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Accommodating underlying pro-environmental attitudes in a rail travel context: application of a latent variable latent class specification

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Abstract

Using data from a stated preference survey conducted in the UK, we show how the relative importance that rail travellers attach to reductions in greenhouse gas emissions and faster journey times varies strongly as a function of underlying attitudes towards the environment. We specify a latent class structure that allocates respondents to two classes with substantially different valuations of greenhouse gas emissions, and show how the allocation of a given respondent to either class is a function of underlying attitudes that also drive the answers to a number of attitudinal questions. We also show how these underlying attitudes are a function of a number of socio-demographic characteristics, with female respondents, older respondents, and respondents with a university degree having a stronger pro-environmental attitude, with the opposite applying to respondents with regular car access.

Keywords: environmental attitudes; greenhouse gas emissions; rail transport; stated preference method

1 Introduction

Given increasing concerns about global warming, there is a growing interest in encouraging more sustainable travel behaviour. While ensuring a gradual shift towards more environmentally friendly modes of transport is a major policy topic, in particular through a shift away from air travel towards rail[1], a further issue

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[1]It should be acknowledged that the actual environmental benefits of this vary widely across regions, in particular depending on the need to provide new rail infrastructure, construction of which has major environmental impacts itself.

is whether the focus of new developments should be on reductions of travel time or ensuring a smaller environmental impact. This is especially relevant in the context of new high speed rail developments.

Policy and infrastructure decisions in this context require an understanding of the importance travellers assign to the environmental impact of their travel behaviour. Such measures go alongside more established indicators such as the monetary valuation of reductions in travel time. A number of studies have investigated valuations of environmental impacts, drawing on diverse research areas, for example looking at the value of reducing greenhouse gas (GHG) emissions of water companies (Chalak et al., 2012), mitigating temperature changes and reducing overall GHG emissions (Ivanova and Rolfe, 2010), carbon capture mechanisms (Loschel et al., 2010; Diederich and Goeschl, 2011), investments in green energy Wiser (2007) and offsetting of CO_2 emissions by air travellers (Brouwer et al., 2008). The majority of this work recognises the potential for significant variations across individual travellers in how they value environmental benefits, with the typical approach being to link them to socio-economic characteristics. Other work recognises that some variations are difficult to link to observed characteristics and makes use of a random treatment of inter-traveller heterogeneity (Carson et al., 2010).

Here, we put forward the notion that while some of the heterogeneity can indeed be linked to measured characteristics of respondents, underlying attitudes and convictions, specifically personal norms, may be the key driver of heterogeneity. This is in line with Prillwitz and Barr (2011), who found that "attitudes towards the environment, sustainability and certain environmentally friendly transport modes have a significant impact on daily travel behaviour". Using data from a stated preference survey conducted in the UK, we examine how such attitudes can be accommodated in a hybrid model that explains both the preferences for travel time and GHG reductions and the answers to attitudinal questions.

2 Data

Our analysis makes use of data collected in the UK in 2008[2]. With only 40% of the UK rail network being electrified at present, there are active plans for increased electrification with a view to obtaining reductions in CO_2 emissions.

[2]While this makes our results somewhat area specific, the same can be said for almost all studies of travel behaviour. By not making the survey relate to one specific journey context, we should avoid some of these issues. Similarly, the dataset is several years old, but the absence of a cost component should ease the concerns about temporal stability. Nevertheless, the relative importance of greenhouse gas reductions may have changed over time in the face of increasing environmental concerns.

At the same time, there are ongoing discussions about future highspeed rail developments, where the initial construction process clearly has a major environmental impact. These contrasting directions are a motivation for understanding the relative importance that travellers place on reductions in travel time and in environmental impact of rail travel. We focus on rail travellers, whose relative valuations could differ from those currently travelling on other modes. This was, however, unavoidable as our survey focussed on a current journey, and also allowed a higher degree of familiarity with the choice context.

