

Variable User Charging: Experiences and Extensions in a World of Carbon Emissions

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Abstract

Road pricing as an economic construct is not a new phenomenon in transportation research. Whilst fuel taxing and toll roads are common within Australia, these initiatives are primarily aimed at road infrastructure financing. Worldwide there has been growing interest in pricing structures designed to aide in congestion management with a recent focus on generating reductions in carbon emissions from vehicle usage.

This paper presents a short review of road and vehicle charging, which is used as the basis for a stated preference experiment that is to be conducted by The University of Sydney. Specifically linked to vehicle carbon emissions, the aim of this experiment, via an array of incentives, is to encourage switching to automobiles emitting lower emissions to determine the willingness to pay for more fuel efficient cars under differing scenarios. The paper will present the proposed project methodology for review. It will discuss how efficient experimental design strategies will used to create the choice scenarios, how respondents process information be investigated, how data on group versus individual decision making will be collected and how potentially influencing attributes underlying the choice process and outcome, from individuals to groups, will be evaluated.

Keywords: Road pricing, vehicle emissions charging, stated preference, willingness to pay, carbon emissions, congestion, pollution, group decision making.

Introduction

Interest at the political level in congestion charging is gaining pace as cities struggle with ways to reduce the effects of growing traffic congestion on the liveability of cities (Hensher and Puckett 2007). Many of the experiences with these programs have focused on reducing congestion in centralised urban areas, though there is growing attention paid to variable charging as a mechanism to reduce vehicle emissions and thus ease pollution. This paper first presents a short review of road and vehicle charging, focusing on congestion and pollution charging, and using these experiences as a background, the paper will discuss an impending study on vehicle emissions charging that will be conducted by the University of Sydney.

Road and Vehicle Charging

Pricing for road and vehicle usage is not a new economic concept having existed in the form of fuel taxes, licence fees, car registration, parking taxes and tolls for many years. These taxes have been used to fund new infrastructure developments or to maintain existing infrastructure that is associated with vehicle use, one of the primary objectives of road and vehicle charging (Litman 2007).

The other objective is with respect to traffic management. Growing populations in many metropolitan areas has resulted in increasing concerns about how the growth of traffic congestion may adversely affect the areas economy. For example, a study by the National Cooperative Highway Research Program (NCHRP) examined how urban traffic congestion affects producers of economic goods and services in terms of business costs, productivity and output. The study demonstrated that congestion effectively shrinks business market areas and reduces the scale economies of operating in large urban areas and that congestion imposes costs to businesses beyond the mere vehicle and driver costs of delay, including potential effects on inventory costs, logistics costs, reliability costs, just-in-time processing costs and reductions in market areas for workers, customers and incoming/outgoing deliveries.

Given that there is a cost attached to the externality of traffic congestion, economic efficiency suggests that the optimal price for road use is where the willingness to pay of demand equals the cost of supply, however in congested conditions the marginal cost of supplying one extra unit of road space increases above the average cost (Knight 1924). Moreover, road users should not only pay for the direct time and environmental costs that they impose on other road users and other people; they should also pay a charge corresponding to the increase in others' fuel costs and wear-and-tear costs (Johansson-Stenman 2006).

In light of such theory, several cities instituted charging structures with mixed results. As early as 1975, Singapore implemented the first congestion charging scheme (the Area Licensing Scheme) requiring drivers to purchase a special supplementary license and display it on a car that was driven in designated Restricted Zones during peak hours. The drop in traffic entering the Restricted Zones was 31 percent despite the growth by a third in employment in the city and by 77 percent in vehicle population during the

same period (Keong 2002). In 1998, thanks to technological developments, the Area Licensing Scheme was replaced with Electronic Road Pricing and this new system allowed for more frequent changes to be made to the road pricing charges, so that it can better optimise road usage. Traffic volume into the restricted zone was reduced by about 10 to 15 percent as compared to the previous scheme, even with the road pricing charges being lower for this system (Keong 2002).

In 2003 London instituted their Congestion Charge Zone, with the objectives of reducing congestion and providing funding for other transport initiatives. Initially, the £8 (\$19AU) entry charge covered an approximate 21 kilometre squared area of Central London, but in 2007 it was extended to parts of West London. Since the scheme's implementation it has been reported that traffic entering the original charging zone remains 21 per cent lower than pre-charge levels, traffic entering the Western Extension has fallen by 14 percent, there has been a six percent increase in bus passengers during charging hours and £137 million (\$323AU million) has been raised (TFL 2008).

As a result of the reduced traffic flows in the Central London area, positive environmental benefits were also observed. NO_x emissions in the charging zone were reduced by approximately 12.0 percent, PM₁₀ emissions were reduced by approximately 11.9 percent, and there was a reduction in emissions of CO₂ 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 (Beever and Carslaw 2005).

A growing global focus on environmental concerns, in particular the role of carbon emissions in global warming, has meant that the efficiency of motor vehicles is being scrutinized perhaps more than ever before. 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 a source of local pollutants such as lead, carbon monoxide and noise (Hensher and Button 2003). In fact, many pricing schemes are now increasingly being targeted towards pollution reduction, with many proposals stressing the environmental impact of the charge rather than the congestion reduction implications (May 1992).

