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REFERENCING, GAINS-LOSSES ASYMMETRY AND NON-LINEAR SENSITIVITIES IN COMMUTER DECISIONS: ONE SIZE DOES NOT FIT ALL!

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Referencing, gains-losses asymmetry and non-linear sensitivities in commuter decisions: one size does not fit all!

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Abstract

In contrast with expected utility theory, empirical findings indicate that decision-makers are sensitive to departures from reference points rather than states. Several tests of the reference-dependent preference framework have been carried out in experimental economics, and to a smaller extent in a choice modelling setting, to date. However, these empirical applications have generally focussed on a single behavioural phenomenon using uniform modelling approaches. This paper aims to broaden existing work by presenting a multi-attribute framework, allowing contemporarily for gain-loss asymmetry, non-linearity and testing for several possible reference points. The framework is tested in the context of commuter choices and reveals important gains in model fit and further insights into behaviour compared to standard modelling approaches, including substantial impacts on implied welfare measures.

Keywords: Choice modeling, discrete choice experiment, reference effects, non-linearity, gain/loss deviations, commuting
JEL: C25, C9, D03, R49

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1 Introduction

The notion that value or utility is strongly influenced by reference points - and above all departures from reference points as defined in prospect theory - is accepted by researchers in a variety of disciplines. This has given rise to numerous corollaries, including asymmetrical utility drawn from gains and losses, non-linear probability evaluations, asymmetrical decreasing sensitivity and endowment effects to the *status quo* condition (Kahneman and Tversky, 1979, Kahneman et al., 1991). Several recent papers have looked at incorporating reference-dependence in a choice modelling setting (De Borger and Fosgerau, 2008, Hess et al., 2008, Lanz et al., 2010, Senbil and Kitamura, 2004, Delle Site and Filippi, 2011). Results indicate improved model fit along with large impacts for welfare measures when referencing is accounted for. However, extant empirical tests of reference-dependent behaviour have left a series of unresolved questions. In particular there is scarce evidence on how referencing influences different attributes and whether other reference points matter apart from currently experienced levels. What is more, in transportation, reference-dependence is typically tested only for travel time and fare and has rarely been explored in situations with complex trade-offs among multiple attributes, a typical feature of real world choices.

In this paper, we compare evaluations of commuter trips in the context of a stated choice (SC) survey. We start with a linear-in-attributes utility specification, progressively incorporating insights from a reference-dependent approach, namely:

- non-linearity and decreasing sensitivity in responses,
- asymmetries when separating attribute reactions into gains and losses from the reference,
- referencing occurring against other cognitive anchors (apart from current conditions).

To account for this last possibility, gains and losses are modelled against additional plausible reference points, namely *ideal* and *acceptable* travel conditions.

Findings indicate sizeable improvements when these effects are accounted for, in terms of model fit as well as significant shift in willingness-to-pay (WTP) and willingness-to-accept (WTA) measures. What is more, our findings show that the valuation of service improvements differs significantly depending on which reference points is used. This analysis has potentially important policy implications in that analysts, such as policy-makers or transit operators, are typically interested in reactions to changes of current trip variables, not states.

The paper is organised as follows. The second section presents a review of existing work, and discusses reference-dependence in the context of commuter behaviour. The data and survey instrument are described in section 3. Section 4 presents the modelling approach. Results are reported in section 5, while section 6 presents the conclusions.

2 Literature

A range of factors beyond the traditionally dominant idea of taste variations influence choices and explain heterogeneity in choice outcomes. McFadden (1999) classified these ‘other’ factors in four (overlapping) groups: context effects, reference point effects, availability effects and superstition effects.

The idea that reference-dependence shapes individual utility is not new in social science disciplines such as economics and psychology. The underlying idea is that individual preferences are not generated or modified in a vacuum, but are dependent on comparisons against a frame of reference.

Prospect theory (PT) is built around the idea that utility is drawn from changes in endowments, not states (Kahneman and Tversky, 1979). This foundation has solved several systematic empirical violations of expected utility theory. The three fundamental features of the PT value function are: i) reference-dependence where deviations determine value, not states; ii) loss aversion with discrepancy between what agents are willing to accept to give up a choice feature and what they are willing to pay to acquire it, where losses incur a steeper inclination in the value function; iii) diminishing sensitivity whereas marginal values of both gains and losses decrease, or dampen, with higher attribute levels.

The extension of prospect theory from simple one-attribute choices with probabilistic (risky) outcomes to risk-less choice (Tversky and Kahneman, 1991) is essential in the context of the current study. Indeed, alternatives are decomposed into multiple attribute evaluations where each attribute has a distinct value function and reference point.

The literature has identified several types of reference effects and a number of these can be appropriately dealt with in a choice experiment setting. Zhang et al. (2004) set out a general framework where utility is defined by the context in which the choice is made. This includes a) features of the choice set (alternative or attribute-specific), b) the background situation (circumstances surrounding the choice) and finally, c) individual features that influence decision-making, including past choice behaviour (social/individual reference). This approach inserts McFadden’s classification into a framework of relative utility, where task, context and personal factors each influence decision making by providing a frame of reference.

2.1 Existing work on asymmetrical preference formation

Choice modelling typically allows for reference-dependence in two main ways. A first approach focusses on a differential treatment of specific alternatives, in particular reference or *status quo* (SQ) alternatives, either through the simple use of constants (Adamowicz et al., 1998), or by explicitly recognising that attitudes towards current alternatives may be different (cf. Ferrini and Scarpa, 2007). This recognition requires a careful treatment of such alternatives in a modelling context, either using error components or alternative-specific coefficients (cf. Scarpa et al., 2005, Hess and Rose, 2009).

A second modelling approach focusses on attributes, and associates different coefficients with positive and negative deviations from the reference. Examples from a transport setting include De Borger and Fosgerau (2008), Hess et al. (2008), Hess (2008), Masiero and Hensher (2010). These studies illustrate that there are indeed important differences between evaluations of improvements and deteriorations from a respondent's current status. Mounting proof indicates that indifference curves for losses are steeper than for improvements, and this can lead to a gap between WTP and WTA. However, the issue of sensitivity to changes in absolute (not accounting for references) versus relative levels (i.e. considering a specific reference-point) for different types of attributes is still poorly understood.

A last, largely unexplored, area of research concerns the link between referencing and personal and interpersonal behaviour. Schwanen and Ettema (2009) underscore the importance of socially imposed reference points, and deviations from these, rather than transport conditions in the timing of collecting children. Mahmassani et al. (1990) look at departure time adjustments in view of tolerance of late arrival at work. Similarly, attitudes to measures such as road-pricing may be highly influenced by perceived control and opinions of significant others (Schade and Baum, 2007), with the same applying to mode choice (VanVugt et al., 1996).

2.2 Existing work on non-linear sensitivities

In parallel developments, researchers are also increasingly questioning the wisdom of relying on linear-in-attributes utility functions (Tapley, 2008). For instance, enduring evidence indicates there may be effects of damping, particularly for cost, with increasing journey distances (Daly, 2010). A limited number of papers have proposed non-linear models for analysing travel attribute sensitivity. In a freight setting, drawing on Swait (2001), Danielis and Marcucci (2007) model a kink in the utility for several freight service attributes. Separating attribute sensitivity below and above the respondent-defined maximum acceptable values significantly improves models. Masiero and Hensher (2010) frame the non-linearity around respondents' current reference values and extend the analysis to control for piecewise marginally decreasing sensitivity. Similarly, Rotaris et al. (2012) compare a wide set of non-linearities and marginally changing attribute sensitivity in freight service evaluation. Such findings have provided valuable insights regarding non-linearities in behaviour.

2.3 Which reference point?

If we accept the idea that behaviour depends on reference levels, then the predictions generated by models allowing for reference-dependence will depend crucially on what the reference level is assumed to be. Unfortunately, research into which reference points should be employed is much more limited than the research concerning how actors react to shifts from reference-values. While Kőszegi and Rabin (2006) suggest that individual reference points may coincide with expectations of future consumption, the choice of reference point in current empirical work appears to be guided by data availability rather than theoretically solid justifications. Moreover, the point of reference that effectively guides behaviour is likely to change in view of the choice context (Loomes et al., 2009).

In a transport setting, Knetsch (2007) argues that the reference will coincide with the expected or normal state of travel for the majority of respondents. Thus, a first point of complexity is that of variability in the phenomenon. That is, respondents are typically asked to respond to SC experiments, carrying a recent or typical trip in mind, with little empirical grounds for which of these is more likely to be the actual reference for personal decision making. In transportation analysis there has scarcely been any empirical exploration of variations in reference points across respondents, and the majority of published work seems to rely on using current trip conditions as the frame of reference. Along these lines, De Borger and Fosgerau (2008) argue, in the context of a car-commuter survey, that the current trip is the most plausible reference point to assess gains and losses of time and money.