It was recognised that the specific wording used in the survey could have a substantial impact on results, not least due to remaining uncertainty in the general population in relation to quantifying environmental impacts. With this in mind, four focus groups were held in UK cities in September 2008 with a view to guiding survey development. The groups explored people's understanding about the environmental impacts of rail use and if and how environmental concerns feature when choosing whether to travel by train. The data from the focus groups provided an understanding of people's perceptions about rail and the environment, and this was used to help design the questionnaire survey, in particular to word questions such that they were meaningful to respondents at the same time as collecting the data needed. It became clear that quantifying environmental impacts in terms of kilograms of CO_2, as is generally done, was relatively meaningless to most people. On the other hand, the focus groups showed that respondents could relate to the notion of greenhouse gas emissions', even if they have a poor understanding of which emissions are included within that. Similarly, the groups highlighted that while respondents found it difficult to relate to a given figure in terms of tonnes of GHG emissions, they could easily understand the concept of a percentage reduction in such emissions.

The survey made use of one specific type of stated preference elicitation method, namely a ranking experiment. Respondents were asked to rank different possible changes to their current rail service in order of preference, focussing on reductions either in travel time for their current journey or in greenhouse gases, each time using percentage reductions. Journey time was preferred to fare because evidence from the focus groups suggested that it was considered a less contentious attribute, potentially avoiding strategic bias. Three levels of reductions in time were presented to each respondent, along with three levels of reductions in greenhouse gases. The respondents were instructed to rank the possible outcomes under the assumption that all else stays equal, e.g. in a situation without increases in price.

In an attempt to mask the intentions of the exercise, two additional outcomes were included in the survey; the chance of a getting a seat and of a train arriving at its destination on time. These two options were not included in the final anal-

Changes to Your Current Rail Journey	**Ranking (1 to 8)** *where 1 - most preferred change & 8 - least preferred change*
Time spent travelling on the train is reduced by 5%	
Amount of greenhouse gases generated by your trip is reduced by 15%	
Amount of greenhouse gases generated by your trip is reduced by 5%	
Time spent travelling on the train is reduced by 15%	
There is a higher chance of getting a seat than currently	
Amount of greenhouse gases generated by your trip is reduced by 25%	
Time spent travelling on the train is reduced by 10%	
There is a higher chance of your train arriving at your destination station on time than currently	

Figure 1: Ranking experiment

ysis[3], and the levels associated with these two options were kept vague (*"higher chance"*) as they were of no relevance to the study - respondent interpretation and possible uncertainty related to the attributes does not affect the ranking between the other components. Figure 1 shows an example of the ranking experiment, where four different versions were used in the sample, with differences in the levels of reductions presented.

Alongside collecting information on a number of socio-economic characteristics, the survey also presented respondents with four attitudinal statements, specifically relating to personal norms regarding taking action to be environmentally friendly *per se*, and catching the train to be environmentally friendly. Evidence was found as far back as 1999 that personal norms were a determinant in pro-environmental behavior, including using means of transport other that the car (Harland et al., 1999). More recent research into environmental awareness and attitudes suggests that a moral norm to take action to help the environment is important in forming intentions to make travel behaviour changes which reduce carbon emissions. The work by Eriksson et al. (2008) and King et al. (2008) corroborates that of Bamberg et al. (2007), who reported finding personal norms to be a significant determinant of intentions to use public transport. Similarly, Abrahamse et al. (2009) reported that intentions to reduce car use were "mostly explained by ... personal norms". These moral norms can be assessed through measurement of perceived responsibility (Eriksson et al., 2008) and moral obligation (Harland et al., 1999; Abrahamse et al., 2009) to take action to be environmentally friendly, and perceived responsibility and moral obligation to travel by

[3] A separate analysis showed that this had no impact on results.

	Strongly agree						Strongly disagree
It is my responsibility to take action to be environmentally friendly.	1	2	3	4	5	6	7
I am morally obliged to take action to be environmentally friendly.	1	2	3	4	5	6	7
It is my responsibility to catch the train more to be environmentally friendly.	1	2	3	4	5	6	7
I am morally obliged to catch the train more to be environmentally friendly.	1	2	3	4	5	6	7

Figure 2: Attitudinal (personal norm) questions

rail for that purpose. Here, we use such indicators in a modelling study of traveller preferences using state-of-the-art techniques. The exact wording is shown in Figure 2 - we asked about obligations and responsibilities separately because the former are binding, whereas responsibilities need not be, and therefore accepting responsibility does not imply commitment to act, whereas feeling morally obliged to catch the train implies some level of commitment to do so when possible. The obligation questions received a lower level of agreement than the responsibility questions, highlighting the differences in interpretation.