Arguably one of the more effective ways to reduce emissions is to form a tax structure that creates incentives to the market participants to move towards emission reduction. Many economies, including the United States, Australia, Canada, Japan, Thailand and others employ this direct method, with a tax levied on the price of petrol. Another method to directly tax fuel usage is to apply a tax based on vehicle fuel economy. For example, the United States applies a tax referred to as the "gas-guzzler tax" which is applied on a graduated scale and based on a car's fuel economy rating. Britain has a more explicit annual tax linked directly to a vehicles measured carbon emissions, with higher emitting vehicles being charged a higher amount.

One of the first variable pricing schemes specifically linked to pollution outcomes was launched in Milan in 2008. The policy was driven by the desire to significantly reduce the level of air pollutant emissions in the urban area. To enter the central area of Milan by vehicle between 7:30am and 7:30pm from Monday to Friday it is necessary to pay for and display an Ecopass ticket. The price of the ticket varies from

€2 (\$4AU) to €10 (\$20AU) depending upon the assessed environmental impact of the vehicle being driven. The stated objectives of the charging schemes 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).

In Australia, motor vehicles remain a major cause of air pollution in urban areas with cars contributing 43 million tonnes of carbon dioxide or equivalent greenhouse gases, which is 8 percent of total national emissions in 2002 with trucks and light commercial vehicles contributing a further 24 million tonnes. Together these represent 13 percent of Australia's total emissions and since 1990 this figure has increased by 28 percent (Australian Greenhouse Office 2002).

The Garnaut Climate Change Review, commissioned by the Australian Federal Government, examined the impacts of climate change on Australia and recommended a policy framework to improve the prospects of sustainable prosperity. It found that with no carbon price in place, transport emissions would 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.

University of Sydney Study: Vehicle Emissions Charging

In light of the Garnaut Review, climate change is firmly on the national agenda. As a result, vehicle emissions charging as a means to reduce both congestion and pollution is now particularly relevant to transport modellers. In terms of optimal policy formation, the performance of road pricing systems relates largely to the way in which charges are levied and the level of charge (Balwani and Singh 2008). There is a scarcity of work in this area, with reference to charging specifically for pollution, that this study will address.

It is envisioned that this project will develop the first full system of stated preference models that can assess the energy and emission changes in car ownership and use associated with incentive-linked strategies and policies, especially new regimes of charging according to use and context instead of via fuel taxes, albeit in the context of higher petrol prices and prices of alternative fuels, taking into account the information processing rules and power relationships of one or more persons involved in the specific choice-making task(s). The candidate integrated system of choices include the number of vehicles in a household, the types of vehicles, fuel choice (including hybrids), and the amount of annual use of each vehicle. After calibration, the model system can be used to assess future impacts of price measures, technological developments, regulations and legislation, and other developments in society such as an ageing population.

Proof of Concept

The Dutch government announced that satellite-based road user charging will be implemented throughout the Netherlands to reduce congestion. Trucks will start paying charges per kilometre travelled in 2011 with cars following a year later. The scheme will involve the scrapping of road tax as well as BMP purchase tax on new cars when the system is introduced, providing a system which taxes vehicle use rather than ownership (ITS International 2007).

Oregon Department of Transportation has published the final report of the Oregon Mileage Fee Concept and Road User Fee Pilot Program, implemented to test a new revenue platform that would replace a fuel tax. The program included 285 volunteer vehicles, 299 motorists and two service stations in Portland. The road user fee was paid at the pump, with minimal difference in process or administration for motorists, compared to how they pay the fuel tax. The report not only concludes that the concept works but that it also provides an electronic platform for creative applications of congestion pricing to manage levels of traffic. In other words, the concept accommodates creation of multiple zones that allow not only local option but also various pricing methodologies. The pilot program successfully tested area pricing but this conceptual system could expand to allow a virtually unlimited number of congestion pricing applications, not only area pricing but also cordon pricing, distance or point tolling of individual facilities and time-of-day pricing of onramps to limited access highways, or combinations thereof, most without roadside infrastructure (ODT 2007).

While rising fuel prices alone may result in some behavioural shift, emissions pricing and higher fuel prices do not have identical effects. Higher oil prices will improve the competitiveness of all alternative fuels but an emissions price will selectively encourage lower-emissions fuels. It is projected that fuels such as coal-to-liquids would have a significant place in the market by 2050 if there were no mitigation, but not if an emissions price were introduced. Moreover, an emissions price will increase the incentive for reducing the use of all fuels that produce emissions, not just petroleum-based fuels (Garnaut 2008). From this, it can be concluded that some form of emissions charging is a requirement for change to occur within a reasonable time frame.

Methodology

Stated preference methods have become a preferred approach to studying the preferences of individuals and organisations in a choice setting and in estimating willingness to pay for specific attributes. The appeal of the methods is widespread, especially in economics, transportation, health, environmental and marketing research and practice, and growing in interest in accounting, finance and logistics. It is within this framework that analysis for the project will take place.

With respect to a specific analytic method, an a priori expectation is that there will be considerable variation in respondent choices as a result of preference heterogeneity and as a result it is expected that a Mixed Logit Model, which allows for variations in

parameter estimates, will be the most prevalent analytic method for this project. However, it is not unexpected that Latent Class Models will also be used in determining market segments in terms of vehicle purchasing behaviour.

