Modelling freight transport demand and reference dependent choice behaviour

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To my family

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Contents

Introduction

The thesis focuses on discrete choice models for freight transport demand with a particular emphasis on the estimation of willingness to pay (WTP) and willingness to accept (WTA) measures. In order to cope with the research objective, I extend the classic discrete choice model specifications towards the frontier of the current literature on asymmetric model specifications in stated choice experiments with a reference pivoted design.

Discrete choice models investigate and explain the choice of an individual (or group of individuals) among alternatives. In this framework, the alternatives must be mutually exclusive, exhaustive and the number of alternatives must be finite (Train, 2003).

Academic interest on discrete choice models has origins in mathematical psychology. In particular, Thurstone (1927) states the law of comparative judgment, that is a measurement model involving the comparison between two items with respect to magnitude of stimuli. Luce (1959) proposes the choice axiom to characterize a choice probability law that defines two fundamental properties regarding dominated and undominated alternatives. Marschak (1960) formulates an interpretation of utility instead of stimuli and formulated a derivation from utility maximization giving the starting point for the so called random utility models (RUMs).

McFadden (1974) introduces the multinomial logit model and its estimation based on the restricted assumptions about the error term of the utility that must be independent and identically distributed (iid assumption). The independence assumption was relaxed by McFadden (1978) through the derivation of the generalized extreme value (GEV) model, a large class of models that allows correlation among the error terms of the alternatives.

Mixed logit models were introduced in the 1980s by Boyd and Mellman (1980), Cardell and Dunbar (1980) and accurately investigated by Train, McFadden and Ben-Akiva (1987a). This class of models is extremely general and flexible, McFadden and Train (2000) prove that any random utility model can be approximated by a mixed logit model. The main power of mixed logit models is that they solve three typical problems of logit models. That is, they allow for random taste variation, for correlation in unobserved factors over time and they allow unrestricted substitution patterns (Train, 2003).

According to prospect theory (Kahneman and Tversky, 1979; Tversky and Kahneman, 1991; Tversky and Kahneman, 1992), individual choice behaviour is subject to a concept referred to as reference dependency. This concept, when framed within the idea of utility maximization, suggests that when evaluating different outcomes, individuals tend to distinguish differently between positive (gains) and negative (losses) deviations from some base reference alternative. This result leads to the notion that utility should be centred on this base reference point and then be defined in terms of domains of gains and losses surrounding this reference point. In this context, two fundamental findings have been found to characterize individual's utility functions; that individuals i) experience loss aversion (i.e., they evaluate higher weights for losses than for gains), and ii) experience diminishing sensitivity to both gains and losses (i.e., decreasing marginal values in both positive and negative domains). The implications of these two characteristics when considered together, imply firstly the marginal utility of individuals for gains and losses are different and secondly, that these marginal utilities can be considered as non-linear. In turn, this implies that the demand curves for individual respondents should be considered to be kinked with the elbow of the kink centred at the site of the reference alternative.

Since the formalization of prospect theory, reference dependence has been tested in several studies through the use of different interview procedures, with particular reference to contingent evaluation (e.g., Bishop and Heberlein, 1979; Rowe et al., 1980) and laboratory experiments (e.g., Bateman et al., 1997).

Stated choice experiments (SCE) currently represent the primary method for collecting data for the purpose of analysing and understanding choice behaviour. These experiments present surveyed respondents with hypothetical choice situations with the resulting model estimation relying on the Random Utility Model framework (McFadden, 1974). The need to firstly, approximate the reality as much as possible in order to increase the behavioural meaning of the results and secondly, accommodate the prospect theory reference dependence assumption, has resulted in increasing attention being given not only towards modelling the impacts of prospect theory, but also towards generating SCE designs that are pivoted around individual specific reference alternatives (see, for example, Hensher, 2008; Rose et al., 2008). According to a pivot-design the utility function associated to each hypothetical alternative can then be specified in terms of gains and losses around the reference alternative values, either in terms of absolute levels or percentages.

The research is divided into four chapters, each one corresponding to a paper submitted to a refereed journal. The same dataset has been used for all the four papers. The data was obtained from a stated choice survey in a freight transport context conducted in the Ticino region (Switzerland) in 2008. The experiment was part of the project NFP54 “Sustainable Development of the Built Environment”, founded by the Swiss National Science Foundation, aimed to analyze the infrastructure vulnerability of the Gotthard corridor, one of the most important European transport corridors. In particular, the fourth paper, presented in Chapter four, includes a further dataset (collected in 2003) which has been combined to the former one in order to validate the robustness of the results obtained.

The focus of the first paper is to model the freight transport demand according to classical mixed logit model specifications and to integrate the model estimates, such as willingness to pay measures, in a cost-benefit analysis tool. The second paper investigates loss aversion and diminishing sensitivity, and analyzes their implications on willingness to pay and willingness to accept measures in a reference pivoted choice experiment in a freight transport framework. The third paper focuses on individual reactions, in a freight choice context, to a negative change in the reference alternative values, identifying the behavioural implications in terms of loss aversion and diminishing sensitivity. Finally, the fourth paper proposes a comparison of willingness to pay and willingness to accept measures estimated from models with both symmetric and reference dependent utility specifications within two different freight transport stated choice experiments.

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Chapter One

Estimation of indirect cost and evaluation of protective measures for infrastructure vulnerability: A case study on the transalpine transport corridor

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Abstract

Infrastructure vulnerability is a topic of rising interest in the scientific literature for both the general increase of unexpected events and the strategic importance of certain links. Protective investments are extremely costly and risks are distributed in space and time which poses important decision problems to the public sector decision makers.

In an economic prospective, the evaluation of infrastructure vulnerability is oriented on the estimation of direct and indirect costs of hazards. Although the estimation of direct costs is straightforward, the evaluation of indirect cost involves factors non-directly observable making the approximation a difficult issue. This paper provides an estimate of the indirect costs caused by a two weeks closure of the north-south Gotthard road corridor, one of the most important infrastructure links in Europe, and implements a cost-benefit analysis tool that allows the evaluation of measures ensuring a full protection along the corridor. The identification of the indirect cost relies on the generalized cost estimation, which parameters come from two stated preference experiments, the first based on actual condition whereas the second assumes a road closure. The procedure outlined in this paper proposes a methodology aimed to identify and quantify the economic vulnerability associated with a road transport infrastructure and, to evaluate the economic and social efficiency of a vulnerability reduction by the consideration of protective measures.

Keywords: infrastructure vulnerability, choice experiment, cost-benefit analysis, freight transport.

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1.1. Introduction

Interruptions in infrastructure networks generate considerable economic and social damages at the regional and national level according to the overall dependency of the network on certain links and the risk associated with this interruption. In the context of increasingly vulnerable networks due to climate change, the attention on transport network reliability has grown substantially in the recent years in the international science community (Bell and Iida 2003, Nicholson and Dante 2004). Berdica (2002) introduces the road transport vulnerability as a complement of reliability, that is, the non-operability of a system due to incidents caused by either natural or man-made hazards.

Vulnerability assessment of a given transport infrastructure is mostly oriented on an engineering approach and regards the identification of the weakest points in a transportation network. Numerous methods have been proposed based on, for example, connectivity reliability (Bell and Ida, 1997), capacity reliability (Cheng *et al.*, 2002) or accessibility index (Taylor *et al.*, 2006).

In an economic prospective, the evaluation of infrastructure vulnerability is oriented on the estimation of direct and indirect costs of hazards. The former are associated with damages on the infrastructure caused by an unexpected event whereas the latter regard the consequences that the damaged infrastructure provokes on the society that depends on it. Although the estimation of direct costs is straightforward, the evaluation of indirect cost involves factors non-directly observable making the approximation a difficult issue. D’Este and Taylor (2003) proposed to calculate the loss of amenity of a link interruption as the change in generalized cost weighted by travel demand. Different algorithms have been proposed, as, for example, the short path algorithm. However, Taylor and D'Este (2004) recognized the limit in using algorithms as estimates of change in the utility of travel.

The estimation of the cost associated with an interruption of an infrastructure link is necessary in order to evaluate the desirability of any protective measure that allows a reduction of the vulnerability of the network to which it belongs. In this sense, a given vulnerability of a network represents a level of (expected) direct and indirect cost of a given hazard risk. Reducing vulnerability via costly protective measures can lead, as a function of the type of measure implemented, to an increased reliability (hazards have less or no consequences due to increased protection) or an increased resilience (networks recover faster from hazards).[1] We will concentrate here on the evaluation of protective measures creating “perfect” reliability (equivalent to a full insurance policy). This does not imply that we advocate zero vulnerability networks. Rather, a cost-benefit analysis of full protection measures on a given link will reveal whether this is economically justified and will in consequence contribute to move towards an economically optimal reliability. A methodology that allows the economic evaluation of the optimal reliability is still needed and required.

The aim of this paper is to estimate the indirect costs caused by a two weeks closure of an important trans-Alpine road corridor and to implement a cost-benefit analysis tool that allows the evaluation of measures ensuring a full protection along the corridor. We analysed one of the most important road infrastructure links in Europe, i.e. the north-south Gotthard road corridor. This corridor exhibits a high level of vulnerability because of its alpine geographical position and its long two-lane only tunnel (the third longest road tunnel in the world). The paper aspires to expand knowledge on how risk management has to be implemented to reduce potential damages and expected impacts and to improve the wider benefits due to enhanced network reliability.

In order to reduce the complexity of the evaluation – evaluating the costs and benefits across the whole European road- and rail network would be an enormous task - the perspective has been reduced in several important ways. In a geographical sense we restrict the analysis to the Swiss Canton of Ticino, a part of the country south of the Alps and north of Italy, with two main trans-Alpine connections to the north – the Gotthard as a main connection and the San Bernardino a less important but still relevant link. Regarding cost we concentrate on indirect cost we limit our analysis to the sector that most depends on that road corridor, that is the Ticino freight transport market (inbound and outbound towards north). For this well delimited context we carried out two stated preference experiments addressed to logistic managers of 27 medium to large firms in Ticino. The first experiment involves choices in actual conditions whereas the second assumes a two week road closure.

[1] For a more detailed explanation of these concepts in a transport context see Husdal 2006)

Discrete choice model specification allows the generalized cost estimation through the derivation of the willingness to pay measures. Indeed, stated preference experiments are the most common techniques used in willingness to pay derivation and they allow to investigate the consumer behaviour in situations where few (or even none) data are available.

The cost benefit analysis is based on the change that an unexpected road interruption caused in the freight transport generalized cost. The evaluation of the economic sustainability of the risks identified along the corridor is then carried out by comparing the increase in the generalized cost with the cost of the protective measures. Finally, a cost benefit analysis tool is provided as a valid support of policy decision makers.

The paper is organized as follows. In section two we provide a brief geographical description of the infrastructure and we introduce the data. In section three we outline the discrete choice theoretical formulation. We present and discuss the model results in section four. The cost benefit analysis is performed in section five along with the introduction of the tool. Finally, conclusion and suggestion for further research are given in section six.

1.2. Data

The study concerns a choice based experiment, analysing the economic impact of a hypothetical closure of the Gotthard corridor[2]. Consequently we investigated the possible adaptive behavioural patterns of different actors in the face of disastrous and/or risky events. The investigation is based on the method of stated preferences. We basically want to model by means of an experimental design how the different actors react to the closure of this important road link across the Alps.

[2] The experiment began with some pilot interviews during February 2008, officially started in March 2008 and was finally concluded in June 2008.

1.2.1 Geographical context

Due to its strategic position the corridor is one of the most important links between the north and the south of Europe. It represents a very important element of the national and international road and rail network facilitating transport and economic interaction between the north and the south of Europe.

Today, roughly 200 km of the Swiss national highway network are exposed to natural hazards, or in other words, every ninth kilometres leads through hazardous areas and hence needs protection. A total of 137 galleries protect the traffic, more than 90 of them are rock fall protection measures. Additionally there are constructive measures directly in the hazard zones, such as protection nets, anchors, etc. The maintenance of these protection measures costs 30 Mio CHF every year[3].

Between 1994 and 2004 freight transport by road and rail across the Alps grew by 68% (rail traffic plus 25%, road traffic plus 60%). Today, the Alps are crossed each year by about 10 million trucks, a third of which passes through Switzerland, 85% of these using the Gotthard route[4].

1.2.2 Stated preferences experiment

We introduced the experiment by conducting an interview with the logistics managers of the most concerned industries (manufacturing) asking them about their general logistics and transportation framework and typical transportation relations across the Alps[5]. These managers were then confronted with alternative transportation services described by the use of three attributes, respectively, cost, time and punctuality. Cost and time attributes are pivoted to the reference values according to the levels shown in Table 1, whereas punctuality is expressed in absolute values.

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[3] "La A2 a Gurtnellen un anno dopo la frana". Comunicato Stampa, Ufficio federale delle strade USTRA.
[4] MONITRAF, Synthesebericht, Monitraf Aktivitäten und Ergebnisse, Endbericht, febbraio 2008, Innsbruck/Zürich.
[5] The decision to concentrate on the freight transport sector stems from past studies demonstrating that the passenger sector (tourism and business travel) exhibit almost negligible additional costs in the sequel of past closures. In particular, we refer to the closure of two months occurred in November 2001 following a frontal truck crash inside the 17 km long tunnel.

The whole experiment was based on a Computer Assisted Personal Interview (CAPI) instrument that randomly generates different profiles according to the assumption of experiment orthogonality. To each respondent 15 choice situations were presented.

Table 1. Attributes and their levels.

Transport Cost	Transport time	Transport Punctuality
-10 %	-10 %	100 %
-5 %	-5 %	98 %
Equal to the reference cost	Equal to the reference time	96 %
+5 %	+5 %	
+10 %	+10 %	

The whole experiment was based on a Computer Assisted Personal Interview (CAPI) instrument that randomly generates different profiles according to the assumption of experiment orthogonality. To each respondent 15 choice situations were presented.

The experiments refer to two different scenarios getting two different datasets. Examples of choice cards that the logistic manager was confronted with are given in Figures 1 and 2. In the first scenario we want to model behaviour with respect to the risk of frequent but short closures experienced currently along the road corridor, whereas in the second scenario we make the hypothesis of a rare incident provoking a two-week closure of the A2 highway.

Figure 1. Example of choice card for long-run decision experiment (first scenario)

Suppose a situation where the road Gotthard corridor is going to be closed for a maximum of two consecutive days every month. Which of the following alternatives would you prefer?

Road (A2)	Combined Transport	Piggyback
Actual cost	5% more than actual cost	5% less than actual cost
Actual time	10% more than actual travel time	5% more than actual travel time
Actual punctuality	100% punctuality	96% punctuality
○	○	○

The first experiment analyzes the strategic decision on whether to stick to the currently chosen alternative (A2) given a known risk, or switch to a different one. In this sense we consider it to be a long-run choice among three different alternatives, namely, road (A2), piggyback and combined transport under the actual possibility of finding the A2 closed on a specific day. The road (A2) alternative remains fixed during the whole experiment since it describes the reference alternative. Its characteristics are those described by logistic managers for the typical transportation service across the Alps.

The second experiment regards a short-run decision since we make the hypothesis of a two-week road closure - a rare event calling for a short term reaction. This choice situation is characterized by four alternatives, namely, road (A13), new road (regulated A13), piggyback and combined transport. In this second experiment the reference alternative is represented by the road (A13) alternative (that is the San Bernardino corridor) since it is the immediate re-routing alternative chosen by most road users when the Gotthard road corridor is closed.

Figure 2. Example of choice card for short-run decision experiment (second scenario)

Suppose a situation where the road Gotthard corridor is closed for two weeks.
Which of the following alternatives would you prefer?

Road (A13)	Piggyback	Combined Transport	New Road (regulated A13)
Transitional cost	10% less than transitional cost	5% less than transitional cost	10% more than transitional cost
Transitional travel time	10% more than transitional travel time	5% more than transitional travel time	Equal to transitional travel time
Transitional punctuality	98% punctuality	96% punctuality	100% punctuality
○	○	○	○

In order to quantify the cost and time for the reference alternative (San Bernardino) we used the additional cost and the additional time with respect to Gotthard corridor resulting from a previous survey with six of the most important shippers in Ticino. There, all interviewed shippers replied with very similar additional cost and time, respectively 300 CHF and 5 hours more for a detour via the San Bernardino route rather than along the Gotthard corridor. We get the values for the road (A13) alternative by summing these additional cost and time to the original reference values. Regarding the punctuality we assume a decrease of 2% with respect to the original value, with a minimum level fixed to the lowest level considered, that is, 96% of transports being punctual. This statement has been confirmed by the shippers interviewed, in particular if we consider the high volume of flows that occurs in a similar situation. To be noted that the validity of the transitional values is restricted to the closure period, that is fourteen days. The new road (regulated

A13) alternative has been introduced to simulate a congestion free San Bernardino alternative (assume a sort of priority policy for trucks) with the original punctuality maintained.

The sample is composed by 27 firms active in the manufacturing sector and, as mentioned before, all of them based in Ticino. The typical transport service described by logistic managers is reported in Table 2. As expected, cost and time vary substantially since they are characterized by the distance between origin and destination and by the weight of the shipment, whereas punctuality is very homogenous and apart from two cases stating a 90% of punctuality in the transportation services all others are between 95 and 100 percent. This is in line with previous studies (see, for example, Bolis and Maggi 2003 and Maggi and Rudel 2008) and confirms the high level of importance that a logistics manager puts on a quality attribute like punctuality.

Table 2. Sample descriptive statistics of typical transport service

Variable	Mean	Median	Std.Dev.	Minimum	Maximum
Cost (CHF)	1300.15	1000	1152.95	136	5400
Time (hr)	33.35	24	27.30	2	96
Punctuality (%)	96.52	98	3.04	90	100
Weight (ton)	7.1309	5.50	7.17	0.04	25
Distance O-D (km)	474.33	300	332.62	92	1360
MADD	2.29	2	0.97	1	5
Damage (%)	0.97	0.4	1.98	0	10
Value (CHF/kg)	203.28	40	487.38	0.36	2400

The descriptives for the damage and loss variables report a very low occurrence, with a sample mean of 0.97% and a median of 0.4%. The damage and loss attribute is widely used but a matter of debate in literature because of its inconsistency and its frequent insignificance in the model estimation. In fact, it is meaningless to have a systematic damage or loss in the transport service because shippers/forwarders will self insure via a systematic solution, for instance a different packaging, or a different truck, or even a different mode of transport. Indeed, accidental damages might be happening but remain an occasional feature and not a characteristic of a transport service. For this reason, we chose to not include this attribute in our experiment. The descriptive statistics collected during the analysis confirm this decision.

Finally, from revealed market shares obtained for the whole logistic in the entire sample results, as expected, that the majority of the transport services rely on road alternative while the rest uses combined transport, either via rail or via ship and air. The piggyback alternative is not relevant confirming the weakness characterizing it due to technical problems and high operational cost.

1.3. Theoretical background

In a stated choice experiment, the respondent *n* is supposed to select the alternative *j* that maximizes his utility,

$$U_{nj} = \boldsymbol{\beta}'\mathbf{x}_{nj} + \boldsymbol{\varepsilon}_{nj} \tag{1}$$

where $V_{nj} = \boldsymbol{\beta}'\mathbf{x}_{nj}$ is the systematic part of the utility and $\boldsymbol{\varepsilon}_{nj}$ is the random term that is Independent and Identically Distributed (IID) extreme value type 1. The estimation of the beta coefficients relies on the class of Random Utility Models (McFadden, 1974).

An advanced and widely used discrete choice model is the Random Parameter Logit (RPL) model, which allows for taste heterogeneity among respondents by letting the beta parameters randomly vary across the sample population (see Hensher and Green, 2003 for a detailed discussion). The following equation describes the choice probability for a RPL model:

$$P_{nj} = \int_{\beta} \left(\frac{\exp(\boldsymbol{\beta}'_n \mathbf{x}_{ni})}{\sum_j \exp(\boldsymbol{\beta}'_n \mathbf{x}_{nj})} \right) f(\boldsymbol{\beta}) d(\boldsymbol{\beta}) \tag{2}$$

where parameters β are drawn by continuous distributions (e.g. normal, log-normal, triangular etc.). The selection of a specific distribution, whenever possible, is based on previous knowledge or on particular behavioural assumptions. However, if no particular hypotheses are available or required, the selection is arbitrary and generally based on the goodness of fit of the data.

In a context of stated choice with repeated choice situations, an additional and indispensable feature of RPL models is the capability to deal with the panel structure by constraining the random parameters to be constant over choice situations. The choice probability in Equation (2) becomes then:

$$P_{nj} = \int_{\beta} \left(\prod_t \frac{\exp(\boldsymbol{\beta}'_n \mathbf{x}_{nit})}{\sum_j \exp(\boldsymbol{\beta}'_n \mathbf{x}_{njt})} \right) f(\boldsymbol{\beta}) d(\boldsymbol{\beta}) \tag{3}$$

where t = 1,…,T indicates the number of choice situations. Since in any RPL model the choice probability integral has no closed form solutions, the estimation process is based on simulations and the log-likelihood takes the following form:

$$LL_n = \sum_n \ln \frac{1}{R} \sum_r \prod_t \frac{\exp(\boldsymbol{\beta}'_n \mathbf{x}_{nit})}{\sum_j \exp(\boldsymbol{\beta}'_n \mathbf{x}_{njt})} \tag{4}$$

where, r = 1,…,R indicates the simulation draw. The following models are based on 200 Halton draws[6].

1.4. Model estimation results

Different Panel RPL models were estimated[7] for the two scenarios and the selection was based according to both model fit indicators and behavioural meaning. Specifically, the evaluation of the model goodness of fit is provided by the final log-likelihood as well as the McFadden pseudo ρ^2 and the Akaike's Information Criterion (AIC).

