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Power, concession and cooperation in freight distribution chains subject to distance-based user charges

By

David A. Hensher & Sean M. Puckett

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ABSTRACT: Freight transport plays an important role within the functions of the road network, yet little is understood about the potential impacts of some travel demand management strategies on freight transport activity. This arises, in part, due to the interdependent nature of decision making within supply chains. To contribute to this shortcoming, this paper offers empirical results from a method designed to estimate attribute-specific measures of relative influence within decision making groups. A choice modelling framework is utilised to consider the relative concession decision makers are willing to make toward the preferences of other group members when attempting to reach group choice equilibrium. The estimated influence measures highlight the relative power each type of decision maker holds with respect to each attribute within the candidate alternatives from which to choose. The alternatives represent supply chain strategies for adjusting to a hypothetical distancebased road user charging system in Sydney, Australia. The measures can be utilised in subsequent transport distribution models to account for the impact each decision maker may have on the decisions made at the group (i.e., supply chain) level in response to a given policy. The results are also useful in gaining a greater normative understanding of the decision-making dynamics within transporter-shipper dyads.

KEY WORDS: ***Variable road user charges, congestion, freight distribution chains, choice modelling, group decision making***

AUTHORS: David A Hensher & Sean M. Puckett

CONTACT: Institute of Transport and Logistics Studies **(C37)**
The Australian Key Centre in Transport Management
The University of Sydney NSW 2006 Australia

Telephone:	+61 9351 0071
Facsimile:	+61 9351 0088
E-mail:	itlsinfo@itls.usyd.edu.au
Internet:	http://www.itls.usyd.edu.au

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1. Introduction

Group decision making depends on the influence structure prevalent within a given group. To reach cooperative outcomes within groups (i.e., those in which a sustainable choice equilibrium is found), one of two conditions must be satisfied: either (1) all decision makers in a group hold coincident personal preferences with respect to the alternative strategies available; or (2) the members of the group must be able to coordinate their preferences such that one alternative is ultimately sufficiently acceptable to all group members that can influence the final outcome. The former condition is the simplest case, in which group preferences coincide with what would occur if each decision maker had the opportunity to choose the group strategy independently. However, the latter case is relatively complex and common, including when no strategy other than the status quo can be agreed upon, when a single strategy is acceptable to all decision makers, and when multiple strategies are acceptable to each decision maker.

Within this latter case, influence structures serve as a mechanism by which the (non-coincident) personal preferences of group members are coordinated toward the ultimate group choice equilibrium. That is, the relative power that each group member holds allows him or her to preserve a certain degree of his or her preferences within the final group strategy, whether it is one of cooperation i.e., all decision makers agree to enact a particular strategy; or non-cooperation i.e., not all decision makers can agree on a particular strategy, and hence the status quo is maintained. When interdependent decision makers do not hold coincident preferences for a given attribute of the alternatives available to them, any mutually-acceptable changes to status quo behaviour require one decision maker to give up relatively more, or receive relatively less than another. Therefore, cooperative outcomes necessitate a mechanism by which less-influential decision makers concede toward the preferences of more-influential decision makers to a degree greater than more-influential decision makers concede toward the preferences of less-influential decision makers. This process of concession represents the manifestation of the relative power held by each decision maker with respect to a given attribute under consideration by the group.

This relationship between power, concession and cooperation represents more than merely a theoretical exercise in game theory, but rather a fundamental dynamic governing the choices that interdependent decision makers deal with across a range of economic situations. Indeed, the forces of interdependence impact choices that are pivotal not only to the decision makers involved, but also to other economic agents who are impacted by the choices made. Within the arena of public policy, one such case centres on the decisions made by interdependent freight stakeholders. Strategies enacted by freight transport providers and their partners are not only the result of interactions between them, but also impact the function of the road network provided by governments and utilised by the public. Consequently, policies under consideration by traffic authorities that may influence freight travel demand (either intentionally or unintentionally), must properly take the influence structures amongst interdependent freight stakeholders into account if they are to yield optimal impacts on the function of the road network with respect to both freight movement and the public, in general.

This paper investigates the effects of interdependence amongst freight stakeholders by presenting evidence on the influence structures within transporter-shipper dyads (i.e., freight transport providers and their customers) under a hypothetical distance-based road user charging system. Given the potential merit of variable user charging systems in managing travel demand, coupled with a dearth of information relating to both the independent preferences of commercial freight stakeholders and the influence structures amongst them, this is of significant empirical importance. The following section presents the preferred research methodology, along with the extant set of related research methods. Section 3 details the empirical procedure utilised to obtain the requisite choice data for our econometric models. This is followed by the presentation of empirical results. Lastly, the paper offers concluding remarks relating to the results and the next step forward in using such evidence.

2. Methodology

To understand the behavioural processes underlying interdependent decision making, we need to understand the influence structures within groups. However, quantifying influence structures can be a difficult task for several reasons, including the difficulty in capturing data on behavioural responses for each attribute relevant to varying degrees by each agent that are suitable for econometric modelling of group choice[1]. In the freight transport context, the lack of market data on the preferences of transporters and shippers under distance-based road user charges makes revealed preference data inappropriate; suggesting that a stated choice experiment, pivoted around a real market experience (in terms of attributes observed in markets) is the way to proceed (Louviere *et al*. 2000). Such data can be used to estimate a series of discrete choice models to reveal the role (i.e, their relative power) in attribute selection of each agent in the chain.

2.1 Existing choice-based models of group decision making

A stated choice framework for interdependent stakeholders must reflect the nature of transactions made within interactions amongst decision makers (i.e., the unit of analysis must incorporate interactivity). The marketing literature has a significant body of research involved in the search for measures of influence in group settings. Key papers include Corfman and Lehmann (1987), Menasco and Curry (1989), Dellaert *et al*. (1998), Arora and Allenby (1999), and Aribarg *et al*. (2002). The methods differ, but the general focus is the same – the behaviour of individuals within group decision-making processes, and the role of influence within that process. In most general terms, methods used to model group decision making structures centre on two main constructs: the group choice, observed or stated, and degree to which the preferences of each individual in the group are accommodated by that choice. A parsimonious representation of this structure is given in equation (1), from Dellaert *et al*. (1998):

$$U_{gp} = \sum_{\text{all i}} (\mathrm{w_i} * \mathrm{V_{ip}}) + \varepsilon_{\mathrm{gp}}, \quad (1)$$

where U_{gp} is the utility that group *g* receives from an alternative *p*, V_{ip} is the utility an individual agent receives from *p*, and ε_{gp} is an error term. In this particular case, the weights range from -1 (the group goes against the individual's wishes) to 1 (the individual's preferences are completely accommodated). Although the specific modelling structure varies across the studies, the

1 This can be problematic for many practical reasons such as the high survey costs, and the difficulty of getting agents in a distribution chain together.

underlying structure is commonly a variant of equation (1). That is, the utility a group of interactive decision makers would receive from a given alternative can be modelled as the sum of individual utilities for that alternative, weighted by a parameter that captures either the extent to which the decision maker gets his or her way. An alternative modelling structure utilises measures of the reciprocal force, the extent to which the decision maker concedes to the preferences of others when reaching agreement (e.g., Aribarg *et al*., 2002). Such concession can be measured as the difference between the utility of the alternative preferred by a decision maker and the alternative selected by the group (Menasco and Curry, 1989; Aribarg *et al*., 2002).

Dellaert *et al*. (1998) use two-stage conjoint analysis to model family vacation decisions. Each group in the study contained three people (one mother, one father and one child), an expansion from the ubiquitous two-person setting. Their theoretical model is based on group utility measures for a product *p* (U_{gp}), in which each group member's utility from an alternative is weighted by influence measures w_i, as shown in (1). The model also considers perceptions of influence, by modelling each individual's projections of the group outcome.

