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**Behavioural responses of  
freight transporters and  
shippers to road user charging  
schemes: An empirical  
assessment**

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**ABSTRACT:** Heavy goods vehicles not only have a non-marginal impact on the performance of the road network in terms of traffic congestion, exposure to risk and accidents, they also provide an essential service in the distribution chain. Both sellers and purchasers of goods rely on an efficient transport system to ensure that goods are available at a time and location that meets the demands of end users. As congestion on the road network grows, especially in urban areas, the calls for 'solutions' increase. Although many of the suggestions to resolve delays due to traffic avoid the call for reform of road pricing, there is a growing recognition that user charges have to be more closely aligned to user cost and user benefit. Aiding this call is a technological capability now in place to facilitate a fine tuning of variable users charges that is inter-operable across networks and almost seamless to the customer. The major challenge we face is behavioural – a need to understand more fully the role that specific charging regimes might play in the distribution of freight and who in the supply chain is affected by specific charges in terms of willingness to pay for the gains in network efficiency. This chapter investigates the potential influence of variable user charges, relative to fuel prices (the current main source of charging), in the freight distribution chain. A choice modelling framework is presented that identifies potential responses from the freight distribution sector to variable user charging within the context of the wider spectrum of costs imposed on the sector, as well as the potential benefits (e.g. time savings) from alternative pricing regimes. We highlight the role that agents in the distribution chain play in influencing sensitivity to variable user charges.

**KEY WORDS:** *User charges, kilometre-based charges, congestion, freight distribution chains, choice modelling, willingness to pay*

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## 1. Introduction

Congestion charging is recognised as an effective instrument in responding to the concerns about high levels of traffic congestion. Although the economic arguments have been known for decades and the technological capability is now widely available, the last bastion of constraint, namely political will, is starting to move in support of implementation. The London experience (Evans 2005, Transport for London 2003) is being used as a catalyst for a broader recognition of what can be done without a political backlash in a Western democratic society. The adage 'it is not a matter of if but of when' seems to be the prevailing view in a growing number of jurisdictions, Stockholm<sup>1</sup> being the most recent (see Hensher and Puckett 2005a, 2007 for a review).

The problem of congested roads is expected to get considerably worse over the coming years. While this places traffic congestion high on government agendas, it does not mean that pricing will also be high agenda as a way to reduce traffic levels. Freight companies have much to gain from less congested roads in terms of opportunity costs, including the number of vehicles required to achieve a specific task set. Less congested roads would also have an indirect benefit to driver recruitment. Indirect road-use charges via fuel taxes are remotely linked to use of congested roads and other vehicle taxes are independent of time and location of vehicle-use.

In late 2005 The European Parliament introduced a bill focused on harmonisation of truck tolls levied on its roads. The bill, first tabled in 2003, is based on the user pays principle and aims to take account of the environmental and social impacts of heavy road freight, shifting some freight from roads onto rail or waterways. Although the proposal has caused much debate (see Einbock 2006, Transport Intelligence 2005), all European countries benefit heavily from road freight but some, like Austria, France and Germany, also suffer high congestion and pollution levels. After heated discussions, it was agreed that these 'external costs' can include *congestion costs*, environmental costs, noise, landscape damage, social costs such as health and indirect accident costs which are not covered by insurance. The Commission ended a dispute between Parliament and Council on how to integrate costs in toll prices by agreeing to develop a calculation method two years after the directive comes into force. As of 2012, Eurovignette will apply to vehicles of 3.5 tonnes or more. Member states are given flexibility on how to levy tolls or charges and these can be raised on the entire road network, not just motorways, when they are part of the Trans-European Network. Toll revenue should be used, through hypothecation, for the maintenance of the road infrastructure concerned or to cross-finance the transport sector as a whole.

Although the focus of the European pricing initiative is broader than an interest in congestion (see McKinnon 2006a), given that efficient pricing includes a large array of internal and external costs, internalizing the costs of congestion is recognized as a relevant component. This emphasis also applies to the debate in the UK on a national road pricing scheme which would replace the road tax licence and fuel taxes for a mileage charge for

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<sup>1</sup> Results from Sweden's experiment as of May 2006 show that car traffic to and from the inner city has fallen by 25% since the scheme was introduced. Public transport patronage has increased by 8% since last year, which translates into a daily increase of 50,000 passengers.

all journeys (McKinnon 2006). Although the scheme would not be introduced for at least a decade, a feasibility study carried out in 2004 suggested that charges could range from 2p a mile (US\$3.6 cents) on rural roads to £1.34 (US\$2.50) a mile for peak time journeys on the country's busiest roads and motorways.

The major challenge we face in implementing a user charging regime is behavioural – a need to understand more fully the role that specific charging regimes might play in the distribution of freight and who in the supply chain is affected by specific charges in terms of willingness to pay for the gains in network efficiency. This chapter investigates the potential influence of distance-based user charges, relative to fuel prices (the current main source of charging), in the freight distribution chain. A choice modelling framework is presented that identifies potential responses from the freight distribution sector to distance-based user charging within the context of the wider spectrum of costs imposed on the sector, as well as the potential benefits (e.g. time savings) from alternative pricing regimes. We highlight the role that agents in the distribution chain play in influencing sensitivity to distance-based user charges.

With the growing interest in distance-based user charges (see Forkenbrock 2004, O'Mahony *et al.* 2000) this paper presents some new evidence on the role that distance-based charges might play in the formation of preferences of freight transporters. Using a computer aided personal survey interview (CAPI), and an embedded stated choice (SC) experiment, we investigated, through a mixed logit model, the trade-offs made amongst a range of time and cost related attributes, including a distance-based charge for a sample of Sydney-based road haulage businesses. In the following sections we detail the empirical context, including the SC experiment, the data collection method and model estimation. The empirical evidence adds new insights into the influence of a distance-based charge on the value of travel time savings and on the value of trip time reliability. This study is part of a larger research activity focussed on the development and application of a new approach to studying the preferences and choices of agents in group decision making contexts (see Hensher and Puckett (2006) and Hensher *et al.* in press for the theoretical antecedents and extensive literature review of other studies).

## **2. Conceptual framework**

Road freight transport commonly involves interactions between decision makers, whether within the same organisation or across organisations (e.g., between a manager of a freight transport company and the manager of a company that is paying the freight transport company to move goods). This interdependent nature of freight leads to significant obstacles when attempting to undertake an empirical study of freight stakeholders. It may be both difficult to design appropriate research frameworks for quantifying behaviour and welfare effects for interdependent stakeholders, and financially prohibitive to utilise extant techniques to carry out the empirical task.

An appropriate research framework for interdependent stakeholders must reflect the nature of transactions made within interactions amongst decision makers. This is not impossible from a conceptual standpoint, yet it necessitates the development of research

frameworks that expand either on extant frameworks that are centred on independent decision makers or are unique to the state of practice. Hence, there is a degree of burden placed upon the analyst that is greater than that within an independent decision-making setting when developing the appropriate theoretical and econometric models.

To quantify the preferences of road freight stakeholders and their clients, one appealing method is interactive agency choice experiments (IACEs), developed by Hensher (see Brewer and Hensher, 2000). IACEs involve an iterative technique by which interdependent respondents have the opportunity to amend their stated preferences within choice menus based on the preferences of other members of the group. The observed process of preference revision enables the analyst to quantify the effects of interactivity whilst maintaining the desirable empirical properties of discrete choice data obtained through stated choice experiments. Unfortunately, it is often infeasible, especially in a freight distribution chain context, to conduct a non-case-based IACE with a meaningful sample size due to the high level of resources required, including difficulties in matching agents.

Given these constraints, we investigated ways to make behavioural inferences for interdependent decision makers within discrete choice analysis. We first developed a general model, named the *inferred influence and integrative power* (IIIP) model, to accommodate a range of feasible empirical tasks (Hensher *et al.*, in press). Within this broad model, we selected the minimum information group inference (MIGI) method to obtain our desired behavioural estimates. MIGI enables the analyst to model the influence structures within decision-making groups, such as the freight transport buyer-seller dyads of key interest within our research application (see Hensher and Puckett, 2005 and Puckett *et al.*, 2006 for a detailed justification), by inferring the effects of interactivity based upon the stated willingness of respondents to concede toward the preferences of the other member of their respective sampled groups. Whilst we do not contend that MIGI is preferable to the direct observation of interactions amongst interdependent decision makers, we suggest that MIGI represents a means of gaining meaningful inference with respect to group decision making when other methods are infeasible.

MIGI experiments are framed in terms of an interactive setting, within which respondents are asked to indicate their preferences among the given alternatives. Specifically, MIGI experiments prompt respondents to indicate how they would rank the alternatives if they had to attempt to reach agreement with the other member(s) of the sampled group. Importantly, the ranking process includes the option of denoting an alternative as unacceptable, to avoid inferring cooperative outcomes that would not likely be observed under direct interaction. In other words, allowing respondents to indicate that they would not concede toward other respondent(s) to a specified degree within a given choice set preserves the potential to infer non-cooperative outcomes for a sampled group.

Unlike IACEs, MIGI does not involve an iterative process in which respondents are presented with information about the preferences of the other respondent(s) in the group and given the opportunity to revise their preferences. Rather, the influence of each respondent in a sampled group is inferred through the coordination of the preference

rankings given by each respondent in a particular sampled group for a particular choice set. Influence is hypothesised to be represented within the preference rankings, in that respondents who are relatively more willing to accept less favourable alternatives are modelled as though they would be willing to offer relatively more concession within a direct interaction with the other group member(s). That is, the preference rankings themselves are indicative of the levels of concession the respondent would offer when interacting with the other member(s) of the group.