To some extent, the use of the current conditions as a reference point is justified on the basis of the theory of mental Travel Time Budgets (TTB), which can also be extended to a stable mental budget for travel fare expenditure (Gunn, 1981). For instance, in the British context, surveys indicate little change in travel time and proportion of household income allocated to travel over the last 35 years (Metz, 2010). A possible explanation is that of habit-based travel decisions, where commuting may become repeated and non-deliberate over time (Verplanken et al., 1997). On the other hand, Mokhtarian and Chen (2004), drawing on work by Mokhtarian and Salomon (2001) argue that commuters might form an *ideal* (albeit realistic, i.e. non-zero) travel time budget which may not coincide with the actual daily trip duration. In this vein, Páez and Whalen (2010) propose a study of commuter satisfaction where the dependent variable is defined as the ratio of $ideal$ to $actual$ commute time. A notable exception to the use of a sole reference point is Masiero and Hensher (2011) where a current and shifted reference point for cost, time, and punctuality is presented to freight operators. The shifted reference points are however not defined by respondents but formulated by the researchers and presented directly in the choice tasks.

2.4 Gaps in existing work

With only a handful of exceptions, applied work has focused on the use of a common reference point, namely the current travel conditions. Moreover, any asymmetry in gains and losses are assumed to follow the same specification, with identical marginal changes in sensitivity. Additionally, the same treatment in terms of reference-dependence and any non-linearity is typically used for all attributes. Indeed, to date, there has been little overlap between studies looking at reference formation and studies looking at non-linear sensitivities, despite the obvious risk of confounding between the two effects. These shortcomings form the motivation for the present work.

3 Survey development

The study draws on data from a UK stated choice survey on intra-mode commuting choices of train and bus users from 2009. Beyond standard attributes such as travel time and fare, a number of service quality features were introduced, namely availability of seating, frequency of delays, extent of delays and the availability of an information service alerting on delays. The attributes and levels are described in Table 1.

In the context of a study looking at a large number of different attributes, a highly detailed representation of crowding (Hensher et al., 2003) or reliability (see e.g. Bates et al., 2001, Batley et al., 2011) was not applicable, and the final survey specification used the number out of ten typical trips for which the respondent would have to stand, and the frequency out of ten typical trips with delays, along with the average delay encountered across such trips.

A key distinction between the present work and past studies on reference-dependence is the inclusion of both certain attributes (e.g. fare) along with uncertain attributes (frequency of crowding and reliability). This allows us to study whether a probabilistic prospect is treated differently than more predictable and stable features such as average travel time and cost. Furthermore, even for the probabilistic attributes, we can look at the sensitivity to “certain” outcomes, namely situations with perfect occurrence (10 out of 10) and situations with no occurrence. The survey used a D-efficient design with appropriate conditions to avoid dominant alternatives (Rose and Bliemer, 2009). In total, 60 choice scenarios were blocked into 6 different sets of 10 tasks, minimising correlation with the blocking variable. In each task, the survey presented respondents with three trip options, where the first alternative always corresponded to the current respondent-specific conditions. The remaining

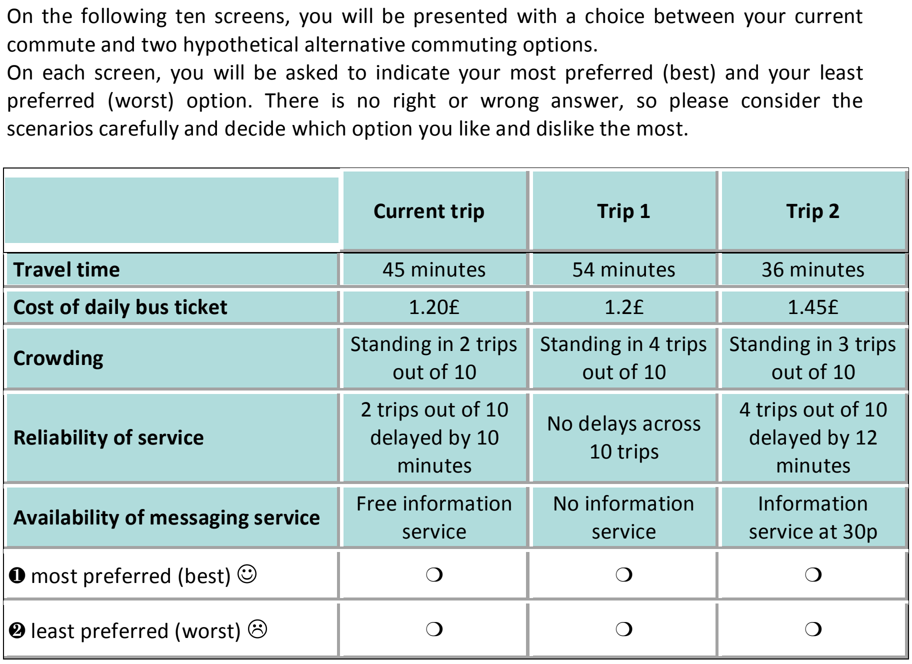
Table 1: Overview of attributes

Attributes	Attribute index	n. of design levels	description of levels (bold=SQ)	Possible attribute values
Travel time (min)	TT	5	-20%, -10%, **+0%**, +10%, +20%	≥ 20
Fare (£)	FA	5	-20%, -10%, **+0%**, +10%, +20%	> 0
Crowding rate (frequency of having to stand out of 10 trips)	CR	5	-2, -1, **+0**, +1, +2	standing in 0/10-10/10 trips
Rate of delay (frequency of delays out of 10 trips)	RA	5	-2, -1, **+0**, +1, +2	delayed for 0/10-10/10 trips
Extent of delay (min)	RB	5	-30%, -15%, **+0%**, +15%, +30%	no restrictions
Information service availability (level,£)	I_NO, I_CH, I_FR	3	no service, charged service, free service	charged service: 15p for bus users, 30p for train users

options were pivoted around the SQ alternative. Respondents were asked to indicate the best and worst alternative, where only the response in terms of the best alternative was used in the current analysis. An example choice screen is shown in Figure 1.

Given our interest in analysing gains and losses from different cognitive anchor points, data on two additional mental reference points (beyond the standard current trip situation) were collected, namely an *acceptable* and an *ideal* level for each trip attribute. To ensure realistic reference points, respondents were explicitly instructed to consider technical constraints and the high usage rate of the transit network. Results for these reference points for travel time and fare are described in Table 2, which show that, in line with expectations, most ideal and acceptable points were lower than current values, but rarely equal to zero. The overall ordering of reference points is also in line with expectations.

The data was collected through an internet panel yielding 400 respondents where 368 were used in the analysis. Data on a series of socio-demographic attributes were gathered, with the main respondent characteristics being summarised in Table 3. The aim was not to obtain a representative sample, but instead to collect data from respondents who currently commute either by rail or bus, thus ensuring that they could relate to the experiment.



On the following ten screens, you will be presented with a choice between your current commute and two hypothetical alternative commuting options.
On each screen, you will be asked to indicate your most preferred (best) and your least preferred (worst) option. There is no right or wrong answer, so please consider the scenarios carefully and decide which option you like and dislike the most.

	Current trip	**Trip 1**	**Trip 2**
Travel time	45 minutes	54 minutes	36 minutes
Cost of daily bus ticket	1.20£	1.2£	1.45£
Crowding	Standing in 2 trips out of 10	Standing in 4 trips out of 10	Standing in 3 trips out of 10
Reliability of service	2 trips out of 10 delayed by 10 minutes	No delays across 10 trips	4 trips out of 10 delayed by 12 minutes
Availability of messaging service	Free information service	No information service	Information service at 30p
❶ most preferred (best) ☺	○	○	○
❷ least preferred (worst) ☹	○	○	○

Figure 1: Example choice task

4 Model specification

The data were analysed within the random utility framework (McFadden, 1974) which assumes that, in choice task t (with $t = 1, \ldots, T$), individual n chooses the alternative j that maximises his/her utility, where the utility for j is given by $U_{j,n,t}$, which is composed of a deterministic component $V_{j,n,t}$ and a stochastic component $\varepsilon_{j,n,t}$. The deterministic component is given by interactions between measured attributes and estimated sensitivities, where, in our case, the point of departure is a base specification hypothesising linear, reference-free attribute sensitivities, with no differential treatment across alternatives. We thus have that:

$$\begin{aligned}
V_{\mathrm{j,n,t}} = {} & \beta_{tt}\mathrm{TT}_{j,n,t} \\
& + \beta_{fa}\mathrm{FA}_{j,n,t} \\
& + \beta_{cr}\mathrm{CR}_{j,n,t} \\
& + \beta_{ra}\mathrm{RA}_{j,n,t} \\
& + \beta_{rb}\mathrm{RB}_{j,n,t} \\
& + \beta_{inf-ch}\mathrm{I}-\mathrm{CH}_{j,n,t} \\
& + \beta_{inf-fr}\mathrm{I}-\mathrm{FR}_{j,n,t} \\
& + (-\beta_{inf-ch} - \beta_{\mathrm{inf}-fr})\,\mathrm{I}-\mathrm{NO}_{j,n,t}
\end{aligned} \tag{1}$$

