The Role of Environmental Attitudes in Emissions Charging and Vehicle Selection

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Abstract

Many of the environmental problems that are both real and sensitive community issues stem from the use of transport infrastructure by passenger and freight vehicles, which are not only a source of congestion, but a source of local pollutants such as lead, carbon monoxide and noise. While there has been extensive literature on the concept of congestion charging and the economic arguments have been known for decades, there have been very few studies that explore road pricing as a function of vehicle emissions. Moreover, a growing global focus on environmental concerns in particular the role of carbon emissions in global warming, has created a social atmosphere where attitudes towards the environment are a pre-eminent focus of news media. In stated choice experiments, such attitudes play a key role in determining willingness to pay measures. This paper, using advanced choice modelling techniques, not only examines the role of vehicle emissions charging but also explores how divergent attitudes towards the environment influences motor vehicle choice, in particular how they impact upon sensitivities to vehicle emissions charging regimes.

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1. Introduction

Pricing for road and vehicle use is not new. Fuel taxes, licence fees, car registration, parking taxes, tolls and congestion charges have existed for many years. Revenue obtained from such charges has typically been hypothecated to fund new transport infrastructure projects and to pay for the maintenance of existing transport infrastructure, with such funding arrangements representing one of the often stated objectives of road and vehicle charges (Litman 2007).

Given the negative externalities that exist with road use such as traffic congestion and pollution, several cities around the world have instituted charging regimes with the stated goal of congestion relief. In Singapore the implementation and subsequent development of the Area Licensing Scheme resulted in traffic volume into the restricted zone being reduced in excess of 30 percent despite increases in population and vehicle ownership over the period 1975 to 1988 (Keong 2002). In London, the introduction of the western extension of the Congestion Charge Zone resulted in a decrease of cars and cabs in the cordoned zone by approximately 21 percent in 2007 (compared to the 2005/06 pre charging conditions), with significant increases in public transport usage within the area (TFL 2008).

The observed traffic reduction in response to these schemes has resulted in growing interest in such policies, in particular what can be done to reduce externalities of traffic congestion whilst at the same time avoiding a political backlash (Hensher and Puckett 2007). Concurrently, a growing global focus on environmental concerns, in particular the role of carbon emissions in global warming, has meant that the fuel efficiency and pollution outputs of motor vehicles is becoming increasingly scrutinized, much more so than ever before. Many of the environmental problems, both real and perceived, stem from the use of transport infrastructure by passenger and freight vehicles, which are a source of local pollutants such as zinc, copper, lead, carbon monoxide and noise (Hensher and Button 2003). Accordingly, there has been a greater call for the better integration of policy with respect to a charging scheme to reduce CO_2 and local air pollution (Begg and Gray 2004).

One of the first variable pricing schemes specifically linked to pollution outcomes was launched in Milan in 2008. The stated objectives of the charging scheme are to reduce the number of vehicles entering the urban area by 30 percent, reduce primary emissions from traffic and transportation by 25 percent, and to promote more obsolete vehicles being excluded from the fleet (Croci 2007). Such environmental goals are not unrealistic, as the incidental impact of congestion charging in London meant that reduced traffic flows created positive environmental benefits. Compared to 2002 levels, as a result of the initial charging scheme implemented in 2003 NO_X emissions in the charging zone were reduced by approximately 12.0 percent, PM_{10} emissions were reduced by approximately 11.9 percent, and there was a reduction in CO_2 emissions of 19.5 percent. This evidence suggests that the congestion charging schemes could assist in attaining targets on air pollution as well as those relating to climate change (Beevers and Carslaw 2005).

In Australia, motor vehicles remain a major cause of air pollution in urban areas, with cars contributing 41.9 million tonnes of carbon dioxide or equivalent greenhouse gases, approximately eight percent of total national emissions in 2007, with trucks and light commercial vehicles contributing a further 19.0 million tonnes. Together, these represent 13 percent of Australia's total emissions, and since 1990 this figure has increased by 26.9 percent (Australian Greenhouse Office 2009). A recent Australian government report predicts that with no carbon price in place, transport emissions will nearly quadruple by 2100, but acknowledges that higher oil prices and an emissions price will increase the price of petroleum-based fuels, potentially lowering demand for them (Garnaut 2008). With the growing interest in examining the link between travel behaviour and climate change, this paper explores the role that that an emissions based charging scheme might play in the formation of preferences for automobile choice.

However, many practitioners believe that individuals tend to overstate their economic valuation of a good by a factor of two or three in the context of stated preference surveys (Murphy et al. 2005). Such deviation from real market evidence is referred to in the literature as hypothetical bias, named such as the bias originates from the hypothetical nature of many stated preference techniques in both the payment for and presence of the attribute in question. While the majority of studies indicate an over-representation of willingness to pay, the impact of hypothetical bias is inconsistent: List and Gallet (2001) indicate that the magnitude of hypothetical bias was statistically less for willingness-to-pay as compared to willingness-to-accept applications; Wardman (2001) and Brownstown and Small (2005) found willingness-to-pay values derived in the stated preference experience were in fact undervalued in comparison to the results from revealed preference studies; and Carlsson and Martinsson (2001) and Lusk and Schroeder (2004) found no evidence of differences in willingness-to-pay values between hypothetical and actual choice experiments.

Whilst efforts to study the influence of hypothetical bias have been confined largely, but not exclusively, to agricultural and resource applications, there has been a growing recognition of this phenomenon within transport related literature. Hensher (2010) provides a detailed overview of differences obtained between willingness-to-pay values from different survey methodologies and offers potential strategies to more closely align stated preference surveys to real market activity, but while econometric theory can partially explain this phenomenon, psychological explanations are equally as important in explaining the divergence between real and experimental valuations, particularly in the context of environmental attributes.