This chapter focuses on the identification of the first preferences of each agent, without consideration of what compromises might be required to establish a cooperative outcome in the distribution chain. Fuller details are in Puckett and Hensher (2006) and Hensher *et al.* (in press). The focus herein is on the empirical specification of the first preference models for transporters and shippers and the estimation of a mixed logit model to reveal agent preferences for specific attributes of the freight distribution activity.

### 3. Modelling approach

To establish the distribution of preferences of transporters and shippers for the range of attributes and packages in a stated choice experiment, we need to develop and estimated a series of mixed logit models in which the sampled agents choose between bundles of attributes, including alternatives that have a distance-based user charge.

We begin by assuming that sampled firms  $q = 1, \dots, Q$  face a choice among  $J$  alternatives, denoted  $j = 1, \dots, J$  in each of  $T$  choice settings,  $t = 1, \dots, T$ . The random utility model associates utility for firm  $q$  with each alternative in each choice situation.

$$U_{q,j,t} = \beta' \mathbf{x}_{q,t} + \varepsilon_{qjt} \quad (1)$$

Firm-specific heterogeneity is introduced into the utility function in equation (1) through  $\beta$ . We allow the ‘firm-specific’ parameter vector to vary across firms both randomly and systematically with observable variables,  $\mathbf{z}_q$ . In the simplest case, the (uncorrelated) random parameters are specified as (based on Greene *et al.* 2006) equation (2).

$$\beta_q = \beta + \Delta \mathbf{z}_q + \Sigma^{1/2} \mathbf{v}_q \quad (2)$$

$$= \beta + \Delta \mathbf{z}_q + \eta_q.$$

or

$$\beta_{qk} = \beta_k + \delta_k' \mathbf{z}_q + \eta_{qk},$$

where  $\beta_{qk}$  is the random coefficient for the  $k^{\text{th}}$  attribute faced by firm  $q$ .  $\beta + \Delta \mathbf{z}_q$  accommodates heterogeneity in the mean of the distribution of the random parameters and  $\delta_k'$  is a vector of parameters indicating the conditioning influence of the observable variables  $\mathbf{z}_q$ . The random vector  $\mathbf{v}_q$  endows the random parameter with its stochastic

properties. For convenience, denote the matrix of known variances of the random draws as  $\mathbf{W}$ . The scale factors which provide the unknown standard deviations of the random parameters are arrayed on the diagonal of the diagonal variance matrix,  $\Sigma^{1/2}$ .

The *mixed logit* class of models assumes a general distribution for  $\beta_{qk}$  and an IID extreme value type 1 distribution for  $\varepsilon_{jtq}$ . That is,  $\beta_{qk}$  can take on different distributional forms.<sup>2</sup> For a given value of  $\beta_q$ , the *conditional* (on  $\mathbf{z}_q$  and  $\mathbf{v}_q$ ) probability for choice  $j$  in choice situation  $t$  is multinomial logit, since the remaining random term,  $\varepsilon_{jtq}$ , is IID extreme value:

$$P_{jtq}(\text{choice } j \mid \Omega, \mathbf{X}_{tq}, \mathbf{z}_q, \mathbf{v}_q) = \exp(\beta_q' \mathbf{x}_{jtq}) / \sum_j \exp(\beta_q' \mathbf{x}_{jtq}) \quad (3)$$

where the elements of  $\Omega$  are the underlying parameters of the distribution of  $\beta_q$ . We label as the *unconditional* choice probability, the expected value of the logit probability over all the possible values of  $\beta_q$ , that is, integrated over these values, weighted by the density of  $\beta_q$  which is conditioned on the observable firm-specific information ( $\mathbf{z}_q$ ), but not on the unobservable  $\mathbf{v}_q$ . From (3), we see that this probability density is induced by the random component in the model for  $\beta_q$ , namely  $\mathbf{v}_q$ . The unconditional choice probability is given as equation (4) (Greene *et al.* 2006):

$$P_{jtq}(\text{choice } j \mid \Omega, \mathbf{X}_{tq}, \mathbf{z}_q) = \int_{\mathbf{v}_q} P_{jtq}(\beta_q \mid \Omega, \mathbf{X}_{tq}, \mathbf{z}_q, \mathbf{v}_q) f(\mathbf{v}_q \mid \mathbf{W}) d\mathbf{v}_q \quad (4)$$

Details on estimation of the parameters of the mixed logit model by maximum simulated likelihood may be found in Train (2003).

One can construct estimates of ‘individual-specific preferences’ by deriving the conditional distribution based (within-sample) on known choices (i.e., prior knowledge), (see also Train, 2003 chapter 11 and Hensher *et al.* 2005). These conditional parameter estimates are strictly ‘same-choice-specific’ parameters, or the mean of the parameters of the subpopulation of individuals who, when faced with the same choice situation would have made the same choices. This is an important distinction<sup>3</sup> since we are not able to establish for each individual, their unique set of estimates, but rather we are able to identify a mean (and standard deviation) estimate for the sub-population who make the same choice. For convenience, let  $\mathbf{Y}_q$  denote the observed information on choices by individual  $q$ , and let  $\mathbf{X}_q$  denote all elements of  $\mathbf{x}_{jtq}$  for all  $j$  and  $t$ . Using Bayes Rule, we find the conditional density for the random parameters,

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<sup>2</sup>As set out in Greene *et al.* (2006), the random parameters specification can accommodate correlation amongst the alternatives. Since  $\beta_q$  can contain alternative specific constants which may be correlated, this specification can induce correlation across alternatives. It follows that the model does not impose the IIA assumption.<sup>2</sup> Restrictions can be imposed at numerous points in the model to produce a wide variety of specifications.

<sup>3</sup> Discussion with Ken Train is appreciated.

$$f(\beta_q | \Omega, Y_q, X_q, z_q, h_q) = \frac{f(Y_q | \beta_q, \Omega, X_q, z_q, h_q) P(\beta_q | \Omega, z_q, h_q)}{f(Y_q | \Omega, X_q, z_q, h_q)} \quad (5)$$

The left hand side gives the conditional density of the random parameter vector given the underlying parameters and all of the data on individual  $q$ . In the numerator of the right hand side, the first term gives the choice probability in the conditional likelihood – this is in (4). The second term gives the marginal probability density for the random  $\beta_q$  implied by (2) with the assumed distribution of  $v_q$ . The denominator is the unconditional choice probability for the individual – this is given by (4). Note that the denominator in (6) is the integral of the numerator. This result can be used to estimate the ‘common-choice-specific’ parameters, utilities, and willingness to pay values or choice probabilities as a function of the underlying parameters of the distribution of the random parameters. Estimation of the individual specific value of  $\beta_q$  is done by computing an estimate of the mean of this conditional distribution. Note that this conditional mean is a direct analog to its counterpart in the Bayesian framework, the mean of the posterior distribution, or the posterior mean. More generally, for a particular function of  $\beta_q$ ,  $g(\beta_q)$ , such as  $\beta_q$  itself, the conditional mean function is

$$E[g(\beta_q) | \Omega, Y_q, X_q, z_q, h_q] = \int_{\beta_q} \frac{g(\beta_q) f(Y_q | \beta_q, \Omega, X_q, z_q, h_q) P(\beta_q | \Omega, z_q, h_q)}{f(Y_q | \Omega, X_q, z_q, h_q)} d\beta_q \quad (6)$$

To avoid confounding our results with differentially unobserved scale effects across transporters and shippers, we pooled the choices of transporters and shippers into one model, estimating separate marginal (dis)utilities for transporters and shippers for each attribute. The value of travel time savings (VTTS) and value of reliability gains (VRG) are obtained from the conditional estimates of the relevant time and cost parameters in the models given below.

### 3.1 An empirical framework for modelling the influence of distance-based road user charges

Preliminary in-depth interviews with a number of stakeholders in freight distribution chains, namely the shipper of goods, the transporter and the receiver of goods, suggested that the majority of decisions on distribution are made by, at most, two agents (Puckett *et al.* 2005). The agency set was defined as the freight transport provider carrying the goods, and the organisation paying the freight transport provider for those services. Any additional party (e.g., a recipient of the goods which does not interact with the freight transport provider) was treated as an exogenous force, setting some constraints on the interaction within the two-member group.

Given the interest in evaluating a range of distance-based user charges that do not currently exist in real markets, we selected a stated choice framework (Louviere *et al.* 2000) within which the transporter defined a recent reference trip in terms of its time and cost attributes (detailed below), treating fuel as a separate cost item to the distance-based



user charge (VUC), with the latter being zero at present. A pivot design using principles of D-optimality in experimental design ( Rose *et al.* 2005, Sandor and Wedel 2001) was developed to vary the levels of existing attributes around the reference levels plus introduce a VUC based on distance traveled but with varying rates per kilometre. With a focus on understanding sensitivity to varying charge levels, any consideration of tailoring a charge to the specific vehicle type in recognition of the costs it imposes on the road system is of secondary interest.

The stated choice alternatives were kept generic to one another, representing various options of re-routing and re-scheduling; however, these alternatives are inherently different to the reference alternative, which does not involve distance-based road user charges. We selected two stated choice alternatives, found to be sufficient to offer the desired variation in attribute bundles, giving a total of three alternatives from which to choose.