Choice Alternatives

The universal finite choice set will comprise three alternatives based on fuel type: 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 estimates for each of the fuel types, as well as the calculation of market shares and demand elasticities (Hensher, Rose et al. 2005a).

Extensive thought was given to the selection of the labels to be associated with each alternative and given the focus on climate change it was decided that an ability to establish the elasticity of demand for low emitting vehicles with respect to a CO₂ emission charge per kilometre was of fundamental interest. Based on the National Emissions Trading Scheme workshop on June 27, 2007 in Sydney, it is apparent that there is uncertainty about which fuels will be commercially viable in the future. As such, in this 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.

For purposes of experiment design, the vehicle type was broken down into six variants: Small, Luxury Small, Medium, Luxury Medium, Large and Luxury Large. This was done so that the experiment would have adequate attribute variance over the alternatives, particularly with respect to price, whilst still having a manageable number of alternatives for the design. It also allows for better representation of the attributes as these are linked to the size of the vehicle in many cases.

Choice Attributes

Following the specification of practicable alternatives, consideration was given to the selection of attributes to use within the choice experiment. For the pilot, there will be nine attributes included in the choice experiment which were refined via review of the available literature on vehicle purchasing, as well as through preliminary analysis of secondary data sets.

The typical monetary costs involved in purchasing and operating a car are included in the design. These are purchase price of the vehicle, the fuel price and the cost of registration (including compulsory third party insurance). In the nature of this experiment fuel efficiency of a vehicle is an important attribute, given that this is the link to which level of emissions surcharge will be set. The remaining attributes, seating capacity, engine size, 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 choice experiment. Appendix 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 reflect that hybrid technology is more expensive than conventional engines.

The final two attributes relate to the mechanism via which vehicle emissions charges will be implemented. The study will 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 vehicles' fuel efficiency given that better fuel economy is strongly associated with lower levels of vehicle emissions (Harrington 1997).

Using an annual surcharge to encourage use of more efficient vehicles is not new, for example England has introduced a new annual vehicle registration tax that is graduated for vehicles in various polluting categories. 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 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 driver of vehicle choice, while the variable charge is the key driver of use.

In terms of measuring how fuel use changes in response to price changes, it has been estimated that a ten percent increase in fuel prices leads to a one and a half percent reduction in car fuel use within one year, but around four percent in the longer run (BITRE 2008), and Goodwin et al. (2004) estimated that reductions in fuel consumption associated with a ten percent increase in fuel prices of two and a half percent within one year and six percent in the longer run. 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. This information helped to determine the surcharge levels.

Appendix 2 shows the levels chosen for the annual and variable surcharges. Both 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 it 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.

Experimental Design

The design of the experiment is a fundamental part of stated preference modelling. A vast amount of research has been done on ways to improve the statistical efficiency of stated choice experiments and one of the important tasks of this research is to identify efficient experimental designs that can deliver statistically significant roles of attributes for a given sample size. The literature has moved away from orthogonal to d-efficient designs where the focus is less on zero correlation but on the asymptotic properties of the standard errors of estimates, as captured through the variance-covariance matrix, given the priors of attribute parameters. Using prior parameter estimates to minimise the asymptotic variance-covariance matrix leads to lower

standard errors and more reliable parameter estimates for a given sample size (Rose and Bliemer 2005).

This research will use improved design criteria centred on sample size efficiency as determined by the t-statistics of each parameter, given the priors. The prior parameters for this study were gathered via literature review, as well as through exploration of secondary datasets that explored vehicle purchasing behaviours. This methodology enables one to focus not only on the design attributes which are expanded out through treatment repetition, i.e. multiple choice sets, but most importantly also the non-expanded socio-demographics and other contextual variables that get replicated as constants within each observation, and whose inclusion should have the greater influence on the efficient sample size (Rose and Bliemer 2008).

For this study, a reference alternative is included in the experimental design, as such an inclusion adds to the relevance and comprehensibility of the attribute levels being assessed (Rose, Bliemer et al. 2008). The use of a respondent's experience, embodied in a reference alternative, to derive the attribute levels of the experiment has come about in recognition of a number of supporting theories in behavioural and cognitive psychology, and economics, such as prospect theory, case-based decision theory and minimum-regret theory (Starmer 2000; Hensher 2004).

In the process of building the experiment design for this pilot study, there are a number of conditions on the interaction of the attributes and alternatives. Firstly, 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. Secondly, if the reference alternative petrol (diesel) the petrol (diesel) fuelled alternative must have the same fuel price as the reference alternative. Lastly, the annual and variable surcharge for the hybrid alternative cannot be higher than that of another vehicle when the alternate vehicle has the same fuel efficiency rating or is more inefficient than the hybrid.