The estimation of the utility functions for the first scenario is based on the following panel RPL specification:

$$\begin{cases} V_{n(\mathrm{PB})} = ASC_{\mathrm{PB}} + \beta_{(PB)\mathrm{C}}\mathrm{C}_{\mathrm{PB}} + \beta_{(PB)\mathrm{T}}\mathrm{T}_{\mathrm{PB}} + \beta_{\mathrm{P}}\mathrm{P}_{\mathrm{PB}} \\ V_{n(\mathrm{CT})} = ASC_{\mathrm{CT}} + \beta_{(CT)\mathrm{C}}\mathrm{C}_{\mathrm{CT}} + \beta_{(CT)\mathrm{T}}\mathrm{T}_{\mathrm{CT}} + \beta_{\mathrm{P}}\mathrm{P}_{\mathrm{CT}} \\ V_{n(\mathrm{RD})} = \beta_{(RD)\mathrm{C}}\mathrm{C}_{\mathrm{RD}} + \beta_{(RD)\mathrm{T}}\mathrm{T}_{\mathrm{RD}} + \beta_{\mathrm{P}}\mathrm{P}_{\mathrm{RD}} + \beta_{n\mathrm{D}}\mathrm{D} + \beta_{n\mathrm{W}}\mathrm{W} \end{cases} \tag{5}$$

[6] See Train (2003) for details.
[7] Models estimation is performed by Nlogit 4.

where $ASC_{(j)}$ refers to the alternative specific constant, $\beta_{(j)C}$, $\beta_{(j)T}$ and β_P are the coefficients associated to cost, time and punctuality while β_{nD} and β_{nW} are the parameters of the firm's logistics specific variables referring to transport service origin-destination distance (in kilometres) and shipment weight (in tonnes). Coefficients β_{nD} and β_{nW} are selected to be triangular distributed[8] whereas all the other coefficients are supposed to be invariant over the sample, that is, the entire information is supposed to be captured by the sample mean.

Table 3. Panel RPL estimate for the first scenario

	Coefficient	(t-ratio)
Means for Random and Non-Random parameters		
Piggyback Constant	-0.98342	(-0.69)
Combined Transport Constant	-1.29087	(-0.91)
Piggyback Cost	-0.00554	(-5.92)
Combined Transport Cost	-0.00539	(-5.79)
Road (A2) Cost	-0.00624	(-4.55)
Piggyback Time	-0.10645	(-3.48)
Combined Transport Time	-0.09660	(-3.22)
Road (A2) Time	-0.10668	(-2.44)
Punctuality	0.37771	(6.62)
Distance O-D	0.00315	(1.29)
Weight	0.06435	(0.60)
Standard deviations for Random parameters		
Ts Distance O-D	0.02570	(3.20)
Ts Weight	0.36608	(2.22)
Sample		405
Final Log-l		-294.70
McFadden pseudo ρ^2		0.338
AIC		1.519

The estimation results for the first scenario are shown in Table 3. The road (A2) alternative has been set as the reference alternative, and then the signs of the alternative specific constants indicate a slight preference for the road alternative even if the t-ratio test does not confirm their statistical significance. The alternative specific coefficients associated to cost and time attributes are all significant at an alpha level of 0.01 (0.05 for road time coefficient) and present the expected negative sign. The generic parameter for punctuality is also strongly significant and positive, reflecting an increase in utility in correspondence of an increase in transport service punctuality.

[8] The selection of the triangular distribution was based on model fit preference. See Hensher and Green (2003) for discussion about triangular distribution use in discrete choice modelling.

The coefficients associated with the two firm specific variables show a mean not statistically different from zero, however they capture a significant heterogeneity among respondents, indicating that part of the respondents prefer to switch to rail-based alternatives as either the transport distance or the shipment weight increases.

The analysis of the first scenario continues with the estimation of the monetary values of the quality attributes (time and punctuality) defined as the ratio of the marginal utility of the quality attribute to the marginal utility of the cost attribute. Within discrete choice class of models the derivation is straightforward since the parameter estimates refer to the marginal utility. In this context, we indicate the value of time (VOT) as β_{jC}/β_{jT} and the willingness to pay for punctuality (WTPP) as $\beta_P/\ \beta_{jC}$.

In Table 4 we report the monetary measures (per shipment and per tonne) of time and punctuality obtained for the three transport alternatives presented in the first scenario. The road alternative shows a value of time (17.1 CHF/hour) similar to previous studies (Bolis and Maggi, 2003, Maggi and Rudel 2008, Zamparini and Reggiani 2007). The VOT for the two rail-based alternatives result in a higher value compared to the road alternative, namely 17.9 and 19.2 for piggyback and combined transport, respectively. This is in contradiction with Zamparini and Reggiani (2007) who analyse the value of time reported in published studies in the period 1990-2005 and observe a VOT higher for road than for rail freight transport. However, it should be noted that among the 46 studies analysed by Zamparini and Reggiani (2007) only 5 contained rail values, , 4 of which were conducted in the period 1990-1992 and one in 2000.

The willingness to pay for an increase of 1% in punctuality goes from 60.5 CHF for road alternative to 70.1 CHF for combined transport. These values confirm recent studies regarding the high importance of punctuality as a transport service quality (see for example, Danielis *et al.*, 2005, Fowkes *et al.* 2004).

Table 4. WTP measures and generalized cost for the first scenario

	VOT	VOT/ton*	WTPP	WTPP/ton*	Market Share	Generalized Cost
Piggyback	19.21	2.63	68.15	9.34	24	1901
Combined	17.93	2.46	70.13	9.61	33	2183
Road (A2)	17.09	2.34	60.50	8.29	43	1886

* Average tons loaded (from sample average) = 7.3

The estimation of the model parameters and the derivation of the monetary values of quality changes makes the computation of the generalized cost straightforward. In fact, according to Hensher and Button (2000), the generalized cost is a linear combination of cost and any variable that is likely to impact on a given transport service. In our case, we assume that transport cost, time and punctuality have an impact on logistics manager's choice. The generalized cost associated to each alternative is then given by the following equation:

$$GC_j = C_j + VOT_j \times T_j + WTPP_j \times (100 - P_j) \qquad (6)$$

where C_j, T_j and P_j are the alternative specific variables cost, time and punctuality. In Table 4 we report the average generalized cost for each alternative alongside the proportion in percentage points indicating the share of the preferences among the alternatives (market share).

The results indicate a consistent proportion of the logistics managers (24%) willing to switch mode of transport from road to piggyback under the hypothetical market condition assumed by the experiment design, that is, a piggyback mode transport really thought as a concrete and efficient alternative to the road.

The combined transport shows the highest generalized cost and confirms the market share registered in the actual market. As expected, the freight transport via road reports the lowest generalized cost and it still is the most preferred alternative even if the logistics manager is well-aware of the chances that frequent road closures might cause a delay to his transport. This result could be explained in several ways, from risk propensity to mode switch inelasticity. However, a more realistic explanation is that, as reported by the majority of the respondents, the rail-based alternatives are not sufficiently competitive in the given logistics context (high frequency low weight shipments, relatively short distance covered across the Alps within Switzerland) to allow a risk reduction by switching the transport mode from road to rail-based alternatives. This holds in spite of important policy efforts (heavy subsidies, open access of freight operators on rail) to shift freight traffic from road to rail, and a high frequency of short closures in winter (mostly due to the heavy snowfall) and in summer (caused by the long queues at the tunnel bottleneck leading to a postponing of departure).

According to the objective of quantifying the economic vulnerability of the road infrastructure under an unexpected and long closure, we set the average generalized cost of a freight transport via road, 1886 CHF, as the starting point of the cost-benefit analysis[9].

In order to obtain the monetary values for time and punctuality associated with an unexpected total closure of the road Gotthard corridor for two consecutive weeks, we introduce the logistics managers to the second scenario. The specification of the panel RPL model is given by:

$$\begin{cases} V_{n(TrNR)} = ASC_{Tr\mathrm{NR}} + \beta_{(TrNR)\mathrm{C}}\mathrm{C}_{Tr\mathrm{NR}} + \beta_{(TrNR)\mathrm{T}}\mathrm{T}_{Tr\mathrm{NR}} + \beta_{Tr\mathrm{P}}\mathrm{P}_{Tr\mathrm{NR}} \\ V_{n(Tr\mathrm{PB})} = ASC_{Tr\mathrm{PB}} + \beta_{(TrPB)\mathrm{C}}\mathrm{C}_{Tr\mathrm{PB}} + \beta_{(TrPB)\mathrm{T}}\mathrm{T}_{Tr\mathrm{PB}} + \beta_{Tr\mathrm{P}}\mathrm{P}_{Tr\mathrm{PB}} \\ V_{n(Tr\mathrm{CT})} = ASC_{Tr\mathrm{CT}} + \beta_{(TrCT)\mathrm{C}}\mathrm{C}_{Tr\mathrm{CT}} + \beta_{(TrCT)\mathrm{T}}\mathrm{T}_{Tr\mathrm{CT}} + \beta_{Tr\mathrm{P}}\mathrm{P}_{Tr\mathrm{CT}} \\ V_{n(Tr\mathrm{RD})} = \beta_{(TrRD)\mathrm{C}}\mathrm{C}_{Tr\mathrm{RD}} + \beta_{(TrRD)\mathrm{T}}\mathrm{T}_{Tr\mathrm{RD}} + \beta_{Tr\mathrm{P}}\mathrm{P}_{Tr\mathrm{RD}} + \beta_{MD}\mathrm{MD} + \beta_{n\mathrm{D}}\mathrm{D} + \beta_{n\mathrm{W}}\mathrm{W} \end{cases} \quad (7)$$

where the two rail-based alternatives share now the choice set with two road alternatives, road via A13 (TrRD) and new road (TrNR). The suffix “Tr” indicates that the attributes (as well as the coefficients and the utility functions) refer to the transitional detour values. We also introduce a further logistics characteristic of the firm, called maximum acceptable delivery delay (MADD), which is a 5 point discrete variable and expresses the delay tolerance allowed by the client, during an unexpected event, without any additional charge to be paid by the supplier.

The logistics managers were then faced with the updated reference alternative profile, and they were reminded that these new conditions hold just for two transitional and consecutive weeks. The results for this second scenario are shown in Table 5. The sign and the magnitude of the alternative specific constants indicate the new road (regulated

[9] In order to verify that our insistence on the frequent risk of short closures had not influenced the respondents’ parameters we also have derived the generalized cost by using a dataset collected among Swiss firms aimed to evaluate the quality attributes in freight transport (described in Rudel and Maggi, 2008). Even running different specification models the resulting generalized cost was very similar to the one obtained with this first scenario.

A13) alternative as the most preferred since it presents the highest ASC value. Nevertheless, the two rail-based alternatives, namely, piggyback and combined transport, are also preferred to the actual road alternative (A13). The cost and time alternative specific coefficients are highly significant (at an alpha level of 0.01) and with the expected sign as well as the generic punctuality parameter.

Table 5. Panel RPL estimate for the second scenario

	Coefficient	(t-ratio)
Means for Random and Non-Random parameters		
New Road Constant	3.81419	(1.98)
Piggyback Constant	3.31834	(1.72)
Combined Transport Constant	3.03794	(1.58)
New Road Cost	-0.00576	(-8.60)
Piggyback Cost	-0.00568	(-8.47)
Combined Transport Cost	-0.00562	(-8.35)
Road (via A13) Cost	-0.00719	(-6.53)
New Road Time	-0.13314	(-5.79)
Piggyback Time	-0.13192	(-5.61)
Combined Transport Time	-0.12924	(-5.41)
Road (via A13) Time	-0.11486	(-3.59)
Punctuality	0.38859	(9.10)
MADD	1.64419	(2.36)
Distance O-D	-0.00041	(-0.12)
Weight	0.01737	(0.13)
Standard deviations for Random parameters		
Ts Distance O-D	0.00983	(2.87)
Ts Weight	0.37209	(2.06)
Sample		405
Final Log-l		-387.22
McFadden pseudo ρ^2		0.509
AIC		1.996

The parameter associated with the logistics firm specific “MADD” variable is significant and positive, showing the logistics manager’s aversion to look for better temporary alternatives as the flexibility in the delivery delay increases. As for the first scenario, the origin-destination distance and the transport weight variables result with mean values of zero but with significant standard deviation helping to capture the heterogeneity across respondents.

From the coefficient estimates we derive the monetary values for time and punctuality associated with each of the four alternatives considered in the second scenario. The VOT and WTPP values, calculated as the ratio of the quality attribute coefficient to the cost coefficient, are shown in Table 6. Compared to the first scenario, the two rail-based alternatives experience a significant VOT increase whereas the WTPP values do not show consistent differences. Similar VOT and WTPP values are identified for the new road alternative. On the contrary, the VOT and WTPP for freight transport on the San Bernardino road corridor (A13) are valued less than those for the Gotthard road corridor (A12) reflecting the well known problems that trucks face along the former corridor (i.e. steep road with low average curve radius). Thus, apart from the road (A13) alternative, the results obtained for the monetary values highlight that in a short term emergency condition the logistics managers increase their perception of time without altering their perception of punctuality. This confirms, as previously stated, the high importance of the transport punctuality that is at its maximum all year long.

Table 6. WTP measures and generalized cost for the second scenario

	VOT	VOT/ton*	WTPP	WTPP/ton*	Market share	Generalized Cost
New Road	23.13	3.17	67.52	9.25	32	2455
Piggyback	23.22	3.18	68.40	9.37	28	2523
Combined	23.01	3.15	69.17	9.48	27	2602
Road (A13)	15.98	2.19	54.07	7.41	13	2304
* Average tons loaded (from sample average) = 7.3						

Finally, the average generalized cost for each transport mode alternative has been computed according to the following equation:

$$Tr(GC_j) = Tr(C_j) + Tr(VOT_j) \times Tr(T_j) + Tr(WTPP_j) \times [100 - Tr(P_j)] \qquad (8)$$

where $Tr(GC_j)$ are the alternative specific generalized costs during the two-week closure period, $Tr(VOT_j)$ and $Tr(WTPP_j)$ refer to the monetary measures estimated from the second scenario and $Tr(X_j)$ are the typical transport cost, time and punctuality variables updated to the new values according to the emergency situation. The results are given in Table 6 together with the second scenario market shares. The reference alternative (A13) shows both the lowest generalized cost and the lowest market share because of the low punctuality set for this alternative. However, the transport by road is still the most preferred since the regulated road alternative (an “uncongested” A13) shows the highest market share and a lower generalized cost than the two rail-based alternatives.

In general, the additional generalized cost estimated is approximately 600 CHF per transport. In particular, the value of travel time saving increases consistently while the willingness to pay for 1 percent more of punctuality is more stable.

1.5. Cost-Benefit Analysis tool

The construction of this module relies on the results of both stated choice experiments described in the previous sections. In particular, the module is built in order to estimate the indirect user cost of a two week closure of the road Gotthard corridor[10]. The results obtained from the first scenario provide the starting value for the generalized cost in an everyday condition while the results obtained from the second scenario are used in the estimation of the additional generalized cost. Figure 3 shows how the main worksheet appears to the user. A detailed help page is also provided by clicking the apposite button.

The structure of the module is organized in six sections:

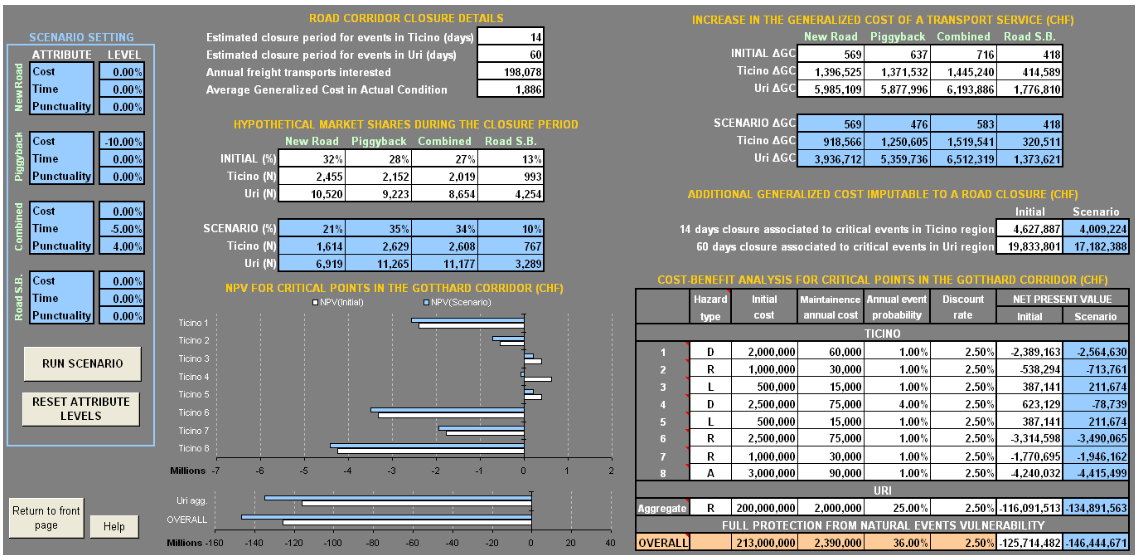
1. Scenario setting: shows the alternatives and the attributes used in the estimation modelling. Zero correspond to the default values, by inputting different values (either positive or negative) we generate a scenario;
2. Closure details: allows different closure period settings and changes in traffic flow and reference generalized cost;
3. Market shares: shows the market shares in percentage and in number[11] for both default and scenario values;
4. Generalized cost: shows the additional generalized cost[12] caused by a two-week closure of the road corridor for the Ticino economy;
5. Cost-benefit analysis for critical points in the Gotthard corridor: allows the computation of the net present values of the selected measures aimed to reduce the whole vulnerability of the road Gotthard corridor;

[10] The tool is available upon request from the corresponding author.
[11] The source of the total amount of trucks passing through the Gotthard corridor is the last AQGV 04 census. We consider only trucks departing from or arriving to Ticino. This amount is inputted in the cell called N and it is free to be changed by the user.
[12] The reference value is put into the cell GC_Gotthard and stems from the first scenario results.

6. Net present values chart: highlights in a histogram chart the net present values of the selected measures distinguishing between default and scenario values.

In the Ticino freight transport market, the estimated indirect cost caused by an unexpected two-weeks closure of the road Gotthard corridor is 4.63 Mio CHF (see Figure 3). Therefore, any infrastructure investment aimed at reducing the probability of a two-week closure should be compared with a saved cost of 4.63 Mio CHF.

Figure 3. Estimation page and example of scenario analysis for long closure



Regarding the cost-benefit analysis section we illustrate nine critical points along the whole corridor, eight of which are those identified in Ticino (south of the Alps) with the geo-scientific risk analysis[13] and one is an assumed hazard in the Canton of Uri (north of the Alps). For each of them a mitigation measure can be defined establishing zero hazards at this point. In other words, the protection of the link against an unexpected long closure is complete regarding this location. The user has to input the initial cost, the annual maintenance cost of the selected measure, the risk of closure according to the annual event probability and the appropriated discount rate. Then, the tool provides the net present value (NPV) for each one of the measures considering a project lifetime of 50 years. Calculating a separate NPV for each mitigation measure implies that we simulate a situation where the whole benefit (savings in generalised cost) is attributed to a single measure but weighted by the probability of the hazard.

[13] The critical points and the protective measures are reported in Appendix, Table A1. We thank Mirko Baruffini for providing with the information.

Assuming a low discount rate of 0.025 and a realistically low event probability of 0.01, measures 3 and 5 against landslides and measure 4 against debris flow result in a positive NPVs. Together they would reduce the risk of closure by 6%. The other measures show negative NPV. This implies that large investments, like e.g. the hypothetical one in URI, or smaller ones in Ticino but for low event probability are not justified if we consider only the indirect benefit for Ticino. Expanding the analysis and adding the direct benefits and above all indirect benefits for the rest of Switzerland, and Europe (transit traffic accounts for 50% of the trans-Alpine passages) might change the results significantly in favour of the measures.

By changing the infrastructure parameters the user can explore alternative policy measures that might lead to different vulnerability outcomes changing the economic efficiency of a given protective measure. For example, by assuming a ten percent cost reduction for the piggyback alternative and, a five percent time reduction and a four percent punctuality increase for the combined transport alternative, the cost of a two-week road closure would be 4 Mio CHF (see Figure 3), that is, 13.4 percent less than the actual estimated loss. This makes the net present value of protective measure 4 not positive anymore.

Finally, the versatility of the module allows the integration of any further information gathered about the exact number of sensible points located along the Gotthard road corridor and the exact monetary value of each measure aimed at mitigating the risk of a long closure.

1.6. Conclusions

This paper has investigated the economic consequences associated with a two-week closure of the Gotthard road corridor, and has analysed the economic efficiency of different protective measures through the implementation of a cost-benefit analysis.

Due to its geographical location and to the seventeen kilometres long two-lane tunnel, the Gotthard corridor experiences a high degree of vulnerability towards unexpected events. In fact, in recent years two disastrous events occurred. In November 2001, a head-on collision between two trucks inside the tunnel caused a two months road interruption while, in May 2006, a rock fall caused a closure of one month.

We provide the indirect cost in the economic sector that most heavily depends on the road corridor, that is, the Ticino freight transport market. The identification of the indirect cost relies on the generalized cost estimation, which parameters come from two stated preference experiments, the first based on actual condition whereas the second assumes a road closure.

The results indicate that a two-week closure of the Gotthard road corridor generates an indirect user cost to the Canton Ticino of 4.63 Mio CHF. As a consequence, the cost of any measure avoiding this risk has to be compared with the potential benefit of saving at least this sum (if benefits to other regions and direct benefits are neglected). In this context, nine critical points along the corridor were identified and the cost-benefit analysis indicates a positive net value for three protective measures resulting in a reduction of the road closure risk of six percent.

The implementation of the cost-benefit tool is essential in testing different scenarios useful in the evaluation of different policy setting. In fact, the tool lets the service transport parameters, cost, time and punctuality, free to change. For example, an improvement of the rail-based alternatives in term of cost, time and punctuality can reduce significantly the road vulnerability.

The procedure outlined in this paper proposes a methodology aimed to identify and quantify the economic vulnerability associated with a road transport infrastructure and, to evaluate the economic and social efficiency of a vulnerability reduction by the consideration of protective measures. Nevertheless, this procedure should be considered as a starting point and further improvements are strongly recommended. We suggest the extension of the economic loss with the estimation of the direct cost. It would be also interesting to enlarge the analysis to a wider geographical area in order to cover a better proportion of the potential infrastructure consumers. Finally, the integration of this module in a GIS environment would make the practitioner confident with the geographical context and the related hazards.