In many of the environmental applications of stated preference methods, the hypothetical facet of the experiment entails the loss of some right, privilege or possession that may have been in the ownership of the individual for some time (for instance the imposition of an emissions charge in this study represents a hereto unexperienced cost on the otherwise “free use” of an individuals motor vehicle). In such experiments, the prospect of losing some object or right after it has been possessed for an extended period of time represents a loss, may incentivise respondents to engage in strategically biased behaviour that is dependent on their attitudes and beliefs with respect to the loss to ensure such a policy is not viable. The converse is also true, in that individuals expressing high levels of environmental concern and pro-environment attitudes often display behaviours and actions that have low levels of congruency with their expressed views (Olli et al. 2001), with several studies providing empirical evidence of unreasonably large willingness to pay valuations obtained where the purpose of the study is transparent and/or contentious and the likelihood of paying for the improvement is small (Wardman and Whelan 2001; Wardman and Shires 2003).

A growing global focus on environmental concerns, in particular the role of carbon emissions in global warming, has created a social atmosphere where attitudes towards the environment are a pre-eminent focus of news media. The growing interest in examining the link between travel behaviour and climate change in conjunction with the biases that my exist with respect to an individual’s behaviour has formed the motivation for this research. Using advanced choice modelling techniques this paper not only examines the role of vehicle emissions charging but also explores how divergent attitudes towards the environment influences motor vehicle choice, in particular how they impact upon willingness to pay for vehicle emissions.

The remainder of the paper is structured as follows. In the following section a review of the development of the stated preference survey is given, with particular reference to the vehicle surcharge component of the study. Section 3 provides a brief overview of the empirical methods employed in the analysis of the survey data. Section 4 describes the general characteristics of the data under analysis and discusses the results of the empirical modelling. Finally, Section 5 provides discussion and concluding remarks, highlighting directions of future research.

2. Methodology

2.1. Development of the Survey

Extensive thought was given to the focus of the study, given the growing social and political interest in identifying possible ways to reduce emissions from automobile ownership and use. It was decided that an ability to establish the elasticity of demand for low emitting vehicles with respect to a CO_2 emission charge per kilometre or per annum per vehicle was of fundamental interest in this context.

The choice set of interest was narrowed down to fuel type alternatives - petrol, diesel or hybrid. It was deemed that a labelled choice experiment was most appropriate for this research given the interest in estimating alternative-specific effects for each of the fuel types, as well as the calculation of market shares and demand elasticities. Numerous sources (e.g., Australian Emissions Trading Scheme workshop on June 27, 2007 in Sydney) have expressed uncertainty about which fuels will be commercially viable in the future. As such, in the choice experiment, the hybrid alternative will not be referred to with respect to a specific fuel type, since the focus is on establishing the influence of various pricing and performance and emission regimes regardless of what the fuel is. The hybrid alternative will simply reflect a vehicle option that is cleaner with respect to emission levels.

Following the specification of the alternatives, consideration was given to the selection of attributes to use within the SCE. Nine attributes were included in the experiment, which were identified via a review of the available literature on vehicle purchasing, as well as through preliminary analysis of secondary data sources. The typical monetary costs involved in purchasing and operating a car were included in the design. These included purchase price of the vehicle, the fuel price and the cost of registration (including compulsory third party insurance). In the experiment, fuel efficiency is an important attribute given that this attribute represents the link to which level of emissions surcharge will be set. The remaining attributes, seating capacity, engine size and country of manufacture, were selected so as to give respondents a realistic and well varied set of alternatives such that cars of differing types could be evaluated and traded against within the experiment. Table 1 displays the levels that have been selected for each attribute. Note that the purchase price for the hybrid alternative is $3,000 more at each level in order to recognise that hybrid technology is currently more expensive than conventional fuel engines.

Table 1: Attribute Levels for Stated Choice Experiment

	Levels	1	2	3	4	5
Purchase Price	*Small*	$15,000	$18,750	$22,500	$26,250	$30,000
	Small Luxury	$30,000	$33,750	$37,500	$41,250	$45,000
	Medium	$30,000	$35,000	$40,000	$45,000	$50,000
	Medium Luxury	$70,000	$77,500	$85,000	$92,500	$100,000
	Large	$40,000	$47,500	$55,000	$62,500	$70,000
	Large Luxury	$90,000	$100,000	$110,000	$120,000	$130,000
Fuel Price	*Pivot off daily price*	-25%	-10%	0%	10%	25%
Registration	*Pivot off actual purchase*	-25%	-10%	0%	10%	25%
Annual Emissions Charge	*Pivot off fuel efficiency*	Random allocation of one of five levels (see Table Two)				
Variable Emissions Charge	*Pivot off fuel efficiency*	Random allocation of one of five levels (see Table Three)				
Fuel Efficiency (L / 100km)	*Small*	6	7	8	9	10
	Medium	7	9	11	13	15
	Large	7	9	11	13	15
Engine Capacity (cylinders)	*Small*	4	6			
	Medium	4	6			
	Large	6	8			
Seating Capacity	*Small*	2	4			
	Medium	4	5			
	Large	5	6			
Country of Manufacture	*Random Allocation*	Japan	Europe	South Korea	Australia	USA

Two attributes requiring particular attention relate to the mechanism via which vehicle emissions charges will be implemented. We test two approaches, a surcharge that is paid annually, and a variable charge that is a function of how much the vehicle is used. Both charges are a function of a vehicle's fuel efficiency given that improved fuel economy is strongly associated with lower levels of vehicle emissions. In this study, it is conceptualised that the annual emissions surcharge will be an additional cost at the point of vehicle purchase, with the desire to minimise this cost resulting in the choice of a more fuel efficient vehicle. The variable cost will then act as a modifier of behaviour, determining how much a chosen vehicle is used. In short, the annual surcharge is hypothesised to be the key environmental driver of vehicle choice, while the variable charge is the key driver of vehicle use.

