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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.

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[1]. 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).

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.

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

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. 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[2] aimed to analyze the infrastructure vulnerability of the Ghottard corridor, one of the most important European transport corridors.

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) [3].

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).
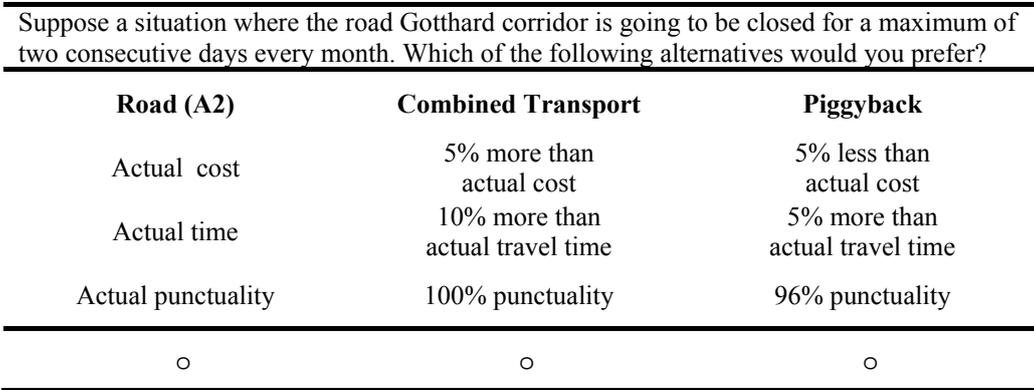
Suppose a situation where the road Gotthard corridor is going to be closed for a maximum of two consecutive days every month. Which of the following alternatives would you prefer?		
Road (A2)	**Combined Transport**	**Piggyback**
Actual cost	5% more than actual cost	5% less than actual cost
Actual time	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 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[4], the Ticino region had 101 medium and 16 large firms corresponding in a employees share of 38% and 23%, respectively. 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[5].

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

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.

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)

$$U_{nj} = \boldsymbol{\beta}'\mathbf{x}_{nj} + \varepsilon_{nj} \qquad (1)$$

where $V_{nj} = \boldsymbol{\beta}'\mathbf{x}_{nj}$ is the systematic part of utility and ε_{nj} is the random term that is Independent and Identically Distributed (IID) extreme value type 1. Following the mixed logit

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[4] Swiss Federal Statistical Office, Neuchâtel.
[5] 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.

class of models we allow for preference heterogeneity by letting the β parameters be randomly distributed (β_n) over the sampled population[6]. 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[7], where the standard deviation is constrained to be equal to the mean[8]. 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 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:

$$\begin{cases} V_{n(\text{PB})} = ASC_{\text{PB}} + \beta_{\text{C}}C_{\text{PB}} + \beta_{\text{T}}T_{\text{PB}} + \beta_{\text{P}}P_{\text{PB}} \\ V_{n(\text{CT})} = ASC_{\text{TC}} + \beta_{\text{C}}C_{\text{CT}} + \beta_{\text{T}}T_{\text{CT}} + \beta_{\text{P}}P_{\text{CT}} \\ V_{n(\text{REF})} = \beta_{\text{C}}C_{\text{REF}} + \beta_{\text{T}}T_{\text{REF}} + \beta_{\text{P}}P_{\text{REF}} + \beta_{n}D + \beta_{n}W + \beta_{n}S \end{cases} \qquad (2)$$

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[9] (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:

$$\begin{cases} V_{n(\text{PB})} = ASC_{\text{PB}} + \beta_{n\text{C(dec)}}C_{\text{(dec)PB}} + \beta_{n\text{C(inc)}}C_{\text{(inc)PB}} + \beta_{n\text{T(dec)}}T_{\text{(dec)PB}} \\ \qquad\quad + \beta_{n\text{T(inc)}}T_{\text{(inc)PB}} + \beta_{n\text{P(dec)}}P_{\text{(dec)PB}} + \beta_{n\text{P(inc)}}P_{\text{(inc)PB}} \\ V_{n(\text{CT})} = ASC_{\text{TC}} + \beta_{n\text{C(dec)}}C_{\text{(dec)CT}} + \beta_{n\text{C(inc)}}C_{\text{(inc)CT}} + \beta_{n\text{T(dec)}}T_{\text{(dec)CT}} \\ \qquad\quad + \beta_{n\text{T(inc)}}T_{\text{(inc)CT}} + \beta_{n\text{P(dec)}}P_{\text{(dec)CT}} + \beta_{n\text{P(inc)}}P_{\text{(inc)CT}} \\ V_{n(\text{REF})} = \beta_{n}D + \beta_{\text{W}}W + \beta_{\text{S}}S \end{cases} \qquad (3)$$

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

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

[7] 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.