Selecting the set of attributes for the choice sets involved an iterative process of finding candidate attributes and determining how they could fit intuitively into the choice sets. Whilst in-depth interviews and literature reviews revealed myriad attributes that influence freight decision making in one way or another (see Puckett *et al.* 2006, Hensher and Puckett 2005, Cullinane and Toy 2000, Danielas *et al.* 2005, Fowkes *et al.* 2004, Bolis and Maggi 2001), we focussed on the subset of these attributes that were most likely to be directly affected by congestion charges. Hence, the attributes that reside within the choice sets are: free-flow travel time, slowed-down travel time, time spent waiting to unload at the final destination, likelihood of on-time arrival, fuel cost and distance-based road user charges. These attributes are either an input into a congestion-charging policy (i.e., changes in fuel taxes, road user charges), or direct functions of such a policy. Whilst other attributes could be hypothesised to be directly or indirectly affected by congestion charging, we found that our specification offered a useful mix of tractability and inferential power.

The levels and ranges of the attributes were chosen to reflect a range of coping strategies under a hypothetical congestion-centred road user charging regime. The reference alternative was utilised to offer a base, around which the stated choice design levels were pivoted. The resulting mixes represent coping strategies including: taking the same route at the same time as in the reference alternative under new traffic conditions, costs, or both; and taking alternative, previously less-favourable routes, departing at alternative, previously less-favourable times, or both, with corresponding levels of traffic conditions and costs.

Congestion charging presently does not exist in Sydney, the empirical setting, hence we needed to utilise available information to set realistic levels for the distance-based charges. Literature reviews revealed that fuel taxes are currently set as a second-best instrument to recover externality costs caused by heavy goods vehicle movements. Furthermore, the literature revealed that policy makers acknowledge that distance-based or mass-distance-based road user charging may be a more efficient method of internalising externality costs. Hence, we decided to specify the empirical study in terms

of potential policy adjustments, in which fuel taxes may be amended in preference of direct road user charges reflecting vehicle tonne kilometres travelled and congestion costs caused. To accomplish this, we utilised the fuel costs within the reference alternative as a base for the hypothetical road user charges. As fuel costs (and hence fuel taxes) increase with vehicle load and distance travelled, they form a useful, market-linked base for these hypothetical charges.

One potential complication that we identified is that changes in levels of service and operating costs (i.e., changes in fuel costs and new road user charges) could lead to upward or downward adjustments in the freight rate charged by the transport company. While obvious, incorporating an endogenous (at least to the freight transport provider) choice that could swamp the changes in costs into the experimental design is not a simple matter. To combat this, we developed a method to internalise this endogeneity and uncertainty, making it exogenous to the final choice. For each stated choice alternative involving a net change in direct operating costs (i.e., the change in fuel costs is not equal to the (negative) value of the new road user charges), respondents from freight firms were asked to indicate by how much of the net change in costs they would like to adjust their freight rate. Hence, the freight rate, which is not a design alternative, yet is clearly an important contextual effect, is allowed to vary across stated choice alternatives under changes in net operating costs.

The reference alternative within each choice set for respondents from freight firms is created using the details specified by the respondent for the recent freight trip. In all cases except for the distance-based charges, the attribute levels for each of the SC alternatives are pivoted off of the levels of the reference alternative, as detailed below. The levels are expressed as deviations from the reference level, which is the exact value specified in the corresponding non-SC questions, unless noted:

- (1) **Free-flow time:** -50%, -25%, 0, +25%, +50%
- (2) **Congested time:** -50%, -25%, 0, +25%, +50%
- (3) **Waiting time at destination:** -50%, -25%, 0, +25%, +50%
- (4) **Probability of on-time arrival:** -50%, -25%, 0, +25%, +50%,

with the resulting value rounded to the nearest five percent (e.g., a reference value of 75% reduced by 50% would yield a raw figure of 37.5%, which would be rounded to 40%). If the resulting value is 100%, the value is expressed as 99%. If the reference level is greater than 92%, the pivot base is set to 92%. If the pivot base is greater than 66 percent (i.e., if 1.5\* the base would be greater than 100%) let the pivot base equal X, and let the difference between 99% and X equal Y. The range of attribute levels for on-time arrival when  $X > 66\%$  are (in percentage terms):  $X-Y$ ,  $X-.5*Y$ ,  $X$ ,  $X+.5*Y$ ,  $X+Y$ . This yields five equally-spaced attribute levels between  $X-Y$  and 99%.

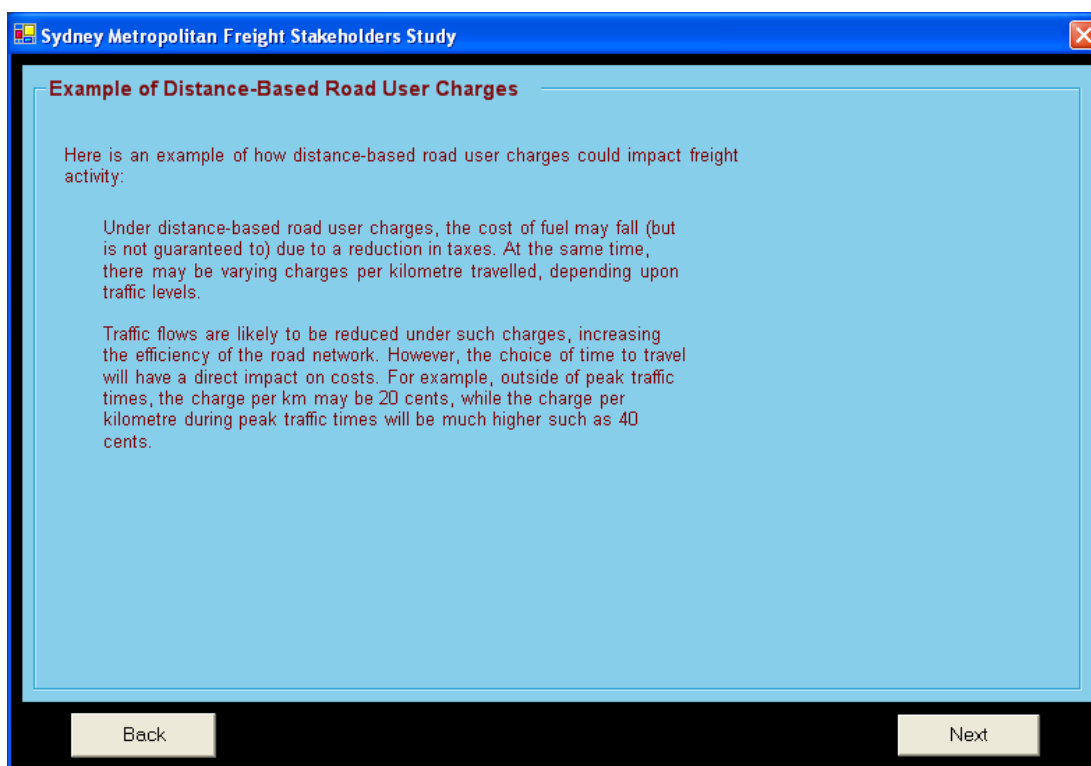
- (5) **Fuel cost:** -50%, -25%, 0, +25%, +50% (representing changes in fuel taxes of -100%, -50%, 0, +50%, +100%)

- (6) **Distance-based charges:** Pivot base equals  $.5 \times (\text{reference fuel cost})$ , to reflect the amount of fuel taxes paid in the reference alternative. Variations around the pivot base are: -50%, -25%, 0, +25%, +50%

The attribute levels include positive and negative deviations from the pivot bases to both cover a range of levels of service and costs that may exist for a given trip option in the future, and to represent alternative means of routing and scheduling a given trip option at one point in time. This makes the choice data sufficiently rich to allow for inference under a range of scenarios. It is apparent that the probability of on-time arrival offers the greatest obstacle from a practical standpoint (see Fowkes *et al.* 2004). This is due to the logical upper boundary of one for the attribute level (i.e., the probability cannot exceed one). Due to the use of respondent-specified pivot bases, one cannot know *a priori* whether all values for the probability of on-time arrival in the SC alternatives would be less than one without specifying sufficient heuristics. Furthermore, the design requires sufficient variation around the pivot base, despite the mathematical constraint. Hence, for cases of reference levels very close to one, a pivot base of 92 percent was selected to allow for sufficient variation in the attribute, whilst limiting the scope of unfavourable values of the attribute in SC alternatives, relative to the reference level.

The choice experiment focusses on the reaction of firms to the introduction of a VUC system in the context of trip service levels, other trip costs, freight rates and time loading and unloading goods. The survey was conducted via computer-aided personal interview (CAPI). This was essential if we were to seed each choice set faced by respondents with the revealed preference information they specify within the pre-choice-set phase of the questionnaire.

Given the focus herein on the role of distance-based user charges, we refer the reader to Hensher *et al.* (2006a) for more details on the survey instrument and modelling of group decision making. Figures 1-3 reproduce the relevant CAPI screens related to the description of distance-based user charges and the SC experiment in which each sampled respondent has to review the attribute packages and make a choice. Our focus herein is on the first preference choice of the transporter and the shipper.



*Figure 1: Questionnaire screen introducing distance-based user charges*

To familiarise respondents with VUCs, we provided an example trip situation of travel times and costs associated with taking a particular hypothetical trip during peak hours, contrasted with the travel times and costs of taking the same trip during the off-peak (Figure 2). The same trip is then discussed under hypothetical VUCs, revealing altered travel times and costs for both the peak and off-peak options.

