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An investigation of taste and reference dependence heterogeneity

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TITLE:	**An investigation of taste and reference dependence heterogeneity**

ABSTRACT:

This paper considers reference dependence and loss/gain asymmetry in a stated choice (SC) study in which the attribute levels pivot around those of a recent trip. A latent class (LC) model is presented that allows for heterogeneity both in the tastes, and the nature and magnitude of any reference dependence. In addition to the expected taste heterogeneity, differences in reference dependence across the sample are observed. For both attributes for which reference dependence is possible in this study, running cost and trip time, a lack of reference dependence is most common, followed by loss aversion, then, for a small but significant minority, gain seeking. Two classes have no reference dependence to either attribute, and are differentiated by the magnitude of the values of time. Two classes present mixed evidence about the reference dependence across the attributes. One class demonstrates loss aversion to both attributes, leading to a clear willingness to pay (WTP)/willingness to accept (WTA) asymmetry, where the mean value represents a near average value of time. Most intriguing is a class, representing about 9 percent of the sample, which exhibits gain seeking to both attributes, and a high value of time. The gain seeking thus pushes the high WTP higher. Such a finding could have implications when evaluating infrastructure investments with respect to highly time sensitive travellers.

KEY WORDS: ***Reference dependence, loss aversion, gain seeking, value of time.***

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1. Introduction

Prospect Theory has provided profound insights into choice in both risky (Kahneman and Tversky, 1979) and risk free Tversky and Kahneman (1991) contexts. Central to the theory is the concept of reference dependence, whereby choice alternatives are not evaluated in absolute terms, but rather in terms of gains and losses relative to some reference point. Under the theory, more weight is placed on losses than gains, with a diminishing marginal sensitivity to both losses and gains.

Whilst rooted in behavioural decision theory, Prospect Theory has seen application in many fields. It has been extensively applied to marketing models (e.g. Bell and Lattin, 2000), especially with respect to price, and is recognised as having particular importance in many environmental economics applications (e.g. Bateman et al., 2009), as the status quo usually plays an important part in such applications.

Van de Kaa (2010) review papers that provide some evidence of Prospect Theory in a transportation context. The present paper places a focus on Prospect Theory in the context of SC studies, which are used extensively in transportation applications. Prospect Theory has been tested and applied in SC studies in a range of domains, including, but not limited to: the provision of utilities (e.g. Lanz et al., 2009), air travel choice (e.g. Hess, 2008), freight transport (e.g. Masiero and Hensher, 2010), and the value of time, with only time and money being traded (De Borger and Fosgerau, 2008; Hjorth and Fosgerau, 2011). Some value of time studies have considered reference dependence in more complex choice tasks, in which time and cost are decomposed into various components, a recent trip is included as a choice alternative, and the remaining alternatives are pivoted around this recent trip (e.g. Hess et al., 2008). This paper continues in this vein, with a particular focus on reference dependence heterogeneity.

Reference dependence heterogeneity could take a number of forms. It is widely recognised in the literature that different reference points may be used, and this has been modelled in a transportation context (Hess et al., 2012). It is also possible that the degree of reference dependence might vary across individuals. Just as reference dependence itself may have a notable impact on the findings of interest in any given study, so too might heterogeneity with respect to this reference dependency. For example, not all individuals might be loss averse with respect to time, and this would have an impact on a distribution of values of time. Some effort has been made to link reference dependence to socio-demographic variables. For example, Hjorth and Fosgerau (2011) found that loss aversion to time increased with age and decreased with education. Finding these systematic sources is important, but the degree of reference dependence may also vary randomly, or have some correlation with tastes. This paper simultaneously considers reference dependence and taste heterogeneity.

A key study informing the approach taken in this paper is that of Bell and Lattin (2000). Their most substantive finding is that failure to account for price heterogeneity can exaggerate loss aversion. It is likely that their findings stem primarily from the revealed preference nature of their scanner panel data, as price conscious consumers typically choose one of the cheaper products, and so most non-chosen alternatives are framed as losses. In an appropriately designed SC study, this should not be an issue. Their other key finding is that for some product categories, both taste and loss aversion heterogeneity can be supported. They employed a LC model, and found that some classes exhibit loss aversion, while others have no reference dependence, suggesting that only some of the sample may be loss averse. However, they do not explore the link between loss aversion and tastes, where this paper does so. Hess et al. (2012) also reveal a degree of reference dependence heterogeneity with an LC model. Three classes represent reference dependence around different reference points, while a fourth class, with a significant share, reveals a lack of reference dependence. However, this model focuses on reference point heterogeneity, and captures taste heterogeneity in a limited (and

	Details of your recent trip	Route A	Route B
Time in free flow traffic (minutes)	30	39	21
Time slowed down by other traffic (minutes)	30	34	39
Trip time variability (minutes)	+/- 10	+/- 8	+/- 13
Running costs	$6.24	$4.37	$5.30
Toll costs	$0.00	$0.00	$4.00
If you make the same trip again, which route would you choose?	Current Road	Route A	Route B
If you could only choose between the two new routes, which route would you choose?		Route A	Route B

Figure 1: An illustrative choice task

potentially confounding) way.