Reference Alternative

In generating the reference alternative, the only attributes that vary across the experiment are the fuel price, annual emissions surcharge and variable emissions surcharge, with the remaining attributes remaining fixed, based on the actual vehicle that was purchased by respondents:

- Fuel price pivots around the daily fuel price as entered by the interviewer. There are five levels of fuel price (-25%, -10%, no change, +10%, +25%).
- The annual emissions surcharge is determined by the type of petrol used by the car most recently purchased and the fuel efficiency of that vehicle. For each fuel type and fuel efficiency combination, there are five levels of surcharge that apply.
- The variable emissions surcharge is also determined by the type of fuel used by the car most recently purchased and the fuel efficiency of that vehicle. For each fuel type and fuel efficiency combination, there are five levels of surcharge that apply.

Petrol, Diesel, Hybrid Alternatives

For the petrol, diesel and hybrid alternatives, all attributes vary, and the combinations of levels are optimised via the design process. While we will always have the same four fuel types alternatives in each choice set (Reference, Petrol, Diesel, Hybrid), the size of the vehicles for each alternative will vary randomly and is endogenous to the design. As before, the level of the annual and variable surcharge that appears in each alternative is conditional on the fuel type and efficiency of the vehicle. The values of fuel price and registration (including CTP) pivot off actual experience:

- Fuel price pivots around the daily fuel price as entered by the interviewer. There are five levels of fuel price (-25%, -10%, no change, +10%, +25%).
- Registration (including CTP) pivots around the actual cost provided by the respondent. There are five levels of registration (-25%, -10%, no change, +10%, +25%).

The Design

As part of designing an efficient experiment, the design is optimised over the values in the reference alternative. As we do not know, a priori, the exact specifications of the vehicle that each respondent has most recently purchased, it is not possible to present each respondent with a fully optimised design. However, an approximate method was used whereby all recent purchases were defined as being one of three different body sizes (small, medium or large) and one of two fuel types (petrol or diesel). Consequently, each respondent will receive choice sets from one of six possible designs, depending on what category their most recent purchase belongs to. Appendix 3 shows the “average vehicle” that was used for each category in generating each experimental design, and the d-error associated with each design.

The following steps outline how each design was calculated. An analytical approach was used whereby the asymptotic variance-covariance matrix was derived via the second derivatives of the log-likelihood function of the model to be estimated. To optimise this design, difference combinations of attributes are trialled, and design with the minimised d-error after repeated iterations is used. The steps followed in generating each design are as follows:

1. Specify design characteristics (Appendix 1);
2. Establish prior parameters estimates (garnered from literature review and secondary data analysis);
3. Generate Bayesian draws for prior parameters;
4. Calculate utilities based on levels and priors;
5. Calculate consequent choice probabilities;
6. Compute the Fisher Information Matrix;

Additional Behavioural Contributions

Modelling Information Processing Strategies

Imagine that you have been asked to review the choice scenario in Figure 1 and indicate which alternative is your preferred. There is a lot of information in this screen that you have to attend to, in deciding what matters in influencing your decision (i.e. what information is relevant). There are likely to be many implicit and often subconscious rules being adopted to process the attributes and alternatives that are used, possibly to cope with the amount of information to assess. This may be because the screen is regarded as too complex in terms of the amount of information and its content that one usually evaluates.

Whether one is invoking a specific processing strategy to cope with cognitive burden or whether these are a subset of the rules you have built up over time and draw on from past experiences is often unclear. It is, however, expected that there are a large number of processing rules that individuals use to help them handle mixtures of relevancy and cognitive burden.

An assumption of the majority of stated preference studies is that all attributes are deemed relevant; however this assumption is often questionable. Research indicates that heuristic rules are the proximate drivers of most human behavior (McFadden 2001a; Berg 2005). The challenge that is faced is to find ways in which information processing rules can be identified and thus be taken into account when representing the choice process in model estimation.

This proposed research will explore ways in which information in a stated preference experiment is processed; which is attributed in part to the dimensionality of the stated preference experiment and in part to recognition that there is substantial heterogeneity in the processing strategies of individuals in a sample. In particular we argue that failure to take into account the relevancy of the information offered in the evaluation process leading to a choice outcome, no matter how 'simple' or 'complex' a design is, will contribute to biases in preference revelation.

Interestingly, recent research has found that the real issue is not the amount of information to process, which became associated with 'complexity', but rather the relevance of the information (DeShazo and Fermo 2002; DeShazo and Fermo 2004; Hensher 2006). This research has revealed the possibility that a study of the implications on choice of the amount of information provided in a choice experiment should be investigated in the context of the broader theme of what rules individuals bring to bear when assessing the information in a choice experiment. These rules may be embedded in prejudices that have little to do with the amount of information in the experiment; rather they may be rational coping strategies that are used in everyday decision making. There is an extensive literature on information processing, which includes prospect theory (Kahnemann and Tversky 1979), case-based decision theory (Gilboa and Schmeidler 2001) and non-expected utility theory (Starmer 2000) which surprisingly has not been adequately integrated into the modelling of the process leading to stated choice outcomes.