Finally, respondents were also asked whether they had *"ever made a decision to travel by train purely or mainly because [they] considered train to be the most environmentally friendly form of transport on offer"*.

Questionnaires were distributed to rail travellers on six long-distance rail services covering a range of national circumstances and collected at the end of the trip. Surveys were carried out throughout the day to ensure a wide profile of passengers. To include a sample of commuters who travel on services where crowding would prevent data collection, mail-back copies of the survey were distributed at four stations in London and at stations in Manchester and Birmingham. A sample of $1,336$ respondents was obtained.

3 Model specification

The stated ranking data were analysed with the help of a hybrid choice model, combining a random utility model with a measurement model for underlying attitudes. We rank exploded the observations for a given respondent, i.e. turning the exercise of ranking the six possible outcomes (excluding the two dummy levels) into a set of five discrete choices, where each outcome is seen as a separate alternative.

Let T_{nj} be the level of time reduction for alternative j for respondent n, where this will be zero for half the alternatives, and let G_{nj} be the level of greenhouse gas reduction for alternative j for respondent n. We allow for deterministic as well as random heterogeneity in how respondents react to these reductions. In particular, we allow for two classes of respondents in a latent class framework, where the allocation of a given respondent to a given class is not observed, i.e. is dealt with probabilistically. We specify separate utility functions for person n and alternative j in the two classes:

$$V_{nj,c_1} = \delta_G \, I_{(G_{nj}>0)} + \beta_{G,c_1} \, G_{nj} + (\beta_{T,c_1} + \delta_{T,w} I_{nw}) \; T_{nj} \tag{1}$$

$$V_{nj,c_2} = \delta_G \, I_{(G_{nj}>0)} + \beta_{G,c_2} \, G_{nj} + (\beta_{T,c_2} + \delta_{T,w} I_{nw}) \; T_{nj}. \tag{2}$$

The marginal sensitivities to percentage reductions in time (β_{T,c_1} and β_{T,c_2}) and GHG (β_{G,c_1} and β_{G,c_2}) are allowed to vary across classes, while the constant δ_G for outcomes with reductions in GHG as well as the shift in travel time sensitivity for respondents on work trips $\delta_{T,w}$ (where I_{nw} is unity if respondent n travels for work) are kept constant across classes.

The probability of the observed ranking for person n is now given by a weighted average of two rank exploded logit probabilities (one per class), with:

$$P_n = \sum_{s=1}^{2} \pi_{n,c_s} \left[\prod_{t=1}^{T-1} \frac{\sum_{j=1}^{J} I_{(R_{nj}=t)} \, e^{\mu_t V_{nj,c_s}}}{\sum_{j=1}^{J} I_{(R_{nj} \geq t)} \, e^{\mu_t V_{nj,c_s}}} \right], \tag{3}$$

where $T = 6$, i.e. the number of alternatives that are ranked, R_{nj} is the observed rank of alternative j (from 1 to 6) and where $I_{(R_{nj}=t)}$ is equal to 1 only if j corresponds to the alternative with rank t. The inclusion of additional scale parameters μ_t (with μ_1 normalised to 1) allows for the fact that the level of noise (or randomness) is not uniform across the rankings.

The probability of a given respondent n falling into either of the two classes is given by π_{n,c_s}. We link this probability to underlying pro-environmental attitudes using:

$$\pi_{n,c_1} = \frac{e^{\delta_1 + \tau \alpha_n}}{e^{\delta_1 + \tau \alpha_n} + 1} \tag{4}$$

$$\pi_{n,c_2} = \frac{1}{e^{\delta_1 + \tau \alpha_n} + 1}. \tag{5}$$

In this specification, δ_1 is used to capture the mean share of class 1 in the sample (relative to class 2), while $\tau \alpha_n$ captures the shift in the probability for respondent

n falling into class 1 as a resulting of that respondent's underlying attitudes. These attitudes are given by α_n, with the estimated sign of τ determining whether increases in α_n lead to increased probability for class 1 (τ being positive) or class 2 (τ being negative).

