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Publication date:
2003

No. 2003–26

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March 2003

ISSN 0924-7815

Consumers and experts: An econometric analysis of the demand for water heaters*

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(This version: 28 February 2003)

Abstract: Consumers can accumulate product information on the basis of a combination of searching, product advertising and expert advice. Examples of experts who provide product information include doctors advising patients on treatments, motor mechanics diagnosing car problems and recommending repairs, accountants recommending investment strategies, and plumbers making recommendations on alternative water heaters. In each of these examples, the transactions involve the sale of goods and services where the seller is at the same time an expert providing advice on the amount and type of product or service to be purchased. In the case of water heaters, the plumber advising a consumer on their choice of water heater will most likely also install the appliance. Because of the information asymmetry there is potentially a strategic element in the transmission of information from expert to consumer. This paper reports on an econometric investigation of the factors that determine the choices made by consumers and the recommendations made by plumbers and the extent to which plumbers act in the best interests of their customers. The empirical work is made possible by the availability of stated preference data generated by designed experiments involving separate samples of Australian consumers and plumbers. We find some evidence that plumbers have higher preferences than consumers for heater characteristics that increase their profit margin.

JEL Classification: C35, L84

* This research was supported by the Australian Research Council through a grant, and through the MEMLAB and Sydney VisLab computing facilities. Benedict Dellaert was heavily involved in the initial conceptualization of this project. His input is gratefully acknowledged. The project has benefited substantially from the technical advice and experience provided by John Clarke and Jordan Louviere and from the excellent research assistance of Adam McCabe and Bernard Conlon. Beneficial comments have been received from attendees of the Industry Economics Conference held in Melbourne 2001, the Australasian Econometric Society Meeting held in Auckland 2001 and seminar participants at the University of New South Wales, Melbourne University, Tilburg University, University of Newcastle (UK) and Dortmund University.

I. Introduction

For some goods, consumers are not well placed to immediately judge product attributes, a situation that leads to a derived demand for information. Product information can be obtained through consumer search, product advertising or from experts who provide advice. It is the latter case with which we are most concerned. Examples of experts who provide product information include doctors advising patients on treatments, motor mechanics diagnosing car problems and recommending repairs, accountants recommending investment strategies, and plumbers making recommendations on alternative water heaters.

Nelson (1970, 1974) makes a distinction between *search* and *experience* characteristics of goods. *Search* characteristics are product attributes about which consumers are able to obtain relevant information and make judgements prior to purchase, whereas *experience* characteristics are attributes about which judgements can only be made some time after purchase of the product, for example, reliability. Darby and Karni (1973) introduced the additional concept of *credence* characteristics, which are attributes that are difficult to evaluate even after purchase. How does a consumer determine whether a replacement car part was changed prematurely or not?

In each of the examples cited above, the transaction involves the sale of goods and services that can be classified as possessing experience or credence characteristics. Another important aspect of these examples is that the expert providing advice on the amount and type of product or service to be purchased is at the same time the seller of those products and services. Darby and Karni (1973) note that for firms involved in the joint provision of diagnosis and services, the combination of information asymmetry, together with the high cost of detection of "fraud", implies that firms may have an incentive to provide false or misleading information.

The involvement of experts in the decision-making process complicates the standard analysis of consumer choice, which may explain the neglect of this aspect in empirical work. A primary aim of our modeling is to overcome this deficiency and hence to provide a better understanding of the interaction between a consumer and an expert in the context of a consumer deciding on what type of water heater to purchase where the advice is provided by a plumber.

In his analysis of the selection of space and water heater systems, Dubin (1986a, p.112) chooses

to avoid the type of problem that concerns us by assuming that:

> "… the structure of supply and demand encourages sellers to act as de facto agents for buyers so that the distinction between construction to stock and construction to order disappears."

Whether such distinctions are important or not would seem to warrant further investigation. Green (1983) recognized the potential for similar influences in his econometric analysis of the choice of space heating fuel, but, unlike Dubin, his modeling distinguishes between houses built by owners and those built for sale. Green (1983, p. 338) notes that this distinction:

> "… was made in order to examine the contention that individuals building for sale will act to minimize the construction costs without regard to what this might do to operating costs."