Using an annual surcharge to encourage use of more efficient vehicles is not new. For example Treasury in the United Kingdom introduced an annual vehicle registration tax in 2009 that is graduated for vehicles in various polluting categories. The annual surcharge applied in this study was established with reference to the percentage increases in annual registration costs in the England taxation structure. With respect to the variable surcharge, it has been estimated that reductions in fuel consumption of two and a half percent within one year and six percent in the longer run are associated with a ten percent increase in fuel prices (Goodwin et al. 2004). It should be noted that the higher the oil price, the lower the emissions price will need to be to make the transition to lower-emissions options competitive. Pivoting off the current price of fuel at the time of the survey development, this information helped to determine the variable surcharge levels.

Tables 2 and 3 show the levels chosen for the annual and variable surcharges. Both of the surcharges are determined by the type of fuel a vehicle uses and the fuel efficiency of that vehicle. For a given vehicle, if it is fuelled by petrol, a purchaser would pay a higher surcharge than if it was fuelled by diesel, which is in turn more expensive than if it was a hybrid. Once the car has been specified in terms of fuel type and efficiency, there are five levels of surcharge that could be applied.

Table 2: Levels for Annual Emissions Surcharge ($)

Petrol		Fuel Efficiency (litres used per 100km)									
		6	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Level	**1**	0	0	0	0	0	0	0	0	0	0
	2	90	105	120	135	150	165	180	195	210	225
	3	180	210	240	270	300	330	360	390	420	450
	4	270	315	360	405	450	495	540	585	630	675
	5	360	420	480	540	600	660	720	780	840	900

Diesel		Fuel Efficiency (litres used per 100km)									
		6	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Level	**1**	0	0	0	0	0	0	0	0	0	0
	2	75	87.5	100	112.5	125	137.5	150	162.5	175	187.5
	3	150	175	200	225	250	275	300	325	350	375
	4	225	262.5	300	337.5	375	412.5	450	487.5	525	562.5
	5	300	350	400	450	500	550	600	650	700	750

Table 3: Levels for Variable Emissions Surcharge

Petrol		Fuel Efficiency (litres used per 100km)									
		6	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Level	**1**	0	0	0	0	0	0	0	0	0	0
	2	0.06	0.07	0.08	0.09	0.10	0.11	0.12	0.13	0.14	0.15
	3	0.12	0.14	0.16	0.18	0.20	0.22	0.24	0.26	0.28	0.30
	4	0.18	0.21	0.24	0.27	0.30	0.33	0.36	0.39	0.42	0.45
	5	0.24	0.28	0.32	0.36	0.40	0.44	0.48	0.52	0.56	0.60

Diesel		Fuel Efficiency (litres used per 100km)									
		6	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Level	**1**	0	0	0	0	0	0	0	0	0	0
	2	0.05	0.06	0.07	0.08	0.09	0.09	0.10	0.11	0.12	0.13
	3	0.10	0.12	0.14	0.15	0.17	0.19	0.20	0.22	0.24	0.26
	4	0.15	0.18	0.2	0.23	0.26	0.28	0.31	0.33	0.36	0.38
	5	0.20	0.24	0.27	0.31	0.34	0.37	0.41	0.44	0.48	0.51

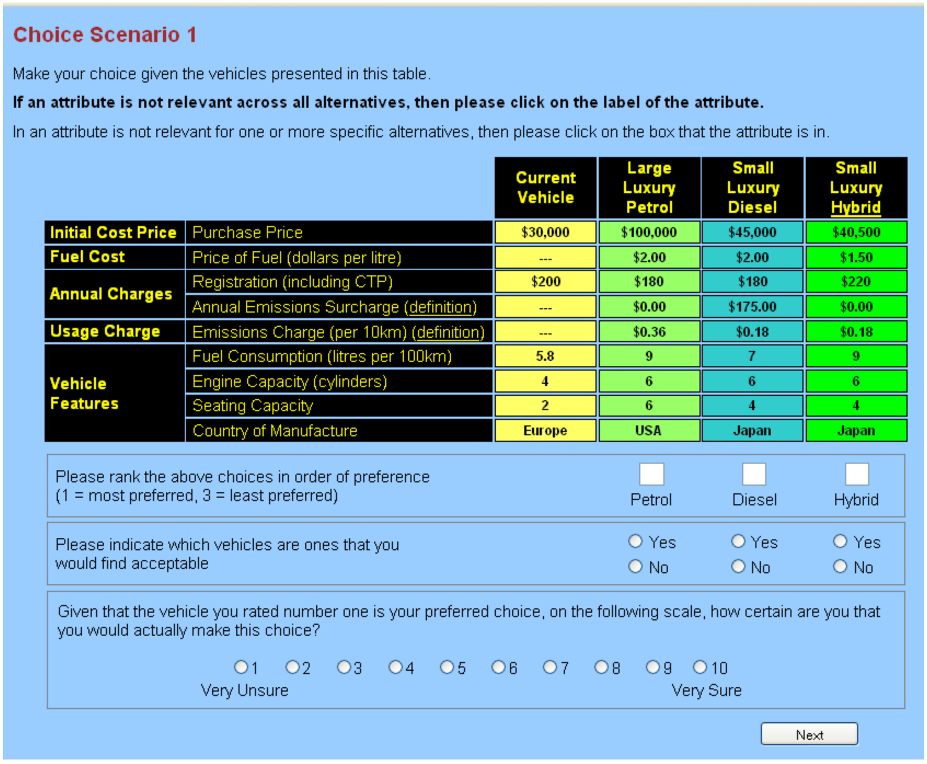
2.2. Experimental Design

In establishing the choice profiles shown to respondents a D-efficient design was used (Rose and Bleimer 2008). A reference alternative is included in the experimental design to add to the relevance and comprehension for the attribute levels being assessed by the individual respondents (see Rose et al. 2008) and can be used to reduce hypothetical bias in stated preference surveys (Hensher 2010). In the process of designing the experiment, there were a number of conditions on the interaction of the attributes and alternatives, complicating the design process. First, the annual and variable surcharge that is applied to an alternative is conditional on the type of fuel used and the fuel efficiency of the vehicle in question. Second, if the reference alternative is petrol (diesel), the petrol (diesel) fuelled alternative must have the same fuel price as the reference alternative. Third, the annual and variable surcharge for the hybrid alternative cannot be higher than that of another vehicle when the alternative vehicle has the same fuel efficiency rating or is more inefficient than the hybrid. Finally, to ensure that respondents faced a realistic choice set, given the size of the reference alternative, one of the remaining alternatives was randomly selected and restricted to be the same size as the reference, another was allowed to vary plus/minus one body size, and the third was allowed to vary freely.