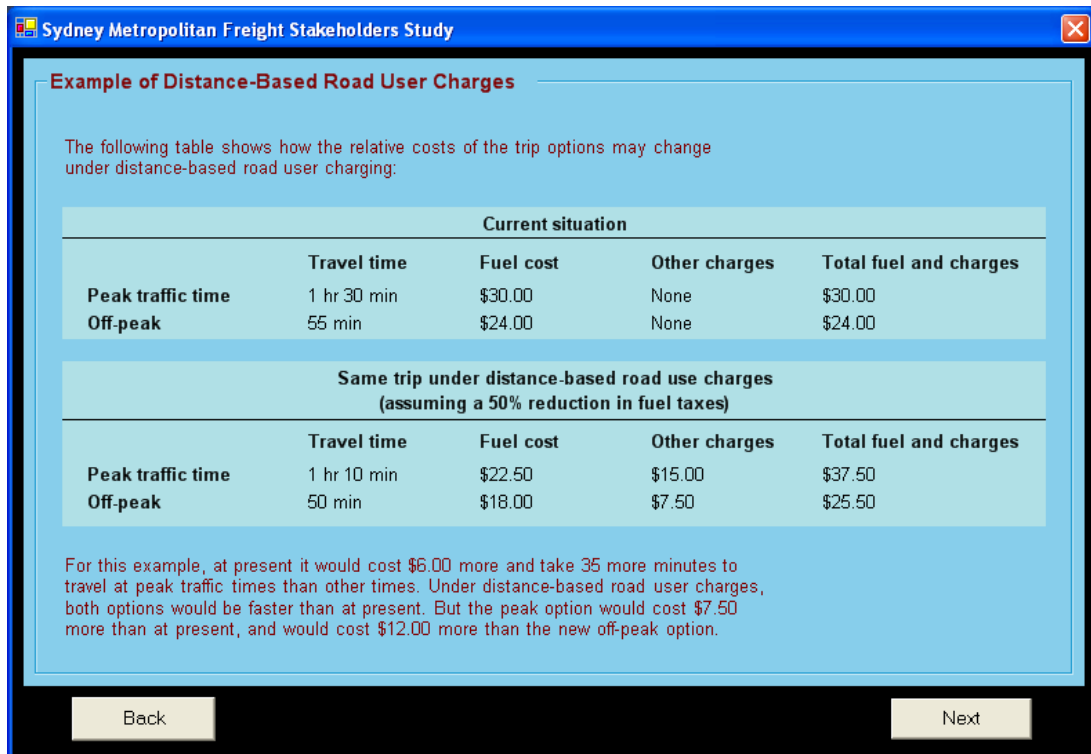


Figure 2: CAPI screen offering an example of the effects of VUCs

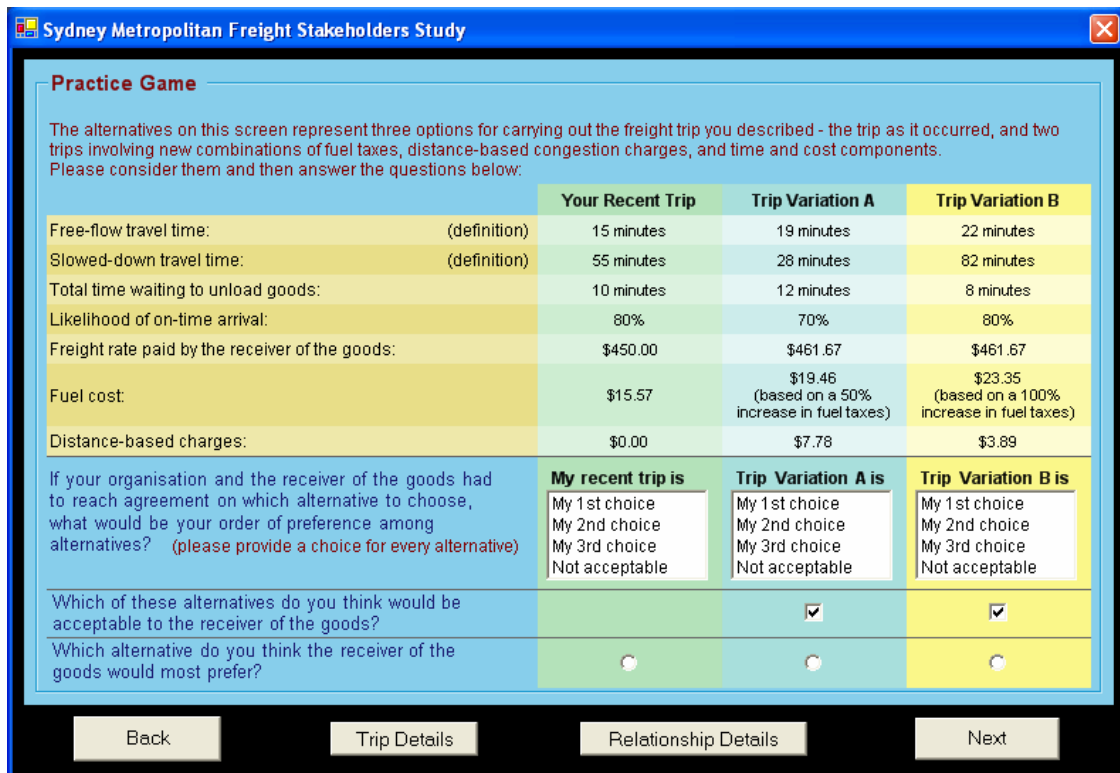
Respondents were faced with four choice sets if representing a freight firm and with eight choice sets if representing a client of a freight firm. The difference is due to the relatively larger burden placed on respondents from freight firms, in that they must supply the trip and relationship-specific details required to establish the choice setting and reference alternative. The exact four choice sets answered by a given respondent from a freight firm are given to the corresponding sampled client. The additional four choice sets faced by the sampled client use the same reference alternative as the other four choice sets.

Respondents were asked to assume that, for each of the choice sets given, the same goods need to be carried for the same client, subject to the same constraints faced when the reference trip was undertaken<sup>4</sup>. Respondents are then informed that the choice sets involve three alternative methods of making the trip (Figure 3): their stated trip<sup>5</sup> and two SC alternatives that involve VUCs. The choice tasks are described to respondents as two straightforward steps. The first step is to indicate which alternatives would be preferable

<sup>4</sup> In introducing the choice experiments, we made no explicit assumption about whether other users than freight distributors would incur the charge, although we did not say that it will only apply to freight transporters. Given that tolls are charged to all modes in Sydney, it is reasonable to assume that the sample would assume that all users would be subject to such charges as currently exists on tollroads in Sydney. We also focused on a specific recent trip and did not allow for responses that might involve changing the type of vehicle or consolidating deliveries, all worthy of future investigation. It was assumed that payment would be by electronic tag and direct debit, as is the popular method in place in Sydney for all modes on tollroads.

<sup>5</sup> The summary of trip details that appears when clicking on "Trip Details" includes: the name of the client or freight firm involved, the type of truck used, the primary contents of the truck, the amount paid for delivery of the goods, kilometres travelled, the last location of loading before delivery, the total number of locations at which the truck delivered goods, the allowable lead time, the time from request of delivery to departure of truck, and, in the case of questionnaires given to sampled clients, the value of the cargo. This last element is omitted from questionnaires given to representatives of freight firms, as they are not prompted for this information.

if the two organisations had to reach agreement, whilst the second step is to indicate what information mattered when making each choice<sup>6</sup>.



*Figure 3: Main choice set screen<sup>7</sup>*

Respondents have the option to click to find a definition for the two travel time attributes, each of which includes an illustrative photograph. Free-flow travel time is described as, "Can change lanes without restriction and drive freely at the speed limit", whilst slowed-down travel time is described as, "Changing lanes is noticeably restricted and your freedom to drive at the speed limit is periodically inhibited. Queues will form behind any lane blockage such as a broken down car".

The specific choice task on the initial screen is, "If your organisation and the client had to reach agreement on which alternative to choose, what would be your order of preference among alternatives?" Respondents are asked to provide a choice for every alternative. The available options for each alternative are: (Name of the alternative) is: {My 1st choice; My 2nd choice; My 3rd choice; Not acceptable}. At least one of the alternatives must be indicated as a first choice, which was not found to be restrictive, given that the

<sup>6</sup> As the tasks are likely to involve some unfamiliar terms, respondents are given definitions of the terms "attribute" and "alternative", and informed that a showcard is available for any unfamiliar terms in the choice sets. Respondents were also informed that any details relating either to the trip or to the relationship between the two firms that are not shown in the choice sets can be found by clicking on the buttons labelled "Trip Details" and "Relationship Details", respectively.

<sup>7</sup> The summary of relationship details that appears when clicking on "Relationship Details" includes: the length of the relationship between the two organisations, their contractual arrangement, the organisations that have input into the routing and scheduling of the trip, and, in the case of respondents representing freight firms, the proportion of business represented by the relationship with the client. This last element is omitted from questionnaires involving sampled clients, as they may not know this information in the marketplace.

reference alternative represents the status quo, which was clearly acceptable in the market. We focus herein on the first preference choice<sup>8</sup>.