This paper extends upon the approach of Bell and Lattin (2000), utilising an LC model to simultaneously handle taste and reference dependence heterogeneity. The model is not restricted to only supporting loss aversion, thus allowing gain seeking to be recovered. Indeed, we provide evidence of gain seeking by a minority of respondents to an SC task. We test for reference dependence across two dimensions, running cost and time, where the ratio of these two provide the value of time, a marginal rate of substitution of key importance in the transportation field. This is performed in a more complex choice environment than some other studies (e.g. De Borger and Fosgerau, 2008), with multiple cost components, and in a choice setting where the recent trip is an alternative. For the dataset employed, we demonstrate a link between certain reference dependence behaviours over multiple attributes on the one hand, and the value of time on the other.

2. Data

The empirical application used in this paper is a stated choice route choice study. In the study, questions were asked that sought information on a recent trip, about which two of the alternatives of the choice task could pivot. In this way, the recent trip serves as the reference point around which gains and losses can be framed. The choice study was conducted in late 2007, as a part of a larger study to evaluate the costs and benefits of a new toll road proposal in Tauranga, New Zealand. An illustrative choice task is depicted in Figure 1.

Three alternatives were presented: the first being their recent trip, which did not vary across choice occasions, and the other two being alternative routes with attribute levels that pivoted around those of the recent trip. Each alternative was described by five attributes. Trip time was broken down into two components: time in free flow traffic, and time slowed down by other traffic. Both time attributes were pivoted around the recent trip value, with variations of -30, -15, 0, 15, and 30 percent. Significant differences in sensitivity to the two time attributes were not found in extensive preliminary analysis, and so all models herein will use a single time attribute which is the sum of the two separate time components. Trip time variability was presented as positive and negative variations around the recent trip time, with variations of 0, 5, 10 and 15 percent. This attribute was found to be insignificant in all models estimated, and so is not included in any models herein. Running cost pivoted around that of the recent trip, with variations of -40, -10, 0, 20 and 40 percent. The toll attribute took on values between $0 and $4, in 50 cent increments. Since no toll roads were available in the area at the time of the study, the toll for the recent trip was always \$0. Consequently, reference dependence cannot be considered for toll, as in all instances the toll represented a loss.

Each respondent completed a total of 16 choice tasks, with the complete experimental design consisting of two blocks of 16 tasks. Respondents were randomly assigned to one of the two blocks, while the order in which the 16 choice tasks were presented was also randomised. The levels of the design were optimised in accordance with efficient design theory, with a d-error measure employed (Rose et al., 2008). The entire survey instrument was programmed as a Computer Assisted Personal Interview (CAPI), that enables the attribute levels to be tailored to (i.e., pivoted around) each respondent's recent trip experience. An interviewer was present and guided the respondents through the survey screens.

Of the complete sample, this paper uses the pooled responses of 136 commuters and 116 non-commuters. Of these 252 respondents, 11 were dropped either for always choosing the same alternatives, or because the recent trip was deemed excessively long for the present analysis. With the remaining 241 respondents completing 16 choice tasks each, the dataset contains a total of 3856 observations.

3. Methodology

First we shall consider the utility expression for the MNL and LC models that do not handle reference dependence. The utilities of the recent trip alternative, REC, and the two pivoted alternatives, $ALTA$ and $ALTB$, are specified as follows:

$$\begin{aligned}
V_{(REC,m)} &= \beta_{REF,m} + \beta_{TOLL,m}TOLL_{REF} + \beta_{RC,m}RC_{REF} + \beta_{TIME,m}TIME_{REF} \\
V_{(ALTA,m)} &= \beta_{ALTA,m} + \beta_{TOLL,m}TOLL_{ALTA} + \beta_{RC,m}RC_{ALTA} + \beta_{TIME,m}TIME_{ALTA} \\
V_{(ALTB,m)} &= \beta_{TOLL,m}TOLL_{ALTB} + \beta_{RC,m}RC_{ALTB} + \beta_{TIME,m}TIME_{ALTB}
\end{aligned} \quad (1)$$

where for each class m, we have alternative specific constants $\beta_{REF,m}$ and $\beta_{ALTA,m}$ (thus normalised around $ALTB$), and coefficients $\beta_{TOLL,m}$, $\beta_{RC,m}$ and $\beta_{TIME,m}$. The observable attributes, $TOLL$, RC (running cost) and $TIME$ do not vary over the classes, and are represented in New Zealand dollars and minutes. For the MNL model, $m = 1$, while for the LC model, $m > 1$.