2.3. Stated Preference Task

Respondents were either individual decision makers or part of a decision making dyad. Individual respondents completed eight choice sets, whereas paired respondents independently completed four choice sets. Each choice set contained three alternatives described by all of the attributes listed in Table 1, and respondents were asked to rank their selections from most preferred to least preferred. An example of the choice screen is shown in Figure 1.

Figure 1: Stated Preference Task



2.4. Attitudinal and Demographic Information

In addition to the choice observations, pertinent demographic information was collected in order to aid in the decomposition of preference structures. Age, gender, employment status, number of hours worked in a typical week, annual income, the number of years a driver's license has been held, the average number of kilometres driven per week, and the number of children in the household was collected. Additional to this, information was collected on the attitudes that respondents held towards global warming, emissions charging and the role of the motor vehicle.

Developed via in-depth interviews and refined via two pilot studies, seven attitudinal questions were deemed relevant to respondents with respect to emissions charging. Asked on a seven-point Likert scale (where 1 equals *Strongly Disagree*, 4 equals *Neutral* and 7 equals *Strongly Agree*) the questions are as follows:

(em1) Climate change important issue

(em2) Vehicles are a main cause of climate change

(em3) People should be encouraged to use environmentally friend transport

(em4) The Government should implement carbon reduction policies

(em5) Drivers of high CO2 cars should pay more

(em6) Vehicle emissions charge is fair to all road users

(em7) A vehicle emissions charge is effective way to reduce vehicle based CO2

2.5. Survey Deployment

The data was collected over a four month period in the second half of 2009. An eligible respondent had to have purchased a brand new vehicle in either 2007, 2008 or 2009, ensuring that they would be familiar with the processes involved in purchasing a new vehicle. Respondents were sourced from a purchased list of recent car buyers, a panel of people who had agreed to be contacted for focus groups or other research by the survey firm, and an external research panel. The survey was completed online at a central location varied throughout the Sydney metropolitan area in order to minimise travel distance for respondents and trained interviewers were present to offer assistance or provide clarification should the respondent need it. A total of 401 individual and paired surveys were completed. The final sample used in model estimation herein comprises 3,172 choice observations from 650 respondents, noting that each respondent participating in the paired choice also participated in an individual choice task independently of each other.

3. Empirical Methods

The models presented in this paper were estimated using mixed multinomial logit and latent class models. Since Greene and Hensher (2003) provide detailed and rigorous description of both these model classes, here we provide only a brief introduction to these two models.

3.1. Mixed Multinomial Logit Model

The mixed multinomial logit model is an advanced type of discrete choice model in which the sensitivities to explanatory variables are allowed to vary randomly across respondents following a pre-specified distribution with estimated parameters, allowing for a heightened level of flexibility. Additionally, the model can also recognise the panel nature of SP data directly in estimation. The model is a generalisation of the multinomial logit model, expressed as:

$$P_{iqt} = \frac{\exp(\alpha' + \beta' X_{iqt} + \sigma' F_{iqt})}{\sum_{j=1}^{J} \exp(\alpha' + \beta' X_{jqt} + \sigma' F_{jqt})} \qquad (1)$$

Where:

α' is a vector of fixed or random alternative specific constants associated with *J - 1* alternatives and *Q* individuals
β' is a parameter vector that is randomly distributed across individuals
X_{iqt} is a vector of individual specific characteristics and alternative specific attributes at observation *t*.
σ' is a vector of non-random parameters
F_{iqt} is a vector of individual specific characteristics and alternative specific attributes at observation *t*.

In this specification, either a subset or all of α' and the parameters in the β' vector can be assumed to be randomly distributed across individuals.

3.2. Latent Class Model

The latent class model assumes that a discrete number of classes are sufficient to account for preference heterogeneity across classes. Therefore, the unobserved heterogeneity is captured by these latent classes in the population, each of which is associated with a different parameter vector in the corresponding utility. The choice probability that an individual *q* of class s chooses alternative *i* from a particular set *J*, which comprises *j* alternatives, is expressed as:

$$P_{iq|s} = \frac{\exp(\beta'_s X_{iq})}{\sum_{j=1}^{J} \exp(\beta'_s X_{jq})} \qquad (2)$$

Where:

s = 1, …, *S*
β'_s is a parameter vector associated with the explanatory variables X_{iq}
Note that this equation is a multinomial logit within class *s*

Additionally, one can construct a classification model as a function of some individual-specific attributes to explain the heterogeneity across classes. The LCM model simultaneously estimates (2) for *S* classes and predicts the probability H_{qs} as individual q being in class s. Then, the unconditional probability of choosing the alternative i is given as:

$$P_{iq} = \sum_{s=1}^{S} P_{iq|s} H_{qs} \qquad (3)$$

4. Empirical Results

4.1. Descriptive Statistics

In terms of the socioeconomic profile of the sample, 51 percent are female and 49 percent are male, the average age of respondents is 46.2 years, who work an average of 30.4 hours per week in mostly a fulltime (58%) or part time (17%) capacity, with an average personal income of between $50,000 and $60,000 per annum. 99 percent of respondents hold a drivers license and have done so for an average of 26.2 years.