The processing of a stated preference experiment has some similarity to how individuals process information in real markets. The processing strategy may be hypothesised to be influenced by relevant information sources readily accessible by agents. Broadly speaking, decision strategies can be characterised into three dimensions: basis of processing, amount of processing, and consistency of processing (Payne, Bettman et al. 1992). Decision strategies are said to differ in regards to whether many attributes within an alternative are considered before another alternative is considered (alternative-based processing) or whether values across alternatives on a single attribute are processed before another attribute is processed (attribute-based processing). Strategies are also said to differ in terms of the amount of information processed (i.e. in terms of whether any information is ignored or not processed before a decision may be made). Finally, decision strategies can also be grouped in terms of whether the same amount of information for each alternative is examined (consistent processing) or whether the amount of processing varies depending on the alternative (selective processing). The six specific strategies defined by Payne et al. (1992) are summarised by the following table:

Table 1: Typology of Decision Strategies

Strategy	Attribute or Alternative-based	Amount of Information	Consistency
EBA	Attribute-based	Depends on values of alternatives and cut-offs	Selective
LEX	Attribute-based	Depends on values of alternatives and cut-offs	Selective
MCD	Attribute-based	Ignores probability or weight information	Consistent
WADD	Alternative-based	All information processed	Consistent
SAT	Alternative-based	Depends on values of alternatives and cut-offs	Selective
EQW	Alternative-based	Ignores probability or weight information	Consistent

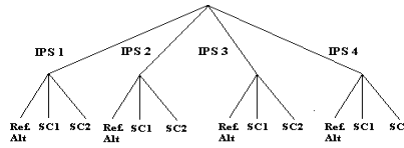
The treatment of information processing via one or more rules can be viewed as a deterministic or stochastic specification. Hensher et al. (2005b) treated information processing deterministically and found that the assumption that all attributes are not ignored leads to estimates of parameters which produce significantly different willingness to pay figures to those obtained when the exclusion rule is invoked.

In contrast to a deterministic specification, which assumes knowledge of the respondent-level likelihood of attribute processing with certainty, a stochastic specification relaxes this assumption. Since the choice made by an individual is conditioned on the processing strategy, and given the two-stage decision process promoted in prospect theory, it is desirable to respecify the choice model as a two-stage processing function wherein each individual's choice of alternative is best represented by a joint choice model involving the individual's choice conditional of the processing strategy and the choice of strategy itself. It is anticipated that the processing rules can be specified as a separate function (below) and the attributes of alternatives are specified in the standard expression:

$$U_{ips_i} = \alpha + \beta_1 \text{AddAtts}_i + \beta_2 \text{IgnAtts}_i + \beta_3 \text{RefDepX}_{1i} + \beta_4 \text{RefDepX}_{2i} + \beta_5 IV_i$$

where IV_i is the expected maximum utility associated with the choice process at the lower level of the tree structure proposed below. It recognises that the information processing strategy is influenced by the actual information setting within which the preferred contract outcome is selected by an agent.

Figure 2: Individual-Specific Decision Structure for SP Assessment



This study proposes to explore the role of information processing strategies on stated preference experiments via an interactive process. In this survey respondents will be provided with a number of pre-designed choice experiments with varying numbers, levels and ranges of attributes across the alternatives which include a reference alternative (from the agents actual experience). Individuals are then able to select the pieces of information, be it entire attributes, alternatives or simply attributes within an alternative that is/are irrelevant to them in their decision making. From this, what information is irrelevant for behavioural processing and what is ignored to avoid cognitive burden can be identified across all designs. A subsequent screen will ask questions about what attributes, if any, are combined, why various alternatives are ignored and what other factors may have influenced choice (Appendix 4).

Additional to this, in the group decision making component of the survey (outlined in the next section of this paper), information processing strategies will be re-evaluated and thus it can be tested, at a general level, if there are differences between strategies employed by individuals versus those employed by groups, and more specifically, if individual processing strategies used by a respondent differ from those used when the respondent is part of a group.

There is a substantial extant literature in the psychology domain on the influence of various factors on the amount of information processed in decision tasks. Recent evidence demonstrates the importance of such factors as time pressure (Diederich 2003), cognitive load (Drolet and Luce 2004) and task complexity (Swait and Adamowicz 2001) in influencing the decision strategy employed during decision tasks. There is also a great deal of variability in decision strategies employed in different contexts, and this variability adds to the complexity in understanding the behavioural mechanisms involved in decision making and choice. It is hoped that the data collected by this study will enable the analysis of how these factors influence the information processing strategies used by respondents in a stated preference experiment.

Modelling Group Decision Making Dynamics

While stated preference is used extensively to model the decision making process of an individual, make probabilistic predictions about their behaviour and estimate their willingness to pay, many choices are not made by individuals alone. Groups of individuals are often required to make decisions, be it residential location, choice of vacation destination, what restaurant to eat at, or in this instance what automobile to purchase. In determining the final outcome for each of these situations the preferences

of many individuals are at play; being traded against one and another until an optimal group solution is reached.

How the interaction of individual group members influence the group's decision making and preference formation processes represents an important dimension of our understanding of economic behaviour. This has resulted in recent calls within the choice modelling literature to examine the role that social interactions play in terms of preference formation. For example, both McFadden (2001a,b) and Manski (2000) have made statements to the effect that as a field of research enquiry, this area should be given high priority by choice modellers.