In the reference dependent models, RC and $TIME$ drop out of the REC alternative. For each of these two attributes, two coefficients are now estimated, one representing in increase in the attribute, e.g. $RC(inc, m)$, and the other a decrease, e.g. $RC(dec)$. $TOLL$ remains, as only losses were observed by respondents, so no reference dependence to it can be modelled. The utility expression now becomes:

$$\begin{aligned}
V_{(REC,m)} &= \beta_{REF,m} + \beta_{TOLL,m}TOLL_{REF} \\
V_{(ALTA,m)} &= \beta_{ALTA,m} + \beta_{TOLL,m}TOLL_{ALTA} \\
&\quad + \beta_{RC(inc),m}max(RC_{ALTA} - RC_{REF}, 0) \\
&\quad + \beta_{RC(dec),m}max(RC_{REF} - RC_{ALTA}, 0) \\
&\quad + \beta_{TIME(inc),m}max(TIME_{ALTA} - TIME_{REF}, 0) \\
&\quad + \beta_{TIME(dec),m}max(TIME_{REF} - TIME_{ALTA}, 0) \\
V_{(ALTB,m)} &= \beta_{TOLL,m}TOLL_{ALTB} \\
&\quad + \beta_{RC(inc),m}max(RC_{ALTB} - RC_{REF}, 0) \\
&\quad + \beta_{RC(dec),m}max(RC_{REF} - RC_{ALTB}, 0) \\
&\quad + \beta_{TIME(inc),m}max(TIME_{ALTB} - TIME_{REF}, 0) \\
&\quad + \beta_{TIME(dec),m}max(TIME_{REF} - TIME_{ALTB}, 0)
\end{aligned} \quad (2)$$

The analysis will include computation of WTP and WTA measures for trip time, with respect to both toll and running cost. For the reference free models, these are:

$$WTP_{TOLL,m} = WTA_{TOLL,m} = \beta_{TIME,m}/\beta_{TOLL,m} \quad (3)$$

$$WTP_{RC,m} = WTA_{RC,m} = \beta_{TIME,m}/\beta_{RC,m} \quad (4)$$

For the reference dependent models, WTP may not equal WTA, and so we compute them as following (cf. Masiero and Hensher, 2010):

$$WTP_{TOLL,m} = \beta_{TIME(dec),m}/\beta_{TOLL,m} \quad (5)$$

$$WTA_{TOLL,m} = \beta_{TIME(inc),m}/\beta_{TOLL,m} \quad (6)$$

$$WTP_{RC,m} = \beta_{TIME(dec),m}/\beta_{RC(inc),m} \quad (7)$$

$$WTA_{RC,m} = \beta_{TIME(inc),m}/\beta_{RC(dec),m} \quad (8)$$

For a full exposition of the latent class model, the reader is referred to Greene and Hensher (2003). In condensed form, the log likelihood of the model can be expressed as:

$$lnL = \sum_{i=1}^{N} \left[\sum_{m=1}^{M} H_{im} \left(\sum_{t=1}^{16} P_{it|m} \right) \right] \quad (9)$$

where there are N respondents, M latent classes, and 16 choice occasions per respondent. H_{im} represents the probability of class m for respondent i, and is generated through an MNL formulation, and $\sum_{t=1}^{16} P_{it|m}$ represents the probability of respondent i making the observed sequence of 16 choices, conditional on assignment to class m. Consequently, the model can handle the panel nature of the data, with coefficients fixed over all of an individual's choices, conditional on assignment to a specific class m.

4. Results

The first two models presented will be MNL models, with and without reference dependence. These show that the findings in this study are reasonable, provide some evidence of reference dependence at the aggregate level, and serve as useful baselines for the models that introduce taste and reference dependence heterogeneity. The next model, an LC model without reference dependence, demonstrates the prevalence of taste heterogeneity, and allows for comparisons with an LC model with reference dependence, in terms of model fit and behavioural interpretations. The key model of interest is the LC model with reference dependence. Each class within the model will be considered in terms of its class specific reference dependence and sensitivities to the attributes. Particular attention will be paid to the relationship between the reference dependence and the sensitivities, and the impact on the discrete distributions of WTP and WTA.

4.1. MNL Model Results

Model 1, reported in Table 1, is an MNL model without reference dependence. Toll, running cost, and travel time are all of correct sign and highly significant. Greater disutility is associated with toll than running cost, which is unsurprisingly. The ASCs are insignificant, indicating neither a left-right bias, nor a preference for or against the recent, untolled trip, relative to the proposed alternatives that frequently have tolls. In all models in this paper, the willingness to pay (to reduce travel time) and willingness to accept (an increase in travel time) nonclementure is adopted in place of the commonly employed value of travel times savings, reflecting an interest in behavioural responses to both gains and losses in travel time, and a need to distinguish between them. All models also report WTA (where appropriate) and WTP with respect to both toll and running cost. A single measure can be computed by weighting at the individual level, but this is not done herein, to allow the differences between the two cost measures to be explored. The two WTP values of $8.16 (with respect to toll) and $11.07 (running cost) are reasonable, and highly significant. Compared to a restricted, constants only model, Model 1 displays a modest improvement in model fit, with a ρ^2 of 0.1634.

