Testing for nonlinearity in the choice of a freight transport service

Lucia Rotaris[1*], Romeo Danielis[1], Igor Sarman[1], Edoardo Marcucci[2]

[1] *Dipartimento di Scienze Economiche, Aziendali, Matematiche e Statistiche, University of Trieste, Italy*
[2] *Department of Public Institutions, Economics and Society, University of Roma Tre, Italy*

Abstract

Manufacturing firms buy transport services with the aim of minimizing their total logistics cost. There is a large amount of literature analyzing how shippers value the various characteristics of a transport service, mostly performed by collecting stated-preference data and estimating discrete choice models. Most of the empirical studies specify the deterministic part of the utility functions as linear in the observed attributes. This implicitly constrains the characteristics of the analyzed transport service to be perfect substitutes, and to have a constant substitutability ratio. Such an assumption is inconsistent with the standard microeconomic theory, typically assuming inputs' decreasing marginal productivity, and may not be realistic. The paper tests the linearity assumption for freight rate, travel time, probability of having damaged and lost freight, frequency, flexibility, mode and punctuality on a sample of Italian small- and medium-sized manufacturing enterprises (SME).

Our findings suggest that the linearity-in-the-attributes assumption should be rejected and that the marginal impact on the utility-of-profit of the attributes is not constant. More specifically travel time and freight rate produce decreasing marginal reductions of the utility-of-profit; while safety (percentage of not damaged or lost shipments) and punctuality (percentage of shipments on time) are responsible for increasing marginal contributions to the utility-of-profit. The substitutability ratios between (a) freight rate and loss and damage, (b) freight rate and travel time, (c) freight rate and punctuality, (d) travel time and damage and loss and (e) travel time and punctuality are estimated and found not constant. Finally, it is found that the willingness to pay for the qualitative attributes obtained with a linearly specified model tend to be overestimated.

Keywords: discrete choice models, nonlinearity, freight transport demand

1. Introduction

Most manufacturing firms have their inputs and products delivered by third party transport providers. Own account transport, although accounting for about 30% of the total ton transported in Italy (ISTAT, 2010), is mainly restricted to very specific sectors such as construction, manufacturing products, and food, and to short distance deliveries. Industrial manufacturing firms prefer to focus on their core activities and buy transport services from specialized providers. The deliveries are often point-to-point, organized to transport an input or a product from a specific origin to a given destination, although they could also comprise some consolidation activities (*groupage*). In the latter case they are performed by couriers serving multiple origins and destinations[1].

---

[*] Corresponding author: Lucia Rotaris (lucia.rotaris@econ.univ.trieste.it)
[1] Research recently carried out with a sample of firms located in the Friuli Venezia Giulia region (Northeastern Italy) found that groupage services are requested in business-to-business transactions for 10% of the deliveries, and in business-to-consumer transactions for 27% of the deliveries (Danielis and Torbianelli, 2007).

A transport service can be characterized by freight rate, travel time, risk of delay, risk of damage and/or loss, frequency, flexibility, transport mode and other attributes. Manufacturing firms (also called shippers) buy transport services with the aim of minimizing their total logistics cost, including inventory, handling and freight rate, and of maximizing their customers' satisfaction.

There exists relevant literature discussing how shippers value different characteristics of transport services. Most of the recent empirical research is performed by collecting stated-preference data and estimating discrete choice models (e.g., de Jong, 2000; Bruzelius, 2001; Fowkes, 2001; de Jong *et al.* 2004; Danielis *et al.*, 2005, Marcucci, 2005; Tavasszy and Bruzelius, 2005; Zamparini and Reggiani, 2007a, 2007b; Puckett and Hensher, 2008). The attributes most frequently investigated are: value of travel time, reliability, damage and loss, and frequency. Let us review them briefly.

Travel time impacts on the total logistic cost is modeled by Tyworth and Zeng (1998) within the inventory theoretic framework as the sum of freight rates, storage costs, stock-out costs, and in-travel storage cost. McKinnon (1995) suggests that a shorter travel time allows spatial concentration - which implies exploitation of economies of scale, tighter scheduling - lower drivers' wage costs, and market expansion, due to higher customers' satisfaction and shorter travel time required to cover longer distances. Bergkvist (2001) adds that faster delivery time may reduce payments delays, increase profits, and reduce the interest cost of capital.

Zamparini and Reggiani (2007a) have recently compared the estimates of the value of time obtained from 17 research projects (from 1994 up to 2001) using stated preferences data for road freight transport services. They report average values (per hour per shipment) equal to 30.16 $_{1999}$ for European countries (Germany, The Netherlands, France) and values comprised within the range 23.4 – 26.8 $_{1999}$ for the USA. Alvarez *et al.* (2007a) have also estimated the value of time (per hour per vehicle) for Spain, arriving at an estimate equal to 31.74 €$_{2007}$ which is in line with previous results. Some studies have shown that the value of time varies by commodity type (Winston, 1981), transport mode (Tavasszy and Bruzelius, 2005), country and average distance travelled. Indeed, shippers with a need for fast transport are generally located close to their main market and show a higher value of time for short distance deliveries compared to longer distance deliveries. Moreover, Bergkvist (2001) has shown that a one-hour decrease in travel time may be of little importance for longer travel time, while it could be very important if the travel time is very short. Finally, Fowkes (2001) demonstrates how the value of time can be significantly affected by the role played by the carrier within the supply chain - that is, if services are supplied by a third party or are organized on own account.

Reliability, typically defined as the standard deviation of travel time, the reduction in the percentage of shipments arriving late, or the percentage of shipments arriving on time, proved to be a highly valuable characteristic of freight transport service. Winston (1981), Wilson *et al.* (1986), and Fowkes *et al.* (1991) are among the first to have estimated its monetary value via discrete choice models. Patterson *et al.* (2007) find that shippers are highly sensitive to reliability, especially for short distance deliveries: when a carrier's on-time reliability improves by 1%, the odds of choosing that carrier increase by 13%. Fowkes *et al.* (2004) perform a discrete choice experiment comprising a sample of forty shippers, hauliers and third party logistics operators specifically aimed at estimating the sensitivity for three types of delay: increased free-flow journey times, increased spread of actual arrival time, and schedule delay in undertaking the journey. The authors find that the value of delay is equal to 107 pence per minute (p/m), the value of spread of journey time is equal to 85 p/m, and the value of schedule delay is equal to 66 p/m. They also discover, as already demonstrated by Henriksson and Persson (2001) and Fowkes et al. (2001), that the value of reliability differs

substantially according to the role played within the supply chain by the firm interviewed (own account operators are less sensitive to spread than hauliers, but much more sensitive to journey time and schedule delay), the journey distance (long distance deliveries have higher values for delay time but lower for spread), the type of distribution movement (just-in-time, quick response, or other type of movements), and commodity type.

The value of the probability of having damaged and lost freight has been less frequently studied within the European context, as reported by Tavasszy and Bruzelius (2005). It has been initially studied in Sweden (Transek, 1992), the Netherlands (de Jong *et al.*, 1992), Germany and France (de Jong *et al.*, 1995). Unfortunately, the results obtained are not directly comparable since the definition of risk of damage differs substantially among different studies and because of the heterogeneity of the samples. Indeed, there are numerous factors influencing the sensitivity for this service characteristic the most important being: distance travelled, national versus international shipment, commodity type and commodity value. According to one of the most recent stated preference surveys on this issue (Patterson *et al.*, 2007), an increase of 1% in risk of damage would decrease the odds of choosing a carrier by about a third (e.g., a probability of 50% for choosing a carrier would fall to about 40%), while an increase of 1% in security risk would reduce the odds of choosing a carrier by 15% (e.g., an initial probability of choosing a carrier equal to a third would decrease to a quarter).

The monetary value of frequency of freight transport has also been seldom estimated. Transek (1990) and de Jong *et al. (1992)* find that it is not significant, whereas PROTRANS (2003) estimates that an increase of frequency from 3 to 5 trips per week on European corridors is equivalent to a freight rate reduction of 16 euros. Bolis and Maggi (2003, p. 11) use an adaptive stated preference approach to interview twenty-two firms localized in Italy and in Switzerland and conclude that while price, travel time, and reliability are important factors in the decision process of the firm, frequency and flexibility are relevant only when firms operate in a just-in-time context, when the product is a final product and/or the firm is serving directly consumer markets or outlets, and when the shippers produce on order and not for stock. Finally, de Jong *et al.* (2004) estimate that for road freight transport a 10% frequency increase is equivalent to almost a 20% reduction of freight rate, while for rail transport the equivalent freight rate reduction increases up to 40%.