In a similar vein, Hubbard (1998) investigates the probability that motor vehicles fail emissions inspections as a function of vehicle and inspector characteristics. The extent of the moral hazard problem is measured by the differences between the failure probabilities associated with inspectors in a private firm that also carries out repairs, and inspectors that are state officials having no affiliation with a repair operation.

Several aspects of the consumer/expert relationship included in our work cannot be tested with the type of data used by Green (1983) and Hubbard (1998). Both of these studies relied on data generated by natural experiments. Our work benefits from the availability of stated preference data collected specifically for this study. These data were obtained using designed experiments involving separate samples of Australian consumers and plumbers.

The Random Utility Model (RUM) that underpins the empirical modeling of discrete choice situations guides the econometric analysis. Mixed logit models previously used by Brownstone and Train (1999) and Revelt and Train (1998) are specified and estimated using simulated maximum likelihood. These provide a flexible framework for representing the distribution of preferences of consumers and plumbers and the resultant choices they make.

Although the data sets for consumers and plumbers were collected separately, our experimental design specified a number of common variables and attribute levels across the two data sets, and included variables that capture the impact of each party on the other. This allows us to compare choice criteria of plumbers with preferences of consumers and enables us to investigate the extent to which plumbers act in the best interests of their customers. Our econometric results indicate that for some, but not all, water heater attributes plumbers and consumer preferences are closely aligned. The ability to explore such relationships is one of the key features of the current work and distinguishes it from previous analyses of the demand for consumer durables.

II. Interaction between consumers and plumbers

A stylized version of the purchase decision faced by the consumer sees the consumer as having to choose between two or more types of water heater, each of which comprises a different bundling of physical attributes, running costs, purchase price and financing options. One of these water heaters is better suited to the consumer's needs but the consumer does not know which one it is. Moreover, even after purchase it would be difficult for the consumer to determine whether the most suitable water heater has been chosen. The consumer interacts with a better-informed expert, a plumber, who provides advice to the consumer who then makes a purchase choice that affects the welfare of both plumber and consumer. Because of the information asymmetry and, in particular, the fact that water heaters have experience and credence characteristics, there are incentives for plumbers to behave strategically in their transmission of information. This structure is reminiscent of the strategic information transmission games formulated by Crawford and Sobel (1982) and Pitchik and Schotter (1987).

Consumers are assumed to base their decision on the attributes of the water heater and the plumber's advice. The willingness of the consumer to accept the advice of the plumber will depend on an evaluation of the plumber's capability. Hence, variables that capture the technical competence of the plumber (e.g. trade certificates) and the nature of the relationship between the two parties need to be included in the consumer's choice model.

Plumbers are assumed to provide two services: advice on the water heater that is best suited to the consumer's needs, and the provision and installation of the water heater ultimately chosen. Because of licensing laws, a plumber will be required for the installation of the water heater. For

advice and other expert services, a plumber is typically not legally required and hence the question is whether the consumer seeks the involvement of the expert or not. However, one could imagine realistic situations where the two roles of advice and installation are divorced. Consumers may go to a retail outlet to obtain their expert advice and on making a choice; they can employ a plumber to make the installation. Separation of the advice and installation services would eliminate the incentives for the advice expert to recommend inappropriately. The assumption made in this study, that the same plumber provides both the advice and does the installation, is supported by our empirical evidence indicating that in a substantial proportion of cases, the plumber acts both as an expert adviser to the consumer and as the tradesman. This is not surprising in markets such as plumbing services where there are economies of scope that mean it is much cheaper to provide the two services jointly.

Plumbers make a recommendation to the consumer based on the consumer's characteristics and needs, and the plumber's own preference for doing the job. There is no reason why this preference should correspond to what is best for the consumer, and there may be incentives for the plumber to give misleading advice. The consumer may, of course, be aware of this aspect of their interaction and might react accordingly by asking for a second opinion or by seeking other quotes for the plumbing work. Wolinsky (1993, 1995) has stressed the role of consumer search for multiple opinions and reputation effects as mechanisms for disciplining the behavior of experts. Even when these mechanisms are unattractive, Emons (1997) demonstrates a similar tendency to non-fraudulent behaviour where observation of market data allows consumers to infer the incentives of experts. Hence, variables relating to the nature of the relationship between the parties are also included in the plumber model. To capture the plumber's preference for doing the job, we include variables such as the profit that they expect to make, the ready availability of the water heater, and the ease of installation.