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Appendix

Table A1. Critical points along the Ticino highway (A2) segment (*).

Location	Hazard	Return period [years]	Type of protection	Cost [CHF]
Giornico	flooding	100	Paving ditch and retaining chamber reinforcement	2'000'000
Giornico	rockfall	100	Rockfall barriers	1'000'000
Bellinzona	landslide	100	Retaining wall	500'000
Capolago	flooding	25	Retaining chamber and related frames reinforcement (check dams, ditches, etc.)	2'500'000
Collina d'Oro (Gentilino)	landslide	100	Retaining wall	500'000
Faido (Chioggiona)	rockfall	100	Wall coupled by rock fall ring nets	2'500'000
Faido (Chioggiona)	rockfall	100	Rockfall barriers	1'000'000
Quinto	avalanche	100	Active measures (avalanche prevention structures as snow barriers, snow racks and wire rope structures) and passive measures (retention or control dams)	3'000'000

(*) We thank Mirko Baruffini for providing whit the information.

Chapter Two

Analyzing loss aversion and diminishing sensitivity in a freight transport stated choice experiment

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Abstract

Choice behaviour might be determined by asymmetric preferences whether the consumers are faced with gains or losses. This paper investigates loss aversion and diminishing sensitivity, and analyzes their implications on willingness to pay and willingness to accept measures in a reference pivoted choice experiment in a freight transport framework. The results suggest a significant model fit improvement when preferences are treated as asymmetric, proving both loss aversion and diminishing sensitivity. The implications on willingness to pay and willingness to accept indicators are particular relevant showing a remarkable difference between symmetric and asymmetric model specifications. Not accounting for loss aversion and diminishing sensitivity, when present, produces misleading results and might affect significantly the policy decisions.

Keywords: freight transport, choice experiments, willingness to pay, preference asymmetry

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2.1. Introduction

Reference dependence, loss aversion and diminishing sensitivity are three essential characteristics that Prospect Theory (Kahneman and Tversky, 1979) defines for a utility function in a decision under risk framework[14]. In particular, an individual decision making process involves the evaluation of gains and losses defined in relation to a reference point (reference dependence), with a higher evaluation for losses than gains (loss aversion) and decreasing marginal values in both positive and negative domains (diminishing sensitivity).

The increasing popularity of designing stated choice experiments pivoted on a reference alternative (see for example, Rose *et al.*, 2008) has led to a growing interest in deriving discrete choice models that could accommodate the prospect theory reference dependence assumption. In this context, Hess *et al.* (2008) estimate models that include different parameters for positive and negative deviations from the reference value, and they demonstrate the existence of loss aversion identifying asymmetric preferences on both commuting and non-commuting car travellers.

The idea of an asymmetric S-shaped utility function, concave above the reference point and convex below it, is given in Kahneman and Tversky (1979), and formalized as a two-part cumulative function in Tversky and Kahneman (1992). Lanz *et al.* (2009) test loss aversion and diminishing sensitivity in an environmental water supply choice experiment, by means of appropriate linear and nonlinear transformation of the utility function.

The presence of loss aversion has a direct influence on one of the most crucial topics in discrete choice modelling, the estimation of willingness to pay (WTP) and willingness to accept (WTA), and in particular, the relation between the two measures. Indeed, in a reference pivoted choice model that does not take into account preference asymmetry, the ratio of WTA to WTP is equal to one. Conversely, the literature presents a variety of studies that set the WTA/WTP ratio to a higher factor (see for example, Boyce *et al.* 1992 and Horowitz and McConnell 2002).

[14] For an application in a risk-less choice situation see Tversky and Kahneman (1991).

The aim of this paper is to investigate loss aversion through asymmetric preferences and diminishing sensitivity by nonlinear asymmetric preferences, and to analyze their implications on WTP and WTA measures in a freight transport choice experiment. The literature on freight transport is poor compared with the passenger transport sector, due we suspect to the complexity of the supply-chain system and the greater effort required in sourcing and getting the cooperation of organisations (in contrast to individuals) in data collection. Zamparini and Reggiani (2007) provide a review of value of time savings in freight transport studies, with the majority based on stated choice experiments. Discontinuity in utility functions has been proposed by Swait (2001) through the concept of "cut-offs" and has been applied to the freight sector by Danielis and Marcucci (2007). However, to the best of our knowledge, no previous studies on freight transport focus on the analysis of asymmetric preferences and decreasing marginal utility, and how these behavioural conditions affect the estimation of measures such as WTP and WTA, which are commonly used by policy makers.

Furthermore, particular attention is given to the punctuality attribute, as an indicator of freight transport service quality. Although a few recent studies mention its relevance (see for example, Danielis *et al.* 2005 and Fowkes 2007) a more in depth analysis is required to better understand the potential of this variable.

The paper is organised as follows. In section two we introduce the choice experiment and present the data's descriptive statistics. We then outline the methodology and present the model derivation in section three. The results are illustrated and discussed in section four. Finally the conclusions are provided in section five.

2.2. Data

The data was obtained from a stated choice survey in a freight transport context conducted in the Ticino region (Switzerland) in 2008. The experiment was part of a project[15] aimed to analyze the infrastructure vulnerability of the Ghottard corridor, one of the most important European transport corridors.

[15] NFP54 "Sustainable Development of the Built Environment", founded by the Swiss National Science Foundation. For more details about the study see Maggi *et al.* (2009) and Masiero and Maggi (2009).

The stated choice experiment involved three alternative choices: road (REF), piggyback (PB) and combined transport (CT). The road alternative is the reference alternative, that is, the typical transportation service described by each logistics manager. The design of the experiment involves three attributes - cost (CHF per transport service), time (hours per transport service) and punctuality (percentage of transport services arriving on time per year). In particular, the cost and time attributes are pivoted around the reference values according to the levels shown in Table 1, whereas punctuality is expressed in absolute values.

Table 1 Attributes and their levels.

Transport Cost (CHF)	Transport time (hours)	Transport Punctuality (%)
-10 %	-10 %	100 %
-5 %	-5 %	98 %
Equal to the reference cost	Equal to the reference time	96 %
+5 %	+5 %	
+10 %	+10 %	

Attributes and levels considered have been chosen based on past experiences with logistics and transport managers of the Ticino region, and after an accurate review of past research (Bolis and Maggi, 2002, Danielis *et al.*, 2005, Rudel and Maggi, 2008) [16].

Suppose a situation where the road Gotthard corridor is going to be closed for a maximum of two consecutive days every month. Which of the following alternatives would you prefer?		
Road (A2)	**Combined Transport**	**Piggyback**
Actual cost	5% more than actual cost	5% less than actual cost
Actual time	10% more than actual travel time	5% more than actual travel time
Actual punctuality	100% punctuality	96% punctuality
○	○	○

Figure 1 Example of choice card for long-run decision experiment (first scenario)

The experiment was based on a Computer Assisted Personal Interview (CAPI) instrument that randomly generates different profiles according to the assumption of experiment orthogonality. Each respondent was presented with 15 choice situations (see Figure 1 for an example of a choice card).

[16] In a freight transport context other attributes have also been investigated, like frequency, flexibility and loss and damages (see Bolis and Maggi, 2002 and Danielis et al. 2005 for details).

The sample is comprised of 27 firms active in the manufacturing sector, all based in Ticino. In particular, the represented sectors are: plastic materials; chemical and pharmaceutical; machine and electronics; engineering; food, beverage and tobacco. The size of the firms ranges from medium (50 to 249 employees) to large (more than 249 employees). Eighteen of the selected firms are medium in size whereas nine are large. In the 2005 census[17], the Ticino region had 101 medium and 16 large firms corresponding in a employees share of 38% and 23%, respectively.

Table 2 Sample descriptive statistics of typical transport service

Variable	Mean	Median	Std.Dev.	Minimum	Maximum
Cost (CHF)	1300.15	1000	1152.95	136	5400
Time (hr)	33.35	24	27.30	2	96
Punctuality (%)	96.52	98	3.04	90	100
Weight (ton)	7.1309	5.50	7.17	0.04	25
Distance O-D (km)	474.33	300	332.62	92	1360

The typical transport service described by logistic managers is reported in Table 2. Within the sample, 20 logistics managers described outbound transport services (going north) with an average distance of 501 kilometres, whereas 7 logistics managers described inbound services (coming from north) with an average distance of 306 kilometres[18].

As expected, cost and time vary substantially since they are characterized by the distance between an origin and a destination and by the weight of the shipment. Punctuality, however, is very homogenous, and apart from two cases that state 90 percent punctuality in the transportation services, the rest are between 95 and 100 percent. This evidence is in line with previous studies, and confirms the high level of importance that a logistics manager places on a quality attribute like punctuality.

[17] Swiss Federal Statistical Office, Neuchâtel.

[18] Due the geographical location of the Ghottard corridor, the research has been addressed to inbound and outbound transport (both short-distance and long-distance trips) towards the north. From the sample surveyed, the share of outbound transport services towards the north is 63% of the total whereas the share of inbound transport services coming from the north is 43% of the total.

2.3. Methodology and Model Description

The identification of the value function plays a crucial role in Prospect Theory since it must reflect the principal differences that Prospect Theory has in respect to Expected Theory. Kahneman and Tversky (1979) state that the value function is:

> *"(i) defined on deviations from the reference point; (ii) generally concave for gains and commonly convex for losses; (iii) steeper for losses than for gains."*

In this context, positive and negative deviations from the reference point define gain and loss domains. The analysis of loss aversion and diminishing sensitivity is then based on the coefficients of the utility function derived from model estimation. Within a Random Utility Model framework (McFadden 1974), the utility function, associated with respondent *n* and alternative *j*, is typically assumed to be linear in parameters, and represented by equation (1)

$$U_{nj} = \boldsymbol{\beta}'\mathbf{x}_{nj} + \boldsymbol{\varepsilon}_{nj} \tag{1}$$

where $V_{nj} = \boldsymbol{\beta}'\mathbf{x}_{nj}$ is the systematic part of utility and $\boldsymbol{\varepsilon}_{nj}$ is the random term that is Independent and Identically Distributed (IID) extreme value type 1. Following the mixed logit class of models we allow for preference heterogeneity by letting the β parameters be randomly distributed (β_n) over the sampled population[19]. Specifically, we estimate the standard deviation for all of the parameters whose behavioural information is not entirely captured by the mean. The selected statistical distribution for the random parameters associated to the three attributes is a constrained triangular distribution[20], where the standard deviation is constrained to be equal to the mean[21]. This is designed to misleading behavioural interpretations (i.e., positive cost or time coefficients) since the distribution is constrained to be bounded between zero and twice the mean (for a proof, see Hensher and

[19] For a detailed discussion on mixed logit models see Hensher and Greene (2003).

[20] Normal, lognormal and triangular distributions were tested during the model estimation phase. Among them, normal and triangular distribution gave similar results in terms of goodness of fits. The decision in using the triangular distribution has been driven by its desirable features within constrained distributions.

[21] In recent research, Hensher and Greene (2009) has suggested that constrained distributions in preference space are behaviourally more plausible than unconstrained distributions, and the derived WTP estimates appear to mimic well the WTP distributions associated with WTP space.

Greene, 2003). On the contrary, the triangular distribution for the parameters associated with the firm specific variables does not present any constraint, since we do not have valid assumptions over the sign of the coefficients.

Recalling the three alternatives under study, the system of the utility functions used in the estimation of the symmetric model is:

$$\begin{cases} V_{n(\mathrm{PB})} = ASC_{\mathrm{PB}} + \beta_{\mathrm{C}}\mathrm{C}_{\mathrm{PB}} + \beta_{\mathrm{T}}\mathrm{T}_{\mathrm{PB}} + \beta_{\mathrm{P}}\mathrm{P}_{\mathrm{PB}} \\ V_{n(\mathrm{CT})} = ASC_{\mathrm{TC}} + \beta_{\mathrm{C}}\mathrm{C}_{\mathrm{CT}} + \beta_{\mathrm{T}}\mathrm{T}_{\mathrm{CT}} + \beta_{\mathrm{P}}\mathrm{P}_{\mathrm{CT}} \\ V_{n(\mathrm{REF})} = \beta_{\mathrm{C}}\mathrm{C}_{\mathrm{REF}} + \beta_{\mathrm{T}}\mathrm{T}_{\mathrm{REF}} + \beta_{\mathrm{P}}\mathrm{P}_{\mathrm{REF}} + \beta_{n\mathrm{D}}\mathrm{D} + \beta_{n\mathrm{W}}\mathrm{W} + \beta_{n\mathrm{S}}\mathrm{S} \end{cases} \tag{2}$$

where ASC is the alternative specific constant (normalized in respect to the reference alternative), and β_{C}, β_T, β_P, are the parameters associated with the three attributes, cost, time and punctuality, respectively. We have also included three more variables in the reference alternative utility expression. Two of these are specific to the typical transport activity, that is, distance O-D in kilometres (D) and weight of the shipment in tonnes (W), whereas stock capacity[22] (S) is firm specific.

The reference pivoted nature of the experimental design allows us to specify and to test the presence of linear asymmetric preferences by introducing few modifications to the set of the alternative utility functions. Specifically, according to the value function definition and following Hess *et al.* (2008) and Lanz *et al.* (2009), we divide each attribute into decrease and increase values by taking the difference between the attribute and its relative reference value. As a consequence, the reference utility function does not include any attributes in its specification. Accordingly, the estimation of the linear asymmetric preference model relies on the following system of utility functions:

$$\begin{cases} V_{n(\mathrm{PB})} = ASC_{\mathrm{PB}} + \beta_{n\mathrm{C(dec)}}\mathrm{C}_{\mathrm{(dec)PB}} + \beta_{n\mathrm{C(inc)}}\mathrm{C}_{\mathrm{(inc)PB}} + \beta_{n\mathrm{T(dec)}}\mathrm{T}_{\mathrm{(dec)PB}} \\ \qquad + \beta_{n\mathrm{T(inc)}}\mathrm{T}_{\mathrm{(inc)PB}} + \beta_{n\mathrm{P(dec)}}\mathrm{P}_{\mathrm{(dec)PB}} + \beta_{n\mathrm{P(inc)}}\mathrm{P}_{\mathrm{(inc)PB}} \\ V_{n(\mathrm{CT})} = ASC_{\mathrm{TC}} + \beta_{n\mathrm{C(dec)}}\mathrm{C}_{\mathrm{(dec)CT}} + \beta_{n\mathrm{C(inc)}}\mathrm{C}_{\mathrm{(inc)CT}} + \beta_{n\mathrm{T(dec)}}\mathrm{T}_{\mathrm{(dec)CT}} \\ \qquad + \beta_{n\mathrm{T(inc)}}\mathrm{T}_{\mathrm{(inc)CT}} + \beta_{n\mathrm{P(dec)}}\mathrm{P}_{\mathrm{(dec)CT}} + \beta_{n\mathrm{P(inc)}}\mathrm{P}_{\mathrm{(inc)CT}} \\ V_{n(\mathrm{REF})} = \beta_{n\mathrm{D}}\mathrm{D} + \beta_{\mathrm{W}}\mathrm{W} + \beta_{\mathrm{S}}\mathrm{S} \end{cases} \tag{3}$$

[22] Stock capacity is a five point discrete variable and expresses the number of days that the production chain could afford without any additional supply.

where $X_{(dec)j} = max(X_{REF} - X_j, 0)$ and $X_{(inc)j} = max(X_j - X_{REF}, 0)$.

A further extension to the model described in (3) involves the analysis of potential nonlinearities in the form of the utility function in both domains of gains and losses. The approach used is a version of a piecewise linear approximation which entails the estimation of different values for different ranges of the selected attribute. Here, instead of different ranges of the attribute, we consider different ranges of the attribute levels since we are interested in preference nonlinearity around a reference point. It is worth noting that the piecewise linear approximation approach has the advantage of maintaining the utility function linear in the parameters, and the capability to detect significant nonlinearities with a small number of ranges (Ben-Akiva and Lerman 1985).

Nonlinearity is introduced in the punctuality attribute identifying two decrease and two increase levels, with respect to the reference point[23]. That is, P(dec--) refers to decreases from 3 percent up to 4 percent, P(dec-) to decreases up to 2 percent, P(inc+) to increases up to 2 percent and P(inc++) to increases from 3 percent up to 10 percent[24]. The utility function for the nonlinear asymmetric preference model can be written as follows:

$$\begin{cases} V_{n(\mathrm{PB})} = ASC_{\mathrm{PB}} + \beta_{n\mathrm{C(dec)}}\mathrm{C}_{\mathrm{(dec)PB}} + \beta_{n\mathrm{C(inc)}}\mathrm{C}_{\mathrm{(inc)PB}} + \beta_{n\mathrm{T(dec)}}\mathrm{T}_{\mathrm{(dec)PB}} + \beta_{n\mathrm{T(inc)}}\mathrm{T}_{\mathrm{(inc)PB}} \\ \qquad + \beta_{n\mathrm{P(dec--)}}\mathrm{P}_{\mathrm{(dec--)PB}} + \beta_{n\mathrm{P(dec-)}}\mathrm{P}_{\mathrm{(dec-)PB}} + \beta_{n\mathrm{P(inc+)}}\mathrm{P}_{\mathrm{(inc+)PB}} + \beta_{n\mathrm{P(inc++)}}\mathrm{P}_{\mathrm{(inc++)PB}} \\ V_{n(\mathrm{CT})} = ASC_{\mathrm{TC}} + \beta_{n\mathrm{C(dec)}}\mathrm{C}_{\mathrm{(dec)CT}} + \beta_{n\mathrm{C(inc)}}\mathrm{C}_{\mathrm{(inc)CT}} + \beta_{n\mathrm{T(dec)}}\mathrm{T}_{\mathrm{(dec)CT}} + \beta_{n\mathrm{T(inc)}}\mathrm{T}_{\mathrm{(inc)CT}} \\ \qquad + \beta_{n\mathrm{P(dec--)}}\mathrm{P}_{\mathrm{(dec--)CT}} + \beta_{n\mathrm{P(dec-)}}\mathrm{P}_{\mathrm{(dec-)CT}} + \beta_{n\mathrm{P(inc+)}}\mathrm{P}_{\mathrm{(inc+)CT}} + \beta_{n\mathrm{P(inc++)}}\mathrm{P}_{\mathrm{(inc++)CT}} \\ V_{n(\mathrm{REF})} = \beta_{n\mathrm{D}}\mathrm{D} + \beta_{n\mathrm{W}}\mathrm{W} + \beta_{n\mathrm{S}}\mathrm{S} \end{cases} \tag{4}$$

$$\text{where, } P_j - P_{REF} = \begin{Bmatrix} P_{(dec--)j} & if & -4 \le (P_j - P_{REF}) \le -3 \\ P_{(dec-)j} & if & -2 \le (P_j - P_{REF}) \le -1 \\ P_{(inc+)j} & if & 1 \le (P_j - P_{REF}) \le 2 \\ P_{(inc++)j} & if & 3 \le (P_j - P_{REF}) \le 10 \end{Bmatrix} \tag{5}$$

[23] Preliminary analysis showed a non significant nonlinearity for cost and time attributes. Therefore, they are treated as linear but asymmetric.
[24] A model with three parameters in the punctuality gains domain has also been estimated. The coefficient associated with an increase from 3% to 4% was statistically not different from the coefficient associated with an increase from 5% to 10% (the 77% of the distribution lies in the range -4% to +4%). Since both models lead to similar interpretation of the results, the selection is based on the model fit.

The estimation of the utility function for the three models presented takes into account the panel structure of the data, consisting of 15 choice situations per respondent. A common way to deal with the panel structure in the mixed logit class of models is to specify the model by imposing the condition that the random parameters are constant over choice situations but not over respondents. Under these assumptions, the probability that respondent *n* chooses alternative *j* is described as follows:

$$P_{nj} = \int_{\beta} \left(\prod_{t} \frac{\exp(\boldsymbol{\beta}'_n \mathbf{x}_{nit})}{\sum_{j} \exp(\boldsymbol{\beta}'_n \mathbf{x}_{nit})} \right) f(\boldsymbol{\beta}) d(\boldsymbol{\beta}) \tag{6}$$

where t = 1,…,T represents the choice situations. Since the integral does not have a closed form, the estimation of the log-likelihood relies on a simulated approximation, and takes the following form:

$$LL_n = \sum_{n} \ln \frac{1}{R} \sum_{r} \prod_{t} \frac{\exp(\boldsymbol{\beta}'_n \mathbf{x}_{nit})}{\sum_{j} \exp(\boldsymbol{\beta}'_n \mathbf{x}_{nit})} \tag{7}$$

where r = 1,…,R indicates the simulation draws. The results of the models estimation, discussed in next section, are based on 200 Halton draws (see Train 2003 for details).

2.4. Results and Discussion

In this section we present and discuss the results of the three models, estimated according to the specifications described in the previous section. The generic symmetric model represents the starting model and facilitates the comparison of the results obtained from the two asymmetric models. The empirical evidence on loss aversion and diminishing sensitivity are discussed through the significance of coefficient estimates and supported with graphs. Particular emphasis is then given to the analysis of the WTP and WTA measures and the behavioural implications when linear and nonlinear asymmetric preferences are considered.

Given the sample size, while it is adequate to study the attributes of the choice experiment, it has limitations when introducing non-choice experiment contextual and firm-specific characteristics. Hence we have focussed on the design attributes, and cannot comment on the role of other influences. Collecting large samples for freight logistics studies is challenging for many reasons (notably cooperation of firms and the substantial cost per interview compared with household surveys). We are of the view that the contribution of this paper is not diminished by this limitation

2.4.1 Model estimation results

Model estimation results are shown in Table 3. In order to evaluate the models fit we report the final log-likelihood and the McFadden pseudo ρ^2. Since the models differ in the number of the estimated parameters, to make the comparison more accurate the Akaike's Information Criterion (AIC) is also reported as it balances the reduction in the log-likelihood function with the increase in the number of parameters. Fifteen treatments for each of the 27 respondents produced 405 observations. All parameters are generic unless identified with the reference alternative.