Table 1: Models 1 and 2: MNL models with and without reference dependence

Model 1: MNL model without reference dependence

	Param.	***t*-ratio**	**Willingness to pay (reference free)**			
			w.r.t Toll	***t*-ratio**	**w.r.t R. cost**	***t*-ratio**
Toll	-0.6487	-24.95				
R. cost	-0.4778	-18.55				
Time	-0.0882	-23.39	$8.16	21.70	$11.07	12.05
Recent trip	0.0272	0.45				
Route A	0.0448	0.85				
Model fits						
Observations	3856					
LL restricted	-3953.26					
LL at convergence	-3307.26					
K	5					
ρ^2	0.1634					
AIC	6624.5					

Model 2: MNL model with reference dependence

	Param.	***t*-ratio**	***t*-ratio (diff) /reference dependence**	**Willingness to pay or accept**			
				w.r.t Toll	**t ratio**	**w.r.t R. cost**	***t*-ratio**
Toll	-0.6399	-24.56					
R. cost inc.	-0.2672	-4.17	6.99				
R. cost dec.	0.6355	11.93	Gain seeking				
Time inc.	-0.0913	-10.80	1.09	$8.56	10.34	$8.62	6.65
Time dec.	0.0827	12.83	Symmetric	$7.75	9.81	$18.57	3.52
Recent trip	0.1991	2.51					
Route A	0.0381	0.72					
Model fits							
Observations	3856						
LL restricted	-3953.26						
LL at convergence	-3300.57						
K	7						
ρ^2	0.1651						
AIC	6615.1						

Model 2 is also reported in Table 1, and is an MNL model with reference dependence. Again, all key parameters are significant, as well as the recent trip constant, which is now positive. The time increase coefficient has a slightly larger absolute magnitude than the decrease coefficient, which would be indicative of loss aversion, however the difference is not statistically significant. By contrast, the absolute value of the running cost decrease coefficient is over twice that of the increase, suggesting gain seeking, and the difference is highly significant. The finding of gain seeking runs counter to the prevailing evidence in the literature, and in part motivates the examination of reference dependence heterogeneity herein. The gain seeking finding in this model will be revisited in the discussion section.

Both WTP and WTA values are reported in Table 2, with the WTA reported in the time increase row, and the WTP in the time decrease row. Given that the null hypothesis of no difference in sensitivity to an increase or decrease in time cannot be rejected, there is little difference between WTP and WTA with respect to tolls, and the figures of $8.56 and $7.75 bracket the reference free estimate of $8.16. The WTP and WTA values with respect to running cost do diverge sharply, due to gain seeking with this cost component. Model 2 represents a small improvement in model fit over Model 1, even after accounting for the extra two parameters estimated.

4.2. Latent Class Model Results

Next, we consider an LC model without reference dependence. The specification search for the model involves varying the number of classes. The selected model, with five classes, is reported as Model 3 in Table 2. Each additional class up to this number led to a significant improvement in model fit. Six or more classes led to estimation problems, including extremely large standard errors, and singular covariance matrices. The model represents a highly significant improvement in model fit over Model 1, the equivalent, reference free MNL model. The ρ^2 increases from 0.1634 to 0.3985, and the AIC decreases from 6624.5 to 4813.8.

We shall consider each of the five classes of Model 3 in turn. Compared to the other classes, class 1 has the largest unconditional class assignment probability, at just over 38 percent, and the lowest of the WTP values. The WTP with respect to toll, at $3.27, is lower than that with respect to running cost, at $4.53. The class also represents a preference for the recent trip over the two hypothetical alternatives. Conversely, class 2 has the smallest assignment probability, at 9.37 percent, and the highest WTPs, at $52.14 and $52.56. Indeed, the extremity of the WTP values characterise the class. Also notable is the similarity of these two WTP values, suggesting an indifference between the two cost components, and a seemingly more rational comparison of costs. This is the only class for which this phenomenon is observed. There is a marginally significant preference against the recent trip, suggesting an openness to new alternatives which in many instances are tolled. Whilst the assignment probability for class 3, at 13.65 percent, is much smaller than class 1, the WTP values are very similar. The key distinction from class 1 is a significant preference against the recent trip for this class, against a preference for in class 1. With a sizeable class assignment probability of just under 25 percent, class 4 has WTP values approximately three times that of classes 1 and 3. Class 5 has WTP values about twice that of the two highly cost sensitive classes (1 and 3). The very strong and very significant recent trip parameter could be indicative of a form of protest against the status quo, and could potentially be reflective of strategic behaviour by individuals keen to have new infrastructure built. Overall, there is strong evidence of taste heterogeneity in the values of time, and preferences for and against the recent trip.

