \*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Note:

**Table A2: Own cost and time (per shipment) elasticities of mode choice (modal market shares in shipments) for three model specifications**

	Independent mode choice	Discrete shipment size and mode	Continuous shipment size and discrete mode
Road cost	-0.002	-0.030	-0.003
Rail cost	-0.438	-0.126	-0.393
Water cost	-0.920	-0.073	-0.639
Air cost	-0.311	-0.001	-0.198
Road time	-0.040	-	-0.025
Rail time	-0.447	-	-0.302
Air time	-1.391	-0.871	-1.454

Source: Johnson and de Jong (2011) Table 8.

Note: “The elasticities only give the impact of substitution between modes. In the second model (with discrete shipment size choice), the changes in costs and time also have an impact on the choice of shipment size. If this is included in the elasticities, the road cost elasticity or demand for road transport for instance becomes around  $-0.5$  (page 14, Johnson and de Jong, 2011)”.