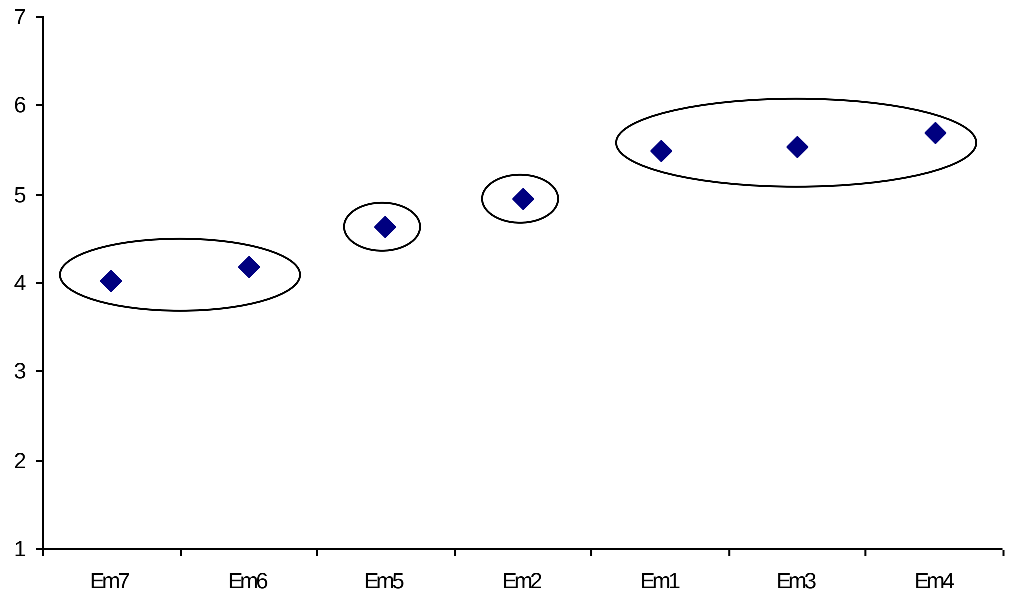
Table 4 summarises the descriptive statistics of the attribute levels for the recent purchase in conjunction with the levels for the chosen alternatives. Petrol is the fuel type that dominates the most recently purchased vehicle. Within the choice task however, the spread of fuel types selected is more uniform, indicating that consumers are not rigid in their preference for fuel type, and that the incentives included in the experience to test switching might have been successful. Similarly, engine capacity has a greater spread for the chosen alternative, compared to the recent purchase where it is dominated by four cylinder vehicles. However, it is worth noting that we allowed engine capacity and fuel efficiency to vary randomly so that any future technological advances in engine efficiency would not be absent in the composition of the experiment. The difference in the seating capacity attribute reveals that individuals may be opting into smaller vehicles in the choice task compared to their most recent purchase, perhaps in response to the charges applied. It is also worth noting that the average price of the chosen alternative is approximately $10,000 more than the current vehicle, indicating that individuals are theoretically prepared to pay more for vehicles of a different, more efficient and less expensive fuel source, given the attributes presented in the choice task.

Table 4: Descriptive Statistics – Recent Purchase and Chosen Alternative

Attribute		Recent Purchase	Chosen Alternative
Size of Vehicle	*Small*	42%	43%
	Medium	25%	30%
	Large	34%	27%
Fuel Type	*Petrol*	93%	39%
	Diesel	7%	26%
	Hybrid	--	36%
Engine Capacity (cyl)	*4*	76%	42%
	6	21%	46%
	8	3%	12%
Seating Capacity	*2*	6%	20%
	4	12%	40%
	5	72%	24%
	6 or more	9%	16%
Country of Manufacture	*Japan*	36%	20%
	Europe	45%	22%
	South Korea	10%	22%
	Australia	8%	18%
	USA	1%	18%
Purchase Price		$32,245 ($14,963)	$44,300 ($23,700)
Fuel Price		$1.22 ($0.07)	$1.22 ($0.22)
Registration		$856.51 ($468.19)	$863.89 ($497.67)
Annual Emissions Charge		--	$202.80 ($198.00)
Variable Emissions Charge		--	$0.15 ($0.14)
Fuel Efficiency (l/100km)		8.9 (2.0)	9.7 (2.8)

With respect to attitudes to the environment and vehicle emissions, significant differences were found between the mean responses for the question (F_6=108.828). Figure 2 presents the mean value for each question. Post-hoc analysis via Tukey HSD was used to examine were attitudinal strength differed. Circled means on Figure 2 indicate homogenous levels of agreement with the statements, responses in separate circles indicate significant mean differences.

Figure 2: Attitudinal Question Mean Values in Homogenous Subsets



On average, respondents were neutral in their attitudes towards vehicle emissions charging being fair to all road users, and that it is an effective way to reduce vehicle based CO_2.They were significantly more agreeing to the statement that drivers of higher CO_2 emitting cars should pay more, and again more in agreement with the statement that vehicles are a main cause of climate change. Lastly, the average respondent was significantly more likely to agree that climate change is an important issue, that people should be encouraged to use more environmentally friendly transit, and that the Government should implement carbon reduction policies - unsurprising in Australia given the level of general support for a carbon pollution reduction scheme.[1]

These results point towards a general level of agreement with climate change being an issue, and that initiatives that mitigate its effects need to be explored. In turn, an a priori expectation is that there would be positive attitudes towards government action against climate change, and thus an over-estimation bias with respect to willingness to pay measures to reduce carbon emissions, using similar rationale to Wardman and Whelan (2001) and Wardman and Shires (2003).

[1] A Nielsen poll published in Fairfax newspapers on the 8th of February 2010 indicated that support for an emissions trading scheme proposal, while at 66 percent in 2009, was now at 56 percent. Whilst the number has fallen, the impact of the global financial crisis and the lack of international consensus on the issue have seen many Australians become more apprehensive about the scheme.