The number of attributes to consider could be potentially burdensome. However, there are at least two reasons why this may not be so. Firstly, each of the attributes is either an element of time or cost. Therefore, although the number of attributes may be viewed as relatively high, there is an intuitive relationship between them. Secondly, as illustrated by Hensher (2006a, 2006b), there is not a monotonically-increasing relationship between the number of attributes and the level of cognitive burden experienced by respondents. Rather, there is a local, but not global, trade-off between complexity and relevance. That is, over a finite range, decision making is relatively easier as the information presented increases. Whilst seven attributes is a significant number, one may argue that a complex decision-making setting requires a complex, and hence relevant, array of information in order to make an informed decision. Therefore, in the case of a complex decision such as a distribution strategy, it is one thing to argue that seven is a large number, but quite another to argue that it is too large.

Whilst the analyst must ensure that choice sets are tractable by taking care to include only the attributes that have been identified as integral to the application, there is a point at which further paring of attributes for the sake of reducing cognitive burden becomes dangerous. Such paring may even add to the cognitive burden of respondents, as there may not be sufficient information to make an informed choice.

#### **4. Profile of the data collection strategy and choice responses**

The survey was undertaken in 2005, sampling transporters who were delivering goods on behalf of a single shipper to and/or from the Sydney Metropolitan area. Initially a sample of transporters were selected and screened for participation by a telephone call. Eligibility to participate in the CAPI survey required a respondent having (i) input into the routing or scheduling of freight vehicles used by your organisation (ii) input into the business arrangements made with your organisation's customers, and (iii) your organisation carry truckloads that contain cargo either sent by, or intended for, one single company. Each completed CAPI interview by a transporter was used to match a shipper based on a hierarchy of criteria. If the actual receiver of the goods is known then that organisation was contacted; however if that organisation refused to participate or was not known, a rule set was implemented that matched the transporter to the shipper. The main rules relate to the market segment of the goods (e.g. perishables being delivered to a major retailer).

The resulting estimation sample, after controlling for outliers and problematic respondent data<sup>9</sup>, includes 108 transporters and 102 shippers, yielding 1,248 observations (432 choice

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<sup>8</sup> Two further tasks are given relating to the role of the other decision maker. Firstly, respondents are asked to indicate which of the two SC alternatives they feel would be acceptable to the other decision maker. Secondly, respondents are asked to indicate which of the three alternatives is likely to be most preferred by the other decision maker. These supplementary tasks serve two purposes: (1) reminding the respondent of the likely preferences of the other decision maker; and (2) allowing the analyst to compare the perceived preferences of the other agent type with the actual preferences of that agent type. That is, the supplementary questions both reinforce the interdependent nature of the choice setting by explicitly asking respondents to consider the preferences of the other decision maker in the choice setting, and serve as a check of the degree of accuracy with which decision makers gauge the preferences of other classes of decision makers with which they interact.

sets faced by transporters and 816 choice sets faced by shippers). The transporters response rate was 45% while that of the shippers is 72%. The remainder of this section presents the results for models of independent preferences for transporters and shippers, based on this sample.

Tables 1 and 2 summarise the mean and standard deviation of attribute levels in the chosen alternatives, represented in terms of the specification of utility functions for transporters and shippers. The choice frequencies across alternatives are remarkably similar for both transporters and shippers, with minimal variation across the groups; alternative A (i.e., the reference alternative) was chosen by 55.8 percent of transporters and 56.3 percent of shippers, alternative B (i.e., the first stated choice alternative) was chosen by 30.6 percent of transporters and 29.7 percent of shippers, and alternative C (i.e., the second stated choice alternative) was chosen by 13.6 percent of transporters and 14 percent of shippers.

**Table 1: Descriptive statistics – transporters (chosen alternatives)**

Time in minutes, cost in dollars, FF\* km in mins\*kms/1000.

	<b>FF/SD Time</b>	<b>On-Time Reliability</b>	<b>FF*Km</b>	<b>Total Cost</b>	<b>Freight Rate</b>	<b>Distance- based Charges/Km</b>	<b>Total Cost*</b>	<b>Distance- based Charges</b>
<b>Alternative A (55.8 % Choice Frequency):</b>								
Mean	250.8	85.1	75.2	193.8	753.0			
Standard Dev.	102.3	14.8	68.1	179.4	382.5			
<b>Alternative B (30.6% Choice Frequency):</b>								
Mean	208.8	92.7	67.7	287.2	858.0	0.23	82.3	
Standard Dev.	82.8	13.0	57.0	207.5	404.7	0.14	100.3	
<b>Alternative C (13.6% Choice Frequency):</b>								
Mean	240.6	88.9	70.9	361.2	1004.5	0.30	133.32	
Standard Dev.	127.6	17.3	68.4	237.9	523.3	0.19	136.34	

<sup>9</sup> Preliminary analysis revealed that the degree of heterogeneity in reference trips was sufficiently high that some outliers obscured the inferential power of the data. After careful consideration, the following observations were removed from the final sample: (a) trips based on a fuel efficiency over 101 litres per 100 kilometres (or approximately twice the average fuel consumption for the larger trucks in the sample); (b) trips based on a probability of on-time arrival less than 33 percent; (c) round trips (or tours) of less than 50 kilometres; and (d) round trips of more than 600 kilometres. The trips eliminated, based on low fuel efficiency, may have obscured the results due to significantly prohibitive values for fuel cost and distance-based charges, reflecting reference trips that are too atypical to be pooled with other trips. An alternative source of obscuring effects via low fuel efficiency may be that the implied values of fuel efficiency were inaccurate, and hence either made the trade-offs implausible to respondents or reflect an inability of the respondent to offer meaningful information on which to base the alternatives. The trips eliminated, based on low probability of on-time arrival, are likely to have obscured the results because the trips involved travel quality significantly worse than the remainder of the sample, making the pooling of these trips into the sample problematic. Similarly, extremely short or long trips may have involved trade-offs that are significantly different to the trade-offs made by respondents in the sample at large.



*Table 2: Descriptive statistics – shippers (chosen alternatives)*

	Free-Flow Time	Slowed- Down Time	Waiting Time	On-Time Reliability	Total Cost	Freight Rate
<b>Alternative A (56.3% Choice Frequency):</b>						
Mean	212.3	43.6	59.1	85.5	202.8	755.9
Standard Dev.	100.5	33.5	70.4	13.9	146.2	405.0
<b>Alternative B (29.7% Choice Frequency):</b>						
Mean	171.5	43.0	59.3	92.5	284.6	909.2
Standard Dev.	103.9	43.2	67.8	12.3	299.9	396.9
<b>Alternative C (14.0% Choice Frequency):</b>						
Mean	140.6	50.8	45.8	87.6	256.9	890.2
Standard Dev.	91.6	50.4	55.6	15.8	199.1	511.2

Whilst both transporters and shippers demonstrated a preference for the reference (i.e., zero-distance-based-charge, zero-change-in-fuel-cost) alternative, the variation in attribute levels of chosen alternatives across the groups reveals different forces that induce transporters to choose stated choice (SC) alternatives relative to shippers. Transporters are willing to choose SC alternatives that offer improvements in travel quality; the mean levels of travel time and on-time reliability are more favourable in the chosen SC alternatives compared to the reference alternative. However, transporters appear only willing to choose these alternatives when the shipper covers the increase in total cost that accompanies the improved levels of service; the difference between the freight rate and the transporter’s costs is larger in the SC alternatives. This is also indicative of a relatively lower disutility of the distance-based charges as the trip distance, and hence level of the charges, increases.

Shippers, on the other hand, appear willing to choose alternatives that offer improved travel times (chiefly free-flow time) and on-time reliability, as long as the proportion of charges passed on to the shipper is less than unity. That is, the mean difference between the freight rate and the transporter’s costs is lower in the SC alternatives chosen by shippers than in the reference alternatives chosen by shippers. Ultimately, it appears that shippers are willing to pay some of the costs associated with the improvements offered by the SC alternatives, but are not willing to cover the costs entirely. However, as with transporters, this may also be indicative of a certain class of trips offering relatively larger benefits of paying the distance-based charges than other trips.

## 5. Empirical model results

Tables 3 and 4 summarise the multinomial logit and mixed logit model results. The multinomial logit (MNL) and mixed logit models yield similar mean estimates for each measure of marginal (dis)utility; however the mixed logit model captures elements of unobserved preference heterogeneity for the travel time attributes. This offers an

improvement over the MNL model by explaining variation around mean parameter estimates, and by relaxing the strict assumption of the independence of irrelevant alternatives. Tests for more complex models (i.e., models accounting for correlations across choice sets or systematic error components) did not improve on the simpler mixed logit model results, our preferred model for explaining the preferences of transporters and shippers.