We recognise that attitudes are unobserved and that only manifestations or imperfect measurements of these attitudes can be captured. In a departure from standard techniques used in an environmental context, where answers to attitudinal questions are treated as error free measures, we treat them as indicators of latent attitudes, using them as dependent variables in a measurement equations component within a hybrid model structure (Ben-Akiva et al., 2002). This accommodates measurement error as well as mitigating risks of endogeneity bias that would arise in a deterministic treatment.

We rely on just a single such variable, capturing underlying pro-environmental tendencies. Specifically, after an extensive specification search, we defined the latent attitude for respondent n as:

$$\begin{aligned}\alpha_n = {} & \gamma_{\text{female}}\, I_{(\text{female}_n=1)} + \gamma_{\text{age}>45}\, I_{(\text{age}_n>45)} \\ & + \gamma_{\text{univ. degree}}\, I_{(\text{univ. degree}_n=1)} + \gamma_{\text{car access}}\, I_{(\text{car access}_n=1)} \\ & + \eta_n, \end{aligned} \tag{6}$$

where this makes use of deterministic interactions with four socio-economic indicators, namely gender (female respondent), age (over 45 years), education (university degree) and whether a respondent has regular car access. The additional term η_n is a random disturbance which we assume follows a Normal distribution across respondents ($g(\eta)$), with a zero mean and a standard deviation of σ_α.

To provide further information about the attitudes of given respondents in the model and aid the estimation of the latent component α_n and its role in Equation 4 and Equation 5, we also use this latent variable to explain the answers to the four main attitudinal questions from Figure 2, Q_1 to Q_4, and the question relating to the use of rail for environmental reasons, Q_5. This part of the model is formed from a number of measurement equations. We recognise the ordered nature of Q_1 to Q_4 by making use of an ordered logit structure, in line with recent work by Daly et al. (2012). For the sake of consistency with Q_5, we invert the values for Q_1 to Q_4, such that 1 means strongly disagree and 7 means strongly agree. The new variables are labelled as Q_1^* to Q_4^*, and the likelihood of the observed value Q_{nk}^* is then:

$$L_{Q_{nk}^*} = \sum_{s=1}^{S} I_{\left(Q_{nk}^*=s\right)} \left[\frac{e^{\nu_{k,s}-\zeta_k\alpha_n}}{1+e^{\nu_{k,s}-\zeta_k\alpha_n}} - \frac{e^{\nu_{k,s-1}-\zeta_k\alpha_n}}{1+e^{\nu_{k,s-1}-\zeta_k\alpha_n}} \right] \tag{7}$$

where ζ_k measures the impact of the latent variable α_n on indicator Q_k, and where $\nu_{k,s}$, $s = 0, \ldots, 7$ are a set of estimated threshold parameters. For normalisation, we set $\nu_{k,7}$ to $+\infty$, and $\nu_{k,0}$ to $-\infty$.

The treatment of Q_5 is rather simpler. With a value of 1 equating to agreement with the statement that the respondent has travelled by rail for environmental reasons, we model the likelihood of this indicator as a binary logit, with:

$$L_{Q_{n5}} = I_{(Q_{n5}=0)} \frac{1}{1+e^{\kappa+\zeta_5\alpha_n}} + I_{(Q_{n5}=1)} \frac{e^{\kappa+\zeta_5\alpha_n}}{1+e^{\kappa+\zeta_5\alpha_n}} \quad (8)$$

where κ is a sample level constant for agreement, and ζ_5 is the impact of α_n on the probability of agreement.