4.2. Stated Preference Analysis

4.2.1. Mixed Multinomial Logit

To establish if preference heterogeneity in the choice behaviour of respondents with respect to vehicle selection is significant a mixed multinomial logit model was used, the results of which are presented in Table 5. All random parameters are estimated using a panel specification with normal distributions employing 200 Halton draws with correlations amongst the set of random parameters allowed. Examination of the estimates reveals that all the design attributes are significant and that the means of the distributions are of the expected signs and the majority of the attributes exhibit significant preference heterogeneity. The negative coefficients for annual and variable surcharges as well as fuel efficiency suggest that, in the context of the choice experiment where emissions charging is present, more fuel efficient vehicles are preferred. This result alone suggests that emissions' charging is a viable method of affecting choice behaviour with respect to encouraging more environmentally friendly vehicles. The relatively large standard deviation parameter for variable emissions surcharging indicates distinct preference heterogeneity, with variable surcharging generating much greater disutility for some respondents compared to others. It is most likely that the sensitivity to this attribute is a function of the amount of vehicle use engaged by the respondent and the purpose of that use. It should also be noted that vehicle use also conditions the choice of vehicle given the link of usage cost to fuel efficiency and fuel prices in particular.

On average, less engine cylinders are preferred though there is significant preference heterogeneity. In general terms, the efficiency of an engine is often related to the size of that engine, however it should be noted that no strict relationship was implied in the attribute specifications for this study and, as shown in Table 6, the correlation coefficient between the random parameter estimates of engine cylinders and fuel efficiency is small. Rather, engine size and fuel efficiency were allowed to vary randomly and independently within a given sensible range, in order to allow for hypothetical choice sets in which alternatives exist given future technological improvements that facilitate gains in fuel efficiency regardless of engine size.

Table 5: Summary of MMNL Model Results

(MNL model findings are available on request)
200 Halton draws, with panel structure accommodated

	Par.	(*t*-ratio)
Random Parameters		
Vehicle price (mean)	-0.049	(-16.71)
Vehicle price (std dev.)	0.033	(9.00)
Fuel price (mean)	-0.775	(-4.97)
Fuel price (std dev.)	1.091	(3.18)
Annual surcharge (mean)	-0.001	(-5.64)
Annual surcharge (std dev.)	0.002	(3.88)
Variable surcharge (mean)	-0.722	(-2.53)
Variable surcharge (std dev.)	1.782	(2.21)
Fuel efficiency (mean)	-0.049	(-3.21)
Fuel efficiency (std dev.)	0.105	(1.84)
Engine cylinders (mean)	-0.065	(-2.14)
Engine cylinders (std dev.)	0.241	(3.55)
Seating capacity (mean)	0.349	(7.93)
Seating capacity (std dev.)	0.533	(3.56)
Non Random Parameters		
Registration	-0.001	(-3.04)
South Korean	-0.223	(-2.84)
Constant for Petrol Alternative	0.272	(2.87)
Constant for Diesel Alternative	-0.340	(-3.52)
Cholesky Matrix: Diagonal Values		
Vehicle price	0.033	(9.00)
Fuel price	0.967	(2.63)
Annual surcharge	0.001	(1.96)
Variable surcharge	1.434	(1.91)
Fuel efficiency	0.018	(0.26)
Engine cylinders	0.150	(0.89)
Seating capacity	0.256	(1.47)

	Par.	(*t*-ratio)
Cholesky Matrix: Below Diagonal Values		
Fuel price : Vehicle price	0.507	(1.95)
Annual surcharge : Vehicle price	0.001	(2.70)
Annual surcharge : Fuel price	0.001	(1.49)
Variable surcharge : Vehicle price	-0.110	(-0.25)
Variable surcharge : Fuel price	1.052	(1.40)
Variable surcharge : Annual surcharge	-0.009	(-0.01)
Fuel efficiency : Vehicle price	0.028	(0.94)
Fuel efficiency : Fuel price	0.030	(0.78)
Fuel efficiency : Annual surcharge	-0.050	(-0.88)
Fuel efficiency : Variable surcharge	0.080	(1.56)
Engine cylinders : Vehicle price	0.013	(0.26)
Engine cylinders : Fuel price	0.035	(0.41)
Engine cylinders : Annual surcharge	-0.029	(-0.27)
Engine cylinders : Variable surcharge	-0.065	(-0.59)
Engine cylinders : Fuel efficiency	-0.171	(-1.30)
Seating capacity : Vehicle price	-0.113	(-1.48)
Seating capacity : Fuel price	0.055	(0.42)
Seating capacity : Annual surcharge	-0.231	(-1.42)
Seating capacity : Variable surcharge	0.261	(1.71)
Seating capacity : Fuel efficiency	0.143	(0.70)
Seating capacity : Engine cylinders	0.248	(1.21)
Error Components		
Petrol & Diesel alternatives	1.385	(12.76)
Hybrid alternative	0.483	(1.01)
Model Fits		
LL(0)	-3484.798	
LL(β)	-2904.163	
$\rho(0)$	0.167	
Adj. $\rho(0)$	0.163	
Number of Respondents	650	
Number of Observations	3172	

Table 6: Estimated Correlations of Random Parameter Distributions

	Price	Fuel price	Annual surcharge	Variable surcharge	Fuel efficiency	Engine cylinders	Seating capacity
Vehicle price	1	0.464	0.524	-0.062	0.267	0.055	-0.212
Fuel price	0.464	1	0.711	0.494	0.378	0.153	-0.007
Annual surcharge	0.524	0.711	1	0.276	-0.029	0.025	-0.346
Variable surcharge	-0.062	0.494	0.276	1	0.773	-0.135	0.47
Fuel efficiency	0.267	0.378	-0.029	0.773	1	-0.213	0.601
Engine cylinders	0.055	0.153	0.025	-0.135	-0.213	1	0.022
Seating capacity	-0.212	-0.007	-0.346	0.47	0.601	0.022	1