The two-stage conjoint analysis of the first stage involves the analysis of individual preferences and projections of the preferences of the other members of the group; the second stage involves the analysis of each individual's projection of the group outcome along with the actual group outcome. The projections of the group outcome can differ from those inferred by the projections in the first stage because each individual was shown estimates of the other group members' preferences. Dellaert *et al*. estimated the perceptions of influence involved in the projections of the group outcome. By estimating influence through the analysis of the actual group outcomes in relation to the outcomes preferred by each individual, it is possible to compare observed influence with perceptions of influence. One shortcoming in this analysis, however, is that the influence measures are global rather than attribute-specific.

Arora and Allenby (1999) focus on attribute-specific measures of influence with a study on household item purchase decisions. As in Dellaert *et al*. (1998), the measure of influence in their model is interacted with individual utilities in identifying the group utility for an alternative (U_{gp}), but the weighted sums of utilities are analysed at the attribute level (U_{gk} is the group utility from attribute *k* of product *p*, x_{gk} is the amount of attribute *k* in product *p* considered by the group, and $\square_{ik}$ is the preference sensitivity of agent *i* for attribute *k*):

$$U_{gp} = \sum_{\text{all k}} U_{gk} + \varepsilon_{gp}, \tag{2}$$

where $U_{gk} = \sum_{\text{all i}} (x_{gk} * \omega_{ik} * \beta_{ik})$. The attribute-specific influence measure, $\square_{ik}$, is unconstrained for any attribute-individual pair, but is constrained to sum to one over all individuals for each attribute. The group preference sensitivity (in the two-agent case) is defined as:

$$\beta_{gk} = \omega_{ik} * \beta_{ik} + (1 - \omega_{ik}) * \beta_{jk}. \tag{3}$$

The empirical study in Arora and Allenby involved a task in which married couples stated their preferences for two goods using a 100-point rating scale for each attribute. Each respondent also indicated the relative influence each person in the couple was perceived to hold in each hypothetical purchase decision; gathered for comparison with the influence measures found later through model estimation. Each couple was given a group task in which group preferences were stated in choice settings. Following this, each couple was asked to provide group perceptions of the relative influence each individual held for each attribute and overall.

Dosman and Adamowicz (2003) offer an innovative method of measuring influence within a two-person household decision-making setting. Power within relationships is measured by comparing the independent preferences of decision makers, estimated using stated choice data, with observed real-market joint choices of holiday activity. Dosman and Adamowicz estimate the relative power of an agent as the proportion of his or her independent preferences that are represented within the group outcome. Based on household resource allocation models (see Vermuelen, 2002 for a review), group utility maximisation is modelled as a function of independent utility maximisation, which enters the group choice analysis exogenously, and the power structure within the relationship.

Building on Browning and Chiappori (1998), who model household preferences for a shared good, indirect group utility $V(\mathbf{p}, M, \delta)$ is expressed in the two-agent case as:

$$V(\mathbf{p}, M, \delta) = \max_{\mathbf{q}, \mathbf{q'}, \mathbf{Q}} \; \delta * u(\mathbf{q}, \mathbf{q'}, \mathbf{Q}) + (1-\delta) * u'(\mathbf{q}, \mathbf{q'}, \mathbf{Q})$$
$$\text{s.t. } \mathbf{p} * (\mathbf{q} + \mathbf{q'} + \mathbf{Q}) = M, \quad (4)$$

where $\boldsymbol{p}$ is a vector of prices, M is household income, δ is a measure of relative power held by an agent, $u(.)$ and $u'(.)$ are the independent utility measures of the two agents, $\boldsymbol{q}$ and $\boldsymbol{q'}$ are vectors of private goods consumed by the two agents, and $\boldsymbol{Q}$ represents a vector of public goods.

Estimates of power are identified by first analysing stated choice data that involved the same attributes as the holiday location decision; this analysis yields estimates of independent utility for each agent. Given these estimates, Dosman and Adamowicz reconcile these preferences with the revealed joint choice of holiday location with the following equation:

$$V_{jn} = \delta(\mathbf{s}_n)(\mathbf{x}_j^n * \boldsymbol{\beta}) + (1-\delta(\mathbf{s}_n))(\mathbf{x}_j^n * \boldsymbol{\beta'}), \quad (5)$$

where V_{jn} is the conditional indirect utility of household n for alternative j, $\boldsymbol{s}_n$ is a vector of household and individual characteristics, $\boldsymbol{x}_j^n$ is the vector of household attributes in j faced by n, and $\boldsymbol{\beta}$ and $\boldsymbol{\beta'}$ are the vectors of independent marginal utilities held by the two agents for the attributes in j. The relative power of an agent is specified as a function of both the degree to which the preferences of the agent are accommodated within the group decision, and of socio-demographic characteristics. A value of δ between zero and one implies that some degree of bargaining takes place between the decision makers, whilst a value of zero or one implies that one decision maker chooses for the group independently.

The method proposed by Dosman and Adamowicz is an elegant means of parameterising power. However, it only yields a global measure of power, whereas relative power may vary significantly across attributes. Whilst the relative influence held by a decision maker may be constant over all aspects of a relationship, this should be tested rather than assumed. There may exist some attributes over which a broadly-dominant decision maker is dominated by another decision maker.

An appealing stated choice method to estimate influence measures 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 an IACE with a satisfactory sample size due to the high level of resources required, including difficulties in matching agents for sampled groups. Not only is it difficult to secure the participation of pairs of real-market or representative freight stakeholders within an experiment that requires feedback between the respondents, it is also difficult to identify the appropriate stakeholders in a timely manner in the first place. This is especially problematic with respect to independent owner-operators of heavy goods vehicles, who, whilst representing a large proportion of the freight vehicle fleet, may not be available to participate in an iterative experiment. Likewise, locating a suitable respondent to represent the customer of a transporter within a given sampled group can be a challenging and time-consuming task, restricting the analyst from utilising an iterative experiment.

The administrative obstacles of IACEs within a freight transport context are not limited to the feasibility of sourcing appropriate respondents. IACEs require relatively more time and effort in evaluating each choice set than standard choice experiments, due to the process of observing the choices of sampled group members, choosing whether to amend one's preferences, and repeating this process until either consensus or impasse is reached. Ultimately, the analyst is not likely to capture nearly as many choice observations per respondent within IACEs as within standard choice experiments. This necessitates, at best, the collection of data from a relatively large sample, which is often financially prohibitive.

2.2 Minimum information group inference

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*., 2006, Puckett and Hensher, 2006). 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*., 2006a for a detailed justification), by inferring the effects of interactivity based on 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 interactive methods are infeasible.

Minimum Information Group Inference (MIGI) models use stated choice (SC) experiments that augment the standard SC format to incorporate an interactive setting within an experiment that is administered to an individual respondent. As with IACEs, each respondent within a sampled group is given a set of identical choice sets. The resulting choice observations are coordinated across respondents, and analysed to infer the effects of interdependency among the sample of interest, without requiring direct interaction among respondents. That is, the effects of interactive agency are inferred *ex post*, by projecting group outcomes based upon the preference rankings given by respondents within an algorithm designed to coordinate these rankings.

Similarly to an IACE, 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.