Over the three models, the reference alternative specific constant is normalized to zero. The signs of the alternative specific constants are negative, confirming the preference for the road alternative (holding all rest constant). The parameter associated with the distance (Km Ref) is positive but with a standard deviation bigger than the mean, suggesting that some of the respondents prefer to switch to rail-based alternatives as the origin-destination distance increases. The weight parameter (Weight Ref) is negative, that is, the preference for rail-based is proportional to the weight of the shipment. Stock capacity plays a role in the transport mode decision process, favouring the rail-based alternatives (in two of three models) when more flexibility is allowed. Since the interpretation of both the alternative specific constants and firm specific variables does not change significantly over the three models, hereafter we focus the analysis on the attributes used in the experiment design, namely cost, time and punctuality, placing particular emphasis on the two asymmetric models.

In the generic symmetric model, the three attribute parameter estimates are strongly significant (at the alpha level of 0.01) and with the expected sign, that is, negative for cost and time coefficients and positive for the punctuality coefficient. Furthermore, all the behavioural information associated with the three attributes is assumed to be captured by the first moment of the distribution, under the assumption of preference homogeneity.

Table 3 Estimation results for Panel Mixed Logit (200 Halton draws), 405 observations

	Generic symmetric		**Linear asymmetric**		**Nonlinear (punct) asymmetric**	
	Coeff.	(t-Ratio)	Coeff.	(t-Ratio)	Coeff.	(t-Ratio)
Means for Random and Non-Random parameters						
Asc Piggyback	-2.5329	(-2.40)	-1.0063	(-0.81)	-6.5128	(-4.29)
Asc Combined	-2.3265	(-2.21)	-0.7252	(-0.58)	-6.2318	(-4.16)
O-D Km Ref	0.0011	(0.80)	0.0068	(3.53)	0.0025	(2.53)
Weight Ref	-0.0877	(-1.54)	-0.2489	(-4.24)	-0.2893	(-4.61)
Stock Capacity Ref	-0.4324	(-1.38)	0.7585	(2.66)	-0.6394	(-2.71)
Cost	-0.0055	(-5.97)				
Time	-0.0964	(-3.28)				
Punct	0.3491	(6.40)				
Cost dec			0.0191	(4.50)	0.0235	(5.64)
Cost inc			-0.0257	(-4.62) -1.07a	-0.0329	(-5.33) -1.29a
Time dec			0.1491	(1.53)	0.1887	(1.98)
Time inc			-0.3197	(-2.52) -1.45a	-0.2886	(-2.32) -0.88a
Punct dec			-2.6624	(-4.95)		
Punct inc			0.2717	(2.77) -4.36a		
Punct dec (--)					-2.2178	(-4.39)
Punct dec (-)					-3.0320	(-4.88) -1.23b
Punct inc (+)					1.7321	(4.05) -1.96a
Punct inc (++)					0.6109	(3.97) 3.23b
Standard deviations for Random parameters						
Ts O-D Km Ref	0.0018	(0.70)	0.0779	(4.90)	0.0607	(6.18)
Ts Weight Ref	1.2075	(2.64)			0.2081	(2.17)
Ts SC Ref	1.6808	(4.28)			2.3425	(5.44)
Ts Cost dec			0.0191	(4.50)	0.0235	(5.64)
Ts Cost inc			-0.0257	(-4.62)	-0.0329	(-5.33)
Ts Time dec			0.1491	(1.53)	0.1887	(1.98)
Ts Time inc			-0.3197	(-2.52)	-0.2886	(-2.32)
Ts Punct dec			-2.6624	(-4.95)		
Ts Punct inc			0.2717	(2.77)		
Ts Punct dec (--)					-2.2178	(-4.39)
Ts Punct dec (-)					-3.0320	(-4.88)
Ts Punct inc (+)					1.7321	(4.05)
Ts Punct inc (++)					0.6109	(3.97)
Final Log-likelihood	-290.7		-233.1		-219.5	
McFadden pseudo ρ^2	0.3467		0.4760		0.5067	
AIC	1.4898		1.2106		1.1628	

a. Asymptotic t-ratio for the difference between decrease and increase parameters (absolute value calculation to account for difference in sign); b. Asymptotic t-ratio for the difference between upper (and lower) levels in the punctuality attribute. Firm specific random parameters follow a triangular distribution. Cost, time and punctuality random parameters follow a constrained triangular distribution (standard deviation equal to the mean).

The results for the first estimated asymmetric preference model (cited as linear asymmetric in Table 3) show a substantial increase in the model fit, quantifiable by the reduction of the AIC measure from 1.49 for the generic symmetric model to 1.21 for the linear asymmetric model. The parameter estimates are all significant at an alpha level of 0.05 except for the coefficient associated to the "time decrease" attribute that shows a weak significance. The negative (positive) sign for the coefficients related to increases (decreases) in time and cost is consistent with common behavioural judgments. In the same way, we find a positive sign associated to an increase in punctuality, and vice versa.

Following Hess *et al.* (2008), we report the asymptotic t-ratio test in order to evaluate the significance of the difference between decrease and increase parameters[25]. The asymptotic t-ratio for the difference between decrease and increase parameters results in a weak significance for cost and time attributes, and a strong significance for the punctuality attribute. Hence the marginal (dis)utility experiences significant asymmetries with respect to the reference point in situations where the respondent is faced with either a gain or a loss. Notably, in all the three attributes considered, the absolute values of the parameter associated with a loss, namely, $\beta_{(inc)}$ for time and cost and $\beta_{(dec)}$ for punctuality, are larger than those associated with a gain ($\beta_{(dec)}$ for time and cost and $\beta_{(inc)}$ for punctuality), suggesting that the utility functions are steeper in the losses than in the gains domain. This proves the presence of loss aversion among the respondent preferences.

By taking the ratio in absolute values, |du/dX(loss)|/|du/dX(gain)|, we are able to quantify the degree of asymmetry, which assumes a value greater than zero in the case of loss aversion. Regarding the linear asymmetric model, the asymmetry ratio for the cost attribute ($\beta_{C(inc)}/\beta_{C(dec)}$) is 1.35, meaning that the disutility of an increase in the transport cost is, in terms of absolute value, 35% higher than the utility associated to a decrease of the same amount. In the same way, the ratio for transport time is 2.14 while it is 9.80 for punctuality. The particularly high degree of punctuality asymmetry reflects the essential role that this attribute plays in the decision process of logistics managers (see Puckett and Hensher 2008), who are extremely averse to a loss in transport service punctuality (more details are given in Figure 2 by comparing the two asymmetric model results).

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[25] The test statistic for $\hat{\beta}_i = -\hat{\beta}_j$ is given by: $\left(\hat{\beta}_i + \hat{\beta}_j\right) \Big/ \sqrt{\mathrm{var}\left(\hat{\beta}_i - \hat{\beta}_j\right)}$, where $\mathrm{var}(\hat{\beta}_i - \hat{\beta}_j) = \mathrm{var}(\hat{\beta}_i) + \mathrm{var}(\hat{\beta}_j) - 2\,\mathrm{cov}(\hat{\beta}_i, \hat{\beta}_j)$.

The third model specification, described in equations (4) and (5), introduces nonlinearity in the punctuality attribute by means of a piecewise linear transformation. The model estimates are shown in the last column of Table 3, cited as “Nonlinear (punct) asymmetric”. Overall, the model is a significant improvement in the goodness of fit compared with the previous linear asymmetric model, with a McFadden pseudo ρ^2 of 0.51 and an AIC measure of 1.16. All the parameter estimates result in at least statistical significance at an alpha level of 0.05, and all the estimated attribute coefficients are coherent in sign.

Preference asymmetry in cost parameters is slightly more evident than in the previous model as stated by the asymptotic t-ratio for difference that is now significant at an alpha level of 0.2. On the opposite side, the strength of the difference between decrease and increase time coefficients is weaker than the linear asymmetric model even if now they both results significant at the 0.05 alpha level. Also for this model, the magnitude of the coefficients associated to negative and positive deviations from the reference point indicate a steeper marginal utility in the losses domain, matching the Prospect theory loss aversion assumption. In particular, the asymmetry ratio reports values of 1.40 and 1.52, for cost and time attributes, respectively.

Nonlinearity in the punctuality attribute is confirmed by the strong significance of the four parameters and their coherence in sign, with the two decrease parameters showing a negative sign in contrast to a positive sign for the two increase coefficients. The asymmetry in the respondent preferences is confirmed by the significance of the asymptotic t-ratio test. Here, we also report the test statistic results for the difference between the two increase levels as well as for the two decrease levels[26]. The test indicates a strong significant difference between the two increase parameters, and a weak significance between the two decrease parameters.

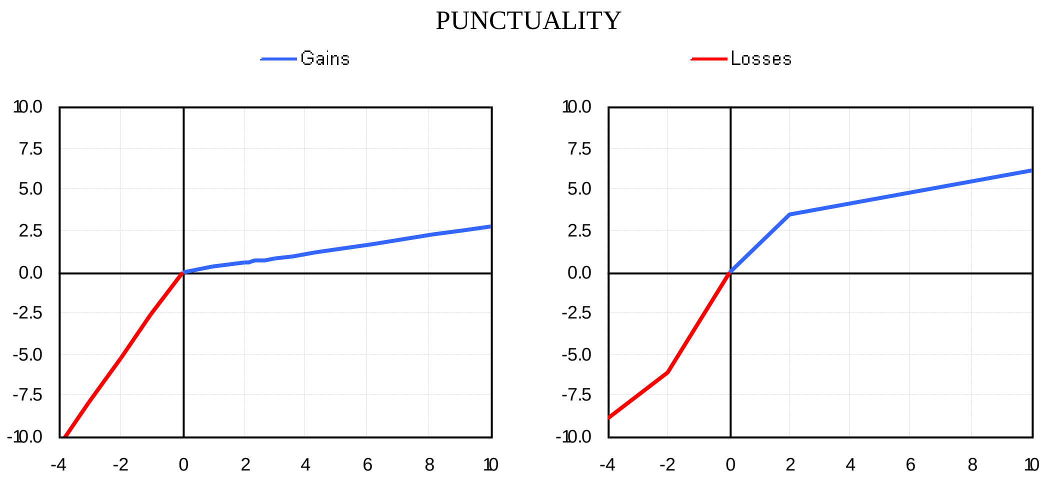
The functional form of the marginal utility associated with the punctuality attribute can be derived by analyzing the model estimates. In this context, diminishing sensitivity is characterized by a concave form ($\beta_{P(inc++)} < \beta_{P(inc+)}$) in the gains domain and a convex form ($\beta_{P(dec--)} < \beta_{P(dec-)}$) in the losses domain. From the model results (Table 3), both

[26] In this case the null hypothesis is $H_0 : \hat{\beta}_i = \hat{\beta}_j$ and the test statistic is:
$\left(\hat{\beta}_i - \hat{\beta}_j\right) \Big/ \sqrt{\operatorname{var}\left(\hat{\beta}_i - \hat{\beta}_j\right)}$, where $\operatorname{var}(\hat{\beta}_i - \hat{\beta}_j) = \operatorname{var}(\hat{\beta}_i) + \operatorname{var}(\hat{\beta}_j) - 2\operatorname{cov}(\hat{\beta}_i, \hat{\beta}_j)$.

inequalities are verified, supporting the presence of diminishing sensitivity for the punctuality attribute. A graphical representation is given in Figure 2, where we plot the marginal utility (y-axis) as a function of positive and negative changes in the attribute (x-axis) according to the two asymmetric models results.

Figure 2 Change in utility according to linear (left) and nonlinear (right) asymmetric models.

Linear Asymmetric Model	**Nonlinear (punct) Asymmetric Model**



The evidence of a strong asymmetric response in punctuality is clearly shown in Figure 2 (left-hand side) where we plot the change in the utility function according to the estimates obtained in the linear asymmetric model. In particular, an increase of two percent in punctuality corresponds to an increase in utility of 0.5 whereas a reduction of two percent corresponds to a reduction of 5.3 in utility. As was previously mentioned, this leads to an asymmetry ratio of 9.8.

Asymmetry is still evident when we account for nonlinearity (by estimating the four parameters, $\beta_{P(dec--)}$, $\beta_{P(dec-)}$, $\beta_{P(inc+)}$, $\beta_{P(inc++)}$) and follows the pattern shown in Figure 2, right-hand side. An increase of two percent leads to an increase of 3.5 in utility in contrast to a reduction of 6.1 for a loss of two percent points in punctuality. Furthermore, a change of four percent in respect to the reference point corresponds to a utility decrease of 8.9 and to a utility increase of 4.1[27], respectively, in the losses and gains domain. Finally, a change

[27] Since the range of the selected variable, P(inc++), goes from an increase of 3 percent up to 10 percent the value for an increase of 4 percent has been approximated by a linear spline interpolation. A cubic interpolation is worth considering in future research given the evidence, in the absence of smoothing, of a slight change in the rate of change over the range evaluated. It is unlikely to impact on the key message presented in the main text.

of two percent in punctuality gives an asymmetry ratio of 1.75 while a change of four percent results in a value of 2.15.

The asymmetric and nonlinear specifications capture both loss aversion and diminishing sensitivity, the two fundamental Prospect Theory assumptions that lead to the classical asymmetric s-shape functional form.

2.4.2 Implication on willingness to pay

The investigation of WTP (or its counterpart WTA), as an indicator of the monetary value of a selected attribute, plays a crucial role in discrete choice modelling. WTP is the ratio of the marginal (dis)utility of an attribute to the marginal (dis)utility of the cost attribute. In the linear additive random utility model, the derivation of WTP is straightforward since the estimated coefficients are, by definition, marginal (dis)utilities. Nevertheless, the computation requires some expedients when the coefficients are treated as random parameters that involve the use of either the conditional or unconditional parameter estimates[28]. The estimation of the monetary values for the two asymmetric models is based on the former method. Hensher *et al.* (2006) compare both approaches and illustrate the benefits of the conditional parameter estimates.

In a symmetric model, willingness to accept (WTA) is equal to WTP and the monetary values for the two quality attributes, time (T) and punctuality (P), are as follows:

$$WTP_{(T)} = WTA_{(T)} = \hat{\beta}_t \big/ \hat{\beta}_c \tag{8}$$

$$WTP_{(P)} = WTA_{(P)} = \hat{\beta}_P \big/ \hat{\beta}_c \tag{9}$$

The estimation of two different parameters with positive and negative deviations from the reference point implies a different computation for both WTP and WTA, making the equality imposed by the symmetric model free to change. For the linear asymmetric model, specified in equation (3), the estimation is then based on equations (10) and (11).

[28] See Hensher and Greene (2003) for a detailed discussion.

$$WTP_{(T)} = \hat{\beta}_{t(dec)} \Big/ \hat{\beta}_{c(inc)} \tag{10a}$$

$$WTA_{(T)} = \hat{\beta}_{t(inc)} \Big/ \hat{\beta}_{c(dec)} \tag{10b}$$

$$WTP_{(P)} = \hat{\beta}_{p(inc)} \Big/ \hat{\beta}_{c(inc)} \tag{11a}$$

$$WTA_{(P)} = \hat{\beta}_{p(dec)} \Big/ \hat{\beta}_{c(dec)} \tag{11b}$$

The WTP and WTA for time are provided from equations (10a) and (10b). Punctuality, however, in the nonlinear asymmetric model, is a nonlinear effect, and hence the monetary measures for punctuality involve a differentiation among the four parameters estimated ($\beta_{P(dec--)}$, $\beta_{P(dec-)}$, $\beta_{P(inc+)}$, $\beta_{P(inc++)}$). The WTP and WTA for the nonlinear and asymmetric punctuality attribute are defined in (12) and (13).

$$WTP_{(P+)} = \hat{\beta}_{p(inc+)} \Big/ \hat{\beta}_{c(inc)} \tag{12a}$$

$$WTA_{(P-)} = \hat{\beta}_{p(dec-)} \Big/ \hat{\beta}_{c(dec)} \tag{12b}$$

$$WTP_{(P++)} = \hat{\beta}_{p(inc++)} \Big/ \hat{\beta}_{c(inc)} \tag{12c}$$

$$WTA_{(P--)} = \hat{\beta}_{p(dec--)} \Big/ \hat{\beta}_{c(dec)} \tag{12d}$$

The results for the WTP and WTA measures from the three different models are summarized in Table 4. As is common practice in a freight transport context, we also report the estimates expressed in CHF per tonne[29]. The estimate of the value of time savings for the generic symmetric model is 17.4 CHF/hour (16.3 USD/hour) which is in line with others previous studies (Bolis and Maggi, 2003, Zamparini and Reggiani, 2007). Willingness to pay for punctuality is 63 CHF (58.9 USD) per percentage point. Maggi and Rudel (2008) find a value of 48 CHF (44.9 USD).

The relevance of punctuality (or reliability) in freight transport is confirmed from the data, and is consistent with evidence from other studies (see for example, Fowkes *et al.* 2004, Danielis *et al.* 2005, and Fowkes 2007). Puckett and Hensher (2008) also discuss the importance of reliability but find relatively small values.

[29] The calculation is based on the sample median; that is 5.5 tonne per shipment.

Table 4 WTP and WTA measures.

	Generic symmetric	Linear asymmetric	Nonlinear asymmetric
Willingness to Pay measures in CHF per shipment (in CHF per tonne)			
WTP time	17.42 (3.17)	8.91 (1.62)	8.31 (1.51)
WTP punct	63.11 (11.47)	14.45 (2.63)	
WTP punct (+)			71.94 (13.08)
WTP punct (++)			23.41 (4.26)
Willingness to Accept measures in CHF per shipment (in CHF per tonne)			
WTA time	17.42 (3.17)	26.22 (4.77)	22.52 (4.09)
WTA punct	63.11 (11.47)	198.99 (36.18)	
WTA punct (-)			208.59 (37.93)
WTA punct (--)			156.71 (28.49)

When asymmetries are considered, the willingness to pay for time savings decreases significantly, from 17.42 to 8.91 CHF/hour (and to 8.31 CHF/hour for the nonlinear asymmetric model). Hess *et al.* (2008) report similar differences, recognizing it as “an effect of allowing for asymmetrical response rates”. On the other hand, in order to accept an increase of an hour in travel time, the transport cost should experience a reduction of 26.2 CHF (22.5 CHF) according to the linear (nonlinear) asymmetric model.

The linear asymmetric model estimates for the punctuality attribute show a lower WTP and a higher WTA compared with the symmetric model. This pattern changes consistently when we account for nonlinearity, especially in the willingness to pay domain. The WTP for an increase of up to two percent in the punctuality of the transport service is now higher than the value estimated from the symmetric model, that is, from 63.1 CHF to 71.9 CHF per percentage point. It then reduces drastically when we consider improvements in the punctuality service of more than two percent, which makes sense given that the punctuality sample median for the reference transport service is 98 percent.

The significant disparity between WTP and WTA measures supports the loss aversion assumption that losses are valued more highly than gains. In this context, Horowitz and McConnell (2002) review 45 studies, conducted on a varied range of goods, and find that the mean of the ratio WTA/WTP is 7.2 while the median is 2.6. Table 5 indicates this ratio for the measures identified from the nonlinear asymmetric model and shows how the ratios are consistent with the existing literature.

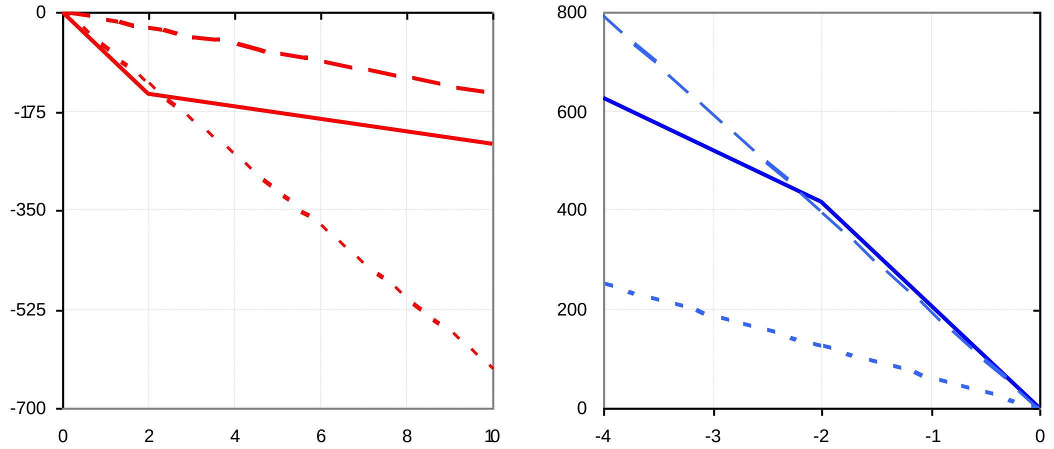
Table 5 WTA/WTP ratio (nonlinear asymmetric model)

	WTA/WTP ratio
Time	2.7
Punctuality (-/+)	2.9
Punctuality (--/++)	6.7

Finally, a graphical comparison among the three different models for WTP and WTA for punctuality is presented in Figure 3. For the WTP domain, the symmetric model approximates the nonlinear asymmetric model in the range (0; 2) then it over-estimates drastically, whereas the linear asymmetric model under-estimates WTP across the entire distribution. For the WTA domain, the symmetric model under-estimates the selected model in the entire distribution, whereas the linear asymmetric model over-estimates in the range (-2; -4).

Figure 3 WTP and WTA for punctuality according to the three models.

WTP	WTA



Models: symmetric (dot-line); linear asymmetric (dashed-line); nonlinear asymmetric (plain-line)

The evidence on the WTP and WTA estimates for the two attribute considered, namely, time and punctuality, suggests that there is a general trend for the symmetric model to over-estimate WTP and under-estimate WTA. Similar evidence is reported in Lanz *et al.* (2009). However, as shown in Figure 3, for loss aversion if we do not allow for nonlinearity in the utility function, there is a high risk of producing misleading evidence.

2.5. Conclusions

This paper has investigated Prospect Theory assumptions with a reference pivoted choice experiment in a freight transport framework. We tested for loss aversion and diminishing sensitivity within a random parameters model as a deviation from the reference alternative.