Research by Hensher introduced the idea of Interactive Agency Choice Experiments (IACE) (Hensher and Chow 1999; Brewer and Hensher 2000; Hensher 2003) in which a network of agents assess a common set of alternatives either sequentially or simultaneously. Rose and Hensher (2003) provide the framework via which the IACE methodology is actualized in this stated preference experiment. Agents are administered a subset of the experimental design such that all agents within the same group receive identical choice profiles. This first pass is concluded when all agents within the group have been administered the experiment. When moving into pass two agents are only administered with choice profiles in which choice agreement with other agents was not achieved in the first pass, and are asked to revise their choice (though agents are free to select the same response). If agreement is made on all profiles, the experiment is terminated for that group as agreement equilibrium has been achieved. In this study it is proposed that the experiment will terminate after 3 attempts at finding an equilibrium result.

In estimating the IACE model, a two stage approach is used. Whilst the following approach can be used without considering the role of information processing strategies on choice, by allowing for variations in information processing strategies, the first extension to the IACE methodology is made:

Stage 1

Each agent participates in a stated choice experiment with common choice sets. The agent-specific models define utility expressions of the form:

$$U(\text{alt } i, \text{ agent } q) \quad i=1, \dots, J; \quad q=1, \dots, Q, \text{ where } \textit{alt} \text{ defines an alternative choice.}$$

For example, with two agents and three alternative outcomes we have $U(a_1q_1)$, $U(a_2q_1)$, $U(a_3q_1)$ for agent 1 and $U(a_1q_2)$, $U(a_2q_2)$, $U(a_3q_2)$ for agent 2, conditional on the processing strategy of the agent. Each alternative, in the empirical study, will refer to an attribute profile or package describing a specific number and type of vehicles and associated usage. It is expected that each agent will focus on different aspects of the package and/or to impose utility weights on each aspect, and this behaviour differs across the group.

The relative attribute preservation of the processing strategy of the agent is identified by prompting agents to indicate the attributes that were ignored or given little attention for each outcome alternative after each choice task. Information about the processing strategy is collected (discussed in the previous section of this paper) and

this information is used to condition the utility expressions as follows: ignored attributes are either assigned a marginal utility of zero for a given alternative and choice set or are treated stochastically such that the exogenous information points to the correct likelihood specification for a respondent with error, so that the likelihood for a respondent is a probabilistic mixture of likelihoods. The base utility expressions (i.e., without any interaction effects or direct covariate effects) are of the general form:

$$U_{qj} = \alpha_j + \beta_{qjk} * x_{qjk} + \varepsilon_j$$

where x_{qjk} is a vector of design attributes associated with agent q and alternative j , β_{qjk} is the corresponding vector of random marginal utility parameters, α_j is an alternative-specific constant and ε_j represents the unobserved effects.

The effect of the processing strategy used by an agent for a given choice set is implemented by setting $\beta_{qjk} = 0$ if k is ignored for a particular alternative j for agent q or through an index of expected maximum utility obtained from a model that accounts, stochastically, for the different processing strategies (discussed in the previous section of this paper).

The mean and the standard deviation of the random preference parameters β_{qjk} across the sample of agents can both be decomposed, and hence explained, by deliberation attributes such as socioeconomic characteristics, prior experience in such negotiations and general process related information such as the number of attributes ignored. Regardless of which approach is adopted, such contextual influences can also be interacted with design attributes in model estimation. This modelling structure lends itself to the heterogeneous and heteroscedastic mixed logit model, which is the econometric model of choice for this research.

Stage 2:

All parameters estimated from Stage 1 are fixed and imported into a joint agent model. For example, with two agents and three alternatives, there are nine joint alternative combinations:

$$U(a_1a_1), U(a_1a_2), U(a_1a_3), \dots, U(a_3a_1), U(a_3a_2), U(a_3a_3)$$

Three of the joint combinations imply non-negotiated equilibrium ($U(a_1a_1)$, $U(a_2a_2)$, $U(a_3a_3)$). In other words, points at which agents make identical choices simultaneously within the first pass.

The Stage 2 choice is between agent-specific combinations with one proposition the chosen pair. A model is then specified of the following form (for two agents):

$$U(a_1a_1) = ASC_{a_1a_1} + \lambda_{qp} * (\beta_{1q}x_{1q} + \beta_{2q}x_{2q} + \dots) + (1-\lambda_{qp}) * (\beta_{1-q}x_{1-q} + \beta_{2-q}x_{2-q} + \dots)$$

$$U(a_1a_3) = ASC_{a_1a_3} + \lambda_{qp} * (\beta_{1q}x_{1q} + \beta_{2q}x_{2q} + \dots) + (1-\lambda_{qp}) * (\beta_{1-q}x_{1-q} + \beta_{2-q}x_{2-q} + \dots)$$

$$U(a_3a_3) = ASC_{a_3a_3} + \lambda_{qp} * (\beta_{1q}x_{1q} + \beta_{2q}x_{2q} + \dots) + (1-\lambda_{qp}) * (\beta_{1-q}x_{1-q} + \beta_{2-q}x_{2-q} + \dots)$$

The lambda's represent power measures for agents, which sum to one, making comparisons of agent types straightforward:

- If the two power measures are equal for a given attribute (i.e., $\lambda_{qp} = (1 - \lambda_{qp}) = .5$), then group choice equilibrium is not governed by a dominant agent. In other words, regardless of the power structure governing other attributes, agents tend to reach perceptively fair compromises for this attribute when bridging the gap in their preferences.
- If the power measures are significantly different across agent types (e.g., $\lambda_{qp} > (1 - \lambda_{qp})$ for two agents), then λ_{qp} gives a direct measure of the dominance of one agent type over the other with respect to an attribute. As λ_{qp} increases, so does the relative power held by an agent. For example, the power measures may reveal that one agent type tends to get their way with regard to monetary concerns, whereas the other agent type tends to get their way with regard to concerns for quality and performance.