Utilising the preference rankings of each respondent in a sample group, group preferences and influence structures are estimated through “power models”. As shown below, the power models offer a means of quantifying group influence structures consistent with the manner proposed by Dosman and Adamowicz (2003). MIGI analysis builds on the econometric structure offered by Dosman and Adamowicz, enabling the analyst to estimate attribute-specific measures of influence. This is an important behavioural step, in that it allows the analyst to gauge the degree to which each type of decision maker holds influence over each attribute in consideration by the group. This proposition should be tested rather than assume that one type of decision maker holds the same degree of relative influence over all aspects of the decision or relationship in question.

The key to the behavioural suitability of this approach is in defining and measuring the real meaning of power. As a multi-dimensional construct, power is best viewed as a latent factor – essentially an unknown parameter – that can be estimated through its characterisation of influences such as length of experience interacting with the other decision maker(s), and comparative socio-economic measures, where the differences suggest lesser or greater divergence in willingness to accommodate the preferences of the other decision maker(s).

The first stage of econometric analysis in MIGI modelling involves the estimation of individual preferences for each agent type. Independent preferences are established by modelling the choices of the most-preferred alternative for each respondent as a function of the attribute levels for each alternative and the contextual effects corresponding to each choice set. That is, despite the interdependent nature of the experiment, standard independent preferences are not only informative outputs on their own, but also offer a basis for comparison with group preferences.

The behavioural process assumes that each agent *q* acts as if he or she is a utility maximiser when choosing a most-preferred alternative *j* in a choice set *p* faced by all members of a sampled group *g*. The base utility expressions (i.e., without any interaction effects or direct covariate effects) are of the general form:

$$U_{qj} = \alpha_j + \boldsymbol{\beta}'_{\mathbf{qk}} * \mathbf{x}_{\mathbf{jk}} + \varepsilon_{qj}, \tag{6}$$

where U_{qj} represents the utility derived by *q* from *j*, $_j$ represents an alternative-specific component of utility (if the design includes either labelled alternatives, or if one wishes to distinguish structurally between a reference alternative and stated choice alternatives), $\boldsymbol{x}_{jk}$ is a vector of design attributes associated with agent *i* and alternative *j*, $\boldsymbol{\beta}_{qk}$ is the corresponding vector of marginal (dis)utility parameters (treated as random parameters if allowed to vary across *q*), and ε_{qj} represents the (potentially individual-specific) unobserved effects.

At this point in the analysis, independent utility estimates have been obtained for each respondent in the sample, and a range of group choices have been projected for each choice set commonly faced by each group. With this information, group preferences may be estimated using a procedure that is consistent with empirical modelling structures that can be utilised for the analysis of interactive agency stated choice data or revealed preference data (e.g., Dosman and Adamowicz, 2003, Hensher and Knowles, 2006). That is, for a given choice set, the projected chosen alternative of the group is compared to the unchosen alternatives in order to estimate a vector of attribute-specific power measures, $\boldsymbol{\tau}_{qk}$.

To accomplish this, estimates of the individual preference parameters for respondents in a group are carried forward as constant exogenous terms into the following *power model*, and multiplied by the corresponding attribute levels for each of the *K* attributes in each alternative *j* in choice set *p* faced by all respondents *q* in group *g*. For each simulated group interaction *gp*, the alternative designated as the choice is the group choice projected using a choice coordination algorithm. The previously-estimated independent marginal utilities derived by each *q* in each *j*, the vector of attribute levels in each alternative $\boldsymbol{x}_{jk}$ and any covariates of interest are the exogenous variables used to calculate the vector $\boldsymbol{\tau}_{\mathbf{qk}}$, which, along with any alternative-specific constants are the only free parameters in the model (equation 7). Whilst the most general two-agent case is offered here, this calculation can be augmented through the inclusion of interaction terms and additional respondents:

$$U_{11} = \alpha_{11} + (\boldsymbol{\tau_{qk}} * \boldsymbol{\beta_{qk}})' * \mathbf{x_{1k}} + ((\mathbf{1}- \boldsymbol{\tau_{qk}}) * \boldsymbol{\beta_{q'k}})' * \mathbf{x_{1k}} + \varepsilon_{11}$$

$$U_{1J} = \alpha_{1J} + (\boldsymbol{\tau_{qk}} * \boldsymbol{\beta_{qk}})' * \mathbf{x_{1k}} + ((\mathbf{1}- \boldsymbol{\tau_{qk}}) * \boldsymbol{\beta_{q'k}})' * \mathbf{x_{Jk}} + \varepsilon_{1J} \quad (7)$$

$$U_{JJ} = \alpha_{JJ} + (\boldsymbol{\tau_{qk}} * \boldsymbol{\beta_{qk}})' * \mathbf{x_{Jk}} + ((\mathbf{1}- \boldsymbol{\tau_{qk}}) * \boldsymbol{\beta_{q'k}})' * \mathbf{x_{Jk}} + \varepsilon_{JJ},$$

where U_{jm} is the estimated utility the group g derives from the joint choice of alternative j by agent q and alternative m by agent q' in simulated group interaction gp, α represents an alternative-specific utility component for the joint choice alternative, $\boldsymbol{\tau_{qk}}*\boldsymbol{\beta_{qk}}$ represents a vector of the product of relative influence measures for a focal agent type and the independent marginal utility derived by q for attribute k in j, $\boldsymbol{x_{jk}}$ represents the vector of levels of each k present in j, $\boldsymbol{((1-\tau_{qk})*\beta_{q'k})'}$ represents a vector of the product of relative influence measures for the other agent $\boldsymbol{(1-\tau_{qk})}$ and the independent marginal utility derived by q' for k in m, $\boldsymbol{x_{mk}}$ represents the vector of levels of each k present in m, and ε_{jm} represents the unobserved effects for the joint choice alternative.

The general case in (7) includes all possible non-agreement outcomes (i.e., those where the choice of one agent does not coincide with the choice of another agent). We refer to it as the first pass group model for cooperation and non-cooperation. It may, however, be preferable behaviourally to restrict the analysis to cases of agreement, in that the ultimate group decision outcome should involve a consensus choice across group members. That is, the final decision of a group should involve either agreement across all members, or impasse, which is likely to result in a continuation of the status quo. When restricting the analysis to cases of agreement, the model reduces to the subset of (7) in which the choices made by both decision makers are coincident (i.e., each agent chooses the same alternative j). We refer to this context as group equilibrium, under which one can estimate influence structures under cooperative and non-cooperative (i.e., status quo) equilibrium outcomes.

The econometric analysis focuses on a pair of power models that reflect the relative power structure present when a given agent type (herein a transport or a shipper) offers concession toward the preferences of the other agent. For example, in the *transporter concession* power model, we present estimates of the influence structure present when transporters offer a degree of concession they state they are willing to offer toward the first preferences of shippers. Likewise, in the *shipper concession* power model, we present estimates of the influence structure present when shippers offer a degree of concession they state they are willing to offer toward the first preferences of transporters. Analysing influence structures in the two most extreme cases of concession, the preference data allow us to infer (i.e., when decision makers are willing to accept the first preference of the other decision maker in their respective groups) estimates of a range of relative power, within which one would expect to find corresponding point estimates if direct interaction between agents could be observed.

The power measures for agents q ($\boldsymbol{\tau_{qk}}$) and q' ($\mathbf{1}\text{-}\boldsymbol{\tau_{qk}}$) sum to unity for each attribute k, making comparisons of influence across agent types straightforward. If the two power measures are equal for a given attribute k (i.e., $\tau_{qk} = (1 - \tau_{qk}) = 0.5$), then group choice equilibrium is not governed by a dominant agent with respect to attribute k. In other words, regardless of the power structure governing other attributes, agent types q and q' tend to reach perceptively fair compromises when bridging the gap in their preferences for *k*. If the power measures are significantly different across agent types (e.g., $\tau_{qk} >> (1 - \tau_{qk})$), then τ_{qk} gives a direct measure of the dominance of one agent type over the other with respect to attribute *k*; as τ_{qk} increases, so does the relative power held by agent type *q* over *q'* for *k*.