A common feature of the studies described so far is that the monetary value of the transport service characteristics differs according to the specificities of the segments studied: commodity type and value, distance travelled, mode of transport, role played within the supply chain, and other factors. All these empirical studies, however, have specified the deterministic part of the utility functions as linear-in-the-attributes. This specification implicitly constrains the characteristics of the analyzed transport service to be perfect substitutes, and to have a constant substitutability ratio, an assumption which may be far from realistic and which should be empirically tested rather than assumed.

Nonlinearity and segmentation have been proved (Algers and Gaudry, 2002) to be either substitutes, or complements, or even independent dimensions of model specification. That implies that both heterogeneity via segmentation and nonlinearity should be tested.

In fact, the realism of the linearity assumption, which keeps on dominating the transport planning practice, has been questioned in a number of recent studies concerning passenger transport such as: Kato (2006), Pinjari and Bhat (2006), Tapley *et al.* (2006), Wardman (2004) and Algers and Gaudry (2002), and Gunn (2001). On the contrary, within the freight transport literature the number of studies testing nonlinearity is still limited. Exceptions are Nijkamp *et al.* (2004) and Rich *et al.* (2009) who find that the logarithm specification of the freight rate attribute produces a better fit of the model, but they neither estimate nor report how the substitutability ratio with the remaining attributes changes over their domain.

Moreover, recently two discrete choice studies have tested the presence of non-linearity and reference dependence in the choice process of freight transport services. Masiero and Hensher (2009) have focused on loss aversion and diminishing sensitivity via a reference pivoted choice experiment and analyzed the implications of these forms of nonlinearities with respect to the willingness to pay and the willingness to accept for freight rate, travel time and punctuality. They detect asymmetric sensitivity for of all the attributes, but verify diminishing sensitivity only for punctuality. They conclude that not accounting for loss aversion and diminishing sensitivity, when present, produces bised results and might significantly affect policy decisions. Danielis and Marcucci (2007), following a suggestion proposed by Swait (2001), have tested a specific form of non-linearity: the presence of soft attribute-cutoffs specified by the respondents during the choice experiment and partitioning the domain of the freight transport service attributes in two segments characterized by different marginal utility. They conclude that the attribute most affected by this form of non-linearity is the probability of loss and damage, followed by freight rate, travel time and late arrivals.

This paper provides a further test of the linearity assumption for freight rate, travel time, probability of having damaged and lost freight, frequency, flexibility, mode and punctuality on a sample of Italian small- and medium-sized manufacturing firms.

In order to improve our knowledge of the implications of the relaxation of the linearity assumption Section 2 describes the random supply choice model that is the most appropriate microeconomic theoretical framework to study how shippers choose among different freight transport services. Section 3 illustrates the sample of firms interviewed and the characteristics of the choice experiment implemented. Section 4 presents the mathematical transformations used to test for the nonlinearity assumption and Section 5 describes the results obtained. Finally, Section 6 draws some conclusions and lists some future research issues.

2. The random supply model

The choice of a freight service is typically a discrete supply decision where a firm selects among different types of alternative services to minimize its production and distribution costs and to adequately satisfy its customers. However, empirical research investigates this choice by applying the random utility model originally developed by McFadden to study demand decisions where a consumer chooses among discrete goods or services trying to maximize his (indirect) utility. What are the implications of adopting a theoretical framework aimed at studying consumers' choices to analyze suppliers' (logistic) decisions? Could these asymmetrical perspectives be reconciled?

A stream of literature has argued that the random utility model is useful to analyze supply issues as well, e.g., Hanemann and Tsur (1982), and developed a random supply choice model. Such research starts by observing that supply decisions comprise not only continuous choices, such as the choice of how much of a certain input to use given its price, but, also discrete choices, such as which products to specialize on or which production technique to use. In fact, discrete and continuous choices are interrelated: optimal continuous decisions depend on the outcome of discrete choices, and vice versa. Discrete/continuous supply choice models are then needed to study many real world issues (see McFadden, 1979; Duncan, 1980; and Bretti *et al.*, 2007, for examples of such models). The choice of the freight service to be used in order to receive an input or to distribute a product discussed in the remaining of the paper is another example of a discrete choice faced by a manufacturing firm producing a good. As such it is to be interpreted as part of the more general goal of the firm to maximize its profits (and/or of minimizing its production and distribution costs).

A discrete/continuous supply choice model can be shown to be consistently analyzed within a single underlying utility-of-profit maximization decision. When there is uncertainty related, for instance, to the sale price level, or to the actual costs of a chosen transportation service, Hanemann and Tsur (1982) show that, as with the theory of supply under certainty, there are two methods for generating a particular parametric supply model. The first is the direct (primal) approach, which consists in specifying a utility-of-profit function and the density function of the random variables affecting the profit (e.g., the expected price of the output), and then solving the expected utility maximization problem for the quantity to be produced. The second is an indirect (dual) approach, which specifies the indirect expected utility-of-profit function, satisfying the appropriate requirements for such a function, and then derives the output supply function as the ratio between the marginal utility of the expected profit with respect to the expected product price and marginal utility of the expected profit with respect to production costs. The indirect expected utility-of-profit function is better suited to analyze discrete choice decisions and represents the counterpart of the indirect utility used in analyzing consumption decisions.

In empirical applications it is appropriate to recognize that, although all the elements of the producer's decision - the cost function, the subjective probability density function for the output price, and the own utility-of- profit function - are known for sure to the producer, they contain some components that are unobservable to the analyst, and are thus treated as random variables. A random discrete/continuous supply choice model, hence, is characterized by several sources of unobserved components: different production technology affecting firms' cost functions, subjective probability density functions for output prices, and different levels of risk aversion affecting the utility-of-profit function. Because there are various sources of randomness, the analyst decides which type of random model to estimate depending on which source of randomness he chooses to emphasize and on how to specify it in the model.

The concepts developed in the discrete/continuous supply choice model have found very little empirical application in the analysis of production choices, whereas they have been used to analyze labor supply. Regarding the choice among alternative freight transport services, only the discrete choice framework is used in the context of utility maximization, disregarding its interaction with other continuous choices related to the production process and with the utility-of-profit functions. This is probably due to the difficulty of capturing interactions, instead focusing on one aspect of the problem at a time. Following Strolz's assumption of separable utility functions, the transport issue is studied with no reference to its interaction with other production decisions. Yet, in order to fully grasp the meaning of these choices, it is important to keep in mind that a freight service type is not chosen *per se*, but due to its substantial interrelationships with other production functions and because it might affect the sales level according to the customers' satisfaction with the delivery service.

Although the estimation of discrete choice models is usually performed using linear-in-parameter utility functions, most applications assume linearity in the variables representing the attributes of the freight service as well, thus implying constant marginal indirect utility-of-profit of the attributes over their domain and constant marginal rates of substitution.

Note that standard microeconomic theory assumes decreasing marginal productivity of input factors, hence, linear isoquants of production with respect to the inputs of the production function and to their characteristics. Constant marginal rates of technical substitution between the inputs of the production process are then only a special case.

Since the random supply model is based on the indirect utility-of-profit, it specifies the effect of a variable both on production and on customers' satisfaction. Hence, assuming linearity and constant marginal indirect utility-of-profit implies either that both effects are constant or that they exactly compensate each other thus producing a constant impact on profits. This is an even stricter assumption and is infrequently observed in real word

production processes as recently tested (Pinjari and Bhat, 2006; Tapley *et al*., 2006). Hence, it should be verified empirically on a case-by-case basis.

In the following section we will describe how we collected the data in order to test the constant marginal rate of technical substitution assumption for some characteristics of freight transport services.

3. The stated choice experiment

Our analysis is based on a dataset collected in Italy in 2005 to study how firms choose between intermodal (rail-road) freight service and road-only freight service when the logistic organization of incoming supplies and outgoing products has to be planned.

The sample used in this paper includes 78 firms localized in Friuli Venezia Giulia, a region in Northeastern Italy, and in the Marche and Lazio regions, both in Central Italy. The sampled firms produce mechanical equipment, metal products and furniture. An important characteristic of the Italian industrial structure is the presence of industrial clusters, or districts, made up of closely-connected SMEs. Among the firms interviewed those producing furniture and localized in the Marche region most closely respect the industrial district concept. All firms outsource their transport services. For the procurement of inputs most firms use free on board (f.o.b.) contracts as opposed to carriage, insurance, and freight(c.i.f.). For product deliveries, few firms sell f.o.b. while the majority sells c.i.f. Only 24% of the firms have used intermodal transport at least once a year, 7% have used it in the past, and 69% never used it. Regarding inventory management practices, more than half of the firms in the sample manage stocks on the basis of orders received, 8% using threshold quantities, 15% according to forecasted orders, 15% according to production plans, and only 11% follow just-in-time principles.