Estimation involves maximising the joint likelihood of the observed sequence of choices and the observed answers to the attitudinal questions. Both model components are conditional on a given realisation of the latent variable α_n, and as a result, the log-likelihood function of the model is given by integration over η_n:

$$LL\left(\Omega_V, \Omega_\mu, \Omega_\pi, \Omega_\alpha, \Omega_Q\right) = \sum_{n=1}^{N} \ln \int_{\eta_n} P_n \left(\prod_{k=1}^{4} \left(L^*_{Q_{nk}}\right) \right) L_{Q_{n5}} g\left(\eta_n\right) \mathrm{d}\eta_n. \quad (9)$$

where P_n is as shown in Equation 3, with class allocation probabilities from Equation 4 and Equation 5, $L^*_{Q_{nk}}$ with $k = 1, \ldots, 4$ as in Equation 7 and $L_{Q_{n5}}$ as in Equation 8. The specific dependency of the individual model components in Equation 9 on the various vectors of parameters is not shown explicitly but is clear from the earlier discussions[4].

4 Results

The results for the model are summarised in Table 1, where the estimates are split into the different model components. Regarding the parameters for the utility functions, we see a positive constant for outcomes with reduced greenhouse gas emissions (δ_G) showing that, all else being equal, such alternatives are chosen more often than those offering a reduction in travel times. The shift parameter $\delta_{T,w}$ is positive, suggesting heightened desire for travel time reductions on work journeys, but the estimate is not significant at usual levels of confidence. The four

[4] All model components were estimated simultaneously, with the model being coded in Ox 6.2 (Doornik, 2001).

marginal utility coefficients, two per class, are all positive and highly significant, showing that reductions in greenhouse gas emissions or travel time have a positive impact on the utility of an alternative. The sensitivity to a 1% reduction in travel time is higher than the sensitivity to a 1% reduction in greenhouse gas emissions, where the differences are much larger in the first class (factor of 5.3) than in the second class (1.5).

The estimates for the scale parameters suggest lower error variance for the choice of the second ranked outcome compared to the highest rank - this is a reflection of the decision on which outcome to rank highest often being the difficult choice between the highest time saving and the highest GHG reduction. The scale for choosing the third ranked alternative is substantially lower, while the scale for later choices is again higher than that for the first rank.

The structural equations for the latent variable show a higher value for the latent attitude of female respondents, respondents aged over 45, and respondents with a university degree, while the latent variable is more negative or less positive for respondents who have regular car access. These estimates are in line with expectation when interpreting the latent variable as a pro-environmental attitude. This interpretation is further supported by the negative and highly significant estimate for τ in the class allocation model, which shows that a respondent with a more positive value for the latent attitude is less likely to belong to class 1, i.e. the class with a greater relative desire for time reductions, and consequently is more likely to belong to class 2, i.e. have a higher desire for greenhouse gas emissions than a respondent in class 1.

Looking at the measurement equations, the findings are consistent with those for the choice model component. Indeed, the positive estimates for ζ_1 to ζ_4 show us that a respondent with a more positive value for the latent attitude is more likely to agree[5] with the four questions relating to perceived responsibility and moral obligation to take action to be environmentally friendly, and perceived responsibility and moral obligation to travel by rail to be environmentally friendly. Similarly, a respondent with a more positive value for the latent attitude is more likely to indicate that he/she has travelled by rail for environmental reasons.

Turning to the implied relative sensitivities in Table 2 for the sample population of respondents, the distribution of the relative sensitivity to a 1% reduction in greenhouse gas emissions expressed in terms of a reduction in travel time. This is obtained by calculating $\pi_{n,c_1}\frac{\beta_{G,c_1}}{\beta_{T,c_1}+\delta_{T,w}I_{nw}}+\pi_{n,c_2}\frac{\beta_{G,c_2}}{\beta_{T,c_2}+\delta_{T,w}I_{nw}}$ for each respondent, where the random component α_n used in the class allocation probabilities leads to a distributed ratio. These simulated distributions are then combined across respondents to obtain a sample level distribution. We see that a 1% re-

[5]The scale for these four indicators was reversed for the analysis.