**Table 3: Multinomial logit model**

<b>Attribute</b>	<b>Parameter (t-statistic)</b>	<b>Parameter (t-statistic)</b>
	Transporter	Shipper
<i>Marginal Utility Parameters</i>		
Constant representing the reference alternative	0.6338 (2.60)	
Free-flow and slowed-down time	-0.0095 (-3.03)	
Probability of on-time arrival	0.0299 (4.25)	
Free-flow time*trip distance	0.0138 (1.95)	
Total cost	-0.0082 (-4.13)	
Freight rate	0.0045 (2.58)	
Distance-based charges per kilometre	-1.4502 (-1.87)	
Total cost*distance-based charges per kilometre	0.0028 (3.23)	
Constant representing the reference alternative		0.8229 (7.73)
Free-flow time		-0.0071 (-6.49)
Slowed-down time		-0.0173 (-5.54)
Waiting time		-0.0069 (-3.34)
Probability of on-time arrival		0.0533 (8.61)
Total cost		-0.0015 (-2.11)
Freight rate		-0.0056 (-5.80)
<i>Model fits</i>		
No Observations	1248 (432 transporters, 816 shippers)	
LL(B)	-1039.387	

**Table 4: Mixed logit model**

200 Halton draws used to estimate the random parameters; all random terms distributed triangular

<b>Attribute</b>	<b>Parameter (t-statistic) Transporter</b>	<b>Parameter (t-statistic) Shipper</b>
<i>Mean Random Parameters</i>		
Free-flow and slowed-down time (transporter)	-0.0114 (-2.90)	-0.0114 (-2.90)
Probability of on-time arrival	0.0289 (3.76)	
Free-flow time*trip distance	0.0178 (2.03)	
Free-flow time		-0.0080 (-5.95)
Slowed-down time		-0.0221 (-5.20)
Waiting time		-0.0071 (-2.79)
Probability of on-time arrival		0.0694 (7.83)
<i>Fixed Parameters</i>		
Constant representing the reference alternative	0.6516 (2.57)	
Total cost	-0.0088 (-4.29)	
Freight rate	0.0050 (2.74)	
Distance-based charges per kilometre	-1.5119 (-1.89)	
Total cost*distance-based charges per kilometre	0.0030 (3.39)	
Constant representing the reference alternative		0.9426 (8.04)
Total cost		-0.0017 (-2.05)
Freight rate		-0.0067 (-5.99)
<i>Standard Deviation of Random Parameters</i>		
Free-flow and slowed-down time	0.0114 (2.90)*	
Probability of on-time arrival	0.0578 (3.79)#	
Free-flow time*trip distance	0.0178 (2.03)*	
Free-flow time		0.0160 (5.95)#
Slowed-down time		0.0441 (5.20)#
Waiting time		0.0142 (2.79)#
Probability of on-time arrival		0.1388 (7.83)#
<i>Model fits</i>		
Number of Observations	1248 (432 transporters, 816 shippers)	
LL(B)	-1036.369	
Adjusted Pseudo R <sup>2</sup>	0.53	

NB. For all mixed logit tables, ^, \*, and # represent unconstrained distributions, distributions constrained with a spread equal to the mean, and distributions constrained to twice the mean, respectively.

The model offers rich behavioural inference. The inclusion of interaction terms with free-flow time (i.e. trip distance) and distance-based charges (i.e. total cost and trip distance) for transporters allows for the model to account for contextual influence on preferences of transporters across types of travel time (i.e., free-flow time and slowed-down time) and cost (i.e., fuel cost and distance-based charges). The data are sufficiently well behaved to enable a linear representation of marginal utility for shippers that explains preferences as well as any alternative specifications that were tested; the only restriction in the model with respect to shippers is that the model is not improved if fuel cost and distance-based charges are considered separately (i.e., the model essentially assumes that shippers form an aggregate of transporters' costs).

### 5.1 Marginal (dis)utility of travel time elements

For transporters, whilst travel time is a source of disutility, the marginal disutility of free-flow time decreases as the interaction between free-flow time and trip distance increases. This implies that transporters acknowledge an inherent value in travel quality; that is, for a

given distance travelled, as the proportion of free-flow time increases, the (dis)utility decreases, as well. The presence of this relationship has direct implications for the relative values of travel time savings (VTTS) held by transporters for free-flow time and slowed-down time. These values are examined below, along with the values of reliability gains (VRG) for transporters and shippers.

The empirical marginal disutility functions for the random parameterised attributes can be written out as a set of equations, drawing on the estimated parameters in Table 4. The marginal disutility is the derivative of utility with respect to the attribute. For example the marginal disutility expressions for travel time and marginal utility of the probability of on-time arrival for transporter, based on random parameters, are:

$$\text{Marginal disutility of travel time} = -0.0114 + 0.0114 * t$$

$$\text{Marginal disutility of on-time arrival probability} = 0.0694 + 0.0694 * t$$

where  $t$  is the triangular distribution. The marginal disutility of trip cost, based on fixed parameters, is:

$$\text{Marginal disutility of trip cost} = -0.0088 + .0030 * \text{dbcperkm} - 1.5119$$

where  $\text{dbcperkm}$  is the distance-based cost per kilometre (\$/km).

The VTTS per transporter is the ratio of Marginal disutility of travel time to Marginal disutility of trip cost (in \$ per trip hour), and the VRG is the ratio of Marginal disutility of on-time arrival probability to Marginal disutility of trip cost (in \$ percentage point of improvement in arrival time probability). These estimates are obtained for each transporter, given the distribution of parameter estimates in the numerator, and this sample averages are obtained by averaging over the distributions.

Before examining the VTTS and VRG measures, it is important to contrast the marginal (dis)utility of transit time for transporters with the corresponding estimates for shippers. Whilst free-flow, slowed-down and waiting time are technically representative of the transit time for a delivery, shippers are not impacted directly by travel time mixes. Hence, any variation in marginal utilities across time components may serve as proxies for other factors, such as service quality. Indeed, shippers show a much stronger disutility for slowed-down time than for free-flow time or waiting time. This may be explained by a perceived relationship between slowed-down time and delay or damage risk. That is, a larger proportion of slowed-down time is indicative of travel in congested conditions, which may result in a greater probability of delay or damage relative to travel outside of congested conditions. Furthermore, strategically-thinking shippers may see benefits of reducing the transporter's costs: by reducing the quantity of time the transporter spends in congested conditions, the transporter is likely to experience lower operating costs, reducing the probability that the freight rate will increase.

The presence of a significant disutility of waiting time for shippers is interesting, in that no such disutility could be identified for transporters. However, the nature of the time is quite different for the two groups. Transporters, especially owner-operators, which form the majority of the freight vehicle fleet, appear to schedule waiting time at destinations as break time. Indeed, there are limits to the amount of travel a driver may legally perform on a given shift, and hence waiting time may not lead to any wasted downtime for transporters, as long as it is within an acceptable range. However, waiting time impacts shippers, in that any time the transporter spends waiting to unload is time that the shipper must spend without being in possession of the goods. Still, waiting time causes less disutility than free-flow time. This is intuitive, in that arrival reliability is no longer an issue once a truck has reached its destination. Hence, time spent in a delivery queue is similar to free-flow time, in that it involves expected processes of bringing the goods into the hands of the receiver. The marked difference between slowed-down time and both free-flow and waiting time supports the notion of concerns with respect to service quality and the freight rate, and the slightly lower disutility for waiting time relative to free-flow time adds to the picture: there is a relatively higher cost to driving, even in free-flow conditions than to waiting in a queue (i.e., labour costs are involved in both cases, but asset-related operating costs are relatively low or nil when waiting). Therefore, reducing waiting time could help to decrease the transporter's costs (whilst also decreasing total transit time of the goods for the shipper), but not to the degree that a reduction in free-flow or slowed-down time could.

VTTS and VRG measures, given in Tables 5 to 7 and Figures 4 to 8 will be discussed as basis of highlighting the behavioural response differences between transporters and shippers in trading off time and cost dimensions of freight distribution.

*Table 5: Value of travel time savings (AU\$ per hour) for Transporters*

	<b>Free-Flow Time</b>	<b>Slowed-Down Time</b>
Mean	\$42.48	\$83.77
Standard Deviation	\$22.95	\$8.88
Minimum	\$-22.64	\$55.67
Maximum	\$99.39	\$162.42
Proportion of Negative Values	1.9%	0%

Transporters demonstrate a clear disutility for travel in slowed-down conditions, with a mean VTTS for slowed-down time twice as high as the VTTS for free-flow time. Furthermore, heterogeneity in preferences with respect to slowed-down time is significantly lower across transporters than heterogeneity in preferences with respect to free-flow time; the ratio of the mean VTTS for slowed-down time to its standard deviation is only approximately one-fifth the corresponding ratio for free-flow time.

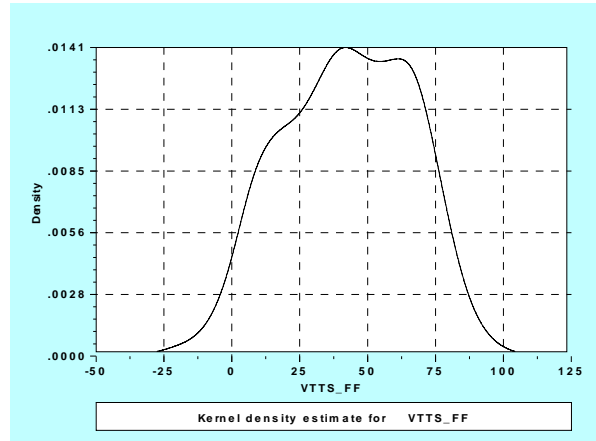


Figure 4: Distribution of free-flow VTTTS for transporters

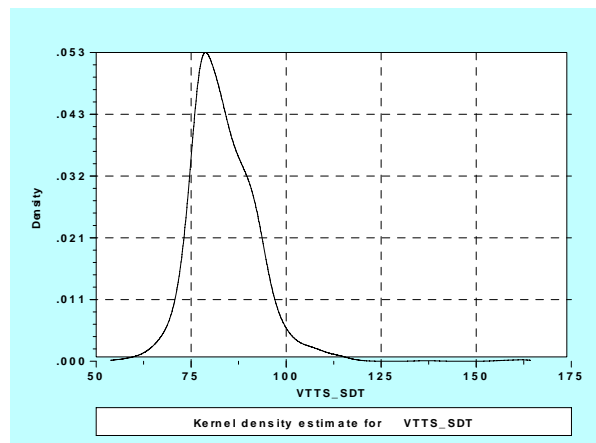


Figure 5: Distribution of slowed-down VTTTS for transporters

The policy implications are clear. Should the implementation of a distance-based user charging system proceed, transporters would stand to gain from improvements in the level of service provided by the traffic infrastructure. Specifically, any reductions in travel in congested conditions would benefit most transporters at a rate that may frequently exceed the corresponding level of the charges. For example, considering a transporter at the mean of the VTTTS distribution, a given trip alternative that offers a savings of 30 minutes of slowed-down time – worth \$41.89 – would benefit from the utilisation of that alternative as long as the distance-based charges did not exceed \$0.41, \$0.83 or \$1.68 per kilometre for a trip of 100, 50 or 25 kilometres, respectively. Given the relatively small spread of VTTTS values around the mean, the majority of transporters would experience similar opportunities.