15 choice tasks were presented to each respondent, usually the logistics manager of the firm (refer to Danielis and Marcucci, 2007, and to Danielis *et al.*, 2005, for further details).

The first part of the interview was aimed at collecting information about the firm, its incoming and outgoing shipments and the freight transport services typically used for both flows, while the second part was designed to collect stated choices between the freight transport service most commonly used (from now on referred to as Status Quo, SQ), and two hypothetical alternatives. Table 1 describes one of the choice tasks used during the interviews.

Table 1- Choice tasks used during the stated preference experiment

Attributes	Alternative 1 (Hypothetical)	Alternative 2 (Hypothetical)	Alternative 3 (Status Quo)
Freight rate	-10% than typical	-15% than typical	typical
Travel time	typical	2 more days than typical	typical
Variation in the probability of damaged and lost freight	10%	5%	typical
Frequency	low	high	typical
Flexibility	low	high	typical
Transport mode	intermodal	road only	typical
Punctuality	100%	70%	typical

The hypothetical alternatives were characterized by the following attributes and levels:
• freight rate: actual freight rate of the typical shipment or +/-15%, +/-10%, +/-5% (higher or lower) than the actual freight rate;

• travel time: actual travel time of the typical shipment or +/- 1/2 day, +1 day, +2 days (longer or shorter) than the actual travel time;
  • variation in the probability of having damaged and lost freight: 0%, 5%, 10%, 20%;
  • frequency: high, low;
  • flexibility: high, low;
  • transport mode: road only, intermodal (rail – road);
  • punctuality (percentage of shipments arriving within the scheduled date): 100%, 85%, 70%.

4. Modeling nonlinearity in freight transport choice

In order to test the hypothesis that the marginal rate of technical substitution of an attribute of the transport service is not constant over its domain, the indirect utility-of-profit model has been specified using different mathematical transformations of the variables entering the deterministic part of the alternative specific indirect utility-of-profit function.

For freight service i the deterministic part of the indirect utility-of-profit V of a firm n can be written as:

$$V_{i,n} = \sum_k \beta_k (x_{i,n})_k$$

where k is the attribute, x is the value of the attribute for freight service i faced by respondent n, and β is the marginal contribution to the utility-of-profit produced by each attribute k.

Four alternative nonlinear mathematical transformations that can be used to test for nonlinearity are the following:

1. The <u>logarithmic transformation</u>. It is based on the logarithmic transformation of the variables representing the attributes:

$$V_{i,n} = \sum_k \beta_k \log(x_{in})_k$$

This transformation is consistent with standard microeconomic theory assuming that, when all other inputs are held fixed, the marginal productivity of any input k will decrease as the quantity used increases, as reported in the following mathematical notation:

$$\frac{\partial V_{i,n}}{\partial x_{k,i,n}} = \beta_k \frac{1}{x_{k,i,n}}$$

2. The <u>power series transformation</u>. It consists into raising the variables representing the attribute specified in the indirect utility-of-profit function to any power predefined by the analyst. However, the higher the degree of the polynomial, the higher the complexity of the interpretation of the parameters. For a second degree transformation of the attribute $k=1$ the indirect utility-of-profit function for alternative i is the following:

$$V_{i,n} = \alpha_i + \beta_{1,1}x_{1,i,n} + \beta_{1,2}x_{1,i,n}^2 + \beta_2 x_{2,i,n} + ... + \beta_K x_{K,i,n}$$

and the partial derivative describing the marginal contribution to the utility-of-profit of attribute $k=1$ is:

$$\frac{\partial V_{i,n}}{\partial x_{1,i,n}} = \beta_{1,1} + 2\beta_{1,2}x_{1,i,n}$$

It should be noted that, within the supply choice framework, the power series transformation is consistent with the decreasing marginal productivity assumption only if the power parameter is greater than 1 (or smaller than 0) and the corresponding β_{kk} parameter is negative. If the power parameter tested is comprised within the $0 - 1$ range, the decreasing marginal productivity assumption is verified only if the corresponding β_{kk} parameter is positive.

3. The <u>Box-Cox transformation</u>. It represents a more flexible transformation allowing the variables to assume the linear, the logarithmic or the power transformation according to the value of the transformation parameter λ that maximizes the log likelihood function:

$$X_{k,i,n}^{(\lambda_{k,i})} = \begin{cases} \dfrac{X_{k,i,n}^{\lambda_{k,i}} - 1}{\lambda_{k,i}} & if \quad \lambda_{k,i} \neq 0 \\ \ln\left(X_{k,i,n}\right) & if \quad \lambda_{k,i} = 0 \end{cases}$$

If the λ parameter is not significantly different from 0 this transformation is equivalent to the logarithmic one, otherwise it becomes a special case of the power series transformation.

The deterministic part of the indirect utility-of-profit function is specified according to the estimated value of λ, as follows:

$$V_{i,n} = \beta_{0,i} + \sum_k \beta_k X_{k,i,n}^{\lambda_{k,i}}$$

The interpretation of the parameters estimated on the bases of this model specification mirrors the explanations already given for the two previously described transformations as exemplified in table 2.

Table 2- Marginal contribution to the utility-of-profit according to the value of the Box-Cox transformation parameter

	$\dfrac{\partial U_m}{\partial X_{mk}} = \beta_{mk} X_{mk}^{(\lambda_{mk}-1)}$	$\dfrac{\partial U_m^2}{\partial X_{mk}^2} = \beta_{mk}(\lambda_{mk}-1) X_{mk}^{(\lambda_{mk}-2)}$	**Returns**
$\lambda = -1$	β_{mk}/X_{mk}^2	$-2\beta_{mk}/X_{mk}^3$	Decreasing
$\lambda = 0$	β_{mk}/X_{mk}	$-\beta_{mk}/X_{mk}^2$	Decreasing
$\lambda = 1$	β_{mk}	0	Constant
$\lambda = 2$	$\beta_{mk} X_{mk}$	β_{mk}	Increasing

Source: Gaudry, 2008, p.2.

4. The <u>piecewise linear specification</u>. This transformation allows for changes of slope of the indirect utility-of-profit function which, held fixed all the variables except the transformed one, consists of two or more straight line segments, with the restriction that the function is overall continuous but has some structural breaks. If the deterministic part of the utility-of-profit function can be written as:

$$V_i = v_i + \beta_b x_b + \beta_c x_c + \ldots$$

where v_i represents the attribute transformed. The piecewise approach requires the following transformations of the $k = a$ attribute:

$$v_i = \begin{cases} \beta_1 x_a & if\ 0 \le x_a \le a_1 \\ \beta_1 a_1 + \beta_2 (x_a - a_1) & if\ a_1 \le x_a \le a_2 \\ \beta_1 a_1 + \beta_2 a_2 + \beta_3 (x_a - a_2) & if\ x_a \ge a_2 \end{cases}$$

with a_1 and a_2 representing the structural breaks of the function.

The consistency of this transformation with standard microeconomic theory depends on the statistical significance of the $\beta_{n,a}$ parameters, the statistical significance of the difference of preceding $\beta_{n-1,a}$ and subsequent $\beta_{n+1,a}$ parameters, and the sign of the difference between the $\beta_{n,a}$ parameters and the preceding $\beta_{n-1,a}$ and the subsequent $\beta_{n+1,a}$ parameters. More specifically, the decreasing marginal productivity of input $k=a$ is verified only if: 1) the $\beta_{n,a}$ are significantly different from zero; 2) they are significantly different from the preceding $\beta_{n-1,a}$ and the subsequent $\beta_{n+1,a}$ parameters and; 3) the difference with the preceding and the subsequent parameters is negative and positive, respectively.

5. Results

We have estimated a multinomial logit (MNL) model with the mathematical transformations described in the previous section using 1170 observations. The mathematical transformation have been tested for all attributes but only the best fitting models are reported in Table 3. We applied the transformations only on the freight rate, travel time, percentage of damaged or lost shipments and punctuality, as the remaining attributes are dichotomous variables. The goodness of fit indexes are based on an initial log-likelihood equal to 1285.

The variable freight rate is measured in euro, damages and losses are measured as the percentage of damaged or lost shipments, travel time is measured in days, and punctuality is measured as the percentage of shipments arriving or leaving within the programmed time schedule. The LL ratio tests indicate that all the nonlinear models (Table 3) fit the data better than the linear model.