Among the non-random parameters, registration is of the expected sign (negative), while vehicles manufactured in South Korea generate significant disutility. The constants indicate that after accounting for the observed attributes, on average petrol is the preferred fuel type, followed by hybrid technologies, with diesel being the least preferred of the three. This is an interesting result given the mean estimates for design attributes intimate a preference for greater fuel efficiency and alternatives that have lower annual and variable emissions surcharges, and that diesel engines tend to be more efficient than petrol alternatives and, across the light, medium and heavy vehicle segments of the passenger fleet, they have lower carbon dioxide emissions (Graham et al. 2008). This disconnect is most likely a function of the potential image that respondents have of diesel in Australia. Specifically, diesel has not been common in cars rather the domain of trucks, buses and other heavy machinery. industrial purposes, making it likely that diesel is perceived as a “dirtier” fuel when compared to petrol. The data collection method employed in this study will enable future research to be conducted on why respondents found certain alternatives to be unacceptable and thus answer these questions. In general, these results show a willingness to consider hybrid technologies, especially in light of the fact that a hybrid vehicle was chosen in 36 percent of choice sets.

4.2.2. Latent Class Model

The latent class model, unlike the mixed multinomial logit which specifies the random parameters to follow a continuous joint distribution, assumes that a discrete number of classes are sufficient to account for preference heterogeneity across classes. Therefore, the unobserved heterogeneity is captured by these latent classes in the population, each of which is associated with a different parameter vector in the corresponding utility function. Consequently, being able to link taste heterogeneity to socio-demographic indicators rather than simply knowing that a given sensitivity follows a certain (assumed) random distribution in the sample population, is not only useful for the analysis of taste heterogeneity but can also provide significant advantages in forecasting (Hess et al. 2009).

Specifying the number of classes is an iterative process, whereby successive models incorporating different number of classes in conjunction with the refinement of the class specific parameters, such that the Akaike Information Criteria (AIC) and Consistent AIC (CAIC) are minimised (Louviere et al. 2000). Consideration should also be given to the application of the model, making sure that the number of classes specified is meaningful and practicable. Using the results reported in Table 7, in conjunction with the interpretability of the model results themselves, it was decided that four classes would be the optimal number within this data. Table 8 presents the latent class model results.

Table 7: Class Selection Criteria

Classes	2	3	4	5
LL	-2955.857	-2816.718	-2745.445	-2758.730
BIC	1.968	1.935	1.947	2.011
AIC	1.898	1.824	1.793	1.815
CAIC	5748.312	5412.843	5213.106	5182.485

Table 8: Summary of LCM Model Results

Class Specific Parameters	Class 1		Class 2		Class 3		Class 4	
	Par.	**(*t*-ratio)**	**Par.**	**(*t*-ratio)**	**Par.**	**(*t*-ratio)**	**Par.**	**(*t*-ratio)**
Petrol Constant	0.033	0.401	-0.358	-2.161	-1.057	-9.243	2.232	14.590
Diesel Constant	0.467	6.391	-0.793	-4.812	-1.913	-14.472	-0.289	-1.674
Price	-0.023	-14.896	-0.100	-10.096	-0.026	-9.616	-0.025	-7.485
Fuel Price	-0.354	-2.369	-1.368	-4.267	0.013	0.047	-0.965	-2.890
Registration	0.000	-2.427	-0.001	-2.519	0.000	-0.170	0.000	-1.129
Fuel Efficiency	0.029	2.130	-0.131	-3.935	-0.091	-4.096	-0.038	-1.358
Engine Capacity	-0.072	-2.743	-0.045	-0.764	-0.130	-3.009	-0.159	-2.795
Seating Capacity	0.531	13.989	0.200	2.423	0.189	3.744	0.063	0.879
Japanese	0.164	1.697	0.493	2.172	-0.572	-3.492	0.717	3.416
European	0.107	1.098	0.560	2.645	-0.534	-3.132	0.792	3.852
South Korean	-0.345	-3.291	0.527	2.376	-0.519	-3.354	0.126	0.639
American	0.055	0.538	0.108	0.462	-0.161	-0.965	0.629	3.012
Variable Surcharge	-1.231	-4.831	-0.356	-0.587	-1.097	-2.512	0.473	0.889
Annual Surcharge	-0.001	-4.765	-0.001	-2.705	-0.003	-7.430	0.000	-0.084
Class Probabilities	***36%***		***31%***		***13%***		***21%***	

Class Assignment Parameters	Class 2		Class 3		Class 4	
	Par.	**(*t*-ratio)**	**Par.**	**(*t*-ratio)**	**Par.**	**(*t*-ratio)**
Constant	-2.247	-2.254	-4.614	-3.279	-1.375	-1.447
Age	0.014	1.125	0.022	1.486	0.043	3.050
Em1	-0.252	-1.942	0.131	0.817	-0.182	-1.496
Em2	0.543	3.725	0.240	1.762	0.437	3.402
Em3	-0.020	-0.129	0.109	0.565	-0.392	-2.797
Em5	0.188	1.711	0.293	2.283	-0.074	-0.665
Em7	-0.120	-1.193	-0.244	-2.227	-0.030	-0.271
No. Children	0.001	0.296	-0.003	-0.817	-0.009	-2.552

As indicated in Table 7, there are four discrete classes within the sample, with each class having different sensitivities to the attributes in the vehicle choice task. This is unsurprising given the level of taste heterogeneity across the attributes exhibited in the mixed multinomial logit model. Significantly, five of the seven emissions attitude questions play a significant role in assigning individual respondents to one of the four underlying classes. Age of the respondent and the number of children in the household are the only demographic roles significant in discriminating between classes.