Table 2: Respondent reported current, acceptable and ideal travel time and fare

Travel time	Current	Acceptable	Ideal	$\Delta curr-acc$	$\Delta curr-ide$	$\Delta acc-ide$
mean	45.79	40.30	35.61	5.49	10.18	4.69
median	40	35	30	5	10	5
st.dev	26.72	23.39	21.94			
% current=acceptable	32%					
% current=ideal	21%					
% acceptable=ideal	31%					
Fare	**Current**	**Acceptable**	**Ideal**	$\Delta curr-acc$	$\Delta curr-ide$	$\Delta acc-ide$
mean	2.86	2.25	2.03	0.60	0.83	0.23
median	1.75	1.48	1.25	0.27	0.50	0.23
st.dev	3.80	3.42	3.19			
% current=acceptable	17%					
% current=ideal	10%					
% acceptable=ideal	34%					

Note: The fare medians are fractions due to the transformation of the stated fare into daily values

Each attribute is linear while the information service attribute is effects-coded to represent the availability of a free (I-FR) and charged service (I-CH), compared to the omitted baseline situation where the service is not available (final line in Equation 1).

We will now discuss the various departures from this base specification, looking in turn at non-linearity and asymmetric gains-losses sensitivity.

4.1 Modelling non-linearity

4.1.1 Continuous variables

Non-linearity is modelled in two different ways depending on the nature of the attribute. For the continuous travel time and cost attributes, a non-linear transformation was used. The point of departure was a Box-Cox transformation (Mandel et al., 1994), where e.g. for travel time, we have:

$$TT^{\lambda}_{j,n,t} = \begin{cases} \frac{(\mathrm{TT}^{\lambda}_{j,n,t}-1)}{\lambda} \text{if } \lambda \neq 0 \\ ln(TT)_{j,n,t} \text{if } \lambda = 0 \end{cases} \tag{2}$$

These transformations were used as a ’diagnostic tool’ and drawing on the results the

Table 3: Descriptive statistics for the sample

Attributes	Definition	Mean	St.dev	% rates
Age (years)	Average of mean age within 7 age bands	34.61	10.95	
Income (£)	Average of mean annual income within 9 income bands	25,136	16,143	
Sex	0=male, 1=female	0.61	0.49	
Education reached	1=mandatory school, 2=high school, 3=university	1.81	0.75	40 % university
Information service	0=not available, 1=available at charge, 2=available for free	0.79	0.95	36% free info. service
Car availability	1=no car availability, 2=car availability	1.51	0.50	51% has car
Current tt (min)	Average stated travel time	45.79	26.72	
Current fare (£)	Average stated daily fare	2.86	3.80	
Current delay (freq)	Average stated number of delays in 10 trips	3.41	2.53	
Current delay (min)	Average stated delay across delayed trips	10.07	9.25	
Current crowding (freq)	Average stated number of times having to stand in 10 trips	3.33	3.07	

attributes were included in the model linearly (e.g $\lambda = 1$) or as a log-transform in cases where λ was not significantly different from 0.

4.1.2 Discrete variables

For the crowding and reliability attributes, eleven possible distinct values arise (0-10). The full extent of non-linearity could be captured by estimating level specific coefficients, however, estimating 10 distinct coefficients (one being normalised) for each possible attribute value is uninformative and has limited utility for policy analysis. Rather, a segmented modelling approach was used so that the non-linearity was modelled by fitting separate coefficients to the segments of the attribute levels, i.e. making use of a piece-wise linear approach. To ensure comparability with the simple linear specification, the piece-wise specification was normalised by centering the estimate on a reference value. In particular, we make use of M different segments, characterised by $M + 1$ different boundary points. Using crowding as the example, we estimate the value of the start and end points, i.e. β_{cr-0} and β_{cr-10}, meaning that $k_1 = 0$, and $k_{M+1} = 10$. This leaves $M - 1$ additional coefficients, namely k_2 to k_M, where, for normalisation, we set $\beta_{cr-l} = 0$, for one value of l, with $2 \leq l \leq M$. The contribution made by the crowding attribute to the utility of alternative j

can then be written as:

$$
\begin{aligned}
V_{j,n,t,cr} = & \sum_{m=1}^{M+1} \beta_{cr-m} \mathrm{I}(\mathrm{CR_{j,n,t}} = \mathrm{m}) \\
& + \sum_{m=1}^{M} \mathrm{I}(\mathrm{k_m} < \mathrm{CR_{j,n,t}} < \mathrm{k_{m+1}}) \left(\beta_{cr-k_m} + \left(\beta_{cr-k_{m+1}} - \beta_{cr-k} \right) \frac{CR_{j,n,t} - k_m}{k_{m+1} - k_m} \right)
\end{aligned} \tag{3}
$$

The results of this process are that at the specific break points identified by k_1 to k_{M+1}, the actual estimates for β_{cr-k_1} to $\beta_{cr-k_{M+1}}$ will be used, while interpolated values will be used in-between. It is important to note that the multiplication by the observed levels ensures that the function is piece-wise linear in the β parameters but continuous in utility, avoiding issues in estimation and willingness-to-pay computation.

4.2 Modelling gains and losses asymmetry jointly with decreasing sensitivity

For modelling asymmetry, we estimate separate coefficients for gains and losses (see e.g. Hess et al., 2008). We also propose a careful and very flexible treatment of non-linearity. In particular, and in line with insights from reference-dependent preference formation, we incorporate a control for two different departures from linearity. The proposed formulation controls for the presence of changing marginal sensitivity as the shift away from the reference point increases, while also evaluating the impact of the specific point of departure of a given respondent on overall sensitivity. Defining $V_{j,n,t,fare}$ to be the contribution made by the fare attribute to the utility of alternative j, and using FA_{ref} as the reference point, we would have:

$$
\begin{aligned}
V_{j,n,t,fare} = & \left(fa_{\mathrm{n}} \,/ \overline{fa} \right)^{\lambda} \cdot \beta_{fa(inc.ref)} I \left(FA_{j,n,t} > FA_{ref} \right) \left(FA_{j,n,t} - FA_{ref} \right)^{\gamma-inc.ref} \\
& + \left(fa_{\mathrm{n}} \,/ \overline{fa} \right)^{\lambda} \cdot \beta_{fa(dec.ref)} I \left(FA_{j,n,t} < FA_{ref} \right) \left(FA_{ref} - FA_{j,n,t} \right)^{\gamma-dec.ref}
\end{aligned} \tag{4}
$$

with fa_{n} delineating the respondent-specific current value for fare and $\overline{fa}$ giving the average across the whole sample. Thus the estimated λ indicates the impact of the currently experienced fare-level on the sensitivity to changes of the $status\ quo$. Here $\lambda = 0$ indicates a neutral effect where the current level has no impact on the sensitivities to shifts. Instead, estimates of $\lambda > 0$ means that as the base level increases, respondents become more sensitive to changes. Our prior is instead that $\lambda < 0$, indicating that at a higher base-level people will be less sensitive to a marginal shift in fare. Such findings may have large implications for the analysis of transport policy that gradually shift the reference value of respondents. The more negative the λ, the more pronounced is the reduction in sensitivity to variations.

Next, $\beta_{fa(inc.ref)}$ is the coefficient associated with increases compared to the reference point FA_{ref}, while $\beta_{fa(dec.ref)}$ is the coefficient associated with decreases. Each time, the multiplication by the indicator function ensures that the correct coefficient is used, while, at the reference point, we have that $V_{j,n,t,fare} = 0$. Loss aversion occurs if $-\beta_{fa(inc.ref)} > \beta_{fa(dec.ref)}$.