For example, in a freight distribution chain, the power measures may reveal that one agent type tends to get its way with regard to monetary concerns, whereas the other agent type tends to get its way with regard to concerns for levels of service. These relationships can be examined further within subsets of agent groups (by decomposition of the random parameter specification of $\boldsymbol{\tau_{qk}}$), in order to reveal deviations from the inferred behaviour at the sample level that may be present for a particular type of relationship.

It is important to note that the range of power measures is unbounded. That is, the only constraint on the power measures is that they sum to one across members of a group. Hence, it is possible to observe power measures either less than zero or greater than one. This is straightforward, in that a (0,1) bound is excessively restrictive for group decision making, especially for cases of trade-offs across fixed attribute bundles. The limited set of pre-specified trade-offs may make it necessary for a decision maker to offer more than requested with respect to one attribute in order to reach agreement on an alternative. Therefore, one may observe a tendency for a given type of decision maker to offer greater concession toward the preferences of another type of decision maker for a given attribute than the initial discrepancy in preferences between the decision makers, resulting in an estimated power measure outside of the (0,1) range.

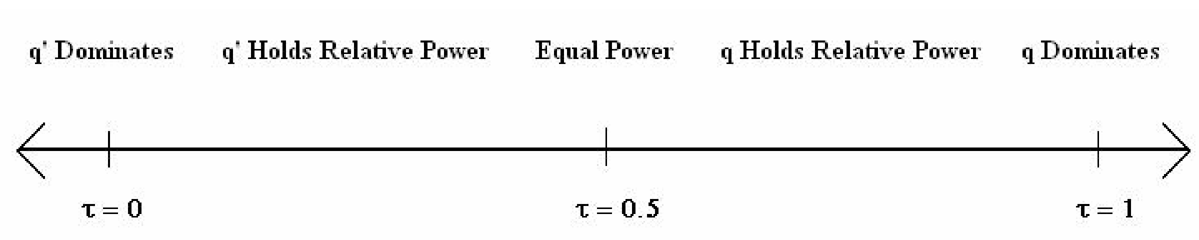


Fig 1: Interpretation of values of τ_{qk}***)***

The distribution of power measures across a given set of decision makers can be decomposed, and hence explained, by both objective and subjective descriptors of the relationship between members of groups within a sample. The mixed logit model, implemented within MIGI analysis, allows the analyst to model relative influence with respect to a given attribute as a function of characteristics within the relationship between interdependent decision makers. Objective descriptors include tangible factors such as measures of market power and the length of the relationship, whilst subjective descriptors include attitudinal statements about the importance of elements within the relationship, and the effectiveness of the relationship in achieving those elements.

Consider a case with three alternatives *1*, *2* and *3 in* a choice set *p* faced by two respondents in a sampled group *g*. In this case there are three potential group choice outcomes when restricting the analysis to agreement outcomes, such as in our models of transporter and shipper concession:

$$U_{11} = \alpha_{11} + (\tau_{\mathbf{qk}} * \beta_{\mathbf{qk}})' * \mathbf{x_{1k}} + ((\mathbf{1} - \tau_{\mathbf{qk}}) * \beta_{\mathbf{q'k}})' * \mathbf{x_{1k}} + \varepsilon_{11}$$

$$U_{22} = \alpha_{22} + (\tau_{\mathbf{qk}} * \beta_{\mathbf{qk}})' * \mathbf{x_{2k}} + ((\mathbf{1} - \tau_{\mathbf{qk}}) * \beta_{\mathbf{q'k}})' * \mathbf{x_{2k}} + \varepsilon_{22} \quad (8)$$

$$U_{33} = \alpha_{33} + (\tau_{\mathbf{qk}} * \beta_{\mathbf{qk}})' * \mathbf{x_{3k}} + ((\mathbf{1} - \tau_{\mathbf{qk}}) * \beta_{\mathbf{q'k}})' * \mathbf{x_{3k}} + \varepsilon_{33}.$$

The specific algorithm for coordinating the choices of group members within the power models is straightforward. Within the power model of concession by agents of type *q*, the group choice is specified as the first preference of the respondent of type *q*' if the respondent of type *q* stated that he or she was willing to accept that alternative as a group choice outcome. If the alternative is unacceptable to the respondent of type *q*, the group choice is specified as a non-cooperative outcome; in this empirical exercise, the non-cooperative case is represented by maintaining the status quo (i.e., the revealed preference alternative). This process is repeated for all power models representing the relative concession a decision maker is willing to offer toward the preferences of another decision maker. To estimate the relative power measures $\tau_{\mathbf{qk}}$ in each power model, group choice observations are projected for each choice set as above, with the independent utility estimates $\beta_{\mathbf{qjk}}$ and $\beta_{\mathbf{q'mk}}$ carried forward from the first modelling stage, and with the attribute levels $\mathbf{x_{jk}}$ and $\mathbf{x_{mk}}$ set equal to those faced in choice set *p* for both choice observations.

The power measures that result from estimating the group choice outcome utility functions highlight the process of concession required when agents with non-coincident preferences attempt to reach group choice equilibrium. That is, whilst the choice coordination algorithm is the mechanism by which group choice is projected in the model, the information that seeds the algorithm in turn allows the analyst to project the degree to which one agent type tends to get its way for a given attribute. Ultimately, whilst the analyst does not directly observe the interaction of two agents, the analyst has the ability to infer the process by which differing preferences converge toward group preference equilibrium.

3. Empirical study

The predominant empirical constraints in urban freight research are: (a) a small population from which to draw; (b) a limited research budget; and (c) the difficulties in gaining the cooperation of freight stakeholders. A limited number of agents to sample (i.e., freight firms and their clients under contracts involving urban goods movement) requires optimisation on two counts: (1) recruiting a sufficient proportion of the population for the sample; and (2) obtaining a sufficient number of choice observations for each respondent. A *MIGI* experiment appeared to be our most desirable alternative for this application. As the closest alternative to an IACE, a MIGI experiment would allow for a relatively larger sample than an IACE due to the relative ease of recruiting participants; that is, no temporal coordination of respondents is required. Furthermore, each choice set in an MIGI experiment is relatively less burdensome than an IACE, allowing for a relatively greater number of choice observations per sample. Lastly, the monetary and temporal costs of coordinating the sample within the MIGI framework are not prohibitive for the application[2]. The relative benefits of an MIGI model with respect to effective sample size and feasibility subject to monetary and temporal budget appear to outweigh the relative negatives of adopting a new and untested method that does not involve directly-observed interactions.

The first step in the process is administering the experiment to representatives of freight firms. Centred on a CAPI survey with a d-optimal experimental design (discussed in Puckett *et al*., 2006), the MIGI experiment involves three distinct procedures: (1) non-stated-choice questions intended to capture the relevant deliberation attributes and other contextual effects; (2) choice menus corresponding to an interactive (i.e., freight-contract-based) setting; and (3) questions on the attribute processing strategies enacted by respondents within each choice set.

Preliminary in-depth interviews with 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*., 2006a). 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.

After a sampled respondent from a freight firm completed the survey, a client of a freight firm matching the classification offered by the respondent was recruited and given a survey involving the identical series of choice sets faced by the corresponding freight firm. The surveys responded to by representatives of clients of freight firms (i.e., shippers) include the same set of attribute processing questions after each choice set that are included in the surveys responded to by representatives of freight firms. However, the non-stated-choice questions faced by the respondent's shipper were a subset of the non-stated-choice questions faced by the respondents from freight firms. This occurred because details regarding the corresponding freight firms are taken as given (i.e., they are directly observed when a freight firm agent participates in the survey), and hence there is no need for the shipper to offer a reciprocal description of the freight firm.