Within this framework it is possible to consider whether plumbers act as "perfect agents" for consumers in the sense of Culyer (1989). Do plumbers make the same choices as consumers would make if consumers possessed the full information held by the plumbers? Perfect agency would exist if the plumber has no ability to mislead consumers, as would be the case, for example, if consumers had full information. This extreme situation destroys one of the central premises of the problem that has been formulated, namely that there is asymmetric information.

We would expect plumber recommendations to be modified in the intermediate situation where some consumers are relatively better informed than others. Another situation where one would expect perfect agency is if the plumber has no incentive to provide misleading advice, as would be the case if the preferences of the two parties were sufficiently similar. Such propositions will be translated into testable hypotheses in the econometric analysis to follow.

III. Data

The main stumbling block in estimating credible empirical models of the appliance purchase decision is the lack of suitable data. Studies of appliance choice typically model appliance *penetrations* in terms of the socio-economic characteristics of the household using surveys of the equipment that exists in the home. Examples are Bartels (1988); Fiebig and Woodland (1994); Plumb (1995); and Vaage (2000). Studies with a more detailed treatment of water heaters include Dubin (1986a,b) and Hartman (1984).

There are a number of problems in using such survey data for understanding the purchase decision.

a) The current occupier may have moved into the home after the original purchase.
b) Even if this is not the case, they may not have been involved in the decision process; the developer/builder/plumber may have made the decision.
c) Even if the current occupiers were involved in the decision, their circumstances may have changed (income etc.); often the purchase was made up to 10 or 15 years before the survey.
d) It is difficult to accurately determine the age of the equipment, and hence to link the purchase with the appropriate purchase cost and expected running costs of the chosen water heater and competing products.
e) A retrofit may have taken place in the past, in which case it is important to know what equipment was in place before the retrofit.

In view of these difficulties, typical appliance choice studies merely identify the relationships between appliance stocks and current home occupiers, and have little value for understanding the decision-making processes actually involved in the purchase of the appliance. In an attempt to overcome these problems our work employs stated preference methods to collect the data

required to model water heater choice.

Despite a history in economics of using intentions data (see the survey of Juster, 1964), in recent times economists have neglected such data, and have opted for working with market or revealed preference data. However, there has been a rapid development in the use of data generated by stated preference experiments in other areas of the social sciences, notably in marketing and transportation; see Louviere, Hensher and Swait (2000) for a recent overview. Part of the reason for this development is the appreciation that stated preference data can provide useful information when revealed preference data are deficient or non-existent.

In this study we use stated preference data that were collected in 1999 from a sample of 129 plumbers and a sample of 312 consumers, who all lived in Sydney, Australia. In order to provide a specific choice context, consumers were told that they needed to buy and install another water heater but that it was not an emergency, and consequently they had some time to consider options. To ensure that respondents were familiar with such a process, they were required to have been involved with the purchase of a water heater in the last two years. Plumbers were asked to consider a situation where a client asks them to recommend, supply and install a new water heater. They were told that the client lives in the house where the heater had to be installed and that the household comprised an adult couple with two children. The existing water heater had to be removed and replaced but again it was not an emergency situation so that the plumber knew the client had time to consider various options.

Both types of respondents were presented with hypothetical choice situations and were asked to choose (in the case of consumers) or recommend (in the case of plumbers) from a set of hypothetical alternatives. Following the recommendation of Carson et al. (1994), both choice experiments included a reference alternative that is constant across all the choice sets. Plumbers were asked which of two hypothetical water heaters they would recommend, but they were given the option of a "constant" reference alternative of not recommending either water heater. In the case of consumers, the "constant" reference alternative was the option of choosing their current water heater in preference to the two hypothetical heaters. This adds to the realism of the choice tasks, and, in the case of the consumer, it also means that we have a combination of stated and revealed preference data. This type of design feature has been used before especially in the area

of transport economics; see Louviere, Hensher and Swait (2000) and references therein.