Table 3- Estimates of MNL models characterized by different mathematical transformation of the variables entering the utility functions

Coefficients	Model 1 - Linear model		Model 2 - Logarithm of cost		Model 3 - Power series of cost and travel time		Model 4 - Box-Cox trasformation of cost		Model 5 - Piecewise of cost, damaged frieght and transit time		Model 6 - Piecewise for damaged freight, time and punctuality, and logarithm for cost	
	Estimate	t-ratio	Estimate	t-ratio	Estimate	t-ratio	Estimate	t-ratio	Estimate	t-ratio	Estimate	t-ratio
ASC_Status Quo	0.14	1.08	0.45	3.19	0.15	1.16	0.455	3.21	0.42	2.71	0.46	2.99
Intermodality (dummy)	0.51	3.12	0.57	3.16	0.45	2.70	0.571	3.18	0.61	3.30	0.57	3.14
Flexibility high (dummy)	0.39	2.17	0.36	1.89	0.33	1.83	0.37	1.91	0.44	2.24	0.37	1.9
Frequency high (dummy)	0.3	1.71	0.11	0.59	0.19	1.06	0.12	0.60	0.03	0.15	0.12	0.6
Cost (€)	-0.002	-6.03			-0.01	-9.50	-12.90	-3.41				
Log Cost (€)			-11.00	-14.37							-11.3	-14.43
Lambda_Cost							-0.02	-0.53				
Cost^2 (€)					0.00000018	7.97						
Cost <= €113									-0.12	-5.05		
€113< Cost < =€220									-0.06	-5.17		
€220< Cost < =€405									-0.03	-9.13		
€405< Cost < =€525									-0.02	-6.32		
Cost >€525									-0.01	-26.84		
Variation in the probability of damage and loss	19.8	15.17	22.00	15.22	20.52	15.20	22.00	15.23				
Variation in the probability of damage and loss within the 10% - 20% range									22.21	6.16	15.1	4.5
Variation in the probability of damage and loss within the 10% - 20% range									27.14	14.89	24.5	13.77
Travel time (days)	-0.31	-4.12	-0.37	-4.61			-0.37	-4.58				
Travel time^2 (days)					-0.05	-5.12						
Travel time <= 0.75 days									-1.50	-2.68	-1.3	-2.39
0.75 days< travel time < 4 days									-0.2	-1.86	-0.22	-2.14
Travel time > 4 days									-0.73	-4.98	-0.57	-3.93
% of punctual shipments	2.65	5.21	2.68	4.79	2.81	5.34	2.68	4.79				
Punctual shipments <= 80%									1.37	0.66	1.51	0.74
Punctual shipments > 80%									3.79	3.56	3.27	3.12
Number of estimated parameters	8		8		9		9		16		12	
Final log-likelihood	-775		-665		-742		-665		-713		-660	
Rho-square	0.40		0.48		0.42		0.48		0.45		0.49	
Adjusted rho-square	0.39		0.48		0.42		0.48		0.43		0.48	

The estimation of the linear MNL model (Model 1) allows us to obtain a high adjusted rho-square (0.39). All parameters, except the status quo alternative specific constant and the frequency parameter, are statistically significant at 5%, and have the expected sign in line with the inventory theoretic model of freight transport demand originally proposed by Baumol and Vinod (1970)[2]. The estimated parameters are negative for freight rate and travel time, because as travel time increases, in-travel inventory costs and stock-out costs[3] increase; the estimated parameters are positive for the probability of not having damaged and lost freight and for the percentage of punctual shipments, because as these two attributes improve, stock-out costs and safety stock costs[4], respectively, decrease.

The estimates reported are related both to the incoming shipments of inputs and to the outgoing shipments of products; they cannot be interpreted as proxies of their marginal productivity because they encompass the effect that they produce both on logistic costs and on expected revenues.

Finally, the intermodal parameter has a positive sign implying that, *ceteris paribus*, the sample prefers the rail-road option rather than the road-only mode of transport.

The <u>logarithmic specification</u> of the freight rate attribute (Model 2) significantly improves the value of the LL function signaling a decreasing impact on the utility-of-profit. The interpretation of this result is controversial. The random supply choice model would imply that the marginal contribution of the costs of the inputs to the indirect utility-of-profit is constant. This implication, however, holds only if referred to a homogenous production process and to incoming flows of inputs. This is not the case of our sample[5]. The empirical evidence reported by Patterson *et al.* (2007. p.12) suggests that high-value, fragile and perishable goods are subject to higher inventory costs, and should be expected to be less sensitive to the freight rate becuase firms are willing to pay more to have them shipped more quickly or safely to reduce inventory costs, while a longer shipment distance is expected to increase shippers' sensitivity to the freight rate. The decreasing marginal reduction of the indirect utility-of-profit estimated for freight rate is consistent, finally, with the "proportionate effect theory" according to which an economic agent "will be less sensitive to a given change in an attribute at higher absolute values of that attribute" (Tapley et al., 2006, p. 8).

The statistical significance of the remaining parameters, their signs and their absolute values do not change significantly if compared with the estimates obtained via the linear MNL, except for flexibility, which is now statistically significant at 10%, and to the status quo alternative specific constant, that is now statistically significant and positive, meaning that, everything else being equal, the respondents would keep on choosing a transport service similar to the service they are currently buying. None of the logarithmic transformations we have tested for the remaining parameters have improved the goodness of fit of the MNL model.

The <u>power series specification</u> (Model 3) improves the LL function relative to Model 1 but not to Model 2. The estimates allow us to conclude that travel time generates increasing

---

[2] The Baumol and Vinod model has been recently reviewed by Massiani *et al.* (2009) by distinguishing between specific versus generic goods, where "a specific good is made for a given customer, based on specifications agreed upon between the producer and the customer, whereas a generic good is produced regardless of who will be the consumer buying it" (Massiani *et al.*, 2009, p. 378).

[3] Stock-out costs are the losses caused by a shortage of stock that decreases customer satisfaction and disrupts production (Blawens *et al.*, 2010).

[4] These are the costs of the inventory which is held over and above the cycle stock because of uncertainty about the length of the order lead time (Blawens *et al.*, 2010).

[5] Our case study, instead, is characterized by high heterogeneity in terms of (a) manufacturing sectors (mechanical equipment, metal products and furniture), producing both specific and generic goods (Massiani et al., 2009), (b) role played within each the supply chain by the firms interviewed, (c) type of shipments, as we collected stated preferences both for incoming and outgoing flows, (d) value, quantity and frequency of shipments, and (e) distance between origin and destination.

marginal reductions of the indirect utility-of-profit; indeed, the parameter of the travel time attribute raised to the second power is negative and equal to -0.05, while the freight rate produces decreasing marginal reductions of the indirect utility-of-profit, as the parameter of the freight rate attribute raised to the second power is positive, although very small. The status quo alternative specific constant, flexibility and frequency are not statistically significant, but the remaining parameters are in line with the estimates obtained via the linear MNL model.

As expected, the Box-Cox transformation (Model 4) produces results almost identical to those obtained using the logarithmic transformation (Model 2), as both the logarithmic transformation and the (second degree) power series transformation are special cases of the Box-Cox transformation, and our previous analysis demonstrated that the logarithmic transformation is superior to the power series model in terms of goodness of fit. It is worth noting that since the λ parameter for the freight rate is not significantly different from 0, the logarithmic transformation is applied to the freight rate attribute.

The piecewise transformation (Model 5) of the freight rate, the probability of not having damaged or lost freight, and travel time allows us to significantly improve the goodness of fit of the model if compared both to the linear and to the power series models, but is inferior to the Box-Cox transformation and to the logarithmic transformation of freight rate. The piecewise transformation, however, proves that the freight rate and travel time produce decreasing marginal reductions of the indirect utility-of-profit, while the probability of not having damaged or lost freight is characterized by an increasing marginal contribution to the indirect utility-of-profit. The results obtained for the travel time attribute with the piecewise transformation are not consistent with those obtained using the power series one, but we are more inclined to trust the piecewise estimates because of both the improved fit of the model and its consistency with previous empirical research on this topic (Bergkvist, 2001).

Finally, we combine a logarithmic transformation of freight rate and a piecewise transformation of the probability of not having damaged and lost freight, of the percentage of punctual shipments and of travel time (Model 6), obtaining the highest rho-square (0.49). On the basis of these results it is possible to conclude that both freight rate and travel time cause decreasing marginal reductions of the indirect utility-of-profit, while both the probability of not having damaged or lost freight and the percentage of punctual shipment are responsible for an increasing marginal contribution to the indirect utility-of-profit. Unfortunately, these estimates are based on a highly heterogeneous sample of firms and comprise stated preferences both for incoming and outgoing freight transport services; for these reasons it is not possible to derive unequivocal conclusions about marginal productivity and the technical rate of substitution between these attributes.