Next we extend the LC model to additionally handle reference dependence, and present Model 4 in Table 3. This time, six classes can be supported. As expected, Model 4 exhibits vastly better fit than Model 2, which handles reference dependence in the MNL framework. Additionally, Model 4 is an improvement over Model 3, the reference free LC model, even after accounting for the additional parameters. The ρ^2 has increases from 0.3985 to 0.4162 and the AIC decreases from 4813.8 to 4710.1.

Now that the reference dependence can vary across classes, a more nuanced picture of reference dependence emerges. For both running cost and time there is evidence of loss aversion, gain seeking, and an absence of reference dependence (i.e. a symmetric response about the reference point). Before each class is examined in turn, consider the incidence rates of each type of reference dependence behaviour, formed by summing the class assignment probabilities of the classes that reflect that behaviour. For both running cost and time, an absence of reference dependence is the most prevalent

Table 2: Model 3: Latent class model without reference dependence

	Prob. /param	*t*-ratio	Willingness to pay (reference free) w.r.t Toll	*t*-ratio	w.r.t R. cost	*t*-ratio
Class 1	**0.3802**	10.25				
Toll	-1.4203	-12.82				
R. cost	-1.0253	-11.36				
Time	-0.0775	-7.56	$3.27	8.23	$4.53	7.20
Recent trip	1.2560	6.73				
Route A	0.0200	0.11				
Class 2	**0.0937**	4.24				
Toll	-0.3094	-3.11				
R. cost	-0.3069	-3.11				
Time	-0.2689	-7.16	$52.14	2.98	$52.56	3.01
Recent trip	-0.7614	-1.73				
Route A	0.5542	3.03				
Class 3	**0.1365**	4.90				
Toll	-0.5313	-7.05				
R. cost	-0.3737	-6.82				
Time	-0.0327	-3.65	$3.69	3.76	$5.25	3.74
Recent trip	-0.6962	-3.59				
Route A	0.0381	0.24				
Class 4	**0.2498**	7.51				
Toll	-1.4873	-12.66				
R. cost	-1.1276	-10.23				
Time	-0.2714	-12.58	$10.95	16.55	$14.44	13.49
Recent trip	-0.4470	-2.37				
Route A	-0.3159	-1.98				
Class 5	**0.1398**	5.15				
Toll	-0.9819	-7.78				
R. cost	-0.7264	-5.62				
Time	-0.1159	-7.70	$7.08	6.64	$9.57	5.60
Recent trip	-5.2333	-6.69				
Route A	0.1161	0.80				
Model fits						
LL at conv.	-2377.89					
K	29					
ρ^2	0.3985					
AIC	4813.8					

Table 3: Model 4: Latent class model with reference dependence

	Prob. /param	*t*-ratio	*t*-ratio (diff) /reference dependence	Willingness to pay or accept							
				w.r.t. Toll	*t*-ratio	Conf. interval Lower	Conf. interval Upper	w.r.t R. cost	*t*-ratio	Conf. interval Lower	Conf. interval Upper
Class 1	**0.2349**	6.28									
Toll	-2.3731	-9.08									
R. cost inc.	-1.7672	-5.19	-0.55								
R. cost dec.	1.5494	5.07	Symmetric								
Time inc.	-0.0982	-2.84	1.08	$2.48	3.01	$0.86	$4.10	$3.80	2.02	$0.12	$7.49
Time dec.	0.1390	4.84	Symmetric	$3.51	4.00	$1.79	$5.24	$4.72	2.86	$1.49	$7.95
Recent trip	-0.1307	-0.46									
Route A	-0.3543	-1.57									
Class 2	**0.0864**	4.15									
Toll	-0.2555	-2.54									
R. cost inc.	-0.0635	-0.25	2.05								
R. cost dec.	0.5075	2.05	Gain seeking								
Time inc.	-0.1798	-4.01	3.00	$42.21	2.49	$9.02	$75.41	$21.25	1.59	-$4.87	$47.37
Time dec.	0.3876	6.00	Gain seeking	$91.03	2.33	$14.58	$167.49	$366.08	0.25	-$2,462	$3,194
Recent trip	0.1514	0.35									
Route A	0.7068	3.51									
Class 3	**0.1232**	4.81									
Toll	-0.5084	-6.59									
R. cost inc.	-0.1249	-0.79	3.05								
R. cost dec.	0.4967	3.95	Gain seeking								
Time inc.	-0.0536	-2.90	-2.63	$6.32	2.79	$1.87	$10.76	$6.47	2.02	$0.19	$12.75
Time dec.	0.0048	0.30	Loss aversion	$0.56	0.30	-$3.17	$4.29	$2.29	0.25	-$15.78	$20.37
Recent trip	-0.6803	-2.48									
Route A	-0.0458	-0.27									
Class 4	**0.1793**	5.94									
Toll	-0.7094	-4.02									
R. cost inc.	-1.3623	-2.41	-3.30								
R. cost dec.	-0.1715	-0.43	Loss aversion								
Time inc.	-0.1421	-1.45	-0.50	$12.02	1.40	-$4.75	$28.80	-$49.73	-0.43	-$275.03	$175.58
Time dec.	0.0966	2.38	Symmetric	$8.17	1.89	-$0.31	$16.65	$4.26	1.45	-$1.49	$10.00
Recent trip	2.3519	4.44									
Route A	0.4880	1.23									
Class 5	**0.1527**	5.75									
Toll	-0.9417	-9.68									
R. cost inc.	-0.9559	-3.79	-2.36								
R. cost dec.	0.4883	2.57	Loss aversion								
Time inc.	-0.1450	-4.46	-1.70	$9.24	4.64	$5.34	$13.14	$17.82	2.16	$1.68	$33.96
Time dec.	0.0933	3.56	Loss aversion	$5.94	3.13	$2.23	$9.66	$5.86	2.30	$0.86	$10.86
Recent trip	-5.1449	-8.78									
Route A	0.1407	1.09									
Class 6	**0.2236**	6.77									
Toll	-1.3049	-11.79									
R. cost inc.	-1.0749	-3.58	-0.35								
R. cost dec.	1.0014	4.29	Symmetric								
Time inc.	-0.2912	-7.38	-1.12	$13.39	7.20	$9.75	$17.03	$17.45	3.47	$7.61	$27.29
Time dec.	0.2399	9.46	Symmetric	$11.03	5.85	$7.33	$14.73	$13.39	2.97	$4.55	$22.23
Recent trip	-0.4393	-1.48									
Route A	-0.1428	-0.85									
Model fits			**Aggregate**	**R. cost**	**Time**						
LL at conv.	-2307.99		Symmetric	0.4585	0.6378						
K	47		Loss aversion	0.3320	0.2758						
ρ^2	0.4162		Gain seeking	0.2095	0.0864						
AIC	4710.0		Total	1.0000	1.0000						