The results suggest a significant and strong improvement in the goodness of fit of the model when preferences are asymmetric. Loss aversion is reaffirmed for all the three choice experiment attributes (cost, time and punctuality) included in the analysis, with the asymmetry producing a steeper utility function for losses than for gains, which are particularly marked for the punctuality attribute. For the three attributes in both the positive and negative domains, a piecewise linear approximation was tested as a way to capture nonlinearity. The cost and time attributes do not show significant nonlinearity, so they are treated as asymmetric but linear in the two domains. Punctuality, on the other hand, presents evidence of nonlinearity in the gains as well as in the losses domain, confirmed by the increase in the model fit and by the asymptotic t statistic. Specifically, the utility function shows a concave form for values above zero and a convex form for values below zero, suggesting that respondents experience diminishing sensitivity in terms of the marginal disutility of punctuality.

Loss aversion and diminishing sensitivity have a significant impact on willingness to pay and willingness to accept. The classic symmetric model shows a tendency to over-estimate WTP and under-estimate WTA. The model estimates show a consistent disparity between the two measures, resulting in a WTA/WTP ratio of 2.7 for time and 2.9 and 6.7 for punctuality up to 2 percent and between 2 percent and 10 percent, respectively.

The relevance of the behavioural contributions of Prospect Theory, embedded in an individual output/price context, is reaffirmed in a firm’s logistic profit/cost context, raising concerns about the symmetric specification commonly used in freight demand studies. Indeed, the majority of the studies that estimate WTP are based on stated choice experiments with symmetric specifications in utility expressions. The findings in this paper on WTP, a common measure in calculating user benefits, raise questions about the errors induced by the linear assumption, in the evaluation of new infrastructure via cost benefit analysis and more generally, on all the situations where WTP and WTA measures are required as part of a policy decision process.

The asymmetric evidence on WTP and WTA shows the importance in travel demand studies and economic appraisal of distinguishing the value attached to an equivalent loss and gain in an attribute level such as travel time. Our evidence suggests that the loss in benefit is considerably higher than the gain, since a transport policy that results in increased travel time carries a much higher value in respect of a unit of lost benefit to users than a reduction in travel time.

Finally, we strongly encourage future research to recognise and account for loss aversion and diminishing sensitivity in the analysis of any freight transport choice experiment based on a reference alternative. Further empirical studies are recommended in order to support the findings. Finally, it would be interesting to analyze diminishing sensitivity in choice experiments that allow for smaller or larger level ranges in order to establish the validity of the evidence herein in a broader domain of attribute levels.

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Chapter Three

Shift of reference point and implications on behavioral reaction to gains and losses

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Abstract

It is widely recognized that individual decision making is subject to the evaluation of gains and losses around a reference point. The estimation of discrete choice models increasingly use data from stated choice experiments which are pivoted around a reference alternative. However, to date, the specification of a reference alternative in transport studies is fixed, whereas it is common to observe individuals adjusting their preferences according to a change in their reference point. This paper focuses on individual reactions, in a freight choice context, to a negative change in the reference alternative values, identifying the behavioural implications in terms of loss aversion and diminishing sensitivity. The results show a significant adjustment in the valuation of gains and losses around a shifted reference alternative. In particular, we find an average increase in loss aversion for cost and time attributes, and a substantial decrease for punctuality. These findings are translated to significant differences in the willingness to pay and willingness to accept measures, providing supporting evidence of respondents' behavioural reaction.

Keywords: Willingness to pay, gains and losses, freight choice, reference alternative

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3.1. Introduction

The importance of considering the individual's choice behaviour as a decision based on the distinction between positive (gains) and negative (losses) deviations from a specific individual reference value has been formulated in prospect theory (Kahneman and Tversky, 1979), and introduced in both risky choices (Kahneman and Tversky, 1979; Tversky and Kahneman, 1992) and risk-less choices (Tversky and Kahneman, 1991). In this context, prospect theory defines two fundamental assumptions involving the utility function, namely loss aversion, where individuals tend to evaluate losses higher than gains, and diminishing sensitivity where individuals show decreasing marginal values in both positive and negative domains.

Application of prospect theory can be found in several economic fields such as, for example, financial markets (e.g., Benartzi and Thaler, 1995), labour economics (e.g., Camerer et al., 1997), health economics (Samuelson and Zeckhauser, 1988) and macroeconomics (e.g., Shea, 1995). Furthermore, the plausibility of the prospect theory has been reinforced using a range of different data types and interview procedures, such as contingent valuation (Rowe et al., 1980) or laboratory experiments (e.g., Bateman et al., 1997).

The recent estimation of discrete choice models with a reference dependence specification has empirically reinforced the plausibility of prospect theory assumptions within the framework of reference pivoted experimental designs (see for example, Hess *et al.*, 2008; Lanz *et al.*, 2009; Masiero and Hensher, 2009). The utility function is expressed in terms of gains and losses around a reference alternative, without loosing the linearity in the parameters assumption underlying the Random Utility Model (McFadden, 1974). Such a specification nests the commonly used specification obtained by imposing equality constraints between the absolute values of the parameter estimates associated with gains and losses.

The improved statistical performance of the reference dependence specification in terms of overall model fit, and the increasing use of reference pivoted experimental designs as techniques to add realism for respondents (Rose *et al.*, 2008), are increasing the role played by the specification of the reference alternative in the model estimation process (see for example, Hess and Rose, 2009 and Rose *et al.*, 2008). However, a crucial issue associated with the reference alternative is the specification of reference values in change contexts or in any framework that might involve a change in the initial values of the reference alternative (e.g. actual values versus expected values). Kahneman and Tversky (1979) note that:

"... A change of reference point alters the preference order for prospect … A discrepancy between the reference point and the current asset position may also arise because of recent changes in the wealth to which one has not yet adapted …The location of the reference point, and the manner in which choice problems are coded and edited emerge as critical factors in the analysis of decision."

Very few studies have analysed the individual adaptation process followed by a change of the reference point. In this context, Arkes *et al.* (2008) conducted a survey to study the individual's adaptation after experiencing losses or gains in a stock price. Schwartz *et al.* (2008) illustrate an approach designed to identify, and hence adjust, the change in the utility perceived after a shift of the reference point in a medical decision making process. As far as we are aware, there are no studies that have investigated the implications on the utility function of changes in parameter estimates when the reference point is shifted.

The aim of this paper is to analyse the impact of a negative shift of the reference point on preference formation in terms of loss aversion and diminishing sensitivity, in a stated choice experiment framework. In particular, we refer to a pooled dataset consisting of two freight transport choice experiments with designs pivoted around two different reference alternatives, where one is the actual (or initial) reference alternative and the other is the expected (or shifted) reference alternative[30]. The identification of potential implications is based on the estimation and comparison of the marginal (dis)utilities associated with the gains and losses. We formulate and test different hypotheses of behavioural reaction and present the implications as willingness to pay and willingness to accept measures.

The paper is organised as follows. In section two we describe the two choice experiments and the context of the survey. Section three provides an overview of the methodology

[30] The survey was conducted within the National Research Program NRP 54 - Sustainable Development of the Built Environment - granted by the Swiss National Science Foundation.

developed as well as the hypotheses associated with behavioural reaction to a negative shift of the reference point. The results are presented and discussed in section four. Finally, in section five we present the conclusions and directions for further research.

3.2. Data

The data is centred around two stated choice experiments conducted in 2008 among logistics managers of medium to large manufacturing industries located in Ticino (Switzerland). The aim of the study was to evaluate the indirect freight transport costs associated with a temporary closure of the Ghottard road corridor, a crucial infrastructure in the European north/south transport connection but also one highly vulnerable with respect to closure due to its geographical context and the presence of the seventeen kilometres long two-lane tunnel[31].

Logistics managers were contacted from eligible industries and asked for an appointment in their office to conduct the stated choice survey using a face-to-face computer assisted personal interview (CAPI). The managers that agreed to participate were asked about their general logistics and transportation structure and to describe a typical road transport activity along the road corridor under study. Information about cost, time and punctuality of the typical road transport trip were then used in order to create the design for the two experiments.

The first experiment involved a choice among three alternatives: road, piggyback and combined transport, respectively. The road alternative was set fixed across respondent choice situations since it represents the reference alternative. The choice context was introduced, stressing the risk of frequent but short closures experienced currently along the road corridor. The second experiment hypothesised a temporary road closure by imposing a shift of the reference road alternative to the second-best road alternative, the San Bernardino road corridor. The magnitude of the imposed shift in terms of cost, time and punctuality of the transport service was obtained from a phone survey conducted with six of the most important shippers in Ticino. All the interviewed shippers indicated a high level of experience gathered from previous closures of the main road corridor, and

[31] For more details about the study see Maggi *et al.* (2009) and Masiero and Maggi (2009).

reported very similar extra cost and time for a detour via the second best road alternative, which most often resulted in an increase of 300 CHF[32] and 5 hours compared to the best road alternative. For punctuality, we assumed a decrease of 2 percent with respect to the original values, with a minimum level fixed to the lowest level considered, that is, 96 percent of transport trips being punctual. This statement has been confirmed by the shippers interviewed, in particular if we consider the high volume of flows that occur in a similar situation. The four alternatives included in the second experiment are second-best road, regulated road[33], piggyback and combined transport.

The two choice experiments were undertaken sequentially with each respondent by explaining the context of the research and making sure they fully understood the survey procedure. The experimental design was built following a reference pivoted approach, for cost and time attributes. Specifically, in the first experiment, the cost and time levels were pivoted around the reference alternative described by each respondent during the preliminary survey, whereas in the second experiment they were pivoted around second-best road alternative consisting of the reference alternative augmented by the detour values according to the values indicated by the shippers in the phone survey. Punctuality was expressed in absolute values for both experiments. Hereafter, the first experiment is referred to as the “initial” scenario, and the second experiment as the “shift” scenario.

Table 1 shows the range and the number of levels used for the three attributes included in the experiments, namely cost, time and punctuality. The selection of the attributes and their levels is based on past experience in stated choice experiment surveys with logistics and transport managers (see for example, Danielis *et al.*, 2005 and Maggi and Rudel, 2008). In order to distinguish between the two reference alternatives across the two experiments, and given the temporary nature of the second experiment, the second-best road values are named transitional, and formally expressed as follows:

$$Transitional\ cost = reference\ cost + 300CHF \quad (1)$$

$$Transitional\ time = reference\ time + 5hours \quad (2)$$

$$Transitional\ punctuality = \min(reference\ punctality - 2,\ 96) \quad (3)$$

[32] Approximate exchange rate 1 CHF = 0.964 USD.

[33] The regulated road alternative simulates a congestion free San Bernardino alternative by assuming a priority policy for trucks which allows the original punctuality to be maintained.

Table 1 Attribute ranges in the stated choice design

	First experiment (initial scenario)			Second experiment (shift scenario)		
	Cost	Time	Punctuality	Cost	Time	Punctuality
Level 1	-10 %	-10 %	100 %	-10 %	-10 %	100 %
Level 2	-5 %	-5 %	98 %	-5 %	-5 %	98 %
Level 3	Reference	Reference	96 %	Transitional	Transitional	96 %
Level 4	+5 %	+5 %		+5 %	+5 %	
Level 5	+10 %	+10 %		+10 %	+10 %	

The experimental design is randomly generated different profiles under the assumption of experiment orthogonality. In both experiments, 15 choice situations were presented to each logistics manager. Figures 1 and 2 show an example of a choice card for the first and second experiment, respectively.

Suppose a situation where the road Gotthard corridor is going to be closed for a maximum of two consecutive days every month. Which of the following alternatives would you prefer?		
Road	**Combined Transport**	**Piggyback**
Reference cost	5% more than reference cost	5% less than reference cost
Reference time	10% more than reference travel time	5% more than reference travel time
Reference punctuality	100% punctuality	96% punctuality

Figure 1 Example of choice card for the first experiment (initial scenario)

Suppose a situation where the road Gotthard corridor is closed for two weeks. Which of the following alternatives would you prefer?			
Second best Road	**Piggyback**	**Combined Transport**	**Regulated Second best Road**
Transitional cost	10% less than transitional cost	5% less than transitional cost	10% more than transitional cost
Transitional travel time	10% more than transitional travel time	10% more than transitional travel time	Equal to transitional travel time
Transitional punctuality	98% punctuality	96% punctuality	100% punctuality

Figure 2 Example of choice card for the second experiment (shift scenario)

In the 2005 census[34], the Ticino region included 101 medium (50 to 249 employees) and 16 large (more than 249 employees) firms corresponding to an employee share of 38 percent and 23 percent, respectively. In total, 60 firms were contacted and asked for their participation in the survey, resulting in a final sample of 27 firms (18 medium 9 large in size). The two experiments were completed from the entire final sample, representing 810 choice observations.

[34] Swiss Federal Statistical Office, Neuchâtel.

3.3. Methodology

The utility function, associated with respondent *n* and alternative *j* for choice situation s is typically assumed to be linear in parameters, and represented as follows:

$$U_{njs} = \alpha_j + \sum_{k=1}^{K}\sum_{d=1}^{2}\beta_{kd}x_{njskd} + \varepsilon_{njs} \tag{4}$$

where α_j is the alternative-specific constant associated with alternative *j* and ε_{nj} is the random term assumed to be Independent and Identically Distributed (IID) extreme value type 1. The *k* coefficients can be specified as dataset-specific, hereafter coded as *d=1* for the initial scenario and *d=2* for the shift scenario[35]. Within the mixed logit class of models, the entire or a subset vector of coefficients associated with the observed variables x_{njk}, are expressed as equation (5).

$$\beta_{nk} = \beta_k + \eta_{nk} \tag{5}$$

η_{nk} is the coefficient standard deviation drawn from a random distribution[36] which captures individual preference heterogeneity. The reference dependence model specification is obtained by specifying the utility function in terms of deviations from the reference values such that

$$U_{njs} = \alpha_j + \sum_{k=1}^{K}\sum_{d=1}^{2}\beta_{nkd}(dec)x_{njskd}(dec) + \sum_{k=1}^{K}\sum_{d=1}^{2}\beta_{nkd}(inc)x_{njskd}(inc) + \sum_{p=1}^{P}\sum_{d=1}^{2}\phi_{npd}z_{np} + \varepsilon_{njs} \tag{6}$$

where "dec" and "inc" stand for "decrease" and "increase", respectively, and $x_{njskd}(dec) = max(x_{ref} - x_j, 0)$ and $x_{njsk}(inc) = max(x_j - x_{ref}, 0)$[37]. The utility function associated with the reference alternative does not include any attribute parameters; however, the firm specific characteristics (z_{np}) that enter the utility functions are treated as in any conventional symmetric model.

[35] This distinction leads to the estimation of both unrestricted and restricted models. The restricted model is obtained by estimating generic coefficients across the two datasets.

[36] The most popular distributions are normal, triangular and lognormal. See Hensher and Greene (2003) for details.

[37] A reference-dependent specification is not new (see for example, Hess et al., 2008). However, to the best of our knowledge there are no applications focussed on a shift of reference point framework.

The specification in Equation (6) allows us to test for loss aversion, which is verified if the coefficient associated with a loss (increase for cost and time and decrease for punctuality attributes) is larger in absolute value than the coefficient associated with a gain (decrease for cost and time and increase for punctuality attributes). However, in order to test for diminishing sensitivity, a form of nonlinearity has to be introduced in the utility function. In this context, several nonlinear specifications have been used in past studies, including the power and exponential functions (Lanz *et al.* 2009), and a logarithmic transformation (Rose and Masiero 2009). However, in order to reflect the discrete nature of the attribute levels, we follow the same approach applied in Masiero and Hensher (2010) - a piecewise function defined in each range of the attribute levels. The generic utility function form that allows us to test for diminishing sensitivity is then expressed as equation (7).

$$\begin{aligned} U_{njs} = \alpha_j &+ \sum_{k=1}^{K}\sum_{d=1}^{2}\beta_{nkd}(dec-)x_{njskd}(dec-) + \sum_{k=1}^{K}\sum_{d=1}^{2}\beta_{nkd}(dec--)x_{njskd}(dec--) \\ &+ \sum_{k=1}^{K}\sum_{d=1}^{2}\beta_{nkd}(inc+)x_{njskd}(inc+) + \sum_{k=1}^{K}\sum_{d=1}^{2}\beta_{nkd}(inc++)x_{njskd}(inc++) + \sum_{p=1}^{P}\sum_{d=1}^{2}\phi_{npd}z_{np} + \varepsilon_{njs} \end{aligned} \tag{7}$$

For the cost and time attributes, $x_{njskd}(inc+)$ and $x_{njskd}(inc++)$ represent deviations from the reference value for increases of 5 percent and 10 percent, respectively. The same logic applies for the two cost and time decrease attributes levels. For punctuality, $x_{njskd}(dec--)$ refers to decreases from 3 percent up to 4 percent, $x_{njskd}(dec-)$ to decreases up to 2 percent, $x_{njskd}(inc+)$ to increases up to 2 percent, and $x_{njskd}(inc++)$ to increases from 3 percent up to 10 percent.

The investigation of a shift in the reference values, and its impact on the perception of gains and losses, implies the comparison between marginal (dis)utilities across the two experiments presented in the previous section. A graphic representation is given in Figure 3. Let R_B and R_S denote the attribute reference points for the initial (i.e., base) and shift scenarios in utility space[38]. A shift in the losses domain reflects a left-side shift of the reference point from R_B to R_S. The consumer reaction to gains and losses in respect to the new reference point depends on the ability to adjust his perception towards the occurred change (Kahneman and Tversky, 1979 and Tversky and Kahneman, 1992). In this context,

[38] The graph is built according to desirable goods (i.e., travel punctuality). Note that in case of undesirable goods (i.e., travel cost and travel time), the direction of the x-axis is opposite-oriented.

a full adaptation to the new scenario would maintain unaltered the change in the utility associated with gains and losses experienced either in the initial or in the shift scenario. This condition can formally be tested through the following hypotheses:

$$\textit{Adaptation hypothesis} \begin{cases} \Delta G''_S = \Delta G_B \;\rightarrow\; H_0 : \beta_{nk2}(inc) = \beta_{nk1}(inc) \\ \Delta L''_S = \Delta L_B \;\rightarrow\; H_0 : \beta_{nk2}(dec) = \beta_{nk1}(dec) \end{cases} \qquad (8)$$

where the marginal utility (ΔG_i) and marginal disutility (ΔL_i), associated with a given attribute level in the gains and losses domains respectively, are identified as the coefficients associated with increases and decreases in the utility functions (6) and (7)[39].

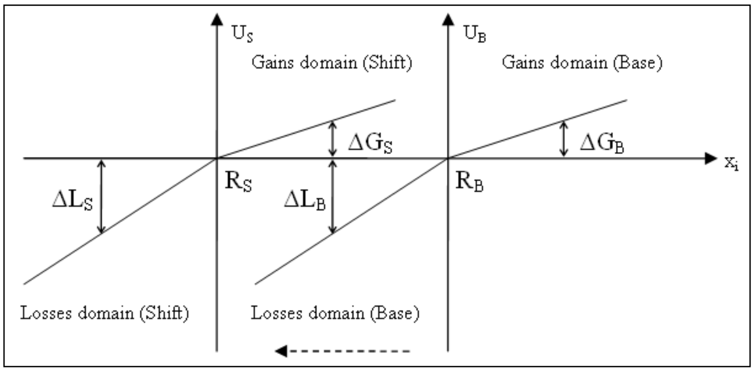

Figure 3 Adaptation Hypothesis

However, different reactions other than the adaptation hypothesis might occur if the individual has not completely adapted to the changed reference values. For example, we could expect a larger impact in the utility for gains in the shift scenario than in the initial scenario if the decision maker is trying to recover the initial loss. Formally,

$$\textit{Gains recovery hypothesis} \begin{cases} \Delta G_S > \Delta G_B \;\rightarrow\; H_0 : \beta_{nk2}(inc) > \beta_{nk1}(inc) \\ \Delta L_S = \Delta L_B \;\rightarrow\; H_0 : \beta_{nk2}(dec) = \beta_{nk1}(dec) \end{cases} \qquad (9)$$

Conversely, we might suppose a further increase in the loss aversion experienced from the decision maker as prevention to additional losses.

$$\textit{Additional losses prevention hypothesis} \begin{cases} \Delta G_S = \Delta G_B \;\rightarrow\; H_0 : \beta_{nk2}(inc) = \beta_{nk1}(inc) \\ \Delta L_S > \Delta L_B \;\rightarrow\; H_0 : \beta_{nk2}(dec) > \beta_{nk1}(dec) \end{cases} \qquad (10)$$

39 The introduction of nonlinearity in the utility functions does not alter the logic of the hypotheses assumed.

The estimation of the utility parameters associated with gains and losses, and their comparison across the two scenarios, allow us to test the hypotheses formulated, as well as any other pattern not discussed.