6. Monetary value of qualitative characteristics of freight transport

In order to evaluate the impact of the relaxation of the linearity assumption on the estimation of willingness to pay (WTP) for qualitative attributes of the transport service, we calculate the value of travel time (VOTT) and the value of safe and punctual transport services as the ratio of the partial derivatives of the deterministic part of the utility-of-profit function with respect to freight rate:

$$\frac{\partial V / \partial \text{ qualitative attribute of transport service}}{\partial V / \partial \text{ freight rate}}$$

The formula for the calculation or the WTP is equal in the case of the linear model to β_q / β_{tc} where q is the quality attribute and it is equal to $\beta_q / (\beta_{tc} * FR)$ in the case of the log-piecewise model.

Table 4 - WTP for travel time, probability of not having damaged and lost freight, and punctual shipments based on the linear and log-piecewise MNL models (euro)

	Model 1 - Linear model	Model 6 - Piecewise for undamaged freight and travel timeand log for freight rate				
		C <= 200	200< C <= 487	487< C <= 600	600< C <= 1300	C> 1300
1% variation in the probability of damage and loss	97					
1% variation in the probability of damage and loss within the 10% - 20% range		1	4	7	12	47
1% variation in the probability of damage and loss within the 0% - 10% range		2	6	12	19	76
half-a-day variation in travel time	75					
half-a-day variation in travel time for trips shorter than 3/4 of a day		6	16	30	50	201
half-a-day variation in travel time for trips within the 3/4 of a day 4 days range		1	2	5	8	34
half-a-day variation in travel time for trips longer than 4 days		2	7	13	22	88
1% variation in the percentage of punctual shipments	13					
1% variation in the percentage of punctual shipments in the more than 80% punctuality range		0.3	0.8	1.5	2.5	10

Note: the parameter for a 1% variation in the percentage of punctual shipments in the lower than 80% punctuality range is not statistically significant for the log-piecewise model; the values defining the freight rate category (C) are specified in euro, each category includes 20% of the sample.

The monetary values obtained via the linear and the log-piecewise models are summarized in Table 4. Because the estimates for the log-piecewise model depend on the absolute value of the cost of the current freight rate (FR), the sample has been subdivided in 5 groups, each containing 20% of the sample. For each segment the mean freight rate has been calculated and it has been used to calculate the respective willingness to pay. A similar procedure had been used by Masiero and Hensher (2009), although they had specified both the freight rate and the qualitative attributes via a piecewise transformation. Similarly to the results obtained by Masiero and Hensher (2009), our estimates are characterized by discontinuity and this is precisely due to the piecewise transformation that had been used.

The first row reports the monetary values of a 1% variation in the probability of having a damaged or lost freight. The amount of the damage or loss was not specified in the stated choice experiments. In the sample the value of the shipments varies from €300 to €1.000.000 with an average equal to €42.084. The linear model specification provides an estimate equal to €97.

The second row reports the monetary estimates of a 1% variation in the probability of having a damaged or lost freight within the 10% - 20% range combined with the segment-specific freight rate in the log-piecewise model. The third row reports the monetary estimates of a 1% variation in the probability of having a damaged or lost freight within the range 0% - 10%. It is noteworthy (see also Figure 1) that:

1) The estimate obtained with the linear model is higher than those obtained with the log-piecewise model;
2) The estimates for a 1% variation in the probability within the 10% - 20% range are lower than those obtained for the 0% - 10% range. A possible explanation is that the impact on the total logistic costs and customer satisfaction is higher when the occurrence of damaged or lost shipments is low.
3) The willingness to pay increases with the freight rate; that is, shippers that pay higher freight rates are more willing to pay for reducing the probability of damage and loss. A possible explanation is the association between the freight rates and the value of the shipment.

Unfortunately, in the literature, there are no estimates directly comparable with our results as either different definitions of risk of damage and loss are used or the willingness to pay values are not derived.
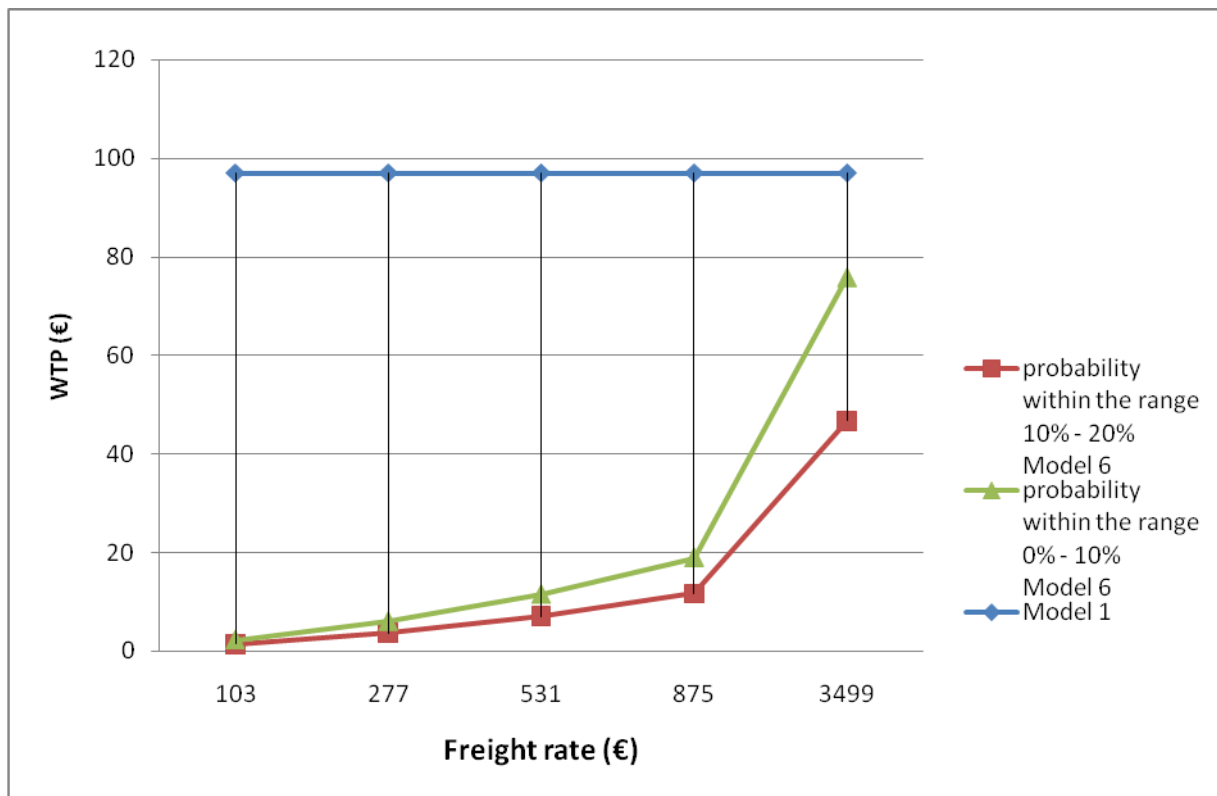

Fig. 1 Willingness to pay for 1% variation in the probability of damaged and lost freight

The fourth row reports the monetary values of a half-a-day variation in travel time. In the sample the travel time varies from ¾ of a day to 9 days with an average of 2.5 days. The linear model specification provides an estimate equal to €150 for a one-day variation.

The fifth, sixth, and seventh rows report the monetary estimates of a half-a-day variation in travel time. It is noteworthy (see also Figure 2) that:

1) The estimate obtained with the linear model is generally higher than those obtained with the log-piecewise specification except when the freight rate is higher than €1.300;

2) The estimates for a half-a-day variation in travel time is higher for trips that are shorter than ¾ of a day, lower for trips that are within the ¾ of a day - 4 days range, and intermediate for trips that are longer than 4 days. These results can be explained by location and production organization principles. Shorter travel times are linked with tighter production and customer relationships. Firms are clustered and their organizations are closely interconnected. An increase in travel time (lead time) by half-a-day on a shipment that usually takes less than a day has a potential high impact on logistics costs and customer satisfaction. On the contrary, for shipments characterized by longer travel time the impact is less important. These results confirm the findings obtained by Tavasszy and Bruzelius (2005).