The parameter γ amounts to an exponential transformation to measure decreasing sensitivity for shifts further away from the reference. Similarly to a Box-Cox transformation $\gamma = 1$ indicates a linear sensitivity, while $0 < \gamma < 1$ measures sensitivities going from strong damping (e.g the natural log-transform) to more linear sensitivities. Finally, $\gamma > 1$ implies the inverse situation of higher marginal sensitivity for values further from the $status\ quo$. In addition we account for the possibility that the shape of marginal sensitivity may be different for gains and losses by estimating separate γ coefficients for increases and decreases. Although prospect-theory predicts that both directions of shifts are subject to uniform decreasing sensitivity, we hypothesise that losses have a much less pronounced damping than improvements.

Finally we look at specifications with two further reference points, namely the $current$ and $ideal$ values. Particularly, this implies substituting FA_{ref} for these additional reference-points. Here, it can be seen that when using the *current* value as the reference point, the contribution by the concerned attribute to the base alternative is zero. This is no longer necessarily the case with these additional reference points, as the current value is typically different from declared $current$ and $ideal$ values.

5 Empirical results

A number of different models were estimated, progressively incorporating controls for status-quo bias, discrete and continuous non-linear impacts of attribute levels, and asymmetric utility drawn from gains and losses. Initial attempts to incorporate the impact of socio-demographic characteristics showed only marginal improvements in fit, and a generic (across respondents) specification was thus used throughout. A list of the models is given below.

Model 1: linear reference-free model

Model 2: like 1, with natural log for fare attribute

Model 3: like 2, with inclusion of alternative specific constants

Model 4: like 3, with expected delay interaction

Model 5: like 4, with reference-dependence for information attribute

Model 6: like 5, with non-linear specification for crowding and reliability

Model 7: like 6, with gain-loss asymmetry for fare from current trip

Model 8: like 6, with gain-loss asymmetry for fare from *acceptable* trip

Model 9: like 6, with gain-loss asymmetry for fare from *ideal* trip

All models were estimated using Biogeme (Bierlaire, 2003). The reported t-statistics are based on estimated robust asymptotic standard errors, where, to account for the repeated choice nature of the data, the panel specification of the sandwich estimator was used (Daly and Hess, 2011).

In line with the objective of accommodating multi-attribute dynamics, each trip characteristic was tested against the different modelling approaches. The finding was that of piece-wise non-linearity for the frequency attributes, crowding and reliability, and continuous non-linearity for fare. Instead, evidence of reference-dependence was found only for fare and the information service. All other modelling explorations drop back to a linear and symmetrical effect.

5.1 Base models

The results for the first four models are summarised in Table 4. We see negative sensitivity towards increases in crowding, both reliability measures, fare, and travel time. We also note that a free delay information service is preferred to the base situation (i.e. no service), while a charged service is seen as less desirable than no service. After tests using the Box-Cox transform, model 2 makes use of log transform for the fare attribute, with the associated coefficient labelled β_{ln-fa}. This is in line with the literature on cost damping, i.e. decreasing marginal (dis)utility with higher levels of the attribute (see e.g. Daly, 2010). No evidence of significant decreasing marginal returns was found for the time attribute. Model 2 is not a direct generalisation of model 1, and a likelihood-ratio (LR) test can thus not be used. However, the evidence from the adjusted ρ^2 statistics points towards a clear improvement in model fit. Model 3 sees the inclusion of two alternative specific constants. The first (δ_1) is a SQ constant, while the second (δ_2) is associated with the middle alternative, with a view to capturing left-to-right reading effects. Beyond the highly significant improvement in log-likelihood over model 2 by 30.48 units in return for two additional parameters, an

Table 4: Estimation results for models 1-4

	Model 1		Model 2		Model 3		Model 4	
Parameters	est.	t-rat.	est.	t-rat.	est.	t-rat.	est.	t-rat.
δ_1	-	-	-	-	0.384	5.76	0.390	5.85
δ_2	-	-	-	-	0.161	3.26	0.163	3.30
β_{cr}	-0.175	-7.58	-0.229	-9.18	-0.220	-8.51	-0.223	-8.58
β_{ra}	-0.177	-7.88	-0.238	-10.25	-0.241	-9.82	-0.187	-5.96
β_{rb}	-0.033	-4.72	-0.040	-5.30	-0.042	-5.35	-0.029	-3.25
$\beta_{exp.delay}$	-	-	-	-	-	-	-0.062	-2.64
β_{inf-fr}	0.179	4.24	0.267	6.39	0.252	6.05	0.251	6.01
β_{inf-ch}	-0.101	-2.04	-0.272	-5.56	-0.168	-3.42	-0.171	-3.47
β_{fa}	-0.979	-4.39	-	-	-	-	-	-
β_{ln-fa}	-	-	-5.600	-18.94	-5.970	-18.89	-6.000	-18.87
β_{tt}	-0.036	-7.67	-0.044	-9.42	-0.047	-9.47	-0.047	-9.50
obs.	3,680		3,680		3,680		3,680	
par.	7		7		9		10	
LL(est.)	-3,711.36		-3,397.43		-3,366.95		-3,360.43	
ρ^2	0.082		0.160		0.167		0.169	
adj. ρ^2	0.080		0.158		0.165		0.166	

important finding is the stabilising effect on the remaining coefficients. In fact, the coefficients for time and log-cost remain remarkably stable across more advanced specifications. In terms of the actual estimates, we note a positive value for both coefficients, which is larger for alternative 1, thus indicating inertia, alongside left-to-right reading effects.

The first three models estimated separate parameters for the rate of delays (RA) and the average extent of delays across affected trips (RB). The fourth model additionally incorporates an interaction between these two variables, equating to the expected delay. This leads to significant improvements over model 3, with a gain in log-likelihood by 6.52 units at the cost of just one additional parameter, giving a LR test value of 13.04, with the 99% critical χ_1^2 value of 6.63. The new coefficient has the expected negative sign, and its inclusion has dampened the estimates for the two single effect coefficients. Here, it should be noted that, given the nature of the data, one delay of 40 minutes is modelled in the same way as four delays of 10 minutes.

5.2 Models incorporating non-linearity and asymmetry

In this section, we now discuss the more advanced specifications that gradually incorporate additional non-linearities and asymmetries in the sensitivity to gains and losses. The results

Table 5: Estimation results for models 5&6

	Model 5		Model 6	
Parameters	est.	t-rat.	est.	t-rat.
δ_1	0.397	5.42	0.360	4.97
δ_2	0.160	3.24	0.163	3.30
β_{cr}	-0.226	–8.66	-	-
β_{ra}	-0.187	-5.94	-	-
β_{rb}	-0.029	-3.21	-0.017	-1.59
$\beta_{exp.delay}$	-0.062	-2.64	-0.081	-2.98
β_{ln-fa}	-6.010	-18.93	-6.020	-18.83
β_{tt}	-0.047	-9.54	-0.047	-9.47
β_{cr-0}	-	-	1.250	7.13
β_{cr-1}	-	-	0.641	3.73
β_{cr-5}	-	-	0	-
β_{cr-9}	-	-	-0.692	-3.77
β_{cr-10}	-	-	-0.885	-4.18
β_{ra-0}	-	-	0.553	4.13
β_{ra-2}	-	-	0	-
β_{ra-9}	-	-	-0.901	-3.16
β_{ra-10}	-	-	-1.450	-4.00
$\beta_{inf-fr,free}$	0.255	3.74	0.267	3.97
$\beta_{inf-ch,free}$	-0.293	-3.92	-0.308	-4.13
$\beta_{inf-fr,other}$	0.226	3.91	0.229	3.92
$\beta_{inf-ch,other}$	-0.116	-1.89	-0.112	-1.84
obs.	3,680		3,680	
par.	12		17	
LL(est.)	-3357.76		-3336.93	
ρ^2	0.169		0.175	
adj. ρ^2	0.166		0.170	

for these five additional models are summarised in Table 5 and Table 6.

5.2.1 Referencing information service

As a first step (model 5), we focus on the information service attribute, looking at differences in sensitivity depending on whether respondents currently have a free service available or not, where no significant differences were found between respondents with no service and a charged service.

By comparing the preferences of the groups that currently have a free information service available ($\beta_{inf-fr,free}$ and $\beta_{inf-ch,free}$) to those that either had a charged service or no such service ($\beta_{inf-fr,other}$ and $\beta_{inf-ch,other}$), it is possible to assess the impact of current experience on utility for different service options (free, charged, not available). The resulting model obtains an improvement in log-likelihood by 2.67 units over model 4, which, at the cost of 2 additional parameters, is significant at the 93% level. The most important observation is that although the positive evaluation of obtaining the service for free is very similar between the two groups, the disutility of having to pay for it is much higher for individuals who currently get the service for free. This is in line with aversion to pricing of a freely enjoyed consumption good, for instance pricing of 'free' urban roads. On the other hand, for the other group, the implied benefit of a free service is slightly smaller, while no service is still just about preferred to a charged service ($-\beta_{inf-fr,other} - \beta_{inf-ch,other} = -0.110$).