Given the panel structure of the data collected from the two stated choice experiments and the use of the mixed logit class of models, the estimation of the utility parameters is derived from the maximization of the following simulated log likelihood:

$$LL_n = \sum_n \ln \frac{1}{R} \sum_r \prod_s \frac{\exp(\boldsymbol{\alpha}_j + \boldsymbol{\beta}'_n \mathbf{x}_{njs} + \boldsymbol{\varphi}'_n \mathbf{z}_n)}{\sum_j \exp(\boldsymbol{\alpha}_j + \boldsymbol{\beta}'_n \mathbf{x}_{njs} + \boldsymbol{\varphi}'_n \mathbf{z}_n)} \tag{11}$$

where s = 1, …, S represent the number of choice situations whereas r = 1, …, R refers to the number of draws. Within the Random Utility Model framework, the coefficients are estimated along with the scale parameter, which reflects the variance of the unobserved component of the utility. Since different data sets have potentially different variances for unobserved utility, the comparison of the magnitude of the coefficients is possible only if the scale difference between the two data sets is taken into account. In this context, several techniques have been proposed in order to cope with difference in scale in jointly estimated choice models that use revealed preferences (RP) and stated preferences (SP) data (see for example, Swait and Louviere, 1993; Hensher and Bradley, 1993; Ben-Akiva and Morikawa, 1997). In this paper we refer to the approach recently used by Hensher (2008) which takes into account difference in scale by estimating the scale parameter for one of the two datasets considered in the pooled data[40]. According to Bhat and Castelar (2002), the scale parameter is expressed as follows:

$$\lambda_{njs} = [(1 - \delta_{njs,SPi})\lambda_j] + \delta_{njs,SPi} \quad i = 1, 2 \tag{12}$$

where $\delta_{njs,SPi}$ is a dummy variable that takes the value 1 for the observations associated with the dataset with the scale parameter normalised to 1, and zero otherwise. The parameter λ_j is derivable by introducing in one of the two data sets (arbitrarily selected) a

[40] It should be noted that in our context the aim is different from a typical RP and SP joint estimation. We are not interested to enrich the data with additional and complementary information, but we are instead looking at the comparison of coefficient magnitudes from different datasets.

set of alternative-specific constants (ASC) that have a zero mean and free variance (Brownstone *et al.*, 2000). In fact, the following relation holds:

$$\lambda_j = \pi / \sqrt{6}\sigma_{ASCj} = 1.28255 / \sigma_{ASCj} \qquad (13)$$

where σ_{ASCj} are the standard deviations of the alternative-specific constants introduced in data set *i*. In our case we estimate the scale parameter associated with the first data set, referring to the initial scenario, consisting of three alternatives, two hypothetical alternatives and the reference alternative respectively. From a preliminary analysis we noticed that the ASCs associated with the two hypothetical alternatives were not statistically different to one another. We decided then to nest the two hypothetical alternatives by constraining the estimation of only two additional ASCs, one for the reference alternative, and the other for the two hypothetical alternatives.[41]

3.4. Model Results

We estimated three pairs of panel mixed logit models using 500 Halton draws[42] with results summarised in Table 2. The first pair of models (M1 and M2) refers to linear symmetric specifications given in equation (4); that is the classic form of specification commonly used in discrete choice modeling. We then introduce the reference dependence models M3 and M4 defined in equation (6) that allows us to test for loss aversion. The last pair of models (M5 and M6) is of the form in equation (7), and still based on the reference dependence specification, but with the integration of attribute piecewise transformations in order to capture potential nonlinearities that are compatible with the diminishing sensitivity prospect theory assumption.

The difference within each pair of models is that the first model has generic-specific coefficient estimates (a restricted model), whereas in the second model the coefficients are treated as dataset-specific (an unrestricted model). This allows us to obtain an immediate,

[41] Note that the assumption of having different variance among alternatives leads to the estimation of a heteroskedastic choice model. In our case, we normalize the variance in respect to the four alternatives associated to the second dataset obtaining a constrained heterskedastic choice models.
[42] See Train (2003) for details about Halton sequence. All models were estimated using a pre-release version of Nlogit 5.

but overall, test on the hypothesis of adaptation by comparing the model fits within each pair of models.

In terms of goodness of fit we report the log-likelihood at convergence, the McFadden pseudo ρ^2 and the Akaike's Information Criterion (AIC) (normalised for sample size) (see Table 2). The best model in explaining the data is model M6 which reports a McFadden pseudo ρ^2 of 0.600 and an AIC index of 1.626 versus a McFadden pseudo ρ^2 of 0.542 and an AIC index of 1.820 obtained for model M2 which shows the poorest model fit measures among the six models estimated. Introducing nonlinearity in the reference dependence specification (models M5 and M6) increases, in general, the goodness of model fits in respect to the linear asymmetric specifications (models M3 and M4), and both specifications outperform substantially the symmetric ones (models M1 and M2). However, a first interesting result is provided from the comparison, within the three pairs of models, of the AIC index which in its calculation account for both a reduction in the log-likelihood and an increase in the number of parameters estimated. According to the AIC index, model M1 is preferred to M2, suggesting that there are no overall significant differences between the coefficients associated with the initial and shift scenarios. We observe exactly the opposite result once we introduce the reference dependence specifications, where models M4 and M6 outperform models M3 and M5 respectively[43].

For each of the six models, we have estimated the scale parameters for the three alternatives associated with the initial scenario, with the aim of levelling any unobserved variance difference between the two datasets, making possible the comparison between coefficient estimates. From the scale parameters that are statistically significant different from one at a confidence level of 0.1, we observe that they all are smaller than one, suggesting a greater variance of the unobserved effects for the initial scenario than for the shift scenario. Although it is plausible to expect a difference in scale between two datasets we had no expectation about the magnitude associated with the stated preferences structure of the experiment in both scenarios.

[43] More formal t-tests are provided further in this section (see Table 3).

Table 2 Estimation result for panel mixed logit model (500 Halton draws)

	M1 Symmetric linear adaptation		M2 Symmetric linear non-adaptation		M3 Asymmetric linear full adaptation		M4 Asymmetric linear non-adaptation		M5 Asymmetric piecewise full adaptation		M6 Asymmetric piecewise non-adaptation	
	Par.	(t-ratio)	Par.	(t-ratio)	Par.	(t-ratio)	Par.	(t-ratio)	Par.	(t-ratio)	Par.	(t-ratio)
Non-Random parameters												
ASC piggyback (initial)	-1.0952	(-1.64)	-1.3330	(-1.99)	-0.6247	(-0.93)	-0.2047	(-0.24)	-1.4228	(-1.74)	-0.6047	(-0.81)
ASC combined transport (initial)	-0.8815	(-1.33)	-1.1233	(-1.69)	-0.4092	(-0.61)	-0.0056	(-0.01)	-1.2207	(-1.50)	-0.4280	(-0.57)
ASC road (shift)	0.0585	(0.17)	0.0722	(0.21)	0.4697	(1.20)	0.5132	(1.23)	-0.1824	(-0.43)	-0.0804	(-0.18)
ASC piggyback (shift)	-0.2702	(-0.77)	-0.2597	(-0.74)	0.0949	(0.24)	0.1042	(0.24)	-0.5856	(-1.35)	-0.5445	(-1.21)
ASC combined transport (shift)	-0.3251	(-0.94)	-0.3159	(-0.90)	0.0052	(0.01)	-0.0047	(-0.01)	-0.5883	(-1.37)	-0.5036	(-1.13)
Km REFs	0.0008	(1.95)	0.0008	(1.98)	0.0009	(1.83)	0.0011	(1.98)	0.0005	(0.98)	0.0008	(1.38)
Weight REFs	-0.0787	(-2.90)	-0.0782	(-2.89)	-0.0620	(-2.22)	-0.0551	(-1.98)	-0.0763	(-2.58)	-0.0649	(-2.27)
Cost	-0.0056	(-10.69)	-	-	-	-	-	-	-	-	-	-
Cost (initial)	-	-	-0.0056	(-6.02)	-	-	-	-	-	-	-	-
Cost (shift)	-	-	-0.0057	(-8.86)	-	-	-	-	-	-	-	-
Cost decrease	-	-	-	-	0.0051	(5.20)	-	-	-	-	-	-
Cost increase	-	-	-	-	-0.0103	(-7.45)	-	-	-	-	-	-
Cost decrease (initial)	-	-	-	-	-	-	0.0058	(3.33)	-	-	-	-
Cost increase (initial)	-	-	-	-	-	-	-0.0075	(-3.56)	-	-	-	-
Cost decrease (shift)	-	-	-	-	-	-	0.0055	(4.14)	-	-	-	-
Cost increase (shift)	-	-	-	-	-	-	-0.0126	(-6.61)	-	-	-	-
Cost decrease -	-	-	-	-	-	-	-	-	0.0065	(3.47)	-	-
Cost decrease - -	-	-	-	-	-	-	-	-	0.0055	(5.42)	-	-
Cost increase +	-	-	-	-	-	-	-	-	-0.0117	(-5.25)	-	-
Cost increase ++	-	-	-	-	-	-	-	-	-0.0098	(-6.82)	-	-
Cost decrease - (initial)	-	-	-	-	-	-	-	-	-	-	0.0086	(2.44)
Cost decrease - - (initial)	-	-	-	-	-	-	-	-	-	-	0.0061	(3.34)
Cost increase + (initial)	-	-	-	-	-	-	-	-	-	-	-0.0078	(-2.17)
Cost increase ++ (initial)	-	-	-	-	-	-	-	-	-	-	-0.0079	(-3.42)
Cost decrease - (shift)	-	-	-	-	-	-	-	-	-	-	0.0071	(2.67)
Cost decrease - - (shift)	-	-	-	-	-	-	-	-	-	-	0.0065	(4.65)
Cost increase + (shift)	-	-	-	-	-	-	-	-	-	-	-0.0174	(-4.51)
Cost increase ++ (shift)	-	-	-	-	-	-	-	-	-	-	-0.0116	(-5.79)
Time	-0.1109	(-6.45)	-	-	-	-	-	-	-	-	-	-
Time (initial)	-	-	-0.0970	(-3.30)	-	-	-	-	-	-	-	-
Time (shift)	-	-	-0.1180	(-5.56)	-	-	-	-	-	-	-	-
Time increase	-	-	-	-	-0.2157	(-4.72)	-	-	-	-	-	-
Time increase (initial)	-	-	-	-	-	-	-0.1061	(-1.74)	-	-	-	-
Time increase (shift)	-	-	-	-	-	-	-0.3061	(-4.93)	-	-	-	-
Time increase +	-	-	-	-	-	-	-	-	-0.3783	(-4.22)	-	-
Time increase ++	-	-	-	-	-	-	-	-	-0.1896	(-4.19)	-	-
Time increase + (initial)	-	-	-	-	-	-	-	-	-	-	-0.2460	(-1.88)
Time increase ++ (initial)	-	-	-	-	-	-	-	-	-	-	-0.0842	(-1.35)
Time increase + (shift)	-	-	-	-	-	-	-	-	-	-	-0.4726	(-4.04)
Time increase ++ (shift)	-	-	-	-	-	-	-	-	-	-	-0.2768	(-4.32)

Table 2 Estimation result for panel mixed logit model (500 Halton draws) – Continued

	M1 Symmetric linear (restricted)		M2 Symmetric linear (unrestricted)		M3 Asymmetric linear (restricted)		M4 Asymmetric linear (unrestricted)		M5 Asymmetric piecewise (restricted)		M6 Asymmetric piecewise (unrestricted)	
	Par.	(t-ratio)	Par.	(t-ratio)	Par.	(t-ratio)	Par.	(t-ratio)	Par.	(t-ratio)	Par.	(t-ratio)
Non-Random parameters												
Punctuality	0.3556	(11.02)	-	-	-	-	-	-	-	-	-	-
Punctuality (initial)	-	-	0.3644	(6.52)	-	-	-	-	-	-	-	-
Punctuality (shift)	-	-	0.3511	(8.84)	-	-	-	-	-	-	-	-
Punctuality decrease	-	-	-	-	-1.3070	(-7.27)	-	-	-1.2655	(-6.99)	-	-
Punctuality decrease (initial)	-	-	-	-	-	-	-1.3186	(-6.63)	-	-	-1.2481	(-6.18)
Punctuality decrease (shift)	-	-	-	-	-	-	-1.3699	(-2.61)	-	-	-1.3623	(-2.59)
Means for Random parameters												
Time decrease	-	-	-	-	0.0668	(1.66)	0.0767	(1.87)	0.0674	(1.57)	0.0762	(1.75)
Punctuality increase	-	-	-	-	0.5757	(6.10)	-	-	-	-	-	-
Punctuality increase (initial)	-	-	-	-	-	-	0.1401	(1.85)	-	-	-	-
Punctuality increase (shift)	-	-	-	-	-	-	0.9878	(5.51)	-	-	-	-
Punctuality increase +	-	-	-	-	-	-	-	-	0.8458	(7.15)	-	-
Punctuality increase ++	-	-	-	-	-	-	-	-	0.5216	(6.81)	-	-
Punctuality increase + (initial)	-	-	-	-	-	-	-	-	-	-	0.7100	(1.96)
Punctuality increase ++ (initial)	-	-	-	-	-	-	-	-	-	-	0.2144	(2.31)
Punctuality increase + (shift)	-	-	-	-	-	-	-	-	-	-	0.9553	(7.06)
Punctuality increase ++ (shift)	-	-	-	-	-	-	-	-	-	-	1.0505	(4.19)
Standard deviations for Random parameters												
Ts Time decrease	-	-	-	-	0.0668	(1.66)	0.0767	(1.87)	0.0674	(1.57)	0.0762	(1.75)
Ts Punctuality increase	-	-	-	-	0.5757	(6.10)	-	-	-	-	-	-
Ts Punctuality increase (initial)	-	-	-	-	-	-	0.1401	(1.85)	-	-	-	-
Ts Punctuality increase (shift)	-	-	-	-	-	-	0.9878	(5.51)	-	-	-	-
Ts Punctuality increase +	-	-	-	-	-	-	-	-	0.8458	(7.15)	-	-
Ts Punctuality increase ++	-	-	-	-	-	-	-	-	0.5216	(6.81)	-	-
Ts Punctuality increase + (initial)	-	-	-	-	-	-	-	-	-	-	0.7100	(1.96)
Ts Punctuality increase ++ (initial)	-	-	-	-	-	-	-	-	-	-	0.2144	(2.31)
Ts Punctuality increase + (shift)	-	-	-	-	-	-	-	-	-	-	0.9553	(7.06)
Ts Punctuality increase ++ (shift)	-	-	-	-	-	-	-	-	-	-	1.0505	(4.19)
Scale Parameters (Initial to Shift scenario)[a]												
Piggyback and Combined transport	0.5284	(1.71)	0.5385	(1.68)	0.3406	(3.01)	5.1699	(-0.98)	0.4347	(2.58)	1.0749	(-0.12)
Road (reference alt)	0.6179	(1.17)	0.6066	(1.26)	3.2904	(-1.51)	0.3726	(2.76)	0.7230	(0.76)	0.3698	(2.65)
Model Fits												
Number of Observations	810											
Log-likelihood at zero	-1576.19											
Log-likelihood at convergence	-722.424		-721.989		-659.339		-644.269		-642.834		-630.602	
Number of Parameters	12		15		15		20		19		28	
AIC	1.813		1.820		1.665		1.640		1.634		1.626	
McFadden pseudo ρ2	0.542		0.542		0.582		0.591		0.592		0.600	

[a] T-ratio for the hypothesis that the scale parameters are statistically equal to one.

However, when pooling stated and revealed preference data, a common practice is to hypothesise that the stated preference data hold a greater part of unobserved variance, even if it is not always verified. In this context, Hensher (2008), for example, does not report any statistically significant differences between stated and revealed preferences in terms of scale parameters.

Looking at the parameter estimates that are in common to all the six models, we notice substantial homogeneity in the alternative-specific constants and the two firm-specific characteristics. Given that the ASC for the reference alternative is normalised to zero in both the initial and shift scenarios, the results show a negative propensity to switch towards rail-based alternatives, while the only other road alternative proposed in the experiments shows a positive sign for models M1 to M4, and a negative sign for models M5 and M6. However, most ASCs are not statistically significant at the alpha level of 0.10, with the exception of the constants referring to the initial scenario and those associated with the piggyback alternative in models M1, M2 and M3 and combined transport in model M2. The firm-specific variables are introduced in the utility of the two reference alternatives without distinguishing between the scenarios, since no significant differences were found from preliminary modelling. The first variable refers to the origin-destination distance (Km REFs) and shows a positive relationship between the reference alternative and travel distance. On the contrary, the firm-specific variable that refers to the weight of the transport (Weight REFs), indicates a preference of hypothetical alternatives proportional to the weight of the shipment.

Turning to the coefficient estimates associated with the three modal attributes, namely cost, time and punctuality, all of the coefficients are of the expected sign and statistically significant. Models M1 and M2 show negative signs for cost and time and positive signs for punctuality, whereas models M3, M4, M5 and M6 report signs of the coefficients consistent with the definition of gains and losses around the reference point, where gains are associated with positive signs and losses with negative signs. For models M3 to M6, a further subset of random parameters has been estimated[44] involving the coefficients associated with gains in both time and punctuality, that is time decrease and punctuality increase respectively. Since we are interested in comparing the means of the coefficients

[44] Note that the ASCs introduced in order to estimate the scale parameters are actually random parameters with zero mean and normal standard deviation.

between the two scenarios, the inclusion of random parameters has been mainly focused on model fits, making sure of the exact empirical identification of the parameter's mean estimates[45]. The random parameters are independent and distributed according to a triangular distribution. Since the comparison of willingness to pay and willingness to accept measures play an important role in the analysis, we chose to constrain the standard deviation of the random parameters to be equal to the mean to ensure the same sign of the coefficient within the distribution[46]. As shown in Table 2, the coefficient associated with gains in time (time decrease) does not distinguish the initial and shift scenarios in models M4 and M6 and diminishing sensitivity in models M5 and M6. These constraints were necessary due to the statistical insignificance reported although the problem has been resolved only in part since the parameter associated to time decreases is significant only at the alpha level of 0.1 in models M3, M4 and M6. Furthermore, we do not allow for nonlinearity in the loss domain of punctuality (punctuality decrease in models M5 and M6) due to the restriction imposed by the design for the shift scenario (see section 2). Indeed, it was possible to estimate nonlinearity in the initial scenario, but for the sake of comparison it has been treated as asymmetric, but linear, in both scenarios.

Analyzing the magnitude of the parameters associated with gains and losses in models with reference dependence specifications (M3, M4, M5 and M6), we notice that all the parameter means associated with losses are in absolute values greater than those referring to gains. This holds for both initial and shift scenarios, supporting the assumption that respondents actually experienced loss aversion. Indeed, evidence of loss aversion has been found by other recent studies and in different contexts (see for example, Hess *et al.*, 2008; De Borger and Fosgerau, 2008; Lanz *et al.*, 2009; Hjorth and Fosgerau, 2009; Bateman et al., 2009). From models M5 and M6, we can also investigate the presence of diminishing sensitivity by comparing the magnitude of the coefficients estimated within the gains and losses domains for different attribute levels. Diminishing sensitivity is clearly evident in model M5 for all the three attributes considered, where the absolute values of the coefficients decrease as the attribute levels increase. This pattern is still present in model

[45] As an identification test, each model has been run with 500 and 1000 Halton assuring the stability of both model fits and coefficients magnitude (see Chiou and Walker, 2007).
[46] See Hensher and Greene, 2003 for proofs and discussions on the use of constrained triangular distribution in discrete choice models. It should be noted that the estimation of the two cost parameters (gains and losses) makes the estimation of the model in the WTP space no longer desirable. However, recent findings (Hensher and Greene, in press) suggest the sensibility of constrained distributions in preference space in approximating WTP measures obtained from models estimated in WTP space.

M6, although some linearity is experienced for the cost coefficients associated with losses in the initial scenario, and for the punctuality coefficients associated with gains in the shift scenario.

The main focus of the paper is to investigate respondents' behavioural changes in response to a shift in the reference values. In this context, we continue the analysis by performing a set of asymptotic t-ratio tests on the parameter estimates obtained for the unrestricted models M4 and M6, which allow us to test the hypotheses formulated in (8) - (10). Formally, the asymptotic t-ratio test is defined, according to the null hypotheses, as follow:

$$H'_0 : \hat{\beta}_i = \hat{\beta}_j \;\rightarrow\; (\hat{\beta}_i - \hat{\beta}_j) \Big/ \sqrt{\text{var}(\hat{\beta}_i - \hat{\beta}_j)} \tag{14}$$

where $\text{var}(\hat{\beta}_i - \hat{\beta}_j) = \text{var}(\hat{\beta}_i) + \text{var}(\hat{\beta}_j) - 2\,\text{cov}(\hat{\beta}_i, \hat{\beta}_j)$. We summarise the results in Table 3, distinguishing the cost, time and punctuality attributes in both asymmetric linear and nonlinear models. The respondents' reaction is highlighted by marking in bold the hypotheses that are statistically verified in terms of t-ratio for both gains and losses domains.

Table 3 Adaptation hypotheses test (t-ratio for null hypothesis in brackets)

		COST	TIME	PUNCTUALITY
MODEL M4 – Asymmetric linear				
Adaptation hypothesis	Gains	**Not Rejected H_0 (0.13)**	**Not Rejected H_0 (-)**	Rejected H_0 (-4.35)
	Losses	Rejected H_0 (1.80)	Rejected H_0 (2.48)	**Not Rejected H_0 (0.09)**
MODEL M6 – Asymmetric piecewise				
Adaptation hypothesis	Gains (+)	**Not Rejected H_0 (0.32)**	**Not Rejected H_0 (-)**	**Not Rejected H_0 (-0.63)**
	Gains (++)	**Not Rejected H_0 (-0.15)**	**Not Rejected H_0 (-)**	Rejected H_0 (-3.14)
	Losses (-)	Rejected H_0 (1.83)	Not Rejected H_0 (1.36)	**Not Rejected H_0 (0.20)**
	Losses (--)	Not Rejected H_0 (1.21)	Rejected H_0 (2.28)	-

Interestingly, the negative shift of the reference point imposed in the second experiment shows a similar pattern for cost and time attributes which is, on the other hand, the mirror image of the punctuality attribute. In particular, looking at the results from model M4, we note that respondents experienced the same change in the utility after gains in cost and time attributes, either in the initial or in the shift scenario, since we cannot reject the null hypothesis that the coefficients are different to one another. We reject instead the null hypothesis in the losses domain, and since the coefficient estimates are larger in absolute value for the shift scenario, this implies that respondents tried to prevent further losses in terms of cost and time attributes. Conversely, respondents show a strong desire to recover the initial loss that affected the punctuality of the transport service. From Table 2, we can see that the coefficient associated with an increase in punctuality is 0.1401 for the initial scenario, and 0.9878 for the shift scenario. For the losses domain, we do not report statistically significant differences between the two scenarios for the punctuality attribute. As a result, respondents experienced a remarkable reduction (almost total) in loss aversion after a negative shift of the reference of the punctuality attribute.