Ultimately, the relatively large negative economic impact of traffic congestion on transporters could fuel significant changes in travel patterns under distance-based user charges. The status quo prohibits certain routing and scheduling alternatives from being

profitable, yet this may no longer be the case under distance-based charging. Not only would transporters stand to gain from an increased set of profitable routing alternatives at a given time of day, but transporters would also stand to gain from shifting trips to times of day that are currently prohibitive for a given route. The potential for mutual gains of efficiency through tighter scheduling and more responsive, reliable travel appear significant enough to engage transporters and shippers to work together to develop a group (i.e., supply chain) response to the implementation of distance-based charging that results in a net benefit for all parties. Whilst this has been suggested in the theoretical literature, a lack of empirical studies could not confirm this result. However, the presence of a significantly higher VTTS for slowed-down time compared to free-flow time under distance-based user charges confirms the theoretical gains to supply chain cooperation. Furthermore, the direct gains that may be afforded to transporters go as far as to imply benefits to transporters when acting unilaterally.

Unilateral action may not be necessary, however, as Table 6 highlights. Whilst transporters demonstrate a value of reliability gains of \$3.54 per percentage point of improvement, shippers place an even higher value on reliability. This is intuitive, as reliability may be a larger item of concern to shippers than travel time (i.e., it is more beneficial to know that shipments are likely to arrive on-time than it is to know that shipments are expected to arrive within a given time frame whose reliability cannot be guaranteed). Using the shipper's only cost measure in the analysis (i.e., the freight rate), the mean VRG for shippers is \$10.32, or almost three times as large as the corresponding VRG for transporters. However, given shippers' significant disutility of costs faced by the transporter, coupled with a lack of precedent for such willingness-to-pay measures, it is plausible that one must include all costs in the calculation, whether they are borne directly by the respondent or are only as indirect sources of disutility (e.g., through the perceived threat of an increased freight rate). Hence, we calculated a VRG for shippers based on a weighted average of the freight rate and the transporter's costs. This variant of VRG is somewhat higher than the VRG based solely on the freight rate; at \$12.67 per percentage point, this VRG estimate implies that shippers are approximately three-and-a-half times more sensitive to the probability of on-time arrival than transporters. Again, this is intuitive, as shippers are impacted by arrival reliability through both the need to satisfy customers, as well as through time sensitivity in the production of items. That is, delays of incoming goods may adversely impact the production or provision of goods worth more than the incoming goods themselves. Transporters face similar concerns with respect to on-time arrival reliability; however the scope of these concerns may be limited to customer satisfaction.

*Table 6 : VRG (AU\$ per percentage point)*

	<b>Transporters</b>	<b>Shippers – Freight Rate Only</b>	<b>Shippers – Freight Rate and Costs</b>
Mean	\$3.54	\$10.32	\$12.67
Standard Deviation	\$0.46	\$1.94	\$2.87
Minimum	\$1.62	\$0.61	\$0.72
Maximum	\$6.93	\$17.30	\$27.89
Proportion of Negative Values	0%	0%	0%

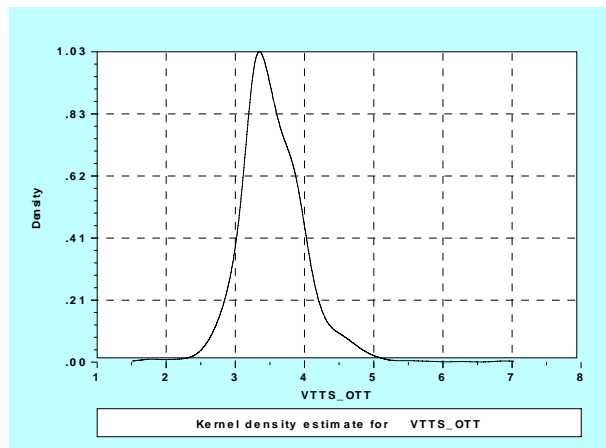


Figure 6: Distribution of transporters' VRG

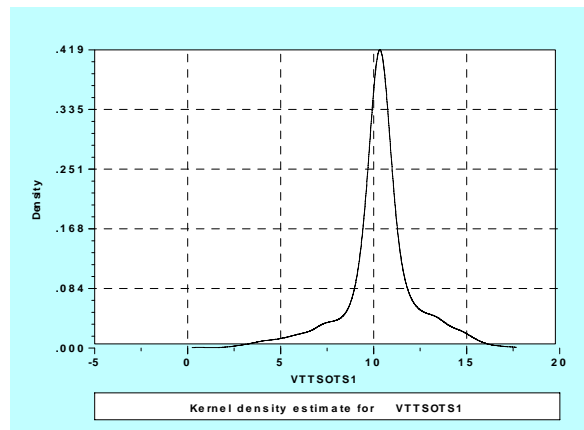


Figure 7: Distribution of Shippers' VRG (Freight Rate Only in Calculation)

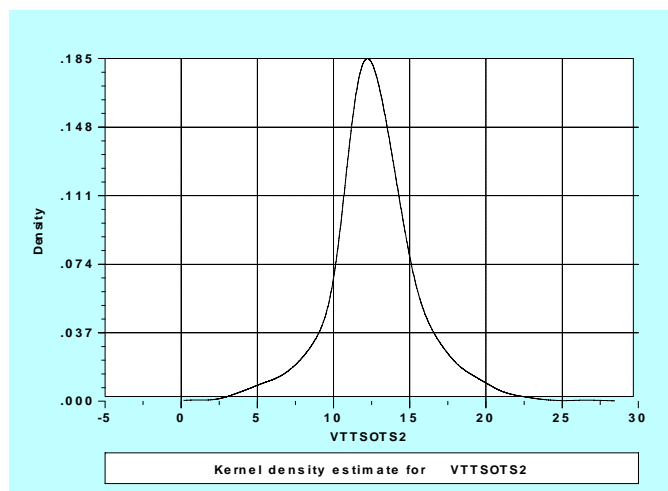


Figure 8: Distribution of shippers' VRG (freight rate and transporter's costs in calculation)



VRG measures are not inherently intuitive, to the extent that, whilst it is straightforward to understand the meaning of the value of an hour saved of travel time (i.e., most people have been delayed for a period of time when attempting to conduct a given activity, and would be able to place a value on that lost time), it is less straightforward to understand the meaning of the value of a percentage increase in the probability of a vehicle arriving on time. However, when placed in context, VRG measures are highly insightful. Consider the mean value of on-time arrival probability in the reference alternatives recalled by transporters, which is around 85 percent. The above estimates of VRG indicate that transporters would be willing to pay \$52.65 to eliminate all uncertainty in on-time arrival from a status quo trip at the mean, and would be willing to pay \$26.33 to eliminate one-half of the present uncertainty. When viewed in tandem with transporters' VTTS for slowed-down time, increases in travel quality offered by distance-based user charging could be of significant benefit to transporters. For example, given a trip involving the mean status quo level of slowed-down time (approximately 45 minutes) and probability of on-time arrival, and utilising the transporters mean VTTS and VRG measures, transporters would stand to gain benefits equivalent to \$115.48 from the elimination of both uncertainty in on-time arrival and slowed-down travel (gross of distance-based user charges), and would even stand to gain benefits equivalent to \$28.87 in the case where uncertainty and slowed-down time were pared down by only 25 percent (gross of distance-based user charges).

The potential benefits to shippers are even stronger. Utilising the more conservative estimate of VRG for shippers, a total reduction of uncertainty in on-time arrival would be worth \$154.80, on average. More moderate reductions in uncertainty of 25 and 50 percent would still be valued by shippers, on average, at \$38.70 and \$77.40, respectively. Hence, although transporters may stand to benefit from distance-based charging independently, the potential benefits for shippers appear sufficient for transporters and shippers to work collaboratively in responses to a distance-based user charging system.

The benefits of travel time savings and reliability gains for transporters can be compared to one another to aid in the quantification of the value of each, as shown in Table 7.