Defining each class in terms of their different preferences is done with respect to the size and significance of the class specific parameters. To determine the characteristics of each class, the class assignment parameters are used, and interpreted relative to the base class, which in this instance is Class 1. Class 1 itself signifies a class of individuals who are sensitive to both the variable and annual emissions surcharges, indeed they are the most sensitive group with respect to the variable component of emissions charging. Unlike the other three classes, they have no preference for petrol over hybrid, but hold a more favourable bias for diesel fuelled vehicles compared to hybrid engines. They prefer more fuel efficient cars with smaller engine capacities, and have the strongest preference for cars with a larger seating capacity. They have no strong preference for location of manufacture, with the exception of a negative preference for South Korean built vehicles.

In contrast, individuals in Class 2 are sensitive to only the annual surcharge and are more inclined to choose hybrid vehicles over both petrol and diesel. They have the strongest preference for fuel efficient cars, but engine capacity is not significant in their choice of motor vehicle. They also have a preference for cars with more seating capacity, vehicles built in Japan and Europe and are the only class to be significantly predisposed to those built in South Korea. Compared to those in Class 1, individuals who disagree with the statement “climate change is an important issue” but agree that “vehicles are a main cause of climate change” are more likely to belong to Class 2.

Individuals in Class 3 have a preference for hybrid cars over both petrol and diesel. They have a preference for Australian manufactured cars over those from Japan, Europe or South Korea. They are sensitive to both variable and annual emissions surcharge, being the most sensitive to the annual surcharge of the four classes. Individuals who agree with the statement that “drivers of high CO_2 cars should pay more” but do not agree that “a vehicle emissions charge is effective way to reduce vehicle based CO_2” are more likely to belong to this class. It is hypothesised that this group may not agree with a vehicle based charge as the modelling indicates that they are relatively more sensitive to it.

With respect to the impact of the two emissions charging regime, the choice of motor vehicle for Class 4 is invariant to both the variable and the annual surcharge. This class has a strong preference for petrol cars over hybrid, though there is no difference between diesel and hybrid. They prefer cars built in Japan, Europe or America relative to Australian built cars, though there is no difference in preference for South Korean cars. Interestingly, Class 4 is the only class for which seating capacity is not a significant determinant of choice. In terms of the people who are more likely to belong to this group, it is the latent class for which age and the number of children play a significant role. The members of this class are more likely to be older and conversely have a fewer number of children, perhaps indicating that the need to perform family duties is not as strong a consideration in the selection of a motor vehicle for this class. The authors suggest that it is not unreasonable to hypothesise that the disposable income within this group may be higher as they no longer have dependents and are more likely to own their own home, meaning that any additional cost of using a motor vehicle is of relatively smaller consequence, as reflected by the insignificant impact of the variable and annual emissions charges.

5. Discussion and Conclusions

In light of the growing interest in environmental externalities of travel behaviour, this paper outlines a study that assesses the potential to reduce fuel consumption and vehicle emissions through a range of behaviourally modifying initiatives, including variable user charging, as well as the role of technological change in respect of vehicle design and performance. Significantly, we find that the application of a vehicle emissions charge and the presence of hybrid technology are significant in influencing vehicle purchasing behaviour. Such results are promising as the optimal policy formation, the performance of road pricing system, relates largely to the way in which charges are levied and the level of charge (Balwani and Singh 2009).

The application of a mixed multinomial logit model reveals that there is significant taste heterogeneity in terms of the impact of these attributes. As a result of these divergent preferences this paper used a latent class model to not only accommodate the preference heterogeneity but to explore determinant factors that may influence the sensitivity of individuals. This model reveals four latent classes of individuals with differing preference structures. In a major finding, these four classes differ in their response to the emissions charging variables: members of Class 1 are sensitive to the annual surcharge and are the most sensitive class with respect to the variable surcharge; individuals in Class 3 also sensitive to both regimes, though are more sensitive to the annual charges; those individuals belonging to Class 2 report sensitivity to only an annual surcharge; and the choices made by those in Class 4 are invariant to either emissions surcharge.

Crucially, class membership and thus behavioural responses to the charging schemes, is a function of the environmental attitudes held by individuals. Previous studies have found that willingness to pay measures are influenced by environmental attitudes (Kotchen and Reiling 2000) and while many studies suggest that such statistics will be higher than behavioural data would specify (Wardman and Whelan 2001; Wardman and Shires 2003), the exact direction of any bias is unknown (Hensher 2010). In this study, the varying combinations of attitudes that are significant in determining class membership indicate that the interplay of attitudes and attribute significance is complex indicating that, in this study, the exact influence of environmental attitudes on willingness to pay is unclear. However, in the context of the questions used here, no one latent class can be defined entirely by pro-environmental attitudes perhaps indicating that any inflationary bias on the parameter estimates may be mitigated. Moreover, from a policy standpoint we have identified that several classes of individuals exist, informing policy makers that any discussion of emissions charging regimes should be had in light of these disparate behavioural classes, understanding that the attitudes of individuals play a significant role in determining class membership and thus changes in such attitudes can impact on their behaviour with respect to the schemes.

In future research we will be exploring further the role of attitudes in further detail. Past research has indicated that wider socio-psychological factors influence behaviour, for example altruistic motives to others of the current generation (McConnell 1983; Randall and Stoll, 1983); or ethical beliefs and feelings of moral responsibility (Spash, 1997; Kotchen and Reiling, 1998). Understanding the impact of socio-psychological attitudes will also be done in a wider context of choice behaviour. The complex and comprehensive nature of the data set used in this paper will facilitate the exploration of attitudes and perceptions accounting for strategies to mitigate the impact of hypothetical bias, accounting for how information is processed by respondents and delineating between decisions made individually or by groups. It is anticipated that the preliminary insights presented in this paper will be advanced as we begin to examine the richness of the data in greater detail.

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