[8] 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.

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

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[10]. 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[11]. The utility function for the nonlinear asymmetric preference model can be written as follows:

$$
\begin{cases}
V_{n(PB)} = ASC_{PB} + \beta_{nC(dec)}C_{(dec)PB} + \beta_{nC(inc)}C_{(inc)PB} + \beta_{nT(dec)}T_{(dec)PB} + \beta_{nT(inc)}T_{(inc)PB} \\
\qquad + \beta_{nP(dec--)}P_{(dec--)PB} + \beta_{nP(dec-)}P_{(dec-)PB} + \beta_{nP(inc+)}P_{(inc+)PB} + \beta_{nP(inc++)}P_{(inc++)PB} \\
V_{n(CT)} = ASC_{TC} + \beta_{nC(dec)}C_{(dec)CT} + \beta_{nC(inc)}C_{(inc)CT} + \beta_{nT(dec)}T_{(dec)CT} + \beta_{nT(inc)}T_{(inc)CT} \\
\qquad + \beta_{nP(dec--)}P_{(dec--)CT} + \beta_{nP(dec-)}P_{(dec-)CT} + \beta_{nP(inc+)}P_{(inc+)CT} + \beta_{nP(inc++)}P_{(inc++)CT} \\
V_{n(REF)} = \beta_{nD}D + \beta_{nW}W + \beta_{nS}S
\end{cases}
\qquad (4)
$$

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

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:

$$
P_{nj} = \int_\beta \left(\prod_t \frac{\exp(\beta'_n \mathbf{x}_{nit})}{\sum_j \exp(\beta'_n \mathbf{x}_{nit})} \right) f(\beta)d(\beta)
\qquad (6)
$$

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:

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[10] Preliminary analysis showed a non significant nonlinearity for cost and time attributes. Therefore, they are treated as linear but asymmetric.

[11] 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.

$$LL_n = \sum_n \ln \frac{1}{R} \sum_r \prod_t \frac{\exp(\boldsymbol{\beta}'_n \mathbf{x}_{nit})}{\sum_j \exp(\boldsymbol{\beta}'_n \mathbf{x}_{nit})} \qquad (7)$$

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).

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

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[12]. 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).

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

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[12] The test statistic for $\hat{\beta}_i = -\hat{\beta}_j$ is given by: $\left(\hat{\beta}_i + \hat{\beta}_j\right)\big/ \sqrt{\operatorname{var}\left(\hat{\beta}_i - \hat{\beta}_j\right)}$, where

$\operatorname{var}(\hat{\beta}_i - \hat{\beta}_j) = \operatorname{var}(\hat{\beta}_i) + \operatorname{var}(\hat{\beta}_j) - 2\operatorname{cov}(\hat{\beta}_i, \hat{\beta}_j)$.

well as for the two decrease levels[13]. 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 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 |
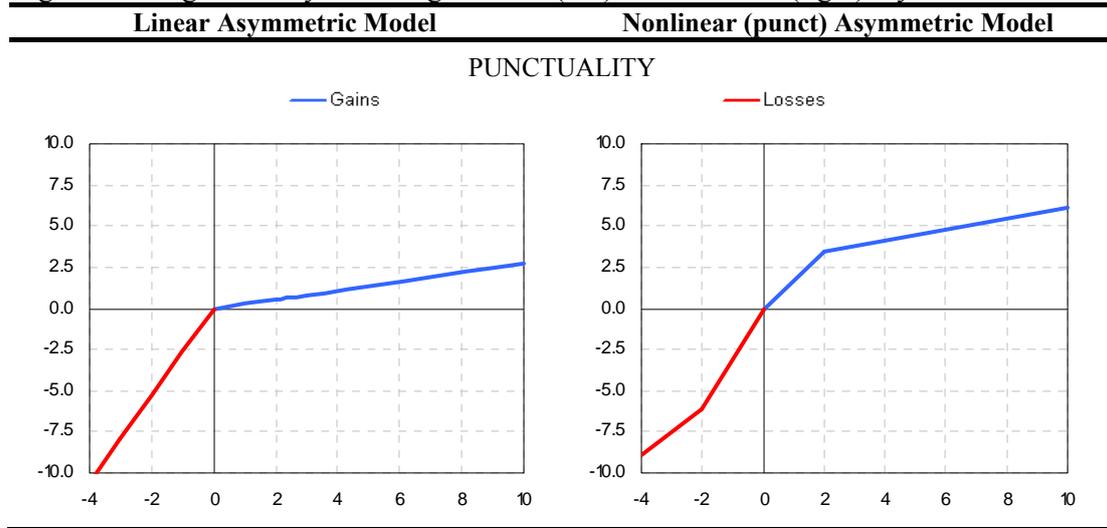
PUNCTUALITY

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[14], respectively, in the losses and gains domain. Finally, a change 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.