5.2.2 Crowding and rate of delays

Our next step in model 6 is to look for non-linearities in the response to the rate of crowding and the rate of delays, making use of the specification described in section 4.1. The model gives us an improvement in log-likelihood by 20.83 units over model 5, at the cost of 5 additional parameters, which is highly significant, as is the improvement over models incorporating the non-linearity in either one of the two coefficients (not reported here).

The actual specification used for the non-linearity differs between the two coefficients, where the specification was informed by a detailed separate analysis. For crowding, we found that splitting the interval into four distinct segments was appropriate, with estimates for the end points, and breaks at the second highest and second lowest levels as well as a level of 5 trains out of ten (set to a base of 0). A different picture is revealed for the rate of delay attribute, where we find evidence of only three distinct segments. The base is set at a level of two out of ten trains, where the value is normalised to zero, with linear interpolation from the level at perfect reliability, i.e. β_{ra-0}. A further breakpoint is identified at the second highest level (i.e. 9 trains out 10). These results are detailed in Table 5

Results are illustrated in Figure 2 which compares the implied sensitivities to the estimates obtained with the simple linear specification from model 5. To overcome potential scale differences between models, WTP and WTA measures are used for the presentation. Moreover, to facilitate comparison, the linear estimate is shifted to coincide with 0 at the same point as the piece-wise approach, using the same baseline of $4/10$ where surrounding values are gains (WTP) and losses (WTA). For crowding, the most notable change in slope is the sharp drop when moving from no crowding to a 10% risk of crowding, while, for reliability, the biggest change is between nine trains being affected and all trains being affected. We notice that the linear specification overstates the response to crowding for higher levels while strongly underestimating the lowest level (i.e. no crowding). Indeed, it is this lack of consideration for the significant positive impact of the condition of never having to stand (CR-0) that unduly affects the estimated slope in the linear specification. This finding replicates the certainty effect where people display preferences for absolutes, and dislike for loss of certainty (Kahneman and Tversky, 1979). For reliability, the linear specification is similarly unduly affected by the high negative utility for the highest rate of delays, leading to an underestimation of the benefits of very low delay rates, while the models are similar in estimating the impact of delays between four and nine out of ten. Both findings highlight the large impact of the extremes of the outcome distribution compared to a linear specification.

As an aside, a further difference arises between model 5 and model 6. Indeed, for respondents who currently have no delay information service or only a charged delay information service, the utility of having no service is now slightly lower than that of having a charged service.

5.3 Asymmetrical response to increases and reductions in continuous attributes

As a final step, we control for asymmetry and increasing/decreasing marginal returns. Asymmetrical response to gains and losses was only observed for the fare attribute (in addition to the earlier asymmetry for the delay information service).

The results of this process are summarised in Table 6, where we apply the formulation set out in eq. 4, additionally controlling for the use of three different respondent-reported reference points (current, acceptable and ideal). Before proceeding with a discussion of the results, it should be acknowledged that the use of respondent reported reference points could potentially lead to endogeneity bias, an issue that deserves further attention beyond this exploratory research.

Starting with model 7, which uses the current fare as the reference point, we observe a LR statistic of 38.36, which, at the cost of 4 additional parameters over model 6, is significant above the 99% level of confidence. The difference in sensitivity between gains and losses $\beta_{fa.inc}$ and $\beta_{fa.dec}$ is not statistically significant (t-ratio=0.78). We note that γ_{inc} and γ_{dec} are significantly different from unity, indicating decreasing sensitivity, although there is no statistically significant difference between gains and losses in the degree of non-linearity. Finally, λ is moderately negative suggesting that for higher base fares the impact of changes decreases. The marginal utility for the specification from the point of view of a respondent with three different base fare levels (2£, 6£, 10£) is illustrated in Figure 3. In the top left figure we can observe that when using current fare as the reference the behaviour in the gains and losses domains is largely symmetrical, with decreasing sensitivity as shifts become larger, and also for higher base fares.

When using the respondent-reported *acceptable* value as the reference point (model 8), we observe an equally large improvement over model 6 as with the *current* value. Here, however, the degree of asymmetry is highly significant ($\left|\frac{\beta_{fa,inc}}{\beta_{fa,dec}}\right| = 2.10$) with a t-ratio

Table 6: Referencing models with asymmetric fare formulations

	Model 7		Model 8		Model 9	
Parameters	est.	t-rat.	est.	t-rat.	est.	t-rat.
δ_1	0.357	4.10	0.267	3.61	0.255	3.45
δ_2	0.176	3.48	0.169	3.39	0.170	3.42
β_{rb}	-0.016	-1.44	-0.014	-1.31	-0.014	-1.25
$\beta_{exp.delay}$	-0.079	-2.92	-0.080	-2.99	-0.080	-3.02
$\beta_{fa.dec}$	1.520	9.40	1.150	4.17	0.471	1.41
$\beta_{fa.inc}$	-1.340	-6.35	-2.420	-14.90	-2.100	-13.19
λ	-0.356	-3.46	-0.978	-11.12	-1.210	-11.78
γ_{dec}	0.375	-6.77†	0.841	-1.06†	0.664	-1.07†
γ_{inc}	0.403	-4.98†	1.000	0.00†	1.210	2.53†
β_{tt}	-0.050	-9.69	-0.049	-9.66	-0.049	-9.67
β_{cr-0}	1.490	8.08	1.250	7.00	1.270	7.09
β_{cr-1}	0.844	4.79	0.640	3.68	0.659	3.76
β_{cr-9}	-0.899	-4.86	-0.710	-3.86	-0.688	-3.78
β_{cr-10}	-1.120	-5.13	-0.900	-4.15	-0.887	-4.14
β_{ra-0}	0.636	4.71	0.567	4.22	0.570	4.25
β_{ra-9}	-1.230	-4.24	-0.891	-3.13	-0.882	-3.09
β_{ra-10}	-1.800	-4.95	-1.460	-3.98	-1.440	-3.91
$\beta_{inf-fr.free}$	0.281	4.17	0.262	3.94	0.262	3.91
$\beta_{inf-ch.free}$	-0.310	-4.09	-0.292	-3.92	-0.291	-3.85
$\beta_{inf-fr.other}$	0.256	4.37	0.235	4.01	0.237	4.03
$\beta_{inf-ch.other}$	-0.132	-2.16	-0.110	-1.83	-0.115	-1.91
obs.	3.680		3,680		3,680	
par.	21		21		21	
LL(est.)	-3,317.751		-3,317.219		-3,301.399	
ρ^2	0.179		0.179		0.183	
adj. ρ^2	0.174		0.174		0.178	
Asymmetry $\beta_{fa.dec}$ vs. $\beta_{fa.inc}$	0.88		2.10		4.46	
t-rat for $\beta_{fa.dec}$ vs. $\beta_{fa.inc}$	0.78		5.52		6.16	

† t-ratio refers to rejecting the null of the coefficient being equal to unity (linearity) of 5.52) showing that respondents view losses as more painful than equivalent gains. In addition, there is significantly less damping in either direction, with $\gamma_{inc} = 1$ implying linear sensitivity for losses and damping for gains $\gamma_{dec} = 0.84$ not significantly different from unity. As can also be observed from the top right graph in Figure 3, this gives a totally different description of behaviour where large losses, for instance an increase from a base of $£6$ to $£8$ giving twice the discomfort in the $acceptable$ compared to the $current$ model. The cost damping as a function of increases in the base (λ) is more marked in this model.

Finally, using the respondent-reported *ideal* value as the reference point (model 9) leads to the best fit of the three models, with an improvement in log-likelihood over model 6 by 71.06 units, retrieving the largest ($\left|\frac{\beta_{fa,inc}}{\beta_{fa,dec}}\right| = 4.46$) and most significant ($t$-ratio of 6.16) degree of asymmetry. Notably, the difference in slope is matched by strong dissimilarities in the non-linearity. Indeed while gains undergo significant damping for larger shifts, the situation for losses is the opposite. As can be seen in the bottom graph of figure 3, for more distant increases in fare, sensitivity actually increases. This significant effect suggests that there is no habituation with losses. The cost damping as a function of the base (λ) is the most pronounced in this model. The remaining parameter estimates remain largely unaffected across the three specifications.

Using the *acceptable* and especially the *ideal* fares as the reference point not only leads to better model performance than with the commonly used *current* fare, but also indicates a higher degree of reported asymmetry. It is also worth noting that as the degree of asymmetry increases, the significance of $\beta_{fa,dec}$ reduces while that of $\beta_{fa,inc}$ increases. This is in part a result of the average *acceptable* fare being lower than the average *current* fare, while the average *ideal* fare is lower still. This means that with a change in the reference point, fewer gains (i.e. reductions in fare) will occur, with the opposite applying for losses (i.e. increases in fare).