*Table 7: Comparison of VTTS and VRG for transporters*

	<b>Equivalent Values at the Mean</b>
One hour of free-flow time savings	12.00 percent increase in the probability of on-time arrival
One hour of slowed-down time savings	23.66 percent increase in the probability of on-time arrival
One percent increase in the probability of on-time arrival	5.00 minutes of free-flow time savings
One percent increase in the probability of on-time arrival	2.54 minutes of slowed-down time savings

When considered at the mean, transporters value one hour of free-flow time savings and one hour of slowed-down time savings as equivalent to a 12 and 23.66 percent increase in the probability of on-time arrival, respectively. The reciprocal of this relationship shows

that a one-percent increase in the probability of on-time arrival is valued equivalently to either a savings of five minutes of free-flow time, or a savings of 2.54 minutes of slowed-down time. The relative values of travel time components and on-time arrival reliability may aid in an understanding of why some trip configurations are preferred to others. That is, each routing and scheduling alternative for a given shipment involves trade-offs not only between time and cost, but also between travel time and reliability. The relative values of each influence the choice of route and time of travel; hence, any change in the levels of travel time and reliability present in each real-market alternative under distance-based charging is likely to lead to changes in travel patterns. However, this behaviour will be constrained by the costs of each alternative, which will change for alternatives, in general.

## **5.2 Marginal (dis)utility of monetary measures**

The preceding section focuses on the preferences of transporters and shippers with respect to components of distribution time, utilising underlying preferences with respect to cost to establish measures of willingness to pay. However, it is important to examine preferences for costs themselves. In a similar manner to travel time measures for transporters, interaction terms in the model allow one to compare the transporters disutility of distance-based user charges to their disutility of fuel cost. Specifically, the interaction between distance-based user charges and distance (i.e., charges per kilometre) and the further interaction between charges per kilometre and total cost reveal distinct disutilities of distance-based use charges and fuel cost for transporters. Whilst both total cost (i.e., an assumption that distance-based charges and fuel cost are valued equally) and distance-based charges per kilometre are both sources of disutility, the interaction between the two elements has a positive relationship with utility. As such, it appears that transporters are less sensitive to distance-based user charges than to fuel cost. That is, as the share of distance-based user charges in total cost increases, the disutility of paying those costs decreases. *Hence, transporters demonstrate that the distance-based user charges produce a benefit (i.e., improved travel quality, including time savings and reliability gains), whereas increases in fuel cost do not offer any benefit at all, or if they do, not to the same extent.*

Figure 9 displays the relationship between the marginal utility of distance-based user charges and the charge levels for transporters. There is significant heterogeneity among those who face total user charges less than approximately \$100, however transporters demonstrate less heterogeneity for user charges above approximately \$100. Furthermore, it is clear that the marginal disutility of the user charge decreases as the charge increases. A simple regression of the marginal utility of the distance-based user charges reveals systematic sources of variation in marginal utility, as shown in Table 8.

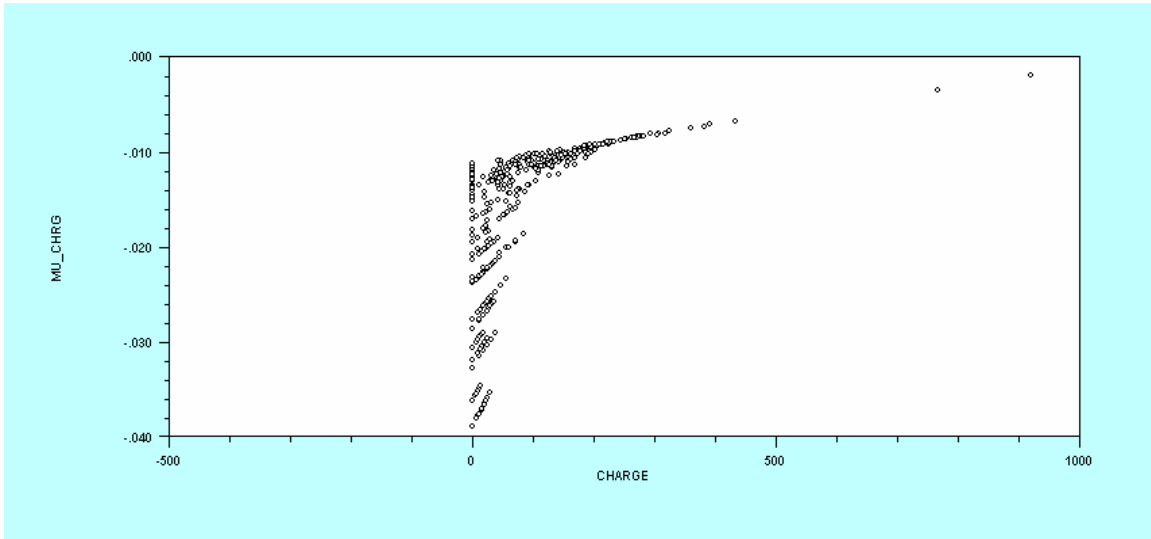


Figure 9: Marginal utility of distance-based charges (\$) versus distance-based charges for transporters

Table 8: Regression of marginal utility of distance-based user charges on covariates for transporters

Attribute	Parameter (t-statistic)
<i>Independent Variables</i>	
Constant	-0.0260 (-57.32)
Years Working in a Similar Role * 10	0.0003 (2.94)
Kilometres Travelled * 100	0.0028 (39.37)
Trip Originated in an Urban Area	-0.0016 (-6.39)
Operates a Truck	0.0015 (4.28)
Sender of the Goods Paid for the Delivery	0.0015 (6.44)
Sender of the Goods Had Input into Scheduling	-0.0010 (-4.49)
Receiver of the Goods Had Input into Scheduling	0.0017 (4.83)
<i>Model Fit</i>	
Number of Observations	1296
Adjusted R-Squared	0.68

The marginal disutility of the distance-based user charges decreases as kilometres travelled increase. Furthermore, marginal disutility decreases as years of experience in one's position increases, and if either the respondent operates a truck personally, the sender of the goods paid for the trip, or the receiver had input into scheduling. The marginal disutility of the distance-based user charges increases if either the trip originated within a metropolitan area, or the receiver of the goods had input into the scheduling of the vehicle.

These results are also intuitive. With respect to sources of relatively lower marginal disutility, the chief physical influence is trip distance. As the kilometres travelled increases, the scope of travel quality gains offered to the transporter increases. Hence, longer trips may reach a sort of critical mass, at which point the time savings or reliability gains offered through the distance-based user charges become sufficiently valuable to

cover the cost of the charges. It appears that decision makers who are relatively more experienced may identify benefits of paying the charges that less-experienced decision makers may not identify. Similarly, those who operate a truck personally experience the effects of lower-quality travel on a regular basis, increasing their appreciation for the benefits the distance-based user charges may offer. The results indicate that the sender of the goods may be relatively sensitive to time or reliability. That is, the sender of the goods may place a high priority on customer satisfaction, which in turn leads to a relatively higher net benefit for the transporter when paying the charges, through satisfying its customer's need to provide goods promptly, reliably, or both. Lastly, the decrease in marginal disutility when the sender of the goods has input into the scheduling of the vehicle may be indicative of a closer relationship between the two firms, increasing the benefits gained through paying the charges.

With respect to sources of relatively larger marginal disutility of the distance-based user charges, we could identify two systematic forces. Firstly, trips originating within a metropolitan area lead to a higher disutility of the charges. This may be a corollary to the relationship between trip distance and marginal disutility described above; trips originating within a metropolitan area are relatively more likely to be shorter trips, and hence the distance-based user charges may not offer sufficiently large travel quality gains to justify the cost in such cases. However, as a distinct effect was identified for urban trips, there may be other physical forces aside from distance influencing marginal disutility. Secondly, the marginal disutility of the charges is larger if the sender of the goods has input into the scheduling of the trip. If the receiver has input into the scheduling of the trip, the relative influence the transporter holds in scheduling the vehicle is diminished, restricting the ability of the transporter to optimise with respect to the charges, hence increasing the marginal disutility of the charges.

Shippers appear to perceive a benefit from reducing the costs of transporters. This mirrors the relationship between transit time measures and utility for shippers, and indeed confirms what may be driving the relationship. That is, shippers may be wary of increased costs to transporters resulting in an increase in the freight rate. However, the relative sensitivity to transporters' costs is much lower for shippers than it is for transporters. This may reflect an expectation that the increases in costs can only be partially passed on to shippers.

The freight rate itself shows remarkable balance across transporters and shippers, with shippers experiencing somewhat more disutility from a given increase in the freight rate than the utility gained by transporters from the same increase, on average. That is, at the margin, there is a net loss of welfare when the freight rate increases. This may be indicative of loss-averse behaviour (i.e., a dollar lost causes greater disutility than a dollar gained), or may simply be an artefact of the equilibrium forces of the market (i.e., given the present levels of competition and marginal costs, the current set of freight rates results in larger price sensitivities for shippers than the corresponding sensitivity of the transporter to fluctuations in revenue).

## 6. Conclusion

This paper has investigated the influence of distance-based user charges, on transporters and shippers, in contrast to other sources of (dis)utility in choosing amongst packages of trip attributes for freight distribution. Importantly we promote the view that an assessment of the role of distance-based user charges on behavioural response cannot be determined in isolation from the full set of attributes that drive decisions on preferred distribution strategies by transporters and shippers.

The most important policy finding is that the distinction between paying via fuel prices and via kilometre-based charges is behaviourally important. In particular, we find that transporters are much more supportive of distance-based user charges, in contrast to fuel prices, because they see a tangible benefit in terms of improved travel quality, including time savings and reliability gains. In contrast, increases in fuel prices do not offer such benefit, and if they do it is much less obvious (even if such higher prices do discourage some amount of road usage by others).

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