As is standard with stated preference experiments, in order to increase the sample size in a cost-effective manner, each respondent was asked to perform not just one choice task as described above, but rather each consumer was asked to perform eight choice tasks, and each plumber sixteen choice tasks. This naturally imparts a panel-data structure to the two data sets. The hypothetical water heaters were characterized by several attributes, the levels of which were manipulated systematically between different choice tasks, and designed to be orthogonal across each data set. Variables ultimately used in the analysis are described in Table 1.

Bartels, Fiebig and McCabe (2001) provide more details of the design and implementation of the stated preference data collection. In addition they perform several checks on the reliability of responses and on how successful our design is in representing realistic choice options. Their analysis shows that consumers had a strong preference for their current heater, choosing this alternative approximately 60% of the time. Obviously this is a choice that they have made recently, and it is not unreasonable to expect them to again choose this heater in preference to others that they are offered. Moreover, when asked about their recent purchase 50% of consumers said they simply stayed with their current heater type and did not consider other options.

Evidently there is considerable inertia in the habits of consumers buying water heaters. Nevertheless, in about 40% of cases the stated preference alternatives were sufficiently attractive for consumers to choose one of the hypothetical heaters. 74.7% of consumers chose a hypothetical heater at least once over the eight scenarios they faced and only three of the 128 distinct hypothetical heaters were not chosen at all. With this sort of variation it should be possible to accurately estimate factors driving these choices.

The hypothetical heaters also seemed credible to plumbers. They recommended all but one of the 128 distinct heaters at least once and no plumber chose the “can’t recommend either” alternative across all scenarios they faced. Over all possible cases the “can’t recommend either” alternative was selected only 10% of the time by plumbers.

Table 1: Variable Descriptions

Variable	Definition
	Heater characteristics *(Consumer and Plumber Models)*
TYPE	Type of heater (electric = 1, gas = 0)
CAP	Capacity of water heater (1.5 times household's needs = 1, just enough =0)
WARR	Length of warranty in (tens) years
	Heater cost variables *(Consumer and Plumber Models)*
PRICE	Total price of heater and installation less rebates to consumer (thousands $)
RUN	Monthly running costs (tens $ where average = $20/month)
	Plumber's ratings relative to household's needs *(Consumer Model)*
NORATE	Plumber making no rating (yes = 1, otherwise = 0)
RATESAT	Plumber's rating satisfactory (yes = 1, otherwise = 0)
RATEVG	Plumber's rating very good (yes = 1, otherwise = 0)
RATEEX	Plumber's rating excellent (yes = 1, otherwise = 0)
	Financing variables *(Consumer Model)*
REBATE	Qualifies for 20% Green rebate (yes = 1, otherwise = 0)
NODEAL	Payment deal (none = 1, otherwise = 0)
CASH5	5% discount if paying in cash (yes = 1, otherwise = 0)
LOAN5	Loan at 5% interest for 12 months (yes = 1, otherwise = 0)
LOAN10	Loan at 10% interest for 12 months (yes = 1, otherwise = 0)
FSTPAY	First payment of loan (due now = 1, due in 3 months time = 0)
	Plumber characteristics and relationship *(Consumer Model)*
NOCERT	Plumber has no government certificate (yes = 1, otherwise = 0)
CERTB	Plumber has both a Green and Gold certificate (yes = 1, otherwise = 0)
CERTGR	Plumber has a Green certificate (yes = 1, otherwise = 0)
CERTGO	Plumber has a Gold certificate (yes = 1, otherwise = 0)
PLCHRG	Plumber charge for installation (rate different to standard = 1, otherwise = 0)
PLDKN	Plumber not known to consumer (yes = 1, otherwise = 0)
	Consumer income *(Consumer Model)*
INCLT50	Income less than $50,000 (yes = 1, otherwise = 0)
INC50-90	Income between $50,000 and $90,000 (yes = 1, otherwise = 0)
INCGT90	Income greater than $90,000 (yes = 1, otherwise = 0)
MINCOME	Individual missing (yes = 1, otherwise = 0)
	Plumber – job related variables *(Plumber Model)*
AVAIL	Availability of heater (in stock now = 1, 3-5 days wait = 0)
INST	Difficulty of installation (job more difficult than average = 1, otherwise = 0)
REBATE	Rebate to consumer or plumber (yes = 1, no rebate of any kind =0)
PROFIT	Quote for supply and installation, less retail price after trade discounts and rebates
	Consumer characteristics and relationship *(Plumber Model)*
SUB	Suburb in which consumer lives (upper middle class = 1, working class = 0)
OTHBIDS	Consumer will ask for other bid (likely = 1, otherwise = 0)
MAG	Consumer has access to Choice magazine (yes = 1, otherwise = 0)
BEF	Consumer has worked with plumber before (yes = 1, otherwise = 0)
FUT	Plumber likely to receive future work from consumer (yes = 1, otherwise = 0)