The findings open a debate on the potential lack of symmetry in evaluations of travel costs. Redmond and Mokhtarian (2001) note, for the case of travel time, that similarity between $actual$ and $ideal$ travel time implies satisfaction with the commute experience whereas deviations in either direction represent dissatisfaction. However, the authors do not offer a detailed analysis of the asymmetry between the experience of such deviations. Instead, our analysis offers evidence that discrepancies between ideal, acceptable and current fare levels, does generate asymmetric effects on utility. As a general finding, falling short of ideal values is much more painful than it is favourable to obtain performances in excess of the ideal state. Importantly, the specification here offers a flexible view of the different functional form that gains and losses may display, depending on the reference-point used and the individual point of departure.

5.4 Implications for monetary valuations

The results in terms of implied willingness-to-pay (WTP) and willingness-to-accept (WTA) measures are reported in Table 7. Owing to the different specification of the fare coefficient across models we use three different methods to obtain monetary valuations. While model 1 uses the estimated fare coefficient as the denominator, in models $2-6$, a log-transform on the fare attribute is used, making WTP a function of the fare level. Here, the values presented are at the sample mean fare of $\pounds 2.72$. In models $7-9$, the WTP and WTA formulae become more complex still, given the nature of the partial derivative against the cost attribute of the full function described in Equation 4. Consistent with the presence of both marginal decreasing sensitivity and differences in the base as illustrated in figure 3 the actual WTP/WTA can be computed for each base and shift of each respondent. Consequently, to obtain the WTP, for each sample observation we utilise all the cases where a fare above the reference value is chosen, and take the average of the resulting WTP measures across these observations. Similarly, standard errors need to be calculated separately for each observation. A similar procedure is used to obtain WTA measures, for cases where respondents choose a fare below the reference.

Starting with the valuation of travel time, we have symmetrical WTP and WTA measures for models 1 to 6. This implies that the amount of money respondents are willing to pay to save one hour of travel time is the same as the amount of money they would require to accept an increase in travel time by one hour. In models 8 and 9, the WTA measure is higher than the WTP measure as a result of the asymmetry in the fare coefficient, with a greater sensitivity to increases than decreases. As previously discussed, the level of asymmetry is higher with the *acceptable* and especially *ideal* reference points. The other main observation for the valuation of travel time is the drop in values when moving away from the linear specification in model 1. The values obtained with the log-transform on fare are lower, but the model fit is significantly better, and standard errors are also lower. The other interesting observation is the stability of the WTP/WTA measure in models $2-6$. The estimated WTP/WTA measures may appear low in comparison with the official UK values of $\pounds 5.04/hr$ (cf. DfT, 2009), but need to be put in the context of the low average fares in the present data.

Turning next to crowding, the results are presented from the point of view of a respondent who currently experiences crowding on 4 out of 10 journeys. The impact of the log-cost specification is once again clear to see and requires no further discussion. In the first five models, a linear specification is used, leading to symmetrical response to increases and decreases from the starting point of 4 out of 10 journeys. The robust t-ratios are clearly also the same for each of the measures. The situation changes in model 6, where the higher sensitivity to the lower levels leads to higher WTP than WTA measures, especially for the

Table 7: Willingness-to-pay and willingness-to-accept measures

	Model 1		**Model 2**		**Model 3**		**Model 4**		**Model 5**		**Model 6**		**Model 7**		**Model 8**		**Model 9**	
Travel time	est.	t-rat.	est.	t-rat.	est.	t-rat.	est.	t-rat.	est.	t-rat.	est.	t-rat.	est.	t-rat.	est.	t-rat.	est.	t-rat.
WTP ($\pounds/hr$)	2.18	3.75	1.27	9.37	1.28	9.09	1.28	9.6	1.28	9.61	1.28	9.53	3.19	8.43	1.26	2.40	1.34	1.38
WTA ($\pounds/hr$)													3.10	7.52	2.47	1.85	9.94	4.14
Crowding (assume current level 4/10)	est.	t-rat.	est.	t-rat.	est.	t-rat.	est.	t-rat.	est.	t-rat.	est.	t-rat.	est.	t-rat.	est.	t-rat.	est.	t-rat.
WTP for reduction to 0/10 (£)	0.72	4.28	0.44	8.80	0.40	8.15	0.40	8.40	0.41	8.47	0.56	6.95	1.60	4.21	0.54	2.36	0.58	1.40
WTP for reduction to 1/10 (£)	0.54		0.33		0.30		0.30		0.31		0.29	3.70	0.91	3.20	0.28	1.85	0.30	1.36
WTP for reduction to 2/10 (£)	0.36		0.22		0.20		0.20		0.20		0.19	3.70	0.60	3.20	0.18	1.85	0.20	1.36
WTP for reduction to 3/10 (£)	0.18		0.11		0.10		0.10		0.10		0.10	3.70	0.30	3.20	0.09	1.85	0.10	1.36
WTA increase to 5/10 (£)	0.18	4.28	0.11	8.80	0.10	8.15	0.10	8.40	0.10	8.47	0.06	3.67	0.19	5.01	0.12	1.79	0.47	4.12
WTA increase to 6/10 (£)	0.36		0.22		0.20		0.20		0.20		0.13	3.67	0.37	5.01	0.24	1.79	0.93	4.12
WTA increase to 7/10 (£)	0.54		0.33		0.30		0.30		0.31		0.19	3.67	0.56	5.01	0.36	1.79	1.40	4.12
WTA increase to 8/10 (£)	0.72		0.44		0.40		0.40		0.41		0.25	3.67	0.75	5.01	0.48	1.79	1.87	4.12
WTA increase to 9/10 (£)	0.89		0.56		0.50		0.51		0.51		0.31	3.67	0.94	5.01	0.60	1.79	2.34	4.12
WTA increase to 10/10 (£)	1.07		0.67		0.60		0.61		0.61		0.40	4.21	1.17	5.56	0.76	1.81	3.01	4.13
Rate of delays (assume current level 4/10)	est.	t-rat.	est.	t-rat.	est.	t-rat.	est.	t-rat.	est.	t-rat.	est.	t-rat.	est.	t-rat.	est.	t-rat.	est.	t-rat.
WTP for reduction to 0/10 (£)	0.72	4.34	0.46	9.26	0.44	9.37	0.34	5.68	0.34	5.66	0.25	4.01	0.68	2.94	0.61	4.71	0.61	3.07
WTP for reduction to 1/10 (£)	0.54		0.35		0.33		0.25		0.25		0.19	4.01	0.51	2.94	0.46	4.71	0.46	3.07
WTP for reduction to 2/10 (£)	0.36		0.23		0.22		0.17		0.17		0.12	4.01	0.34	2.94	0.30	4.71	0.31	3.07
WTP for reduction to 3/10 (£)	0.18		0.12		0.11		0.08		0.08		0.06	4.01	0.17	2.94	0.15	4.71	0.15	3.07
WTA increase to 5/10 (£)	0.18	4.34	0.12	9.26	0.11	9.37	0.08	5.68	0.08	5.66	0.08	3.10	0.26	4.62	0.15	1.78	0.60	4.12
WTA increase to 6/10 (£)	0.36		0.23		0.22		0.17		0.17		0.16	3.10	0.51	4.62	0.30	1.78	1.20	4.12
WTA increase to 7/10 (£)	0.54		0.35		0.33		0.25		0.25		0.24	3.10	0.77	4.62	0.45	1.78	1.80	4.12
WTA increase to 8/10 (£)	0.72		0.46		0.44		0.34		0.34		0.33	3.10	1.03	4.62	0.60	1.78	2.40	4.12
WTA increase to 9/10 (£)	0.90		0.58		0.55		0.42		0.42		0.41	3.10	1.28	4.62	0.75	1.78	2.99	4.12
WTA increase to 10/10 (£)	1.08		0.69		0.66		0.51		0.51		0.66	3.93	1.88	5.19	1.23	1.81	4.89	4.13
Average delay	est.	t-rat.	est.	t-rat.	est.	t-rat.	est.	t-rat.	est.	t-rat.	est.	t-rat.	est.	t-rat.	est.	t-rat.	est.	t-rat.
WTP ($\pounds/hr$)	2.03	3.52	1.17	5.17	1.15	5.24	0.8	3.22	0.79	3.17	0.46	1.59	1.00	1.95	0.36	1.14	0.37	0.35
WTA ($\pounds/hr$)													0.97	1.61	0.71	1.62	2.75	4.01
Expected delay	est.	t-rat.	est.	t-rat.	est.	t-rat.	est.	t-rat.	est.	t-rat.	est.	t-rat.	est.	t-rat.	est.	t-rat.	est.	t-rat.
WTP ($\pounds/hr$)	-		-		-		1.68	2.65	1.69	2.65	2.18	2.98	5.07	3.56	2.06	1.59	2.21	1.30
WTA ($\pounds/hr$)													4.92	3.16	4.05	1.81	16.38	4.06
Delay information service	est.	t-rat.	est.	t-rat.	est.	t-rat.	est.	t-rat.	est.	t-rat.	est.	t-rat.	est.	t-rat.	est.	t-rat.	est.	t-rat.
WTA for free service to charged service (£)	0.29	2.38	0.26	6.03	0.19	4.97	0.19	4.98	0.25	4.28	0.26	4.52	0.62	11.19	0.47	0.75	1.87	1.69
WTA for free service to no service (£)	0.26	3.11	0.13	3.95	0.15	4.97	0.15	4.69	0.10	1.85	0.10	1.95	0.26	3.50	0.20	0.75	0.79	1.69
WTP for no service to free service (£)	0.26	3.11	0.13	3.95	0.15	4.97	0.15	4.69	0.15	3.61	0.16	3.70	0.41	5.42	0.39	6.87	0.39	5.32
WTA for no service to charged service (£)	0.02	0.31	0.14	3.58	0.04	1.05	0.04	1.15	0.00	0.08	-		0.01	0.16	-		-	
WTP for no service to charged service (£)	-		-		-		-		-		0.00	0.04	-		0.01	0.55	0.01	0.28
WTP for charged service to free service (£)	0.29	2.38	0.26	6.03	0.19	4.97	0.19	4.98	0.15	3.17	0.15	3.13	0.42	5.13	0.37	6.56	0.38	5.20
WTA for charged service to no service (£)	-		-		-		-		-		0.00	0.04	-		0.01	0.27	0.02	0.69
WTP for charged service to no service (£)	0.02	0.31	0.14	3.58	0.04	1.05	0.04	1.15	0.00	0.08	-		0.01	0.09	-		-	