These relationships can be examined further at the sub-type level (by decomposition of the random parameter specification of λ), in order to reveal deviations from the inferred behaviour at the sample level that may be present for a particular type of relationship. This model is straightforward to estimate, holding all β 's fixed, with each λ_{qp} and the alternative-specific constants free parameters. λ_{qp} as a power indicator can be a random parameter and a function of other criteria.

This research will further extend the IACE methodology by capturing data not only on individual preferences and their subsequent role in the formation of group preferences, but by also collecting comparative data on true group choice (i.e. situations where agents are acting in concert rather than in sequence as implied by the IACE methodology). Given the data it is proposed that not only can the direct influence on choice that each individual member has via the interactive component of the experiment be demonstrated, but that choices made by groups whose members consult directly whilst in the decision making process can also be modelled and compared.

Perceived Influence

The IACE methodology incorporated in this research allows us to establish the relative influence each group member has in a group decision. An innovative element of this study is that information will also be collected on the perceived influence that each agent has.

Each respondent will be required to estimate the degree of relative influence they have over an attribute, the relative influence of the other agent on that attribute, and whether or not a third party was consulted and the influence that person(s) had.

Perceived influence may have a large role in the way in which an individual (in the wider context of a group decision) processes attributes. If an individual perceives another group member to have influence over an attribute they may not ignore that attribute, rather "give it over" to the stronger party. The attribute may still be

important to the individual, but the individual may give it over as part of a bargaining strategy, or feel that the other member is in a better position to assess the attribute. Though subtle, this is an important difference between ignoring the attribute completely.

The inclusion of a third party agent has wider implications for the modelling of decision making, in so far as the role that the presence/absence of a credible expert has on the importance of attributes and influencing the way in which they are processed.

Hypothetical Bias

The concept of hypothetical bias in stated choice experiments has gained traction (Brownstone and Small 2005; Hensher 2008). Broadly speaking, the hypothetical nature of choice experiments creates a bias away from real market evidence. In response to this a number of strategies may be employed to increase behavioural consistency.

One method to increase the comparative realism of experiments is to provide a reference alternative that is a known experience (Rose and Bliemer 2008; Rose, Bliemer et al. 2008). In this instance such a reference alternative is provided, that is based on the current choice of vehicle, the current cost structures, and actual usage.

A second method is the inclusion of “cheap talk” scripts that directly encourage respondents to avoid hypothetical bias (Cummings and Taylor 1999; List 2001; Aadland and Caplan 2003; Brown, Ajzen et al. 2003). This study uses this method by stating the following:

“It is important to note that studies such as these are used to develop government policy; as such your answer could have a very real impact on future road user charging. It is important that when answering this survey you act the way you would in real life.”

Also included in this research is a question that asks respondents to estimate the confidence with which they would hypothetically purchase the good at the stated price. This information has been found to be a valuable predictor of hypothetical bias (Johannesson, Blomquist et al. 1999).

Another way to examine hypothetical bias is to check the model predictions against actual outcomes. It may be feasible to revisit respondents some time after the experiment and determine if a new car was purchased (or not), and if so what are its levels on the relevant attribute. There may be some tentative merit in comparing the predicted attribute importance in terms of engine size, seating capacity, country of manufacture, etc (even though these are biased due to the presence of the pricing structure attribute) to the actual outcome.

Attribute Cut-offs

Linked to research on information processing, Swait (2001) first proposed attribute cut-offs decision problem formulation; stating that incorporating the impact of cut-offs in models of demand may substantially improve the ability to predict behavioural changes. He shows that his model is able to represent fully compensatory, conjunctive and disjunctive decision making strategies. Indeed it has been found that conventional choice models overestimate the importance of the attributes and that incorporating attribute cut-offs allows for significant improvements to be made by introducing non-linearity's at points specified by individual respondents (Danielisa and Marcucci 2005).

Before all of the choice scenarios, we ask a series of questions to elicit what threshold values on each attribute (lower, upper) would they exclude from consideration. Linked to information processing, incorporating attribute cut-offs facilitates the testing of whether there are bounds on attribute levels that impact on how an attribute is processed. It is an additional and realistic refinement on attributes being ignored or not, whether cut-offs change as a function of other attributes, and whether attribute level has a role in influencing willingness to pay statistics.

Conclusion

This paper outlines the proposed University of Sydney 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, fuel quality and substitution.