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[13] In this case the null hypothesis is $H_0 : \hat{\beta}_i = \hat{\beta}_j$ and the test statistic is:

$$\left(\hat{\beta}_i - \hat{\beta}_j\right)\Big/\sqrt{\operatorname{var}\left(\hat{\beta}_i - \hat{\beta}_j\right)}, \text{ where } \operatorname{var}(\hat{\beta}_i - \hat{\beta}_j) = \operatorname{var}(\hat{\beta}_i) + \operatorname{var}(\hat{\beta}_j) - 2\operatorname{cov}(\hat{\beta}_i, \hat{\beta}_j).$$

[14] 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.

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.

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[15]. 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:

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

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

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).

$$WTP_{(T)} = \hat{\beta}_{t(dec)} \big/ \hat{\beta}_{c(inc)} \qquad (10a)$$
$$WTA_{(T)} = \hat{\beta}_{t(inc)} \big/ \hat{\beta}_{c(dec)} \qquad (10b)$$

$$WTP_{(P)} = \hat{\beta}_{p(inc)} \big/ \hat{\beta}_{c(inc)} \qquad (11a)$$
$$WTA_{(P)} = \hat{\beta}_{p(dec)} \big/ \hat{\beta}_{c(dec)} \qquad (11b)$$

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).

$$WTP_{(P+)} = \hat{\beta}_{p(inc+)} \big/ \hat{\beta}_{c(inc)} \qquad (12a)$$
$$WTA_{(P-)} = \hat{\beta}_{p(dec-)} \big/ \hat{\beta}_{c(dec)} \qquad (12b)$$
$$WTP_{(P++)} = \hat{\beta}_{p(inc++)} \big/ \hat{\beta}_{c(inc)} \qquad (12c)$$
$$WTA_{(P--)} = \hat{\beta}_{p(dec--)} \big/ \hat{\beta}_{c(dec)} \qquad (12d)$$

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

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[16]. 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.

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.
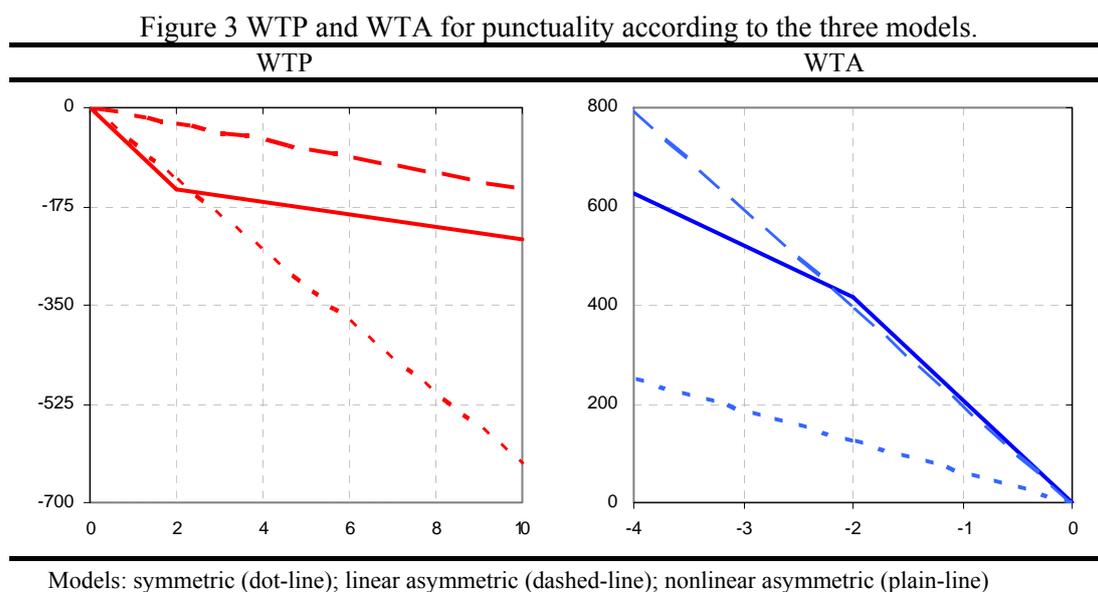
Table 5 WTA/WTP ratio (nonlinear asymmetric model)

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

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

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

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.

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.

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.

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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