lowest level of crowding, in line with the observations in Figure 2. It should be noted that these observations relate solely to non-linearity and are not the results of any gains-losses asymmetry as no such asymmetry was observed in the data, albeit that some may be captured by the non-linearity specification. In models $7-9$, the gap between WTP and WTA gradually increases as a result of the gains-losses asymmetry in the fare coefficient (with $\beta_{fa,inc}$ used for WTP and $\beta_{fa,dec}$ used for WTA), and in model 8, the extent of asymmetry for the fare coefficient leads to WTA being higher than WTP. The lower t-ratios in the WTA domain in model 8 are a direct result of the lower significance for $\beta_{fa,dec}$ in that model. In all cases the standard error associated with losses are more elevated than for gains. The opposite situation for model 9, where WTA measures have higher t-ratios, is due to the extreme asymmetry in the fare function where the elevated WTA make up for their higher standard errors.

The results for the rate of delays use a similar approach, once again based on a starting point of 4 out of 10 trains being affected by delays. We observe symmetrical results in models 1 to 6, with the expected drop in WTP and WTA when moving to a log-cost specification in model 2. The other observation relates to a drop in values in models 5 and 6, which is a result of the additional $\beta_{exp.delay}$ coefficient capturing some of the sensitivity to delays. In model 6, we introduced non-linearity in the response to the rate of delays, and the main effect is the big jump in WTP for avoiding a situation where all trains are affected by delays. In models $7-9$, the asymmetry between WTA and WTP becomes more pronounced as a result of the gains-losses asymmetry in the fare coefficient.

When looking at the WTP/WTA for average delays, we once again see the drop when moving to a log-cost formulation in model 2, and a further drop in model 4 as a result of some of the sensitivity to delays being captured by the additional $\beta_{exp.delay}$ coefficient. The use of a non-linear specification for the rate of delays in model 6 further reduces the role of β_{rb} and hence the resulting WTP/WTA measures. On the other hand, when looking at the WTP/WTA for expected delays, we see an increase as a result of moving to a non-linear specification for the rate of delays in model 6. The observations in relation to the gains-losses asymmetry as a result of the reference-dependent fare coefficient in models $7-9$ are in line with results for the other trade-offs.

For the delay information service, a number of different values can be computed. In the first four models, generic coefficients are estimated independently of whether respondents currently have a delay information service or not. In these models, the free service is always valued higher than not having a service, which, in turn, is preferred to a charged service. As a result, we can compute a WTP for moving from a charged service to either no service or a free service, and a WTP for moving from no service to a free service. In these initial models, the corresponding three WTA measures are equal to their WTP counterparts, given not just the symmetrical fare coefficient, but specifically also the generic treatment independently of the current availability or not of a delay information service. This changes in model 5 (with two different points of departure) and already creates asymmetries as e.g. the move from free to charged is valued more negatively than the move from charged to free. In models 7, 8, and 9, these asymmetries are influenced further by the loss aversion in the fare coefficient. In all but three of the models, the charged service is valued more negatively than not having a service, leading to a WTP for moving from charged to no service, or a WTA for moving from no service to a charged service. In models 6, 8 and 9, this situation is reversed for those respondents who currently do not have a service or have a charged service. Overall, we see a strong aversion for respondents with a free service to move to a charged service, where, after model 5, the associated WTA measure is substantially higher than the corresponding WTP for moving from a charged service to a free service. This shows that offering a free information service with the aim of progressively introducing a charge for it may lead to undesired effects.

The impact of these asymmetries in the cost evaluation has some interesting consequences for the value of time (VOT) measures. As can be observed in Figure 4, the VOT evaluation is very stable across model specifications 2 to 6, after the initial drop resulting from the use of a log-transform on the fare attribute. However, the large disparities observed for improvement in the fare levels lead to a significant increase in the WTA for deteriorations in travel time. Albeit limited to one dataset, these results should serve as a warning to practitioners. Apparent stability in VOT measures despite changes in specification and associated improvements in fit could be deceptive and could be the result of not allowing for appropriate asymmetries in sensitivities. It remains to be seen whether the stability of the WTP measures (as opposed to the WTA measures) is specific to the data at hand.

6 Conclusions

This paper sets out a series of discrete choice modelling formulations to account for different ways that referencing influences choices in a commuting setting. Special attention is paid to extending the empirical tests of reference-dependent decision making to a multi-attribute context. This means not simply applying a uniform modelling treatment to all attributes but instead choosing the most appropriate specification for each attribute. We additionally allow for several different reference points, in line with the idea that constrained acceptable or ideal trip conditions may be the actual point of reference hence determining the utility of different options.

Overall, the flexible treatment of the commute attributes reveals a series of interesting points on how changes in these attributes are perceived. For example, the lack of asymmetry in gains and losses of travel time indicates that once a specific amount of time is stably allocated for commuting purposes, deviations, at least in the short run, are perceived the same way for improvements and deteriorations. The contrasting asymmetry and decreasing sensitivity for the daily fare, however, suggests a more complex picture when ratios of time and cost are considered. Indeed, respondents display a pronounced un-willingness to accept increases in travel time in exchange for fare compensation. Importantly several dimensions, such as the slope, base-line an marginally changing sensitivity contribute to the complex differences between upward and downward shifts in the cost attribute.

Evaluations of the frequency of delays and crowding reveal non-linearities in the sensitivity of going from the extreme of no crowding/delays to a situation of constant crowding/delays. A linear specification consistently overestimates sensitivity to higher frequencies of crowding while it fails to quantify the positive impact of never having to stand. For the frequency of delays the linear attribute specification instead fails to assess the large penalty for reaching a situation of a sure delay (10 out of 10 trips). For these attributes there is no important improvement derived from modelling gains and losses from current states. This confirms the notion that in evaluating risk of crowding and delays, defined as probabilistic frequency measures, the current experience plays little role in defining utility for alternatives. Instead, it appears that reaching absolute levels of crowding/delay is more important, particularly when it comes to the extremes.

The proposed framework moreover offers proof concerning the important shifts when allowing for evaluations against several potential reference points. Reference-dependence with regard to points other than current trip conditions lead to important improvements in fit and further insights into the asymmetry of WTP/WTA measures.