3) The willingness to pay increases with the freight rate; that is, shippers that pay higher freight rates are more willing to pay for reducing travel time. A possible explanation is the association between the freight rate and the in-transit value of the shipment.
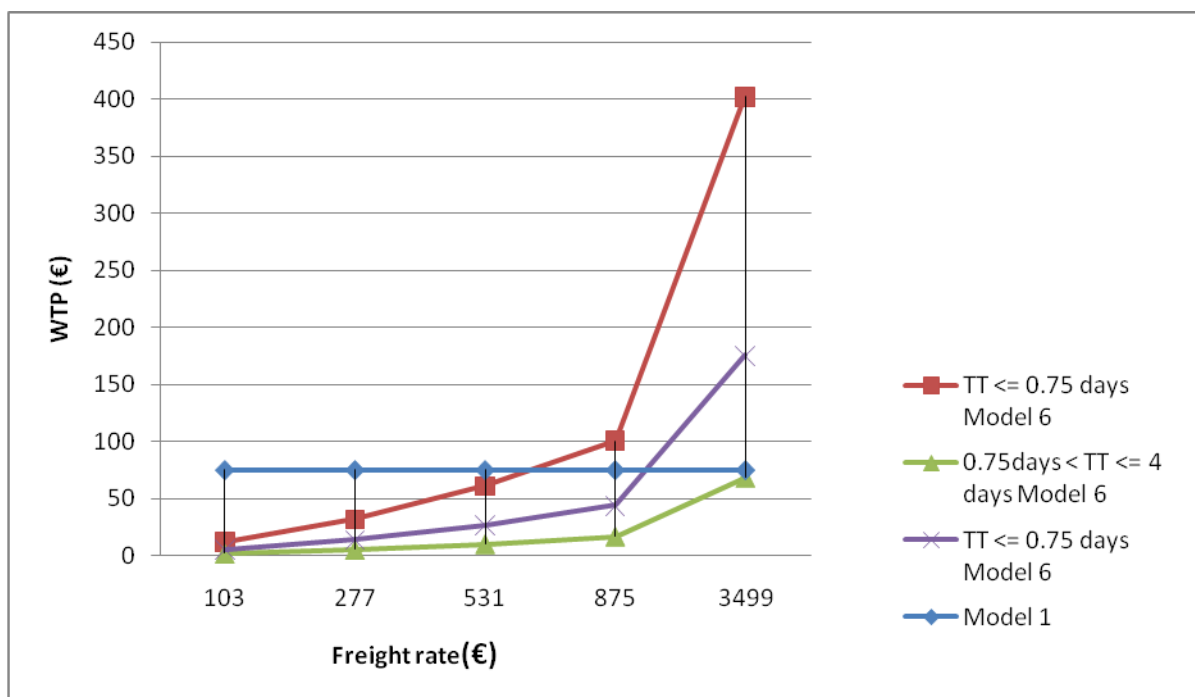

Fig. 2 Willingness to pay for a half-a-day variation in travel time (TT)

Our estimates are based on half-a-day variations and cannot be easily compared with those presented in the literature since the latter are in terms of travel time per hour per shipment. We preferred to test half-a-day variations instead of hourly variations because the shippers we interviewed stated that an hour difference in the goods arrival make little or no difference to them. Furthermore, the comparison between road and intermodal travel times is more a matter of days than of hours. Consequently, it is not easy to compare our value of travel time estimates with those presented in the literature. Zamparini and Reggiani (2007b) report values ranging from 0.80 (for rail) to 47.21 (for road) expressed in $_{2002}$, with an average of 20.25. If, for sake of comparison, we assume that a day consists of 8 working and travel hours, our VOTT estimates are those reported in Table 5.

Table 5- WTP for travel time per hour based on the linear and log-piecewise MNL models (euro)

	Model 1 - Linear model	Model 6 - Piecewise for undamaged freight and travel time and log for freight rate				
		C <= 103	103< C <= 277	277< C <= 531	531< C <= 875	C> 875
half-a-day variation in travel time	18.8					
half-a-day variation in travel time for trips shorter than 3/4 of a day		1.5	4.0	7.5	12.5	50.3
half-a-day variation in travel time for trips within the 3/4 of a day 4 days range		0.3	0.5	1.3	2.0	8.5
half-a-day variation in travel time for trips longer than 4 days		0.5	1.8	3.3	5.5	22.0

The VOTT estimate obtained with the linear model is in line with international average estimates reported by Zamparini and Reggiani (2007b). However, the value differs according to trip length (as measured by travel time) and freight rate. The range reproduces the variations found in the international literature and can be considered a possible explanation for the large variations found in previous studies. A further feature constraining the comparability of our estimates is that they are not mode-specific.

The eighth and ninth rows in Table 4 report the WTP for a 1% variation in the percentage of punctual shipments. It is noteworthy (see also Figure 3) that:
1) The estimate obtained with the linear model is always higher than those obtained with the log-piecewise model;
2) The value increases with the freight rate, most probably due to higher stock-out costs.
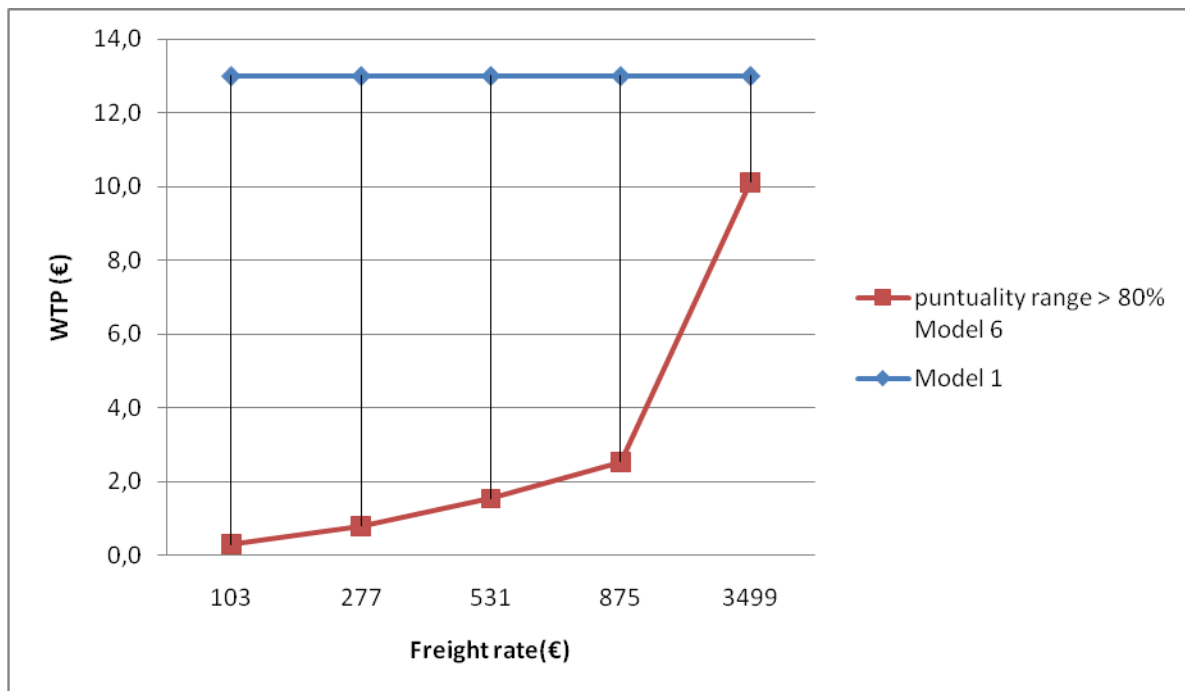