behaviour, at 45.85 and 63.78 percent for running cost and time respectively. Next most common is loss aversion, at 33.2 and 27.58 percent. Least common, but still substantially represented, is gain seeking, at 20.95 and 8.64 percent. This is particularly different to the MNL model for running cost. In the MNL model, gain seeking was essentially inferred for the entire sample, yet here, it represents just 20.95 percent of the sample, and is the least common referencing behaviour. A possible explanation for this will be provided in the discussion section, after each class has been examined carefully.

The latent class structure allows each class to capture heterogeneity not just in tastes, but in loss aversion as well. Consequently, for each class reported in Table 3, both the taste and reference dependence heterogeneity will be discussed. As with Model 2, the reference dependence will be analysed by considering the relative magnitudes of the increase and decrease coefficients for running cost and time, as well as the significance level of the differences. As with Model 3, the taste heterogeneity will be examined primarily through a comparison of marginal rates of substitutions, to overcome issues of scale, although as with Model 2, potential reference dependence means that both WTP and WTA, and particularly the differences between them, are of interest. To further facilitate a comparison of WTP and WTA, 95 percent confidence intervals are constructed around these values. Particularly interesting are the links between the two forms of heterogeneity, that of tastes and of reference dependence.

Class 1 has the largest unconditional class assignment probability, at 23.49 percent. The sensitivities are symmetric about the reference point for both running cost and trip time, given a lack of significance of the difference between the absolute values of the loss and gain parameters. Consequently, WTP and WTA are very similar, with largely overlapping confidence intervals. The WTP and WTA values themselves are the lowest of all classes. Thus, in this study, those with the lowest value of time exhibit no reference dependence. It may be that a high sensitivity to the two cost components is leading to more attention being paid to the entire range of costs, over both gains and losses.

Class 2 exhibits strong gain seeking for both running cost and time. For running cost, there is a sensitivity to gains, but as evidenced by an insignificant parameter, no sensitivity to losses, at least within the attribute ranges tested (i.e. up to 40 percent higher cost than the recent trip). For time, both the increase and decrease parameters are significant, but with the sensitivity to a decrease over double that to an increase, with the difference significant. The gain seeking for time leads to the WTP for a one hour time decrease in travel time, at \$91.03, being over double the willingness to accept a time increase, at \$42.21, when considered with respect to toll. Thus this class represents very time sensitive travellers, and is reminiscent of class 2 in Model 3. Indeed, with class assignment probabilities of 8.64 and 9.37 percent respectively, the classes are likely to be largely representing the same respondents (an investigation of the conditional class assignment probabilities supports this view). Given the insensitivity to an increase in running cost, it is not surprising that the WTP with respect to running cost is insignificant. The WTA with respect to running cost is marginally significant, and about half that relative to toll.

Given the discrepancies over the WTP and WTA values, a question arises as to which marginal rate of substitution the analyst should use. For a proposed toll road that is likely to see travel time benefits, WTP with respect to toll makes the most sense, and so for this class of traveller, the highest of the significant WTP/WTA values would be applied, with a WTP of \$91.03, considerably higher than the largest discrete WTP in Model 3 (\$52.14, class 2). By contrast, in an application such as considering the value of time in the context of road detours for non-tolled infrastructure (Masiero and Hensher, 2011), willingness to accept with respect to running cost would be the most appropriate measure. For this class in this dataset, the appropriate marginal rate of substitution is considerably lower, at \$21.25 per hour.