3.1 Designing the stated choice experiment

Given the interest in evaluating a range of trip attribute profiles in terms of dimensions of time and money, especially variable 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 variable user charge (VUC). A pivot design, using principles of d-optimality in experimental design, was developed to vary the levels of existing attributes around the reference levels plus to introduce a VUC based on distance travelled 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.

2 The empirical study presented in this paper involved just over 200 interviews at a total cost in 2005 of $Aud60,000.

The stated choice alternatives were kept generic to one another, representing various options of re-routeing and re-scheduling; however, these alternatives are inherently different to the reference alternative, which does not involve variable 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 (Puckett *et al*., 2006a, Hensher and Puckett, 2005), we focussed on the subset of these attributes that were most likely to be directly affected by congestion-centred variable road user charges. The attributes defining 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 distance-based road user charging regime. The reference alternative was used as 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 used 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 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. Whilst this is clearly within the set of possible strategies to be enacted by the transporter, incorporating an endogenous (at least to the freight transport provider) choice into the experimental design that could swamp the changes in costs 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 variable 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*(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. The probability of on-time arrival offers the greatest obstacle from a practical standpoint. This is due to the logical upper boundary of one for the attribute level. Given 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 a computer-aided personal interview (CAPI). This was essential to seed each choice set faced by respondents with the RP information they specify within the pre-choice-set phase of the questionnaire.

Fig 2-4 reproduce the relevant CAPI screens related to the description of variable user charges and the SC experiment in which each sampled respondent has to review the attribute packages and make a choice.

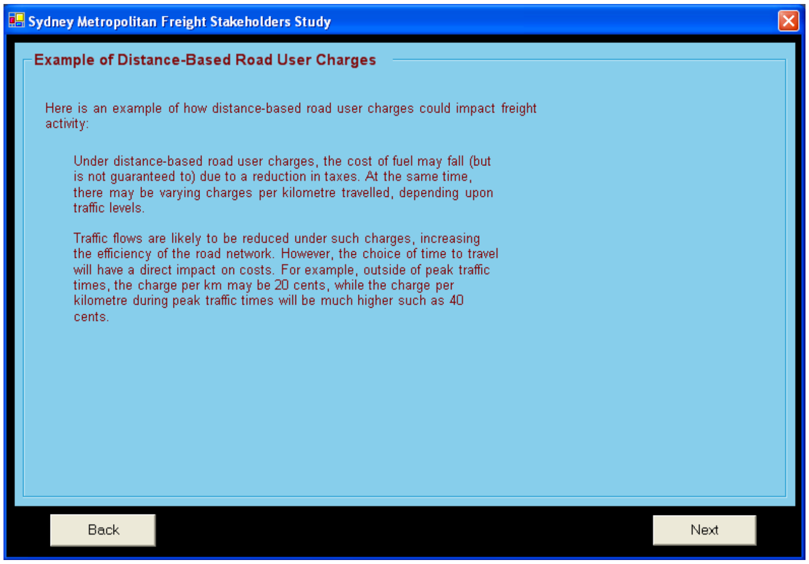
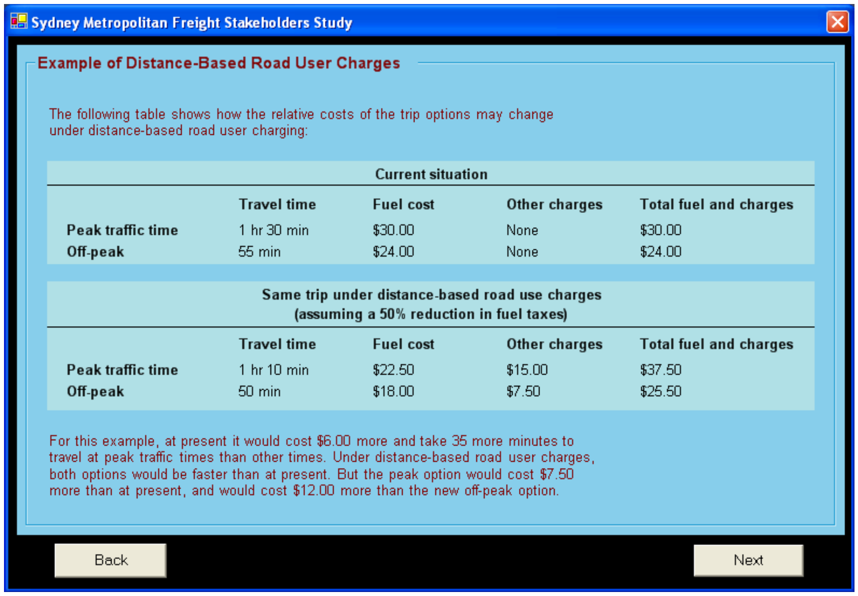


Fig 2: Questionnaire screen introducing variable user charges

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 3). The same trip is then discussed under hypothetical VUCs, revealing altered travel times and costs for both the peak and off-peak options.


Sydney Metropolitan Freight Stakeholders Study

Example of Distance-Based Road User Charges

The following table shows how the relative costs of the trip options may change under distance-based road user charging:

Current situation

	Travel time	Fuel cost	Other charges	Total fuel and charges
Peak traffic time	1 hr 30 min	$30.00	None	$30.00
Off-peak	55 min	$24.00	None	$24.00

Same trip under distance-based road use charges (assuming a 50% reduction in fuel taxes)

	Travel time	Fuel cost	Other charges	Total fuel and charges
Peak traffic time	1 hr 10 min	$22.50	$15.00	$37.50
Off-peak	50 min	$18.00	$7.50	$25.50

For this example, at present it would cost $6.00 more and take 35 more minutes to travel at peak traffic times than other times. Under distance-based road user charges, both options would be faster than at present. But the peak option would cost $7.50 more than at present, and would cost $12.00 more than the new off-peak option.

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Fig 3: 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. Respondents are then informed that the choice sets involve three alternative methods of making the trip (Figure 4): their stated trip[3] and two SC alternatives that involve VUCs. The choice tasks are described to respondents as two steps. The first step is to indicate which alternatives would be preferable if the two organisations had to reach agreement, whilst the second step is to indicate what information mattered when making each choice[4].

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[3] 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.

[4] 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.

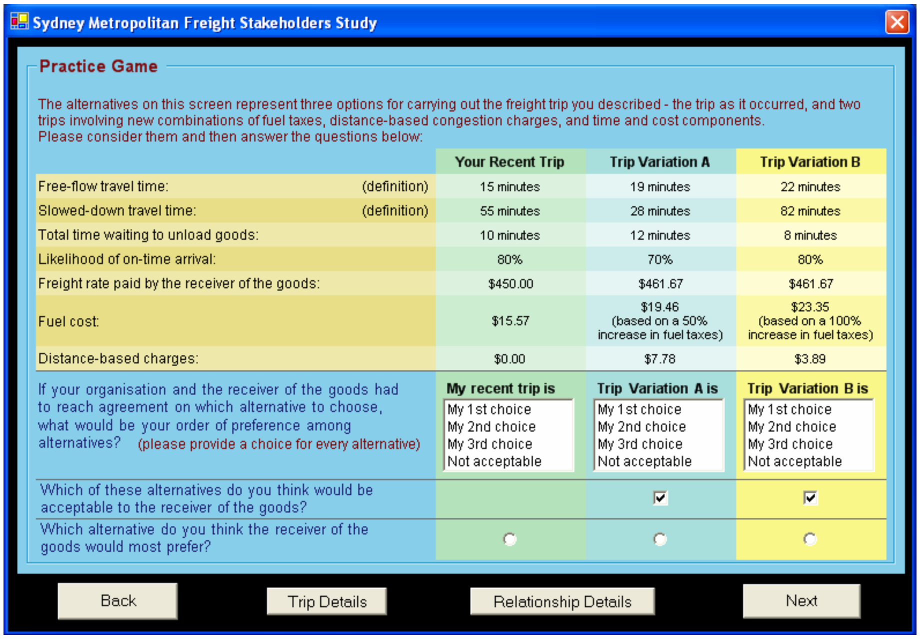

Fig 4: Main choice set screen[5]

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 reference alternative represents the status quo, which was clearly acceptable in the market. We focus herein on the first preference choice[6].