Fig. 3 Willingness to pay for 1% increase in shipments punctuality

The rate of technical substitution between half-a-day travel time and a 1% variation of the probability of having damaged or lost freight within the 0% - 10% and 10% - 20% range respectively is depicted in Figure 4. The rate is systematically larger if calculated on the basis of the log-piecewise model rather than the linear model. The substitutability ratio between travel time and safety decreases as travel time and safety increase, because of the decreasing opportunity cost of travel time and safety.
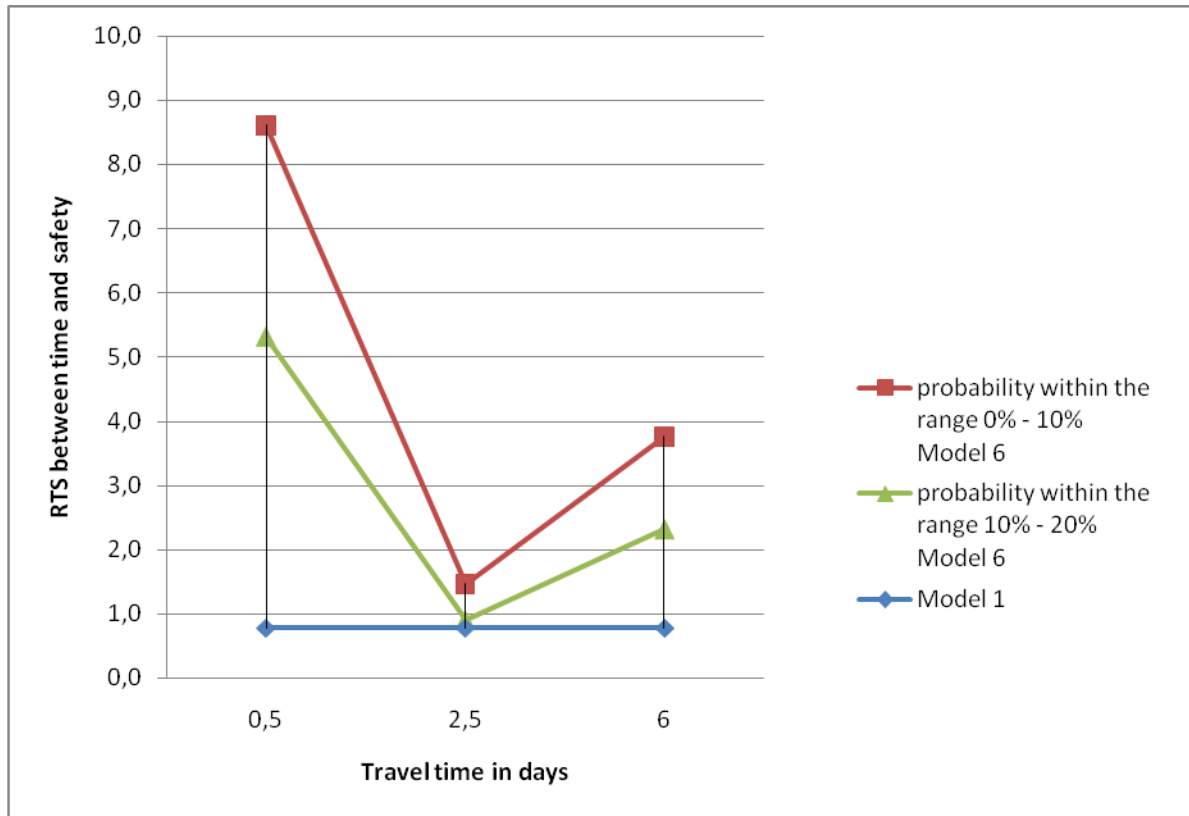

Fig. 4 - Rate of technical substitution between travel time and probability of damaged and lost freight

The rate of technical substitution between half-a-day travel time and a 1% variation of punctual shipments is depicted in Figure 5. Similarly to the previous case the rate is larger if calculated on the basis of the log-piecewise model rather than the linear model. The substitutability ratio between travel time and punctuality decreases as travel time increases because of the decreasing opportunity cost of travel time.
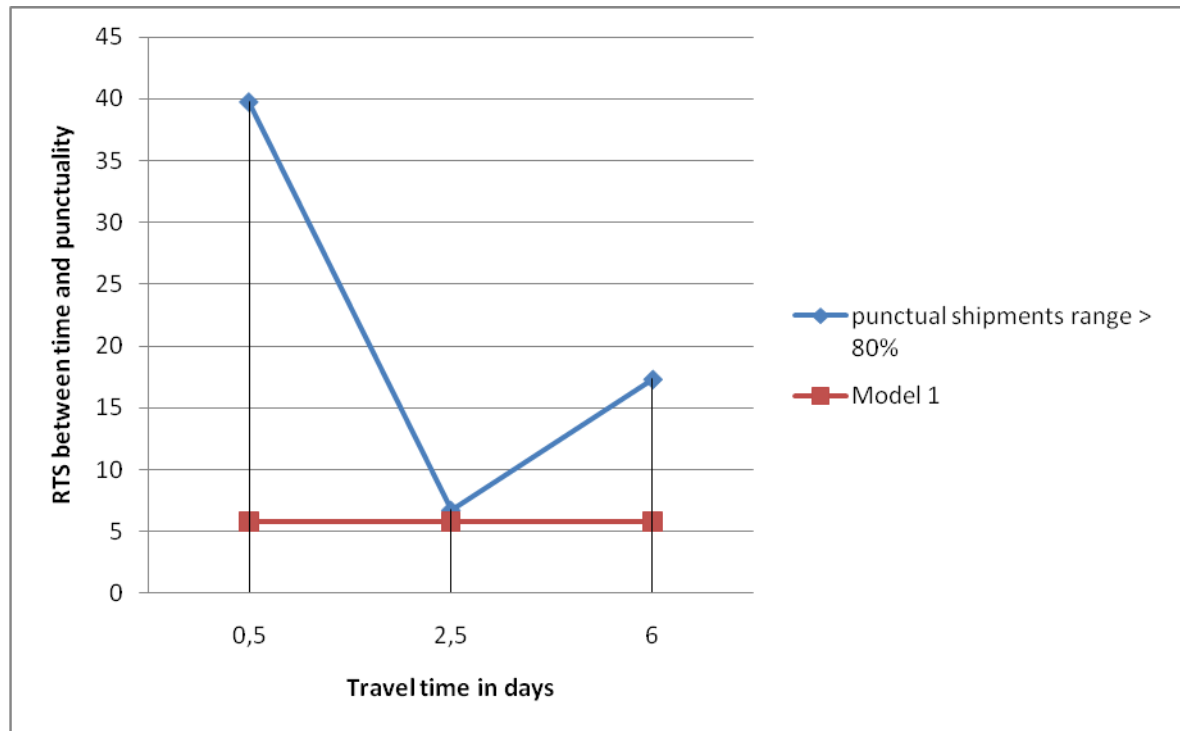
Fig. 5 - Rate of technical substitution between travel time and percentage of punctual shipments

7. Conclusions

The choice of a freight transport service is typically a discrete supply decision aimed at both minimizing the production and distribution costs and maximizing customer satisfaction.

Empirical research based on stated preference data has so far used the random utility model, originally developed to study consumption choices, and specified the deterministic part of the utility (of-profit) function as linear in the observed attributes. This implicitly constrains the attributes of the transport service to be perfect substitutes and to have a constant substitutability ratio. However, standard microeconomic theory typically assumes decreasing marginal productivity and a variable rate of technical substitution.

In this paper we have modeled the choice of a freight transport service by a manufacturing firm by using the random supply choice model developed by Hanneman and Tsur (1982) and we have relaxed the assumption of linearity of the utility-of-profit function with respect to freight rate, travel time, punctuality, and risk of damage and loss.

Our results prove that the linearity in the attributes assumption should be rejected and that the marginal impact on the utility-of-profit of all the attributes analyzed is not constant. Travel time and the freight rate produce decreasing marginal reductions of the utility-of-profit; safety (percentage of damaged or lost shipments) and punctuality (percentage of shipments on time), instead, are responsible for increasing marginal contributions to the utility-of-profit.

We have also estimated the substitutability ratios between (a) freight rate and loss and damage, (b) freight rate and travel time, (c) freight rate and punctuality, (d) travel time and loss and damage and (e) travel time and punctuality, and we have found that they are not constant.

It is also found that the estimates of WTP for qualitative attributes obtained with the linear model are similar to those presented in the literature, but tend to be generally overestimated.

Hence, using estimates based on linear specification to design transport policies may lead to inoptimal outcomes.

Our results, however, are characterized by at least three caveats: (a) the specificity of the sample, limiting the transferability of our results to other contexts and manufacturing sectors, (b) the joint analysis of shippers' preferences for both incoming and outgoing flows, implicitly assumed homogenous, while incoming and outgoing flows most probably have different logistic constraints requiring different transport services characteristics, and (c) the (not controlled for) heterogeneity of the manufacturing sectors included in the experiment differing by shipment value and size, packaging constraints, frequency constraints, generic versus specific procurements, average origin-destination distance, role played by the suppliers and buyers within the supply chain, and technology used for the production process.

The analysis presented in this paper can be improved in a number of ways. The most important ones, in our judgment, are to: (a) select attribute levels with a sufficiently large interval range in order to test for nonlinearity; (b) control for heteroschedasticity by selecting a homogenous sample and by collecting all relevant information that allows a richer specification of the model.

References

Algers, S., Gaudry, M. (2001) "Are Nonlinearity and Segmentation Substitutes, Complements, or Unrelated in Logit Models? The Swedish Intercity Passenger Case", in Gaudry, M., Tegnér, G. (eds), *Transport Demand and Mode Choice: The Impact of Non Linearity*, Elsevier Science, Oxford.

Alvarez, O., Cantos,P., Garcıa, L. (2007) "The value of time and transport policies in a parallel road network", *Transport Policy* 14, pp. 366–376.

Baumol, W. J., Vinod, H. D. (1970) "An inventory Theory Model of freight Transport Demand", *Management science* 16 (7), pp. 413-421.

Bergkvist, E. (2001) "Freight Transportation; Valuation of Time and Forecasting of Flows", *Umeå University Economic Studies*, No. 549, Umeå

Blauwens, G., De Baere, P., Van de Voorde, E. (2010) *Transport economics*, De Boeck, Antwerp.