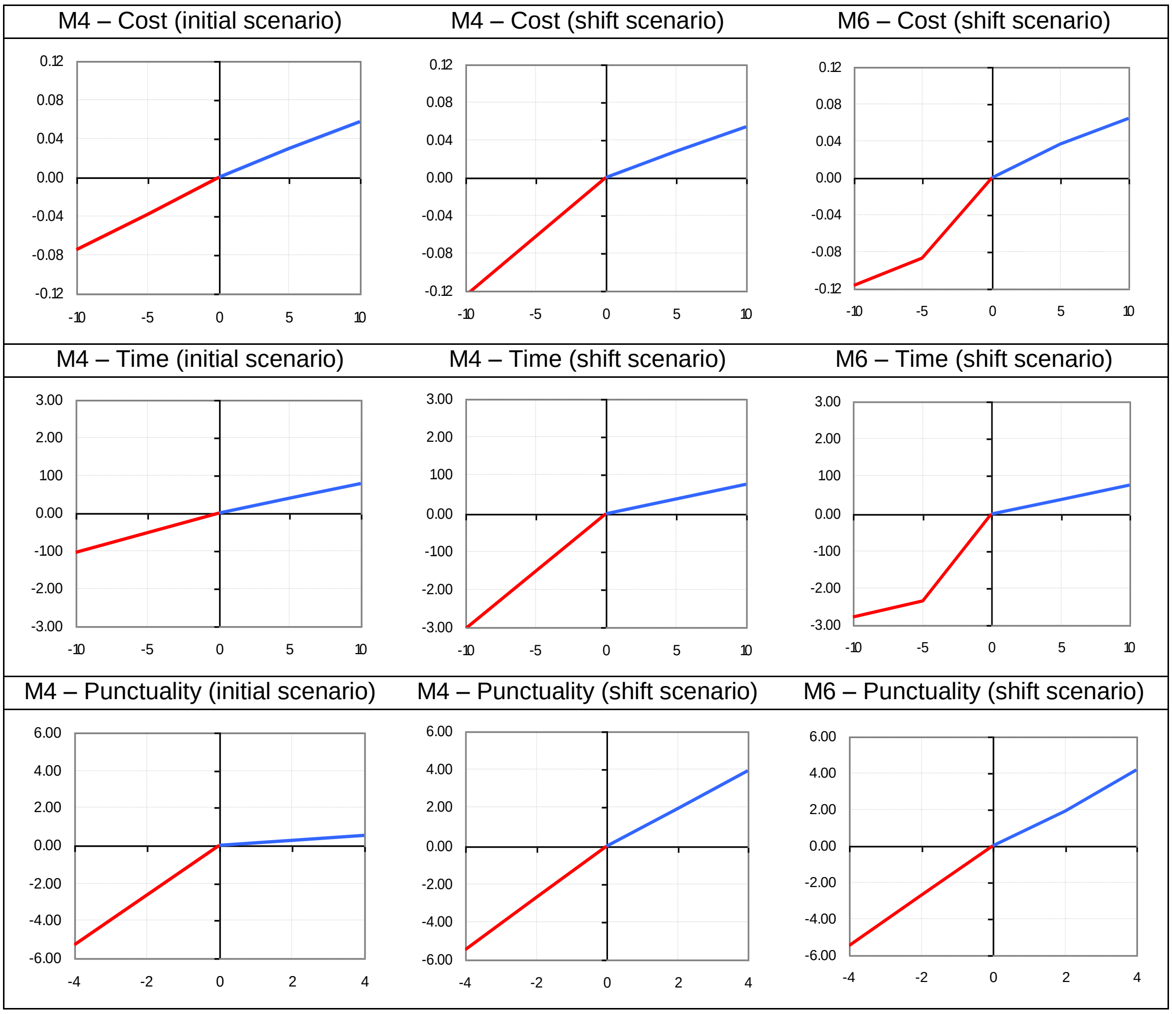

Figure 4 Changes in utility for initial and shift scenarios (M4) and shift scenario (M6)

A similar pattern is verified for model M6 for the cost and time attributes, although the t-ratio for the second and first levels in the losses domain of cost and time attributes report a weak significance (1.21 and 1.36, respectively). The introduction of nonlinearity in model

M6 gives an interesting result for the punctuality attribute. The t-ratio (-0.63) does not suggest any statistical difference between the initial and shift scenarios for a two percent increase in the punctuality attribute. This can be explained by the high importance that this attribute represents for logistics managers (see also, Bolis and Maggi, 2003; Maggi and Rudel, 2008) who, even reporting a punctuality average of 98 percent, consider attractive a further increase of 2 percent.

We graphically support the results on reaction hypotheses by plotting, in Figure 4, the changes in the utility function according to the coefficient estimates obtained in model M4 for both the initial and shift scenarios, as well as for the shift scenario of model M6. Indeed, from the charts related to model M4 (Figure 4, first two columns), it is clearly evident that there is an increase in loss aversion experienced by respondents for cost and time attributes as a resulting effect of protecting themselves from further losses. On the other hand, the punctuality attribute shows an almost symmetric utility function in respect of gains and losses domains. The pattern for the initial scenario is characterised by a weak loss aversion in the cost and time attributes, which is particularly marked for the punctuality attribute. In this context, it is relevant to emphasise the completely opposite pattern associated with the shift scenario. We observe similar findings for the unrestricted asymmetric piecewise model (M6), which suggests a more pronounced loss aversion for the cost and time attributes in the shift scenario than in the initial scenario, but a substantial reduction in the punctuality attribute. Furthermore, we also note a change in the trend of diminishing sensitivity across the two scenarios, especially in the losses domains. In fact, the initial scenario registers a significant diminishing sensitivity for the punctuality attribute while the shift scenario reports significant diminishing sensitivity for cost and time attributes.

Table 4 summarises the willingness to pay (WTP) and willingness to accept (WTA) measures across the six models estimated, stressing the significant implication regarding a negative shift of the reference values. We base the comparison on the conditional estimates for the mean, reporting the standard deviation for the measures that involve random parameters. For the symmetric models (M1 and M2), although the model fits does not report a significant difference between the restricted and the unrestricted model specifications, the mean WTP measures for travel time savings in model M2 show an interesting difference across the two scenarios. In particular, the WTP for travel time savings is 17.32 CHF/hr (approx. 16.10 USD/hr) for the initial scenario, whereas it is 20.78 CHF/hr (approx. 19.32 USD/hr) for the shift scenario. The WTP measures for punctuality show a slighter difference. Regarding the symmetric model M2, the WTP measures obtained for the initial scenario are in line with previous studies (see for example, Bolis and Maggi, 2003, Zamparini and Reggiani, 2007, Maggi and Rudel, 2008).

The WTP decrease drastically when the utility function is specified according to the reference dependence assumption, which allows us to take into account for the WTA/WTP discrepancy (see, Horowitz and McConnell, 2002 for a review). Focusing on model M4, the initial scenario indicates a WTP for travel time savings of 10.22 CHF/hr and a WTA of 18.42 CHF/hr, setting the WTA/WTP ratio at 1.80, whereas we observe a WTP of 6.02 CHF/hr and a WTA of 55.96 CHF/hr for the shift scenario, which results in a ratio of 9.29.

Table 4 WTP and WTA measures (CHF/hr for time and CHF/percentage point for punctuality)
[ ] = standard deviation

	Symmetric linear		Asymmetric linear		Asymmetric piecewise	
	(restricted)	(unrestricted)	(restricted)	(unrestricted)	(restricted)	(unrestricted)
	M1	M2	M3	M4	M5	M6
Willingness to Pay measures in CHF per shipment (INITIAL SCENARIO)						
WTP time	19.63	17.32	6.47 [0.54]	10.22 [0.65]	-	-
WTP time (-)	-	-	-	-	6.49 [0.70]	9.85 [0.58]
WTP time (--)	-	-	-	-	7.68 [0.83]	9.72 [0.57]
WTP punctuality	62.94	65.07	46.92 [21.17]	18.61 [1.62]	-	
WTP punctuality (+)	-	-	-	-	69.53 [20.90]	89.01 [17.51]
WTP punctuality (++)	-	-	-	-	47.42 [15.76]	25.70 [3.06]
Willingness to Pay measures in CHF per shipment (SHIFT SCENARIO)						
WTP time	19.63	20.78	6.47 [0.54]	6.02 [0.71]	-	
WTP time (-)	-	-	-	-	6.49 [0.70]	4.37 [0.48]
WTP time (--)	-	-	-	-	7.68 [0.83]	6.63 [0.74]
WTP punctuality	62.94	61.81	46.92 [21.17]	52.00 [37.60]	-	
WTP punctuality (+)	-	-	-	-	69.53 [20.90]	52.36 [19.46]
WTP punctuality (++)	-	-	-	-	47.42 [15.76]	58.50 [34.93]
Willingness to Accept measures in CHF per shipment (INITIAL SCENARIO)						
WTA time	19.63	17.32	42.12	18.42	-	
WTA time (+)	-	-	-	-	58.26	28.76
WTA time (++)	-	-	-	-	34.68	13.73
WTA punctuality	62.94	65.07	255.28	228.88	-	
WTA punctuality (-)	-	-	-	-	213.22	174.66
Willingness to Accept measures in CHF per shipment (SHIFT SCENARIO)						
WTA time	19.63	20.78	42.12	55.96	-	
WTA time (+)	-	-	-	-	58.26	66.19
WTA time (++)	-	-	-	-	34.68	23.88
WTA punctuality	62.94	61.81	255.28	250.46	-	
WTA punctuality (-)	-	-	-	-	213.22	200.64

A similar structure for the WTP and WTA for travel time is outlined by model M6, although the diminishing sensitivity reported for time and cost attributes reveals a larger WTA/WTP discrepancy in the proximity of the reference values, both within and across the initial and shift scenarios. The consequence of a negative shift of the reference point suggests, therefore, a significant and substantial increase of the WTA/WTP ratio for travel time, where respondents experienced a lower WTP and a higher WTA with respect to the initial scenario. Reflecting the reaction hypotheses, the behavioural response to a negative shift of the reference value in terms of WTP and WTA for transport service punctuality shows an opposite pattern. In fact, the WTA/WTP discrepancy exhibits a general reduction passing from a ratio of 12.29 for the initial scenario in model M4 to 4.81 for the shift scenario. It is interesting to note the change in the respondents' behaviour highlighted by the introduction of nonlinearity in model M6. In this case, for the initial scenario, the WTP for punctuality is particularly high for an increase of two percentage points (89.01 CHF/percentage point), but decrease dramatically for larger increases (25.70 CHF/percentage point), reflecting the very high sample median of 98 percent for the reference transport service. Nevertheless, we observe a levelling of these two values for the shift scenario (52.36 and 58.50 CHF/percentage point, respectively) which imposed a reduction of two percentage points over the reference alternative values.

3.5. Conclusions

This paper has investigated the reaction experienced by decision makers facing a negative shift of the reference point within a reference pivoted stated choice experiment framework. The analysis has been based on two choice experiments conducted amongst logistics managers, and collected in Switzerland in 2008. The experiments were designed to identify the indirect freight transport costs associated with a temporary closure of the main reference road alternative. The first experiment reflected the initial conditions, and hence was designed around the typical (or initial) reference alternative. We then introduced the hypothesis of road closure and updated the initial reference alternative values according to the second best road alternative (shifted or expected reference alternative) values which were then used to pivot the design of the second stated choice experiment.

Under an assumption of prospect theory, a change in the reference point affects the structure of individuals' preferences. In order to investigate any potential reaction within the sample interviewed, we pooled the data from the two experiments and estimated three pairs of models. Within each pair of models, the distinction has been made by performing the restricted and unrestricted model specifications, where the restriction involved the specification of generic coefficients across the two datasets. The first pair of models assumed a symmetric specification. We introduced the reference dependence specification in the second pair of models, and estimated linear asymmetric parameters for both gains and losses. In the third pair of models, we further allowed for asymmetric nonlinearity in gains and losses domains by estimating, through a piecewise transformation, different parameters for different attribute levels.

The model results for the two reference-dependent specifications indicate that respondents experienced a significant reaction when facing a negative shift of the reference point. The unrestricted version of the models outperforms the restricted one, providing significant support to the prospect theory assumption regarding the alteration of respondent preference structure. From a comparison of the parameter estimates, we observed that respondents, on average, increased their loss aversion for cost and time attributes reflecting a willingness to prevent further losses. On the contrary, for the punctuality attribute, we registered a decrease in the loss aversion due to a considerable increase in the marginal utility associated with gains reasonably explained as the propensity to recover the initial loss. These results not only confirm the priority of the punctuality attribute within the logistics managers' choice of freight transport services but also indicate that a small decrease in the punctuality quality has a high impact on preference formation, even for a limited timeframe, as supposed in our study.

The results obtained for the symmetric specifications do not indicate any statistically significant reaction in terms of model performance. We note therefore a clear difficulty of the classic economic theory in capturing changes in behaviour under a shift reference point context, although this is not surprising given the symmetric structure of these specifications.

The estimates of WTP and WTA measures from the reference dependence models report a WTA substantially higher than the WTP, which is in line with expectations. Comparing the two scenarios, the results suggest that a negative shift of the reference point causes a reduction in the WTP and an increase in the WTA for travel time, and an overall increase of the WTP, and a slight increase of the WTA for transport service punctuality. The significance of the differences in terms of WTP and WTA measures across the two scenarios is a relevant finding. Policy makers should therefore consider the consumers potential reactions in any context involving a shift of the reference point. In particular, we think about reference pivoted stated choice experiments studying the introduction of toll roads or congestion pricing schemes in general. In these cases, particular attention should be addressed to the specification of the reference values.

Further research is suggested in order to support these findings in different empirical contexts. Given that our study was based on a shift of the reference point in the short run and limited in time, we recognise the relevance of these findings in choices affecting everyday life concerning transitional road detours for infrastructures maintenance, and we advise the implementation of cost benefit analysis studies in this direction. However, we also suggest the need for further investigation in a context involving a permanent shift of the reference point, such as the introduction of pricing schemes. Finally, the analysis of a positive shift of the reference point would be of interest in order to support recent findings (e.g., Arkes et *al.* 2008), noting that individuals tend to adapt more completely to gains (positive shifts) than to losses (negative shifts).

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Chapter Four

Accounting for WTP/WTA discrepancy in discrete choice models: Discussion of policy implications based on two freight transport stated choice experiments

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Abstract

A key input in cost-benefit analysis is represented by the marginal rate of substitution which expresses the willingness to pay, or its counterpart willingness to accept, for both market and non-market goods. The consistent discrepancy between these two measures observed in the literature suggests the need to estimate reference dependent models able to capturing loss aversion by distinguishing the value attached to a gain from the value attached to a loss according to reference dependent theory. This paper proposes a comparison of willingness to pay and willingness to accept measures estimated from models with both symmetric and reference dependent utility specifications within two different freight transport stated choice experiments. The results show that the reference dependent specification outperforms the symmetric specification and they prove the robustness of reference dependent specification over datasets designed according different attributes levels ranges. Moreover we demonstrate the policy relevance of asymmetric specifications illustrating the strong implications for cost-benefit analysis in two case studies.

Keywords: WTP/WTA discrepancy, freight choice, policy evaluation

4.1. Introduction

A key input in the economic evaluation of transport measures is represented by the marginal rate of substitution which expresses the willingness to pay (WTP), or its counterpart willingness to accept (WTA), for both market and non-market goods. Indeed, in the analysis of travel demand a lot of effort has been put into modelling individual preferences in order to obtain the trade-off between time and cost, commonly known as value of travel time saving (VTTS). In this context, Hensher (2001) reports that in the quantification of user benefits for transport project appraisal the VTTS accounts for 60 per cent. Mackie et al. (2001) indicate that around the 80 per cent of the monetised benefits within cost-benefit analysis (CBA) is attributable to VTTS.

Revealed preferences (RP) and stated preferences (SP) are the main methods for collecting data suitable for the estimation of WTP and WTA measures within the discrete choice class of models (McFadden, 1974; Train et *al.*, 1987; Ben-Akiva et *al.*, 1993). In particular, stated choice experiments have become a consolidate instrument that allow for the analysis of individual preferences by letting the respondent choose among a set of hypothetical choice situations.

Increasing attention has been paid to generating experiment designs by pivoting the hypothetical situations around individual specific reference alternatives. However, the data collected are typically modelled in the same way as data collected from RP or non-pivoted SP. That is by letting the utility function be symmetric in respect to positive and negative deviations from the reference alternative levels. Within symmetric utility specification the WTA value results to be the mirror of the WTP value, which results in line within the Hicksian surplus theory in a context where WTP and WTA are small relative to the income (see Randall and Stoll, 1980 for a proof). However, the consistent discrepancy between WTP and WTA measures observed in the literature[47] suggests the need to estimate asymmetric models able to capturing loss aversion by distinguishing the value attached to a gain from the value attached to a loss according to reference dependent theory (Kahneman and Tversky, 1979; Tversky and Kahneman, 1991; Tversky and Kahneman, 1992). In this regards, recent studies have analysed reference dependent utility

[47] A review by Horowitz and McConnell (2002) based on 45 studies sets the median of the ratio WTA/WTP to 2.6.

specifications in a stated choice framework supporting the hypothesis that classic symmetric models tend to over-estimate WTP and under-estimate WTA (see for example, Hess et al. 2008; De Borger and Fosgerau, 2008; Masiero and Hensher, 2010). Indeed, the direct relationship between loss aversion and WTA/WTP discrepancy has been tested and proved in a laboratory experiment (Bateman el al., 1997) and in a stated choice experiment (De Borger and Fosgerau, 2008).

Although well recognized and discussed in several papers (see for example, Hanemann, 1991; Brown and Gregory, 1999; Graves, 2009a; Graves, 2009b) the divergence between WTP and WTA is not taken into account in the majority of the discrete choice models specification carrying potential upward biased estimates of WTP measures for policy makers. On the other hand, the estimation of reference dependent discrete choice models re-opens the debate on which measure between WTP and WTA is most desirable in the economic evaluation of transport projects.

In this paper we propose a comparison of WTA and WTP measures estimated from models with both symmetric and reference dependent utility specifications within two different freight transport stated choice experiments conducted among Swiss logistics managers in 2003 and 2008, respectively. In this context, the freight transport sector occupies a minor part in the research literature involving the transport sector in general. However, the impact of the value of freight transport time saving (VFTTS) in the evaluation of the profitability of investments in transport infrastructures must not be neglected since it can represent up to 50 per cent of the potential VTTS (Zamparini and Reggiani, 2007). In particular, we focus the analysis on proving the robustness of the loss aversion validity (and WTA/WTP divergence) within pivoted freight transport stated choice experiments defined under different experimental design assumptions. The results are based on the estimation of random parameters logit models on both the single dataset collected in 2003 and the pooled dataset containing the two stated choice experiments.

In the derivation of WTP and WTA measures, the selection of the density function for the random parameters has a great impact. Indeed, if all parameters are set as random then the estimation of the marginal rate of substitution involves the ratio of two random distributions which present substantial evaluation problems. Train and Weeks (2005) proposed the estimation of discrete choice models in WTP space overcoming the problem of ratio distributions by involving the WTP distribution directly in the model estimation. However, the estimation of models in WTP space requires the normalization of the model for the cost attribute. This is a restriction for reference dependent models that have two cost attributes, for gains and losses respectively (see Rose and Masiero, 2009). Masiero and Hensher (2010) specify a reference dependent model where the random parameters are assumed to be triangular distributed and constraining the standard deviation of the coefficient to be equal to the mean. Although the use of constrained triangular distribution leads to desirable estimates of the parameters since it avoids the estimation of irrational values (i.e. positive coefficient for cost and time), the heterogeneity across the sample is only assumed and not estimated. In order to analyse the spread of the random parameters distribution when respondent face with gains and losses we decide to fix the cost parameter and let the attribute associated to the other parameters to be Normal distributed. This method has good properties in terms of model identification, WTP estimation and rational assumption about the cost coefficient (see Revelt and Train, 2000).

A specific purpose of this paper is to discuss the policy implications that arise from the WTA/WTP discrepancy. In this context, we propose to reconsider the concept of WTP and WTA use in transport investment appraisal focusing the discussion on the rationale of using asymmetric WTP and WTA instead of symmetric WTP. We illustrate the argument with two hypothetical infrastructure investments, one for improvement of the current situation, the other for maintenance.

The paper is organized as follows. In section two we describe the two stated choice experiments used in the analysis. The methodological background is presented in section three whereas the models estimates are shown in section four along with comments on the results. In section five we outline the potential policy implications associated to WTA/WTP discrepancy. Conclusions and final remarks are provided in section six.

4.2. Data

The data refers to two freight transport stated choice experiments conducted among Swiss logistics managers in 2003 and 2008, S-2003 and S-2008 respectively. The first dataset referred to the evaluation of relevant service characteristics in freight transport (see Maggi and Rudel, 2008 for details) whereas the second dataset is part of a project[48] aimed to analyze the infrastructure vulnerability of the Gotthard corridor, one of the most important European transport corridors (see Masiero and Maggi 2009 for details).

The freight transport services considered in the two stated choice experiments are represented by conventional origin-destination services and they are expressed as function of cost (CHF per transport service), time (hours per transport service) and punctuality (percentage of transport services arriving on time per yearly). An additional attribute is considered in the first dataset expressing the yearly percentage of transport services which register damages to the goods transported.

Table 1 Description of the stated choice experiments

	DATASET S-2003	DATASET S-2008
Attributes and Levels		
Transport Cost (CHF)	-40 %, -20 %, Reference, +20 %, +40 %	-10 %, -5 %, Reference, +5 %, +10 %
Transport time (hours)	-40 %, -20 %, Reference, +20 %, +40 %	-10 %, -5 %, Reference, +5 %, +10 %
Transport Punctuality (%)	96 %, 98 %, 100 %	96 %, 98 %, 100 %
Damages (%)	6 %, 4 %, 2 %	
Design		
Experiment	Unlabeled	Labeled
Alternatives	Alternative A and Alternative B	Road, Piggyback and Combined transport
Reference in Design	Not included	Road
Number of Choice tasks	20	15

The hypothetical alternatives included in the designs of the two stated choice experiments have been created by pivoting the cost and time attributes levels around a reference alternative previously described by the logistics managers. Although logistics managers reported also reference values for punctuality and damages, these two attributes are presented in absolute values for technical convenience. The levels associated to each attributes in the two datasets are shown in Table 1 which also highlights the main differences between the two experimental designs[49].