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[5] 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.

[6] 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.

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 elements 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 (2006, in press), 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 relevant information to make an informed choice.

The resulting estimation sample, after controlling for outliers and problematic respondent data[7], includes 108 transporters and 102 shippers, yielding 1,248 observations (432 choice sets faced by transporters and 816 choice sets faced by shippers). The transporters response rate was 45% whilst that of the shippers is 72%.

4. Empirical results

4.1 Propensity to hold coincident preferences

Before discussing the power model results, it is informative to consider the relative propensities for each potential combination of first preferences held by transporters and shippers. The relative frequency of each joint choice outcome demonstrates the degree to which cooperation may be observed in group decision making settings without significant concession (i.e., when the first preferences of each decision maker coincide). These frequencies also reveal the predominant discrepancies in preferences that may need to be negotiated when decision makers do not hold coincident preferences. It is important to uncover whether transporters and shippers may have a

[7] 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 variable 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.

tendency to prefer the same strategies (e.g., maintaining the status quo, enacting a distribution strategy that results in greater reliability at a higher operating cost); likewise, it is important to uncover whether there are any predominant discrepancies in preferences across decision makers that would need to be resolved through negotiation (e.g., transporters tend to prefer the status quo, but shippers tend to prefer strategies that involve altered levels of service and costs). Table 1 highlights the propensities of transporters and shippers within each sampled group to prefer a given (coincident or non-coincident) pair of alternatives on offer.

Table 1: Joint first preferences of transporters and shippers

Choice Outcome	**Frequency**
(RP = reference trip), SP = stated choice alternative	
Cooperative Outcomes:	
Both Prefer RP Trip	35.1%
Both Prefer the Same SP Trip	15.9%
Non-Cooperative Outcomes:	
Transporter Prefers RP Trip; Shipper Does Not	21.3%
Shipper Prefers RP Trip; Transporter Does Not	20.8%
Both Prefer a SP Trip, but Not the Same	7.0%

In just over half of the choice sets faced by respondents, transporters and shippers preferred the identical alternative. This is important in itself, as it reveals that the extent of barriers to cooperative outcomes between buyers and sellers of urban freight services may not be as extensive as one may expect. In other words, despite the differing goals across transporters and shippers, the preferred strategy for one decision maker within the sample was often the preferred strategy for the other decision maker. Even more important, the forces leading to coincident preferences are not represented only within the choice to maintain the status quo. That is, transporters and shippers demonstrated a significant propensity to prefer a common stated preference alternative over the revealed preference trip. Hence, although the most common joint strategy was to prefer the status quo, in over 30 percent of cases of coincident first preferences, transporters and shippers preferred to enact a new strategy involving positive distance-based charges, and new mixes of levels of service attributes and operating costs. Ultimately, transporters and shippers not only may have the potential to negotiate in an effort to reach consensus on enacting alternatives to the status quo, but may also jointly support a given alternative.

Negotiation, and hence influence structures, still have a powerful role to play within transporter-shipper dyads under a variable user charging system, however. In just under half of the choice sets faced by respondents, transporters and shippers preferred separate alternatives. Hence, in order to reach group choice equilibrium, decision makers would have to offer concession towards each other's preferences. The overwhelming manifestation of this case involved one decision maker preferring the status quo, whilst the other decision maker did not; in only seven percent of cases did each group member most prefer a distinct SP alternative. This is not an unexpected result, as the relative benefits of new alternatives could feasibly benefit one decision maker disproportionately. Interestingly, there was no discernable tendency for such variation in relative benefit to occur on behalf of one type of decision maker. Rather, the frequency with which only transporters preferred the RP alternative is virtually identical to the frequency with which only shippers preferred the RP alternative (21.3% to 20.8%, respectively). This implies that the attributes of the available strategies are likely to dictate the degree to which transporters and shippers must offer concession toward one another in order to reach group choice equilibrium; divergent preferences with respect to the status quo and new alternatives do not appear to be systematically governed by the class of decision maker itself.

4.2 Power structures under projected interactions – power model results

We now turn to model outputs from the power models discussed in Section 2. The *shipper concession* and *transporter concession* models represent our estimated outer bounds of ranges of relative influence held by transporters and shippers over the attributes within the empirical study. Each model projects the group choice for a given choice set as either: (a) the first preference of the respondent toward whom concession is offered by the focal agent type, if the focal agent stated he or she is willing to accept that alternative as the group choice; or (b) the revealed preference alternative, if the focal agent was unwilling to accept the other decision maker's first preference as the group choice. For example, within the shipper concession model, the group choice for a given choice set is projected as the first preference of the transporter if the shipper stated he or she is willing to accept that alternative as the group choice. If the shipper stated that the alternative is unacceptable, no new strategy would be guaranteed to be a consensus choice, and hence the status quo (i.e., the revealed preference alternative) would be maintained.

The attribute-specific power measures resulting from each of these models reflect the relative concession each decision maker is willing to offer. That is, the models represent the degree to which each type of decision maker is willing to accommodate the preferences of the other decision maker when their first preferences do not coincide. This is represented empirically through power measures that are considered in reference to 0.5, a value which indicates that each decision maker is willing to offer the same level of concession with respect to the attribute in question. Values significantly above (below) 0.5 indicate that transporters (shippers) hold significant power relative to shippers (transporters), and hence are likely to achieve group choice equilibria that preserve a relatively greater proportion of their own preferences.

The power measures are calibrated against the estimated utility that each decision maker would realise from each attribute within each alternative. Details of the independent and first pass power models are given in Hensher *et al*. (2006) and Puckett and Hensher, (2006). The focus below is on the concession-based group equilibrium models.

4.2.1 Shipper concession model

As shown in Table 2, after projecting group choices based upon the stated willingness of shippers to concede toward the preferences of transporters, it is apparent that transporters and shippers have a strong capability of achieving a consensus strategy.

Table 2: Frequencies of projected group choice equilibria (shipper concession)

Choice Outcome	**Frequency**
Cooperative Outcomes:	
Revealed Preference Trip Accepted by Both	56.3%
Stated Preference Trip Accepted by Both	39.4%
Non-Cooperative Outcome:	
Transporter's Preferred SP Trip Unacceptable to Shipper (RP Trip Maintained)	4.3%

In only 4.3 percent of choice sets was the first preference of the transporter unacceptable as a group choice to shippers. Within the consensus outcomes, there was considerable support for both the revealed preference (RP) trip and stated preference (SP) alternatives. Although the status quo was the most likely observed group choice outcome, in almost forty percent of choice sets faced, the transporter preferred an SP alternative *and* the shipper was willing to accept that alternative as the group choice.