The findings from this paper clearly show the importance of an attribute-by-attribute treatment of specification issues such as non-linearity and reference-dependence. There are potentially important impacts for policies derived from the findings in this paper. For one, the evaluation of the commuter experience is affected by a variety of non-linear sensitivities as for the cases of crowding and the frequency of delays. What is more, certain attributes are evaluated in terms of deviations from a reference point rather than absolute stand-alone service features, as for the case of fares. Appropriately accounting for these effects can improve the appraisal of the welfare drawn from (changes in) service features. Future research in this field needs to extend these analyses to encompass a wider variety of situations characterised by habitual and novel choices to understand the impact of reference-dependence. A further extension that would improve the applicability of these findings is relating the modelling findings to personal features, attitudes, task-perception and other context and personality effects, as well as incorporating inter-respondent heterogeneity in sensitivities.

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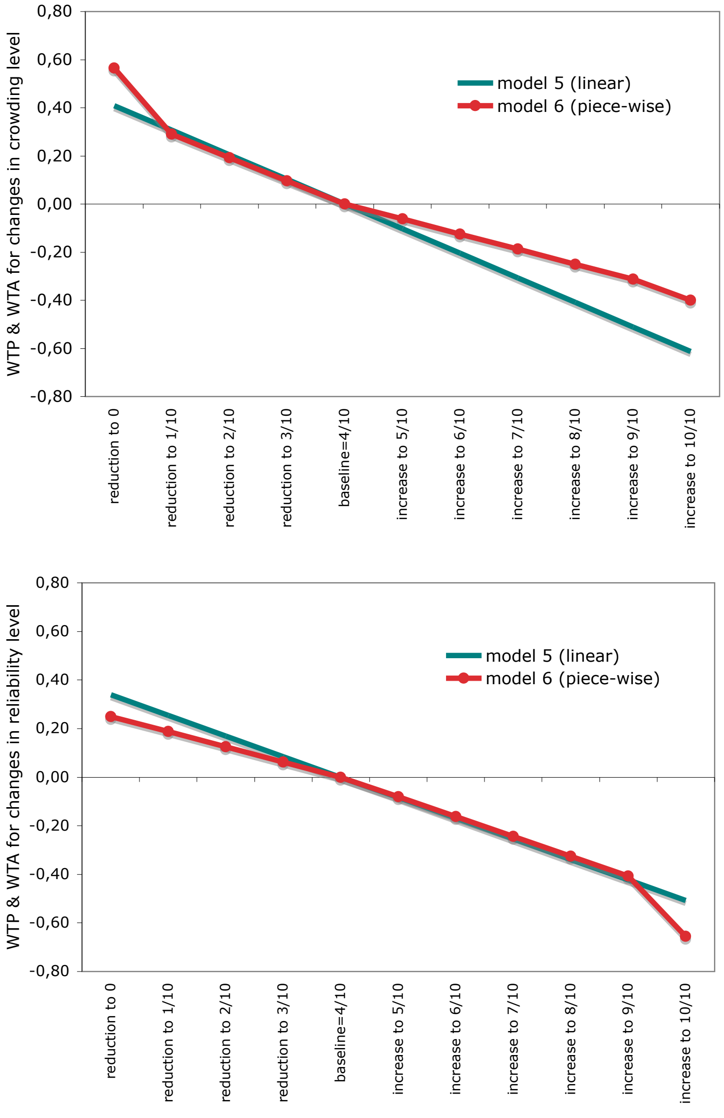

Figure 2: WTP & WTA for normalised scalar and piece-wise crowding and delay

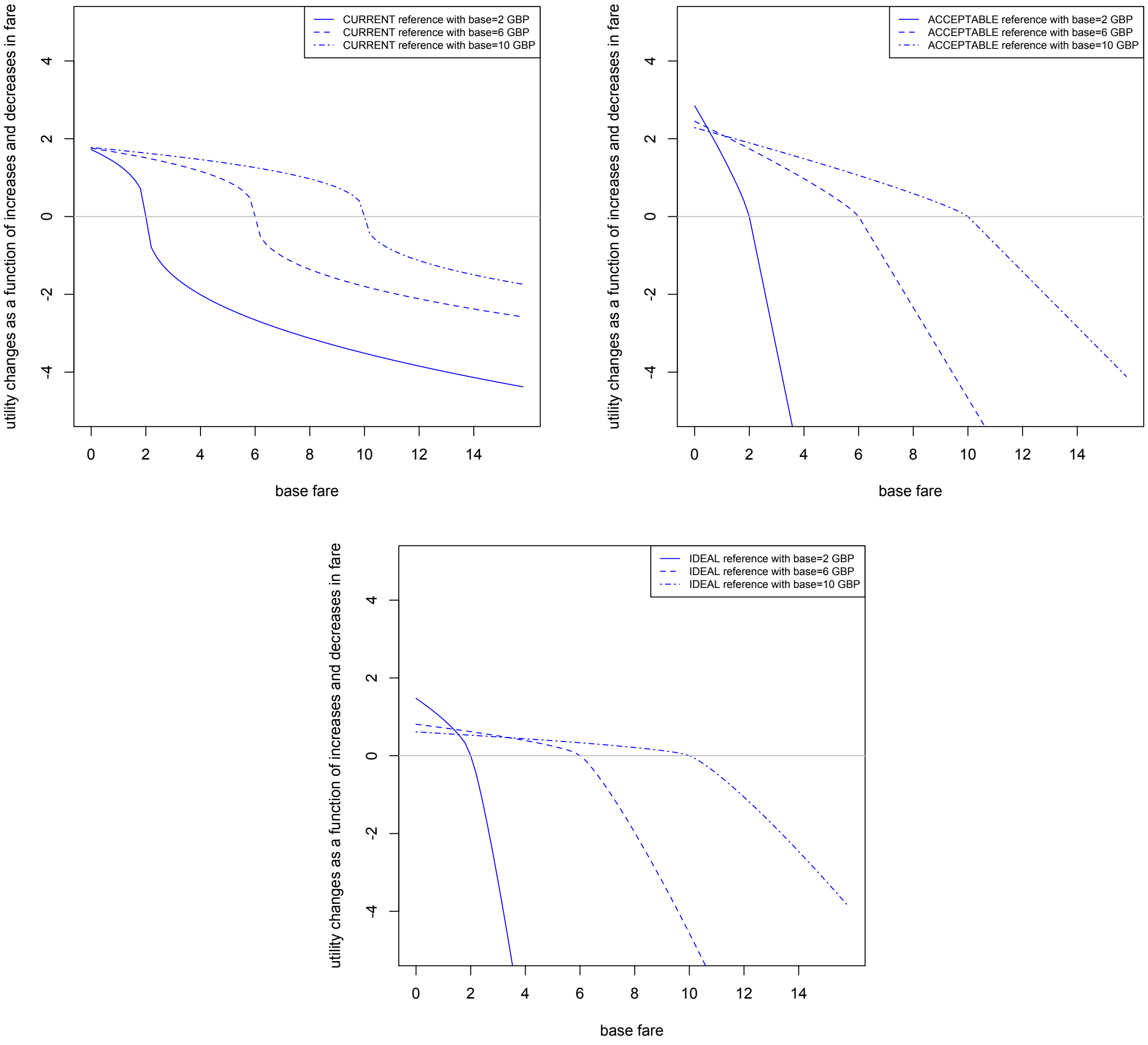

Figure 3: Utility for gains ans losses of fare (with different reference-points and base values)

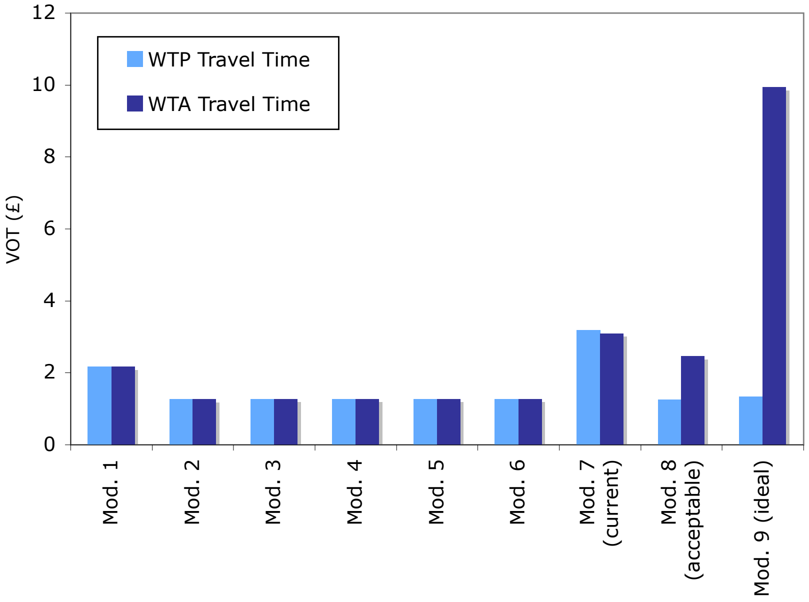

Figure 4: VOT of all models