Major practical outcomes that will flow from this research program include the development of a powerful new planning and decision support tool, with a rich underlying behavioural and economic basis, to assess the likely responses to policies designed to influence the composition of a household's vehicle fleet and its use. Additional to this economic and environmental contribution, this research also seeks to integrate a number of strands of research that have yet to be combined into a fully specified stated preference system framework. These include:

- The information processing strategies adopted by each respondent in each of the stated preference experiments.
- The recognition of more than one decision maker, and hence the need to seek choice responses from at least two persons involved in a specific choice outcome.
- The modelling of group decision making to establish supporting and non-supporting influences on cooperative outcomes.
- The design of more efficient experiments for a given sample size and hence cost outlay, that benefits from selection of priors and optimisation on the asymptotic t-ratios of candidate design attributes and non-design socio-economics and contextual variables.

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Appendix 1

Attribute Levels for Stated Preference Experiment

Purchase Price	<i>Small</i>	\$15,000	\$18,750	\$22,500	\$26,250	\$30,000
	<i>Small Luxury</i>	\$30,000	\$33,750	\$37,500	\$41,250	\$45,000
	<i>Medium</i>	\$30,000	\$35,000	\$40,000	\$45,000	\$50,000
	<i>Medium Luxury</i>	\$70,000	\$77,500	\$85,000	\$92,500	\$100,000
	<i>Large</i>	\$40,000	\$47,500	\$55,000	\$62,500	\$70,000
	<i>Large Luxury</i>	\$90,000	\$100,000	\$110,000	\$120,000	\$130,000
Fuel Price	<i>Pivot off daily price</i>	-25%	-10%	0%	10%	25%
Registration	<i>Pivot off actual purchase</i>	-25%	-10%	0%	10%	25%
Fuel Efficiency (L / 100km)	<i>Small</i>	6	7	8	9	10
	<i>Medium</i>	7	9	11	13	15
	<i>Large</i>	7	9	11	13	15
Engine Capacity (cylinders)	<i>Small</i>	4	6			
	<i>Medium</i>	4	6			
	<i>Large</i>	6	8			
Seating Capacity	<i>Small</i>	2	4			
	<i>Medium</i>	4	5			
	<i>Large</i>	5	6			
Country of Manufacture	<i>Random Allocation</i>	Japan	Europe	South Korea	Australia	USA

Appendix 2

Levels for Annual Emissions Surcharge

Petrol		Fuel Efficiency (litres used per 10km)									
		6	7	8	9	10	11	12	13	14	15
Level	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2	90.00	105.00	120.00	135.00	150.00	165.00	180.00	195.00	210.00	225.00
	3	180.00	210.00	240.00	270.00	300.00	330.00	360.00	390.00	420.00	450.00
	4	270.00	315.00	360.00	405.00	450.00	495.00	540.00	585.00	630.00	675.00
	5	360.00	420.00	480.00	540.00	600.00	660.00	720.00	780.00	840.00	900.00

Diesel		Fuel Efficiency (litres used per 10km)									
		6	7	8	9	10	11	12	13	14	15
Level	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2	75.00	87.50	100.00	112.50	125.00	137.50	150.00	162.50	175.00	187.50
	3	150.00	175.00	200.00	225.00	250.00	275.00	300.00	325.00	350.00	375.00
	4	225.00	262.50	300.00	337.50	375.00	412.50	450.00	487.50	525.00	562.50
	5	300.00	350.00	400.00	450.00	500.00	550.00	600.00	650.00	700.00	750.00

Levels for Variable Emissions Surcharge

Petrol		Fuel Efficiency (litres used per 10km)									
		6	7	8	9	10	11	12	13	14	15
Level	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	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 10km)									
		6	7	8	9	10	11	12	13	14	15
Level	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	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	0.20	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

Appendix 3

Average Vehicle used for Design Optimisation

	Small		Medium		Large	
	Petrol	Diesel	Petrol	Diesel	Petrol	Diesel
Purchase Price	\$25,000	\$28,000	\$33,000	\$36,000	\$40,000	\$43,000
Fuel Price	\$1.50	\$1.65	\$1.50	\$1.65	\$1.50	\$1.65
Registration (incl. CTP)	\$600	\$600	\$600	\$600	\$600	\$600
Fuel Efficiency	8	8	10	8	12	10
Engine Capacity	4	4	4	4	6	6
Seating Capacity	4	4	5	5	5	5
Country of Manufacture	Japan	Europe	Japan	Europe	Australia	Europe

Minimised d-error for Designs Selected for Use

Design	D-error
Small Petrol	0.014455
Small Diesel	0.013831
Medium Petrol	0.014430
Medium Diesel	0.013668
Large Petrol	0.014845
Large Diesel	0.014397

Appendix 4

Information Processing Questions

Individual Information Processing

1. For each of the following choices, did you add up the components of:

	Current	Petrol	Diesel	Hybrid
Annual Charges (Annual Emissions Surcharge and Registration)?	<input type="radio"/> Yes <input type="radio"/> No	<input type="radio"/> Yes <input type="radio"/> No	<input type="radio"/> Yes <input type="radio"/> No	<input type="radio"/> Yes <input type="radio"/> No

2. In using the information to make a choice did you:

Combine any of the attributes in some other way? Yes No

If so, how did you combine them?

3. When making a choice you indicated that the following choices were unacceptable, can you explain why?

I eliminated **Petrol (body type)** because:

I eliminated **Diesel (body type)** because:

I eliminated **Hybrid (body type)** because:

4. Are there any other factors that we have not included that influenced the choices that you made?