Considered in tandem with Table 1, an interesting picture emerges. When the first preferences of transporters and shippers did not coincide, it was nearly as likely for the transporter to prefer the RP trip as it was for the transporter to prefer a SP trip. After considering the concession that shippers stated they were willing to offer toward the first preferences of transporters, it is apparent that shippers are invariably willing to accommodate a transporter's preference for the RP trip. That is, even if shippers prefer a SP alternative, they are willing to accept the status quo as a group strategy. This is consistent with the choice of maintaining the status quo when a decision maker is unwilling to accept the first preference of the other decision maker as a group choice outcome. However, such impasse may not be likely to occur very often, as Tables 1 and 2 imply: not only were shippers willing to accept the RP trip as a group outcome in all cases, but shippers were also willing to accept an SP trip preferred by the transporter in 85 percent of choice sets in which shippers preferred a separate alternative. Hence, as the 4.3 percent rate of impasse underscores, shippers demonstrate a strong willingness to support supply chain strategies that transporters prefer, whether they involve maintaining current strategies or embracing new levels of service coupled with new mixes of costs.

Turning to the econometric models of shipper concession, Tables 3 and 4 present the results of the shipper concession model.

Table 3: Shipper concession model (mixed logit)

300 Halton draws used to estimate the random parameters; all random terms distributed triangularly

(# indicates a spread of the distribution equal to two standard deviations;
^ indicates an unconstrained distribution)

Attribute	**Parameter** (t-statistic relative to 0) [t-statistic relative to 0.5]
Mean Random Power Measures (>0.5 represents relative power to transporter; <0.5 represents relative power to shipper)	
Probability of on-time arrival	1.1048 (7.54) [1.29]
Fuel cost	1.3343 (2.55) [1.59]
Variable charges	3.1636 (5.33) [4.49]
Freight rate	0.5647 (3.27) [0.37]
Fixed Power Measure (>0.5 represents relative power to transporter; <0.5 represents relative power to shipper)	
Free-flow and slowed-down time	1.1703 (2.50) [1.43]
Heterogeneity around Means of Parameters	
Free-flow and slowed-down time * Number of years the companies have been working together	-0.0979 (-2.42)
Variable charges * Number of years the companies have been working together	-0.0325 (-1.60)
Fuel cost * Number of years the companies have been working together	0.0701 (2.03)
Standard Deviation of Random Parameters	
Probability of on-time arrival	2.2095 (7.54)#
Fuel cost	4.7091 (3.20)^
Variable charges	4.6392 (2.43)^
Freight rate	1.1295 (3.27)#
Model Fit	
Number of Observations	404
LL(B)	-335.385
Adjusted Pseudo R^2	0.23

Table 4: Descriptive statistics of power measures (shipper concession)

	FF/SD Time	**On-Time Reliability**	**Variable Charges**	**Fuel Cost**	**Freight Rate**
Mean	0.1444	1.0991	2.8233	2.0539	0.5656
Standard Dev.	1.2476	0.2918	0.8543	1.0985	0.1005
95% Range of Values	-3.7267 – 1.1214	0.3518 – 1.7618	0.7786 – 3.7367	-0.0328 – 4.8589	0.4457 – 0.8798
Minimum	-8.6238	0.0372	-1.3056	-1.2558	0.3709
Maximum	1.1704	1.9294	4.0049	8.4883	0.9800
Values Below 0.5	51.5%	3.7%	1.2%	5.9%	19.6%
Values Above 0.5	48.5%	96.3%	98.8%	94.1%	80.4%

Within the concession models, transit time measures were combined into one variable, to improve statistical significance. This aggregate measure was the only attribute to have all explicable heterogeneity captured through decomposition by the number of years the transporter has been carrying goods for the shipper. Both cost measures for transporters were also decomposed by this covariate, yet still display significant unobserved random taste heterogeneity after accounting for these effects. The transit time aggregate has a low mean value, implying a tendency for shippers to hold relative power with respect to transit time. However, as shown in Table 4, the distribution of values is split fairly evenly (51.5 percent in favour of shippers, 48.5 percent in favour of transporters).

Only the mean parameter estimate for variable charges demonstrates a power value significantly different to 0.5. However, the means of the distributions for variable charges and on-time reliability are more than two standard deviations away from 0.5.The means of the power measures and proportions of values above 0.5 imply that transporters have the potential to hold significant relative power over on-time reliability, variable charges and fuel cost, in addition to the strong potential to hold relative power with respect to the freight rate. Furthermore, the magnitude of the relative power held by transporters with respect to variable charges and fuel cost is significantly high, implying a tendency for the transporter to dominate with respect to these costs.

Returning to the effects of decomposing parameters by the length of the business relationship; the relative power of shippers with respect to transit time and variable charges are shown to increase as the length of the relationship increases. That is, the longer the transporter has been carrying goods for the shipper, the more likely the shipper is to hold relative power with respect to transit time, whilst the relative power of the transporter with respect to variable charges falls. Conversely, the dominance of the transporter with respect to fuel cost increases as the length of the business relationship increases.

4.2.2 Transporter concession model

To make inferences with respect to the power structures between transporters and shippers without directly observing their interactions, the analyst can contrast the results from the shipper concession model with those from the transporter concession model; i.e., the model accounting for the degree to which transporters are willing to accommodate the first preferences of shippers. Table 5 summarises the frequencies of group choice equilibria projected after considering the concession transporters stated they were willing to make toward the preferences of shippers:

Table 5: Frequencies of projected group choice equilibria (transporter concession)

Choice Outcome	**Frequency**
Cooperative Outcomes:	
Revealed Preference Trip Accepted by Both	55.8%
Stated Preference Trip Accepted by Both	34.9%
Non-Cooperative Outcome:	
Shipper's Preferred SP Trip Unacceptable to Transporter (RP Trip Maintained)	9.3%

Each class of joint choice outcome demonstrates a remarkably similar propensity to occur as in the shipper concession model. Whilst in the shipper concession model the projected group choice outcome is the (transporter-preferred) RP and SP trip 56 and 39 percent of the time, respectively, the projected group choice outcome in the transporter concession model is the (shipper-preferred) RP and SP trip 56 and 35 percent of the time, respectively. This implies that, at the sample level, transporters tend to hold similar propensities not only to prefer either their experienced trips or new alternatives, but also to be willing to accept the first preferences of their partner.

However, this is not entirely true. As with shippers, transporters were willing to accept the status quo as the group choice equilibrium in all cases. However, transporters appear less willing to concede toward the preferences of shippers with respect to alternatives involving distance-based charges. Although 85 percent of transporter-preferred SP alternatives were acceptable as group choice outcomes to shippers who preferred a separate alternative, only 67 percent of shipper-preferred SP alternatives were acceptable as group choice outcomes to transporters who preferred a separate alternative. Transporters appear to be relatively more rigid when it comes to enacting new strategies. Still, transporters appear willing to act cooperatively with shippers, in general. That is, should a compromise need to be reached, both transporters and shippers appear capable of finding suitable common ground when negotiating. Tables 6 and 7 present the results of the transporter concession model.