Class 3 is associated with gain seeking for running costs, and loss aversion for time. For both attributes, one of the taste coefficients is not statistically different from zero, indicating a lack of response to the attribute levels across the corresponding domain. The insignificant time decrease parameter means that none of the WTP values are significant. Since the running cost decrease parameter is very similar to the toll parameter, the two WTA measures are almost the same ($6.32 and $6.47), with WTA with respect to toll having a slightly tighter confidence interval. These WTAs are a little less than the mean WTP and WTA values from the MNL models.

Class 4 exhibits loss aversion for running cost, with the coefficient for a decrease in this attribute having the wrong sign, but being highly insignificant. Whilst time increase is only very marginally significant, the difference between an increase and a decrease is not significant, and so the response is symmetric about the reference point. Most of the WTP and WTA values have low levels of significance and wide confidence intervals. Only the WTP with respect to toll is significant at an acceptable level, and is approximately the value obtained from the MNL models.

In class 5, all running cost and time parameters are significant. Loss aversion to both running cost and time is evident, although only at the 90 percent confidence level for time. The loss aversion results in WTA being notably higher than WTP for both toll and running cost. The average of the WTP and WTA corresponds well to the corresponding WTPs from Model 1 ($7.59 vs $8.15 for toll; $11.84 vs $11.07 for running cost). Thus, this class has very typical average values of time, just skewed with a strong loss aversion.

In the final class, all running cost and time parameters are significant. Whilst the increase parameters are slightly larger in magnitude than their decrease counterparts, neither of the differences are significant, and so the class exhibits no reference dependence. The WTP and WTA values are somewhat higher than their MNL counterparts, and most other classes. Class 6 bears some similarity to class 1, the other class with no reference dependence, except that this class has considerably higher WTP and WTA values. Indeed, an examination of the conditional class assignment probabilities, not reported, reveals a high level of mixing between the two classes, which is likely capturing intermediate WTP/WTA values for those respondents, under the same absence of reference dependence.

The proceeding point raises the prospect of using the conditional parameter estimates as a way of analysing reference dependence heterogeneity, where the analysis thus far has relied on the unconditional class assignment probabilities and parameter estimates. One challenge in such an analysis is obtaining some measure of the significance of the conditional parameter estimates. We will reserve an examination of the conditional parameter estimates for future analysis. It is worth noting, however, that many of the respondents were assigned to one class with very high probability. Of the 241 respondents, 158 (65.6 percent) were assigned to a class with a probability of 95 percent or higher, and 99 (41.1 percent) were assigned with a probability of 99 percent or higher. This suggests that many of the respondents are represented by a single class with very high probability, and so each class is closely reflective of the tastes and reference dependence behaviours of many of the sampled individuals.

5. Discussion

Of key interest is why specific classes of respondent exhibit the patterns of reference dependence (or independence) that they do. The approach taken herein essentially links the respondents' reference dependence behaviour with their value of time, as well as other preferences for and against the recent trip alternative. For example, in these data, the least time sensitive respondents exhibit no reference dependence, the most time sensitive respondents are gain seeking, and a class of respondent that is loss averse over both running cost and time has approximately the average value of time, albeit one that is asymmetric about the reference point. This is useful, as it was shown herein to have a strong influence on the distribution of WTP and WTA values across a sample of respondents who are certainly heterogeneous in their tastes, and from this analysis, seemingly heterogeneous in their reference dependence behaviours. Nonetheless, this does not get to the very root of why these respondents are exhibiting the reference dependent behaviours that they are, although we may speculate as to the cause.

Another approach is to link the extent of reference dependence to observable socio-demographic characteristics (e.g. Hjorth and Fosgerau, 2011; Johnson et al., 2006), rather than that which is latent. One way to do this in the modelling framework proposed herein is to parameterise the class assignment component of the LC model, beyond mere constants. This was attempted with a number of socio-demographic and experience variables, with little success. Perhaps the problem is that such covariates would have to be associated with both taste and reference dependence heterogeneity.

The evidence of some gain seeking in this study is relatively unusual, as the literature generally suggests that individuals are loss averse, or perhaps not reference dependent. It is therefore worth looking carefully at the classes in Model 4 that represent gain seeking. Class 2 is the most striking of these, with its very high value of time. Johnson et al. (2006) found in their study that knowledge of an attribute reduces loss aversion. Perhaps those with very high values of time are more frequent travellers, and more knowledgable about the time and cost attributes. The indifference between the two cost components in this class lends credence to this argument. It could be that rather than just eliminating loss aversion, extensive knowledge of the attributes is leading to gain seeking. There remains a chance that the gain seeking behaviour is a consequence of the experimental design, however the symmetry of the attribute levels likely makes the modelling effort somewhat impervious to asymmetries in the availability of attribute levels representing gains and losses. Another consideration with respect to the experimental design is the believability of the attribute levels presented. If the respondents do not find certain gains and losses believable, then this may appear as reference dependence. Caution is warranted.