Table 1: Estimation results

Number of individuals:	1,336
Number of observations:	6,680
Log-likelihood (overall):	-12,699.80
Log-likelihood (choice component):	-4,692.34

Utility functions

	est.	t-rat. (0)
δ_G	1.5333	9.61
β_{G,c_1}	0.1317	16.70
β_{G,c_2}	0.2113	27.43
β_{T,c_1}	0.7027	16.47
β_{T,c_2}	0.3261	18.04
$\delta_{T,w}$	0.0125	1.12

Scale parameters

	est.	t-rat. (1)
μ_2	1.7215	6.77
μ_3	0.2698	-20.57
μ_4	2.0483	7.16
μ_5	1.8438	5.91

Latent variable specification

	est.	t-rat. (0)
γ_{female}	0.3284	5.64
$\gamma_{\text{age}>45}$	0.1387	2.28
$\gamma_{\text{univ. degree}}$	0.1182	1.95
$\gamma_{\text{car access}}$	-0.2126	-2.99

Class allocation probabilities

	est.	t-rat. (0)
δ_1	0.3285	3.06
τ	-0.9974	-12.09

Measurement equations

	est.	t-rat. (0)
$\nu_{1,1}$	-5.0499	-19.28
$\nu_{1,2}$	-4.6385	-19.61
$\nu_{1,3}$	-3.8479	-19.31
$\nu_{1,4}$	-2.5510	-15.77
$\nu_{1,5}$	-1.1786	-8.10
$\nu_{1,6}$	0.4716	3.20
ζ_1	1.5564	15.19
$\nu_{2,1}$	-4.5231	-19.74
$\nu_{2,2}$	-3.7006	-18.07
$\nu_{2,3}$	-2.8817	-15.63
$\nu_{2,4}$	-1.7148	-10.14
$\nu_{2,5}$	-0.2454	-1.53
$\nu_{2,6}$	1.3169	7.66
ζ_2	1.7651	16.27
$\nu_{3,1}$	-7.1265	-7.97
$\nu_{3,2}$	-5.4949	-7.14
$\nu_{3,3}$	-3.5728	-5.59
$\nu_{3,4}$	-0.3349	-0.65
$\nu_{3,5}$	3.1767	5.30
$\nu_{1,6}$	7.2472	8.18
ζ_3	6.0164	8.95
$\nu_{4,1}$	-4.8471	-9.62
$\nu_{4,2}$	-3.5824	-7.72
$\nu_{4,3}$	-2.2592	-5.24
$\nu_{4,4}$	0.3700	0.91
$\nu_{4,5}$	3.2673	7.34
$\nu_{4,6}$	6.6083	11.58
ζ_4	4.7188	14.17
κ	-1.6351	-13.12
ζ_5	1.0434	11.72

duction in CO_2 is always valued less highly than a 1% reduction in travel time, although significant variations arise across respondents, as indicated by the standard deviation as well as minimum and maximum values for the ratio, which equate to the extreme values in the two classes.

Table 3 looks at separate socio-economic groups. That female respondents, and respondents with a university degree have a stronger pro-environmental attitude is in line with expectation, while the *a priori* assumptions about an age effect are possibly less strong. Similarly, it is not surprising to see a negative effect for respondents with regular car access. However, each of these parameters, while statistically significant, is small in magnitude when put into the context of a random component η in the latent variable specification that is normally distributed with a mean of zero and a standard deviation of one. Indeed, this means that actual variation in attitudes across respondents is to a large extent not related to measured socio-economic characteristics. In terms of explaining the heterogeneity in the actual choice model, we see a high level of heterogeneity being captured by the latent class specification (noting the differences in coefficients between classes) where the allocation to these classes is to a substantial extent driven by the latent attitude (noting the highly significant estimate for τ). On the other hand, the deterministic shift parameter $\delta_{T,w}$ plays almost no role. This is reflected in Table 3 which shows the aforementioned levels of variation in the relative sensitivities in each of the socio-economic groups, but with only minor differences between groups.