Bolis, S., Maggi R. (2003) "Logistics Strategy and Transport Service Choices-An Adaptive Stated Preference Experiment", *Growth and Change - A journal of Urban and Regional Policy*, Special Issue STELLA FG 1, (34), pp. 4.

Bretti G., D'Apice C., Manzo R., Piccoli B. (2007) "A continuum-discrete model for supply chains dynamics", *Networks and Heterogeneous Media* 2, pp. 661 – 694.

Brooke, A.S., Caves, R.E., Pitfield, D.E. (1994) "Methodology for predicting European short-hall air transport demand from regional airports: An application to East Midlands International Airport", *Journal of Air Transport Management* 1(1): 37-46.

Bruzelius, N. (2001) *The value of logistics improvements in CBA of transport investments—a survey*, A Report from SAMPLAN 2001:1.

Danielis R., Marcucci E. (2007) "Attribute cut-offs in freight service selection", *Transportation Research Part E* 43, pp. 506–515.

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

Danielis R., Torbianelli, V. (2007) "The demand for transport and logistics services in the Friuli Venezia Giulia Region", *Pomorstvo*, pp. 129-138, ISSN: 1332-0718.

De Borger, B., Fosgerau, M. (2008b) "Discrete choices and the trade-off between money and time: A test of the theory of reference-dependent preferences", *Journal of Urban Economics* 64, pp. 101–115.

de Jong, G., Bakker, S., Pieters, M., Wortelboer-van-Donselaar, P. (2004) "New values of time and reliability in freight transport in the Netherlands", in: *Proceedings of the European Transport Conference*.

de Jong, G.C., M.A. Gommers, Klooster, J.P.G.N. (1992) "Time valuation in freight transport: Methods and results", Paper presented at the XXth Summer Annual Meeting, PTRC.

de Jong, G.C., Y. van de Vyvere, Inwood, H. (1995) "The value of freight transport: A cross country comparison of outcomes", *World Conference on Transport Research*, Sydney.

de Jong, G. (2000) "Value of Freight Travel-Time Savings", in Hensher, D.A. and K.J. Button (eds.) *Handbook of Transport Modelling*, Elsevier, UK.

Duncan, G. M. (1980) "Formulation and Statistical Analysis of the Mixed, Continuous/Discrete Dependent Variable Model in Classical Production Theory", *Econometrica* 48, pp. 839-852.

Fowkes, A.S. (2001) "Values of Time for Road Commercial Vehicles", Working Paper 563, Institute for Transport Studies, University of Leeds.

Fowkes, A.S., Firmin, P.E., Tweddle, G., Whiteing, A.E. (2004) "How Highly Does the Freight Transport Industry Value Journey Time Reliability - and for What Reasons?" *International Journal of Logistics: Research and Applications* 7, pp. 33-44.

Fowkes, A.S., Nash, C.A., Tweedle, G. (1991) "Investigating the market for inter-modal freight technologies", *Transportation Research A* 25(4), pp. 161-172.

Gaudry, M. (2008) "Non Linear Logit Modelling Developments and High Speed Rail Profitability", Working Paper 12, Département économie et sociologie des transports, Institut National de Recherche sur les Transports et leur Sécurité, Marne-la-Vallée, France.

Gunn, (2001) "Spatial and temporal transferability of relationships between travel demand, trip cost and travel time", *Transportation Research Part E* (37), pp. 163-189.

Hanneman, W.M., Tsur, Y. (1982) "Econometric models of Discrete/Continuous Supply Decisions under Uncertainty", Working Paper 195, Department of agricultural and resource economics, University of California, Berkeley.

Henriksson, C., Persson, C. (2001) "Tidsvärden och transportkvalitet - INREGIA:s studie av tidsvärden och transportkvalitet för godstransporter 1999", Underlagsrapport till SAMPLAN 2001, http://www.sika-institute.se/Doclib/Import/106/sa_2001_1_u9.pdf

Hess, S., Rose, J.M., Hensher, D.A. (2008) "Asymmetric preference formation in willingness to pay estimates in discrete choice models", *Transportation Research Part E* 44(5), pp. 847–863.

ISTAT (2010) "Il trasporto merci su strada Anni 2006-2007", Statistiche in breve, http://www.istat.it/salastampa/comunicati/non_calendario/20100402_00/testoint

Kahneman, D., Tversky, A. (1979) "Prospect Theory: An Analysis of Decision under Risk", Econometrica 47(2), pp. 263-291.

Kato, H. (2006) "Nonlinearity of the utility function and the value of travel time savings: empirical analysis of interregional travel mode choice of Japan", *Proceedings of European Transport Conference* 2006, Strasbourg.

Marcucci, E. (2005) *Introduzione ai modelli a scelta discreta per lo studio dei trasporti*, Carocci Editore, Roma.

Masiero L., Hensher, D.A. (2009) "Analyzing loss aversion and diminishing sensitivity in a freight transport stated choice experiment", *Transportation Research Part A* 44 (5), pp. 349-358.

Massiani, J., Danielis, R., Marcucci, E. (2009) "Specific vs. generic goods: implications for transport demand analysis", *International Journal of Transport Economics* 36(3), pp. 377 – 395.

McFadden, D. (1979) "Econometric Net Supply Systems for Firms with Continuous and Discrete Commodities", Working Paper, Department of economics, Massachusetts Institute of Technology, Cambridge.

McKinnon, A. C. (1995) "The contribution of road construction to economic development", Paper presented at the T&E Workshop on Roads and the Economy, Brussels, Belgium, 8 December 1995.

Nijkamp, P., Reggiani, A., Tsang, W.F. (2004) "Comparative modelling of interregional transport flows: Applications to multimodal European freight transport", *European Journal of Operational Research* 155, pp. 584–602.

Patterson, Z., Ewing, G., Haider, M. (2007) "Mode and Carrier Choice in the Quebec City - Windsor Corridor: A Random Parameters", Paper presented at The 6th Triennal Symposium on Transportation Analysis (TRISTAN VI) 10-15 June, Phuket Island, Thailand.

Pinjari A.R., Bhat, C.R. (2006) "On the nonlinearity of response to level-of-service variables in travel mode choice models", *Transportation Research Record* 1977, pp. 67-74.

PROTRANS, (2003) Deliverable 5 European Commission, Brussels.

Puckett, S.M., Hensher, D.A. (2008) "The role of attribute processing strategies in estimating the preferences of road freight stakeholders under variable road user charges", *Transportation Research E* 44(3) , pp. 379-395.

Rich, J., Holmblad, P.M., Hansen, C.O. (2009) "A weighted logit freight mode-choice model" *Transportation Research Part E* (45), pp. 1006–1019.

Swait, J.D. (2001) "A Non-compensatory Choice Model Incorporatine Attribute Cutoffs", *Transportation Research Part B* 35 (10), pp. 903-28.

Tapley, N., Wardman, M., Whelan, G. (2006) "Nonlinearities in discrete choice attribute valuations", paper presented at the European Transport Conference, 18-20 September, Strasbourg, France.

Tavasszy, L., Bruzelius, N. (2005) "The value of freight transport time: A logistics perspective – State of the art and research challenges", in Report of the one hundred and twenty seventh round table on transport economics held in Paris on 4th-5th December 2003, European Conference of Ministers of Transport, OECD Publications Service.

Transek (1992), *Godskunders transportmedelsval*, VV 1992:25, October.

Tyworth, J.E., Zeng, A.Z. (1998) "Estimating the effects of carrier transit-time performance on logistics cost and service", *Transportation Research Part A* (32) , pp. 89–97

Viera, L.F.M. (1992) The value of service in freight transportation, *Ph.D dissertation*, MIT, Cambridge, MA.

Wardman, M. (2004), Public transport values of time, Transport Policy 11: 363-377.

Wilson, F. R., Bisson, B. G. Kobia, K. B. (1986) "Factors That Determine Mode Choice in the Transportation of General Freight", *Transportation Research Record* 1061, pp. 26-31.

Winston, C. (1981) "A Disaggregate Model of the Demand for Intercity Freight Transportation", *Econometrica* 49 (4), pp. 981-1006.

Zamparini, L., Reggiani, A. (2007a) "The value of travel time in passenger and freight transport: An overview." in van Geenhuizen, M., Reggiani, A., Rietveld, P. (Eds.) *Policy analysis of transport networks*. Ashgate Publishing, Aldershot.

Zamparini, L., Reggiani, A. (2007b) "Freight Transport and the Value of Travel Time Savings: A Meta-analysis of Empirical Studies" *Transport Reviews* 27 (5), pp. 621–636.