The evidence of gain seeking by some respondents also has implications in how the values of time may be applied. Consider again the evidence of gain seeking amongst those with very high values of time in class 2 of Model 4. This behaviour makes a potential infrastructure investment more appealing in terms of serving the highly time sensitive traveller, as the willingness to pay a toll for an improvement in travel time is pushed up by the gain seeking. At least for this class of traveller, this contrasts with the suggestion by Masiero and Hensher (2011) that the inclusion of reference dependence in the modelling effort will make infrastructure investment less viable. It may be that the gain seeking is uncommon, and unique to the present study. Naturally, further research would help ascertain whether this is the case.

This study has also shown the potential consequences of not accounting for heterogeneity in reference dependence. A more complex picture of reference dependence may be masked. Also, the mean estimate of the degree of reference dependence may be biased to a value that is not representative of the more widespread reference dependence behaviour. For example, Model 2 revealed gain seeking for running cost, yet this was the least representative in Model 4 of the three reference dependence behaviours, where a lack of reference dependence was most common, followed by loss aversion. What may have been happening is that a very strong exhibit of gain seeking by a minority of respondents skewed the aggregate result to a finding of gain seeking overall.

A widely used alternative to the LC model is the random parameters logit (RPL) model, whch employs a continuous mixture of coefficients to represent preference heterogeneity. Numerous papers have investigated reference dependence using the RPL model (e.g. Rose and Masiero, 2010; Masiero and Hensher, 2010). Whilst these papers have not investigated heterogeneity in reference dependence per se, the specifications they have used allow for it, with the appropriate interpretation. If a parameter is used each for gains and losses, then making each of these parameters random creates a distribution of coefficients. Even if the mean of the distributions signifies loss aversion on average, if the distributions overlap (after taking the absolute values of the coefficients), then some draws from the distributions will result in gain seeking. Part of the problem with this approach is that the interpretation is hard to make, particularly around the boundary between loss aversion and gain seeking, and determining what might be representing a lack of reference dependence. A number of specifications of reference dependence in the utility expressions are available, and some may be more appropriate than others in this context. By contrast, the LC model approach is easier to interpret, and at least with the unconditional estimates, statistical tests can be readily applied to check for the significance of the reference dependence behaviour. Of course, all of the other advantages of the LC model over the RPL model also apply, including ease of specification and speed of estimation.

6. Conclusion

In the context of an SC study with attribute levels that pivot around those of a recent trip, this paper simultaneously estimates taste and reference dependence heterogeneity, and examines the link between the two. The approach taken is an extension of that proposed by Bell and Lattin (2000). A latent class model estimates sensitivities to gains and losses for appropriate attributes, such that the relative magnitudes of the gains and losses can vary freely across classes. Relative measures of WTP and WTA across classes provides information about taste heterogeneity. The ratios of the gains and losses, and the significance of these ratios, provides information about reference dependence for segments of the sample, and potential differences across classes inform the analyst about the existence or otherwise of reference dependence heterogeneity. Within a class, WTP/WTA measures can be compared with the loss/gain ratios to investigate any link between the two.

In our baseline MNL model, with reference dependence, but without taste or reference dependence heterogeneity, we find controversial evidence of strong gain seeking behaviour. As expected, a conventional LC model without reference dependence reveals strong taste heterogeneity. The model that allows for taste and reference dependence heterogeneity finds evidence of both, and leads to a large improvement in model fit over the less flexible models. For both attributes for which reference dependence was modelled, running cost and time, a lack of reference dependence is most common, followed by loss aversion, then gain seeking. Crucially, the overall picture of gain seeking for running cost in the MNL model is overturned, with gain seeking now a small but significant minority. This raises questions about how a small number of instances of gain seeking or loss aversion may strongly influence an homogenous measure of reference dependence. Two of the classes reveal a symmetric response to gains and losses, where the classes are distinguished by the magnitude of the value of time. Another two classes reveal mixed reference dependence evidence over the two gain/loss attributes. One class exhibits loss aversion to both running cost and time, leading to a WTA that is notably higher than the WTP. Most interesting of all is a class that represents both very high time sensitivity, and strong gain seeking. This gain seeking effectively inflates the VTTS to a very large $91.03 per hour, where a finding of loss aversion would have had a deflating effect. Such a finding has implications when the values are applied, as for example it could make an infrastructure investment more viable in terms of serving that segment of the market.

A number of avenues for future research present themselves. More analysis of the conditional parameter estimates is warranted. It would be useful to model both the random variations in reference dependence as in this study, and any systematic influences as well. Finally, more testing is warranted on other datasets, so that the generalisability of the methods and findings can be investigated. Of particular interest is whether other studies exhibit some degree of gain seeking, even if only by a small minority of respondents.

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