The collection of the data involved face-to-face interviews based on Computer Assisted Personal Interview (CAPI), where logistics managers were asked to indicate their

[48] NFP54 "Sustainable Development of the Built Environment", funded by the Swiss National Science Foundation.
[49] The attributes levels values for dataset S-2003 differ from those reported in the Table in Maggi and Rudel (2008) which by mistake are not correctly reported there.

preferred alternative in each choice task. For both the choice experiments, the sample focused on medium (50 to 249 employees) and large (more than 249 employees) companies. Regarding S-2003 data, 35 firms operating in the food and wholesale sector were represented and a subset of the sample answered to the same experiment twice, discriminating for inbound and outbound across the two experiments. After having removed the extreme cases (in terms of cost, time and punctuality values revealed by logistics managers) in order to obtain similar range of minimum and maximum values across the two samples, S-2003 data consists of 42 experiments, representing 840 choice observations. The sample associated to S-2008 data is composed of 27 firms operating in the manufacturing sector, representing 405 choice observations. By pooling the two datasets we obtain 69 valid experiments, representing 1245 choice observations. The descriptive statistics of the reference transport services described by logistics managers are reported in Table 2.

Table 2 Descriptive statistics for attributes of the reference transport service

Variable	Mean		Median		SD		Min		Max	
	S-2003	S-2008	S-2003	S-2008	S-2003	S-2008	S-2003	S-2008	S-2003	S-2008
Cost (CHF)	894.4	1300.1	800	1000	533.1	1152.9	120	136	2500	5400
Time (hr)	15.1	33.3	7	24	26.3	27.3	2	2	168	96
Punctuality (%)	98.5	96.5	99	98	1.7	3.0	94	90	100	100
Damages (%)	0.3	-	0	-	0.6	-	0	-	2	-

4.3. Methodology

Within the Random Utility Models (RUM) framework, the utility function associated with respondent *n* for alternative *j* in choice task *s* is defined as the combination of a systematic component and an unobserved component, where the systematic part is assumed to be linear in parameters such that

$$U_{njs} = \alpha_j + \sum_{k=1}^{K} \beta_{nk} x_{njsk} + \varepsilon_{njs} \tag{1}$$

where α_j represents the alternative specific constant, β_{nk}, is the vector of *k* coefficients associated to the set of attributes, and the unobserved part, ε_{njs}, is Independent and Identically Distributed (IID) extreme value type 1. The subscript *n* in β_{nk} denotes the random parameters logit class of models, where the coefficients (all or a subset) are assumed to be heterogeneous across the respondents according to a specific density function. In this context, the Normal distribution is the most referred in the literature although log-normal and triangular distributions are also used (see Hensher and Greene, 2003).

The derivation of the marginal rate of substitution is straightforward and leads to WTP and WTA estimates. For symmetric specification models they are defined as follows:

$$MRS = \frac{\frac{d}{dx_{njsk}}\beta_{nk}x_{njsk}}{\frac{d}{dx_{njsk}}\beta_{nk}x_{njsk}} \Rightarrow WTP = -WTA = \frac{\beta_{nk}}{\beta_{n,\cos t}} \tag{2}$$

As shown in Equation (2), symmetric models assume by construction that WTP and WTA are identical in the absolute values.

A deviation from the classic symmetric model specification, formulated in Equation (1), is represented by the reference dependence model specification which allows the estimation of different coefficients for both positive and negative deviations from the reference values. The utility function is then defined as follows:

$$U_{njs} = \alpha_j + \sum_{k=1}^{K}\beta_{nk}(dec)x_{njsk}(dec) + \sum_{k=1}^{K}\beta_{nk}(inc)x_{njsk}(inc) + \varepsilon_{njs} \tag{3}$$

where (dec) and (inc) indicate decreases and increases respectively, and x_{njsk} *(dec)* = *max*($x_{ref} - x_j$, *0)* and x_{njsk}*(inc)* = *max*($x_j - x_{ref}$, *0)*. The estimation of different parameters for gains and losses with respect to the reference values allows to test for asymmetries in the utility function[50] and eventually to test for the presence of loss aversion. Moreover, the WTP and WTA measures are not forced to be symmetric anymore since they are separately estimated according to the following relation:

[50] Note that the reference dependence specification nests the symmetric specification.

For undesirable goods: $WTP = \frac{\beta_{nk(dec)}}{\beta_{n,\mathrm{cost}(inc)}}$; $WTA = \frac{\beta_{nk(inc)}}{\beta_{n,\mathrm{cost}(dec)}}$ (4)

For desirable goods: $WTP = \frac{\beta_{nk(inc)}}{\beta_{n,\mathrm{cost}(inc)}}$; $WTA = \frac{\beta_{nk(dec)}}{\beta_{n,\mathrm{cost}(dec)}}$ (5)

The relationship between loss aversion and WTA/WTP divergence can then be easily proved from Equations (4) and (5). In fact, loss aversion holds if the absolute value of the coefficient associated to losses is bigger than the absolute value of the coefficient associated to gains. That is, for undesirable goods: $|\beta_{nk(inc)}| > |\beta_{nk(dec)}|$; whereas for desirable goods: $|\beta_{nk(dec)}| > |\beta_{nk(inc)}|$. If loss aversion holds for both goods in the numerator and the cost attribute then WTA > WTP.

Given the panel structure of the data and the use of the random parameters logit class of models, the estimation of the utility parameters is derived from the maximization of the following simulated log likelihood:

$$LL_n = \sum_n \ln \frac{1}{R} \sum_r \prod_s \frac{\exp(\boldsymbol{\alpha}_j + \boldsymbol{\beta}'_n \mathbf{x}_{njs})}{\sum_j \exp(\boldsymbol{\alpha}_j + \boldsymbol{\beta}'_n \mathbf{x}_{njs})} \qquad (6)$$

where $s = 1, \ldots, S$ represent the number of choice situations whereas $r = 1, \ldots, R$ refers to the number of draws[51].

4.4. Model results

The estimation of symmetric and reference dependent models is performed firstly on the S-2003 data and then on a joint dataset, where we pooled S-2003 and S-2008 data (for model estimation based on S-2008 see Masiero and Hensher (2010)[52]). This allows us to test for robustness of reference dependent specification across different datasets. The estimation of the models for the pooled dataset includes also the computation of the scale

[51] Refer to Train (2003) for details.
[52] Note that Masiero and Hensher (2010) use constrained triangular distribution for random parameters whereas here we use unconstrained normal distributions for attribute parameters and a fixed cost coefficient.

parameters for the three alternatives of dataset S-2008 in order to take into account the difference in the scale associated to different datasets. In doing this, we normalize the scale of S-2003 dataset to one upon the second dataset[53]. The estimation of the models is based on 500 Halton draws and performed using Nlogit 4.

The model results are shown in Table 3. The first two columns (M1 and M2) refer to symmetric model specification and reference dependent model specification for S-2003 data whereas the last two columns (M3 and M4) refer to the same models specification but for the pooled dataset. The overall evaluation of model fits is based on the log-likelihood at convergence, the Akaike's Information Criterion (AIC) and the McFadden pseudo rho squared (ρ^2).

Comparing these three measures we register that the reference dependent model specification outperforms the symmetric one in both the datasets used. In particular, the McFadden pseudo ρ^2 rises from 0.7267 to 0.7446 for S-2003 data and from 0.6651 to 0.6943 for the pooled dataset. These findings exclude the hypothesis that the restricted symmetric models are more parsimonious than the unrestricted reference dependent models.

The scale parameters estimated for the alternatives of dataset S-2008 within the joint estimation result statistically different from 1 providing evidence for a significant difference in the scale of the two datasets used in the analysis. In particular, the scale parameters for piggyback and combined transport alternatives indicate that the unobserved effects are characterized by a considerably lower variance compared to dataset S-2003. On the contrary the unobserved effects associated to the reference alternative report a bigger variance if compared with the alternatives in dataset S-2003.

Examining the coefficient estimates for the symmetric models (M1 and M3) associated with the attributes we observe that they all are of the expected sign that is, negative for damages, cost and time attributes and positive for punctuality. Both mean and standard deviation (for random parameters) estimates result statistically significant at an alpha level

[53] See Hensher (2008) for details.

of 0.05 except for the standard deviation of the time parameter in S-2003 data which results statistically significant at an alpha level of 0.10.

Table 3 Model results

	M1 Symmetric		**M2** Reference Dependent		**M3** Symmetric		**M4** Reference Dependent	
	Par.	**(t-ratio)**	**Par.**	**(t-ratio)**	**Par.**	**(t-ratio)**	**Par.**	**(t-ratio)**
Means for Random and Non-Random parameters								
ASC Alternative A	0.1223	(0.93)	0.1284	(1.16)	0.1480	(1.52)	0.1599	(1.36)
ASC Piggyback	-	-	-	-	-1.0933	(-1.71)	0.8495	(1.05)
ASC Combined transport	-	-	-	-	-0.8716	(-1.37)	1.0408	(1.28)
Cost	-0.0038	(-12.59)	-	-	-0.0036	(-12.68)	-	-
Time	-0.0691	(-2.91)	-	-	-0.0740	(-3.49)	-	-
Punctuality	0.2890	(6.37)	-	-	0.2880	(9.45)	-	-
Damages	-0.3959	(-10.76)	-0.4870	(-10.39)	-0.4042	(-10.74)	-0.5303	(-10.54)
Cost decrease	-	-	0.0033	(5.69)	-	-	0.0041	(6.71)
Cost increase	-	-	-0.0052	(-7.88)	-	-	-0.0060	(-8.56)
Time decrease	-	-	0.0662	(1.82)	-	-	0.0809	(2.49)
Time increase	-	-	-0.0718	(-2.39)	-	-	-0.1315	(-2.83)
Punctuality decrease	-	-	-0.3454	(-2.94)	-	-	-0.6127	(-4.15)
Punctuality increase	-	-	0.2640	(2.11)	-	-	0.2272	(2.76)
Standard deviations for Random parameters								
Ns Time	0.0586	(1.92)	-	-	0.08504	(3.32)	-	-
Ns Punctuality	0.3395	(5.90)	-	-	-	-	-	-
Ns Time decrease	-	-	0.0772	(2.78)	-	-	0.1017	(2.76)
Ns Time increase	-	-	0.1013	(1.91)	-	-	0.1807	(2.75)
Ns Punctuality decrease	-	-	0.6099	(5.18)	-	-	0.8077	(5.52)
Ns Punctuality increase	-	-	0.3812	(3.15)	-	-	0.3215	(4.10)
Scale parameters								
Scale ALT Piggyback	-	-	-	-	19.384	(-2.00)[a]	15.952	(-2.54)[a]
Scale ALT Combined transport	-	-	-	-	6.854	(-2.70)[a]	6.704	(-2.14)[a]
Scale ALT Reference	-	-	-	-	0.417	(2.59)[a]	0.297	(2.86)[a]
Conditional WTP measures [standard deviation]								
Travel Time	17.69 [7.22]		12.61 [6.16]		20.39 [12.49]		13.23 [6.33]	
Punctuality	62.80 [48.70]		52.44 [36.57]		79.16 [0.00]		36.30 [27.13]	
Conditional WTA measures [standard deviation]								
Travel Time	17.69 [7.22]		21.72 [13.52]		20.39 [12.49]		32.71 [24.23]	
Punctuality	62.80 [48.70]		101.65 [137.57]		79.16 [0.00]		152.22 [146.38]	
Model Fits								
Number of Observations	840		840		1245		1245	
Log-likelihood Restricted	-1351.93		-1351.93		-2003.75		-2003.75	
Log-likelihood at convergence	-369.48		-345.28		-671.13		-612.47	
Number of Parameters	7		12		11		17	
AIC normalized	0.8964		0.8507		1.0958		1.0112	
McFadden pseudo ρ2	0.7267		0.7446		0.6651		0.6943	

[a] The t-ratio is calculated on the assumption that the scale parameter is different from one.

Looking at the reference dependent model specifications (M2 and M4), where cost, time and punctuality attributes are defined in terms of gains and losses, we observe a similar consistency. That is, parameters associated with gains (cost decrease, time decrease and punctuality increase) are positive in sign whereas the parameters associated with losses (cost increase, time increase and punctuality decrease) are negative in sign. Moreover, we find that loss aversion holds for all the three attributes and in both dataset specifications. In fact, the parameters associated with losses are in absolute value bigger than the parameters associated with gains. The standard deviation for the random parameters results higher for the parameters associated with losses meaning that the preferences of the logistics managers are more heterogeneous when logistics managers are faced with losses.

The conditional estimates for WTP measures from symmetric models are in line with current research literature (see Zamparini and Reggiani (2007) for a review). In particular, the willingness to pay for time is 17.7 CHF/hour[54] and 20.4 CHF/hour for symmetric models M1 and M3, respectively. The willingness to pay for punctuality is a key factor, as reported in similar studies (e.g., Danielis et al., 2005; Fowkes, 2007), for logistics managers who show a considerable sensitivity regarding punctuality of the transport service. For symmetric models the WTP for punctuality reaches 62.8 CHF and 79.16 CHF per percentage point for M1 and M3, respectively.

Looking at the reference dependent model specifications in M2 and M4, we are able to distinguish between WTP and WTA. In particular, referring to the estimates for the pooled dataset (M4) we find that the WTP for time is 13.23 CHF/hour whereas the WTA for time is 32.71 CHF/hour. On the other hand, the WTP for punctuality is 36.30 CHF for an increase in punctuality by one percentage point whereas the WTA is 152.22 CHF for a decrease of punctuality of one percentage point. Punctuality still remains a crucial factor, especially when logistics managers are faced with a reduction of this service attribute. The WTA/WTP discrepancy registered is fairly marked for both the marginal rates of substitution considered. In this context, the ratio WTA/WTP is 2.5 for time and 4.2 for punctuality which results in line with past studies (see for example, Horowitz and McConnell (2002) for a review).

[54] Approximate monthly average exchange rate for April 2010, 1 CHF = 0.93 USD.

4.5. Policy implications

In the previous section we demonstrated how the estimation of reference dependent choice models leads to asymmetric estimates of WTP and WTA measures according to the research literature on WTA/WTP discrepancy. This has implications on policy evaluations since these measures are a key input in order to decide if a certain policy is economically convenient or not. Indeed, assuming that WTP and WTA values are not symmetric sets the discussion on the appropriate use of these measures. Different policy measures or infrastructure investments are designed for different purposes which imply either the use of WTP or WTA values. In this section we focus on infrastructure investments and in particular on transport projects, defining three categories according to the expected outcome of consumers WTP and WTA values.

In Table 4 we show the expected sign of consumers' WTP and WTA values associated with a new infrastructure depending on whether the impact on actual conditions represents a worsening, a conservation or an improvement in terms of consumers' utility. Infrastructures that lie in the worsening category are those which carry considerable environmental consequences such as the construction of a nuclear power station. In this case, the expected willingness to pay for having a new nuclear power station is expected to be negative whereas the willingness to accept is expected to be particularly high. Typically the calculation of the social impact associated to such infrastructures is based on ad-hoc stated choice experiments designed directly in the WTA space. Since in this paper we are interested in the economic appraisal of transport infrastructure investments we do not discuss this category any further.

Table 4 Expected consumers WTP and WTA values due to an infrastructure investment

	IMPACT ON ACTUAL CONDITIONS		
	WORSENING	**CONSERVATION**	**IMPROVEMENT**
WTP	negative	zero	positive
WTA	positive	positive	positive
Appropriate Measure	WTA	**WTA**	**WTP**

Within transport projects, many investments deal with the conservation of the current conditions. Indeed, transport infrastructure operation and maintenance are necessary in order to maintain a certain level of quality (e.g., travel time) that would otherwise be impossible to maintain due to the constant increase of traffic flows. These infrastructure investments can often be very expensive, depending on the transport network involved, and the convenience of the investment needs to be evaluated. In this case, the willingness to pay is expected to be zero since we are asking the users to face a situation where the quality of service remains stable at the actual level. Therefore, the user benefit associated with such investments should be calculated using their willingness to accept for a loss in service quality (e.g., an increase in the travel time) which would be the consequence if the investment were not realized.

The typical situation in the economic appraisal of a transport project is however the evaluation of an investment against an improvement of the actual condition. This is the case of a new transport infrastructure, where the willingness to pay is now positive and reflects the maximum (marginal) amount that consumers are willing to pay for the improvement (e.g., a reduction of the travel time). Therefore, the willingness to pay should be used in the computation of user benefits.

4.5.1 Case Studies on freight transport

Based on the estimates from models M3 and M4 (reported in Table 3) we illustrate the implication of WTA/WTP discrepancy in the case of hypothetical policy measures for freight transport in Switzerland. In particular, we compare two cost-benefit analyses (CBA) distinguishing between the two categories highlighted in Table 4, conservation and improvement, respectively.

We hypothesize two different large investments along the Gotthard corridor which is the most important link across the Alpine region. The first investment refers to the construction of a second “Gotthard road tunnel” increasing the number of lanes from two to four representing a significant improvement in terms of travel time and punctuality. The second investment consists of protective galleries and tunnels on the north and south access to the Gotthard road tunnel. This represents a maintenance intervention assuming that climate change leads to a dramatic increase of hazards.

Table 5 describes the case studies. We realistically assume for both projects an identical initial cost of 900 million CHF[55] and we set the annual maintenance cost to 50.000 CHF. The population is set to 650.000 units according to the Swiss transport policy goal regarding the yearly number of trucks foreseen to cross the road corridor after 2018. The infrastructure lifetime and the discount rate are assumed to be 50 years and 4.5 percent, respectively.

Table 5 Case studies assumptions

Setting	
Initial Cost	900.000.000
Annual Maintenance Cost	50.000
Discount rate	4.5 %
Population	650.000
Infrastructure lifetime (years)	50
Scenario	
Change in Time attribute	10 %
Change in Punctuality attribute	1 %

The hypothetical scenario envisages a reduction of freight travel time of 10 percent and an increase in the punctuality of the freight transport services of 1 percent. In the first case these improvements are due to the elimination of queues caused by the current bottleneck. In the second case we assume that the increasing hazards would cause an increase in the travel time and punctuality which could be avoided by the investments. Given this scenario and given the WTP and WTA estimates from models M3 and M4 (for convenience reported in Table 6) we calculate the average generalized cost of the actual transport services as described by logistics managers and the average generalized cost of the same transport services but under the scenario assumptions[56], applying asymmetric WTP in the first case and asymmetric WTA in the second case and, for comparison, symmetric WTP in both cases. The benefits for the freight transport sector associated to the hypothesised scenario are then derived by taking the difference of the generalized cost over the population considered[57].

[55] The reference cost for the second "Gotthard road tunnel" is based on the estimate published in "Ticino Business", *Camera di commercio, dell'industria, dell'artigianato e dei servizi del Cantone Ticino, Lugano*, November 2008.

[56] The generalized cost is calculated as the sum of the cost, time and punctuality where time and punctuality are expressed in monetary values according to the WTP and WTA estimates.

[57] To be noted that in the computation of the benefits we did not distinguish for intra-country transports and transports that use the corridor as connection between different countries. Indeed, it is reasonable to assume lower WTP values for the latter transport segment. However, we are convinced that our estimates are still

Table 6 Case studies results

	CASE 1 IMPROVEMENT	CASE 2 MAINTENANCE	CASE 1 = CASE 2
	Asymmetric WTP	Asymmetric WTA	Symmetric WTP = WTA
Travel Time	13.23	32.71	20.39
Punctuality	36.30	152.22	79.16
Net Present Value	**- 57 million**	**1,988 million**	**698 million**

These results shown in Table 6 demonstrate the relevance of estimating WTP and WTA separately and applying them appropriately. Using the traditional approach, and hence overestimating WTP for an improvement and underestimating WTA for maintenance, both projects would be accepted. Applying asymmetric WTP for the improvement results in a negative net present value demonstrating that 900 million investment is not justified for a 10 % and a 1% percent improvement in travel time and punctuality, respectively. On the other hand, an equally expensive maintenance investment with same impact is largely justified. In a general sense it is therefore demonstrated that applying symmetric WTP may lead in different contexts to significant over or under investments.

4.6. Conclusions

This paper has investigated the policy implications of WTA/WTP discrepancy in a freight transport context. The analysis has focused on the estimation of discrete choice models for two freight transport stated choice experiments. In particular, we estimated a set of random parameters logit models comparing between the classic symmetric specification which does not distinguish between WTP and WTA, and the reference dependent specification which relaxes the symmetry assumption allowing for the estimation of different parameters associated to gains and losses. We outlined then the policy implications supporting the discussion with hypothetical examples on the freight transport sector in Switzerland.

The results show that the reference dependent specification outperforms the symmetric specification and they prove the robustness of a reference dependent specification for datasets designed to accommodate different attribute level ranges. Loss aversion has been

conservative since we fixed the population to 650.000, the Swiss policy objective, representing around the 50 percent of the actual figure.

registered for all attributes investigated in the analysis leading to a significant WTA/WTP discrepancy. As a consequence, our results confirm the findings reported in the recent research literature that is, that symmetric models tend to overestimate WTP values and to underestimate WTA values.

The policy implications associated with WTP and WTA measures estimated from reference dependent choice models are indeed interesting. The paper defined three main categories of infrastructure projects labelled worsening, conservation and improvement, respectively. For each category, the two measures (WTP and WTA) have been discussed and the most appropriate measure for the evaluation of the investment has been selected. The focus has then been on two categories that typically reflect transport projects, that is, transport infrastructures aimed to conserve or to improve the actual quality of the service. We pointed out a major difference between these two categories suggesting that the infrastructures aimed to conserve the actual conditions should be evaluated using the consumers WTA (contradicting the current state-of-the-art which apply the WTP) whereas the infrastructures aimed to improve the actual conditions should be evaluated, as classic research literature states, using the consumers WTP. However, using symmetric WTP estimates will underestimate the benefit of the latter kind of investment. Based on reference dependent model estimates and given our distinction for the type of infrastructure we conclude that the evaluation of investments aimed to conserve (improve) the actual conditions is underestimated (overestimated) if current guidelines apply.

Finally, we strongly encourage policy oriented analysts to estimate reference dependent choice models appropriately derived from reference pivoted choice experiments. The persistence in using symmetric discrete choice models as an instrument for deriving marginal substitution effects for policy purpose might most probably lead to biased evaluation in the form of significant overestimation or underestimation of the economic benefits of transport projects.

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