Thus far, we have solely talked about valuations in terms of percentage changes. However, these valuations can also be monetised, albeit with the need for a number of assumptions. With the average UK rail journey length being 40.3km, and the average journey time:length ratio being 1.9km/min, we obtain an average journey time of 21.2mins. With an average CO_2 emission figure of 61g/km, this journey would thus on average produce 0.0024583 tonnes of CO_2, meaning that a 1% saving in CO_2 would equate to 0.000024583 tonnes. The relative sensitivities obtained above can now be used to calculate the implied monetised value of a 1% reduction in CO_2 by using the average UK value of travel time savings of £8.29 per hour (Department for Transport, 2009), on the assumption of transferability of such valuations. If grossing up of marginal changes were acceptable, then these results could be used to calculate valuations for making a journey of 21.2 minutes carbon neutral, giving a mean measure of £1.14, where the average fare a journey of this length can vary widely in the UK, ranging from under £3 to over £10.

Table 2: Distribution of relative sensitivities and implied valuations

	mean	std.dev.	min	max
value of 1% reduction in CO_2 expressed in % reduction in travel time	0.39%	0.09%	0.19%	0.65%
implied willingness for 1% reduction in CO_2 for average length UK rail journey (pence)	1.14p	0.28p	0.56p	1.88p
implied willingness to pay for making average UK rail journey carbon neutral	£1.14	£0.28	£0.56	£1.88

Table 3: Estimates of relative valuation of greenhouse gas reductions and travel time reductions across socio-economic groups

				mean		std.dev.	
gender	age	education	car access	non-work	work	non-work	work
male	< 45	no degree	not regular	0.39%	0.37%	0.09%	0.09%
male	< 45	no degree	regular	0.37%	0.35%	0.09%	0.09%
male	< 45	univ. degree	not regular	0.4%	0.38%	0.1%	0.09%
male	< 45	univ. degree	regular	0.38%	0.36%	0.09%	0.09%
male	≥ 45	no degree	not regular	0.4%	0.39%	0.1%	0.09%
male	≥ 45	no degree	regular	0.38%	0.37%	0.09%	0.09%
male	≥ 45	univ. degree	not regular	0.41%	0.4%	0.1%	0.09%
male	≥ 45	univ. degree	regular	0.39%	0.38%	0.1%	0.09%
female	< 45	no degree	not regular	0.42%	0.4%	0.1%	0.09%
female	< 45	no degree	regular	0.4%	0.38%	0.1%	0.09%
female	< 45	univ. degree	not regular	0.43%	0.41%	0.1%	0.09%
female	< 45	univ. degree	regular	0.41%	0.39%	0.1%	0.09%
female	≥ 45	no degree	not regular	0.43%	0.42%	0.1%	0.09%
female	≥ 45	no degree	regular	0.41%	0.4%	0.1%	0.09%
female	≥ 45	univ. degree	not regular	0.44%	0.43%	0.1%	0.09%
female	≥ 45	univ. degree	regular	0.42%	0.41%	0.1%	0.09%

5 Conclusions

This paper has looked at travellers' relative sensitivities to travel time and greenhouse gas emissions, using trade-offs captured using a stated preference survey carried out in the UK.

Our expectation was that there was substantial scope for variations across respondents in these relative sensitivities, and that these variations could at least to some extent be linked to underlying attitudes towards the environment. To accommodate this heterogeneity and the role of attitudes in explaining it, we made use of a latent class model which allows for two classes of respondents, where the probability of allocating a respondent to a given class is a function of this respondent's attitude towards the environment, which itself is treated as latent and is informed by a measurement model component which explains respondents' answers to a number of attitudinal questions.

The results show that, in a model with two classes, we obtain two substantially different relative valuations to time and greenhouse gas emissions. There is also a small deterministic effect, with higher time sensitivity on work trips, but the random variation plays a bigger impact. The latent variable construct has a major role in explaining the allocation to the two classes, as well as the answers to the attitudinal questions. Female respondents, older respondents, and respondents with a university degree, have a more positive attitude towards the environment, with the opposite applying to respondents with regular car access. Respondents with a more positive latent attitude are more likely to fall into the class with higher sensitivity to greenhouse gas emissions, while they are also likely to express more environmentally friendly views in their answers to attitudinal questions and questions about rail use.

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