Table 6: Transporter concession model (mixed logit)

300 Halton draws used to estimate the random parameters; all random terms distributed triangularly

(and # indicate distributional spreads of one and two standard deviations, respectively)*

Attribute	**Parameter** (t-statistic relative to 0) [t-statistic relative to 0.5]
Mean Random Power Measures (>0.5 represents relative power to transporter; <0.5 represents relative power to shipper)	
Probability of on-time arrival	1.1075 (10.98) [6.02]
Fuel cost	-0.1231 (-0.69) [-3.51]
Variable charges	1.6617 (4.94) [3.45]
Fixed Power Measure (>0.5 represents relative power to transporter; <0.5 represents relative power to shipper)	
Free-flow and slowed-down time	0.2118 (0.53) [-0.71]
Freight rate	-0.0478 (-0.30) [-3.48]
Heterogeneity around Means of Parameters	
Free-flow and slowed-down time * Number of years the companies have been working together	-0.0561 (-2.34)
Free-flow and slowed-down time * Years shipper has been working with one's organisation	0.0672 (1.85)
Free-flow and slowed-down time * Importance of being in charge of decision making (transporter)	-0.0234 (-2.29)
Freight rate * Years shipper has been working with one's organisation	0.0250 (1.88)
Freight rate * Number of drivers employed by the transporter	-0.0011 (-1.64)
Standard Deviation of Random Parameters	
Probability of on-time arrival	1.1075 (10.98)*
Fuel cost	0.1231 (0.69)*
Variable charges	3.3234 (4.94)#
Model Fit	
Number of Observations	404
LL(B)	-293.054
Adjusted Pseudo R^2	0.25

Table 7: Descriptive statistics of power measures (transporter concession)

	FF/SD Time	**On-Time Reliability**	**Variable Charges**	**Fuel Cost**	**Freight Rate**
Mean	0.1473	1.1087	1.6735	-0.1231	0.0275
Standard Dev.	1.0131	0.0944	0.4229	0.0011	0.3339
95% Range of Values	-1.9890 – 1.7416	0.8599 – 1.3114	0.5136 – 2.2087	-0.1256 – -0.1211	-1.0728 – 0.5998
Minimum	-5.0044	0.8037	-2.2275	***-0.1292***	-0.1292
Maximum	2.3480	1.5787	2.5112	***-0.1192***	0.7374
Values Below 0.5	65.3%	0%	2.2%	100%	97.0%
Values Above 0.5	34.7%	100%	97.8%	0%	3.0%

Transporters appear most resistant to yield power over on-time reliability and variable charges when conceding toward shippers. This resistance appears absolute with respect to on-time reliability, with a mean power measure greater than unity, and with no estimated power measures below 0.5. The transporters' relative power with respect to variable charges under concession is also trong; the mean power measure is well above unity, with only 2.2 percent of estimated values below 0.5.

However, shippers appear to have the potential to hold relative power with respect to the remaining variables. This relative power is weakest for transit time, with approximately one-third of estimated power measures above 0.5. The mean power measure for transit time is close to zero, however, implying a strong potential for the shipper to hold significant power over transit time. The relative power represented by shippers in this model is strongest for fuel cost and the freight rate. In the case of the former, shippers have the potential to dominate, with a mean power measure below zero and no estimated values above 0.5. In the case of the latter, the mean power measure is near zero, with only three percent of estimated power measures above 0.5.

Returning to systematic sources of taste heterogeneity, power measures for transit time demonstrates a positive relationship with the amount of time the decision maker for the shipper has been working with his or her organisation (i.e., the greater the experience of the decision maker for the shipper, the greater the relative power of the transporter). Conversely, transit time displays a negative relationship with the length of the relationship and the importance the transporter places on being in charge of decision making. That is, the longer the transporter has been carrying goods for the shipper, and the more important it is to the transporter to be in charge of decision making, the greater the power of the transporter with respect to transit time. The length of the relationship also has a positive relationship with power measures for the freight rate. Conversely, power measures for the freight rate are negatively related to the scale of the transporter; the more drivers utilised by the transporter, the greater the ability of the shipper to keep the freight rate relatively low.

4.2.3 Comparison of results under shipper concession and transporter concession

Comparing the results from the shipper concession and transporter concession models, enables inferences to be made about the range of power structures that are likely to be observed amongst road freight transport operators and their customers under variable charging. There are three main types of power structures that are likely to be observed at the variable level: relative power held by transporters, relative power held by shippers, and balanced power (either on average, with power depending upon relationship characteristics, or overall, with a general tendency for power to be balanced). Across the models, all three types of relationships are observed. Transporters appear to hold strong power with respect to on-time reliability and variable charges, regardless of the degree of concession offered by either type of decision maker. Shippers, on the other hand, appear to hold relative power with respect to transit time. Power over fuel cost and the freight rate, however, varies with the relationship at hand. Not only is this variation systematic, but it also is indicated by a broad range of power structures that could appear, depending upon the degree of concession both types of decision makers are willing to offer.

Hence, the power models suggest that policy measures centred on the implementation of variable charges are likely to impact urban goods movement mainly through the influence of the preferences of transporters. That is, despite the interdependent nature of urban goods movement, transporters appear to hold power over the response of supply chains to a variable charging system. Likewise, the power models suggest that policy measures affecting the reliability of the road network are likely to involve supply chain responses based upon the preferences of transporters. However, shippers' preferences are inferred to dominate the supply chain response to policy measures influencing transit time, rather than the transporter. Likewise, shippers may be more likely than transporters to influence supply chain responses to factors impacting the freight rate and transporters' operating costs (i.e., fuel cost). Therefore, policy makers cannot focus solely on the preferences of one type of decision maker when attempting to infer the impact of a given policy measure on urban goods movement. However, respondents indicated that both transporters and shippers are potentially willing to concede relatively more toward the preferences of their partners with respect to the freight rate and fuel cost. Ultimately, it appears that the response of supply chains with respect to these monetary variables is relationship-specific, with no strong tendency for one type of decision maker to hold relative power.

5. Concluding remarks

This paper has presented the results of a study whose objective is to identify the effects of interdependency on decision making within transporter-shipper dyads. Influence structures across buyers and sellers of freight transport services were examined in the context of power, cooperation and concession. Power was found to vary across the attributes considered with both transporters and shippers holding relative power over at least some attributes of freight distribution strategies. There also appear to be some attributes over which relative power is a function of specific elements of a relationship rather than of the functional role of a decision maker.

Underlying the inferred power structures is the relative concession that each decision maker stated he or she was willing to make toward the preferences of the other group member within the survey. Transporters and shippers demonstrated similar propensities to be willing to accept the preferred strategy of their sampled partners as a group strategy, indicating a low resistance to offering levels of concession required to achieve cooperative outcomes. Both groups demonstrated remarkably similar propensities to prefer a given type of strategy. However, shippers were more willing than transporters to accept the preferred strategy of the other group member when the other group member preferred the revealed preference alternative whilst they preferred a stated preference alternative. Hence, transporters appear to be somewhat more resistant to adopting new strategies that may involve a new mix of benefits relative to the status quo.

Overall, the evidence suggests that transporters and shippers are predominantly committed to cooperative outcomes when faced with new opportunities or new challenges, such as a new distance-based charging system. The overwhelming propensity of transporters and shippers to either prefer the same strategy initially, or to be willing to enact each other's preferred strategies, indicates that satisfactory, cooperative group choice equilibria can be established when facing a new range of distribution alternatives. Considering all of the implications in tandem, the main policy message is that one should expect a broad range of strategic supply chain responses to a distance-based charging system. Some supply chains are likely to prefer strategies that minimise changes in operating costs after accounting for the charges, whilst others are likely to take advantage of the charges to yield desired improvements in reliability and transit time. Reliance on an average response from a population is likely to be misleading.

Finally, the methods proposed and implemented empirically under the MIGI paradigm have real value in transportation studies that are driven behaviourally by a suite of travel demand models. The calibration of physical transport models to predict the group-level changes in distribution activity that may occur under a given future pricing and service level (i.e., accessibility) of the road network should account for the multi-dimensional (i.e., attribute-specific) influence structures within transporter-shipper dyads and draw on the power-weighted role of specific attributes in predicting traffic level by route and time of day. To recognise this paradigm is to acknowledge the inadequacy of an uninformed transfer of the paradigms used in passenger travel demand studies.

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