Because of our focus on the relationship between a consumer and an expert plumber, it is natural to ask how important expert advice is in the choice of consumer durables such as a water heater. In our sample of 129 plumbers, 67.4% indicated that, in their most recent job, consumers asked for their advice about the type and model of water heater to install. This is somewhat higher than the 61.3% when the 312 consumers were asked a comparable question. However, the consumers in our stated preference survey were screened. In a separate representative sample of Australian consumers commissioned from Newspoll, 45.1% of respondents indicated that they received advice from their plumber when buying a water heater. Naturally this advice need not be heeded. However, a surprisingly high proportion (94.2%) of respondents who sought advice indicated that they accepted at least some of the plumber's recommendations. While the impact of plumbers is possibly not as great as they think, it seems plausible that for a substantial proportion of cases the plumber's advice will be sought and will have some impact on the choices made by the consumer.

To put these findings in a broader context, the 312 consumers in the stated preference study were asked to indicate on a five point scale their willingness to seek advice from eleven different types of experts. Of these eleven types of experts, people were most willing to accept the advice of a policeman on parking restrictions or the advice of their doctor. Plumbers were on a par with mechanics advising someone about engine repairs. In these cases the average response on the five point scale was somewhere between level 2, "accept most and probably do", and level 3, "may have doubts but do most". People were least likely to accept the advice of a hairdresser/barber advising them on shampoos or their accountant advising them about share investments. In terms of investigating the interplay between consumers and experts, plumbers seem to be a good choice in that their advice is unlikely to be accepted blindly, nor is it likely to be completely ignored.

IV. Mixed logit choice model

Each of our consumers and plumbers face a choice amongst J alternatives repeated under S alternative scenarios or choice situations. Both cases can be represented in a common framework where the utility that individual i derives from choice j in scenario s is denoted by

$$(1) \qquad U_{isj} = X'_{isj}\beta_i + \varepsilon_{isj}$$

where X_{isj} is a K x 1 vector of explanatory variables and β_i is a conformable vector of coefficients.

Conditional on β_i, and assuming the disturbance terms ε_{isj} to be distributed as iid extreme value, the standard multinomial logit specification results with the probability that individual i chooses j in scenario s given by:

$$(2) \qquad P_{isj} = \frac{\exp(X'_{isj}\beta_i)}{\sum_h \exp(X'_{ish}\beta_i)}.$$

As is well known, the specification with common parameters β_i for all individuals suffers from the undesirable independence of irrelevant alternatives (IIA) property. A generalization that accounts for the panel structure of the data and that allows for possible heterogeneity amongst consumers and plumbers involves introducing parameter heterogeneity by setting:

$$(3) \qquad \beta_{ki} = Z'_i\beta_k + \sigma_k\omega_{ki} \qquad k = 1,\ldots,K$$

where Z_i is a vector of observed characteristics of respondent i, the β_k are parameter vectors and $\sigma_k\omega_{ki}$ represents unobserved heterogeneity in the preference weights. We will assume that the ω_{ki} follow standard normal distributions, independent of each other and of the ε_{isj}. Notice that this specification allows for β_{ki} to vary over individuals, but not over the repeated choices made by that individual. Error correlation is introduced across choices but this correlation is not perfect because of the presence of the independent extreme value term ε_{isj}.

The resultant random parameter or mixed logit model has recently become very popular in empirical work, providing a flexible and computationally practical discrete choice specification. [See Brownstone and Train (1999), McFadden and Train (2000) and Revelt and Train (1998) for applications and further support for this type of specification.]

The standard way to estimate this model is simulated maximum likelihood. Let ω_{ki}^r be independent draws from $N(0,1)$ ($r = 1,\ldots,R$; $k=1,\ldots,K$; $i = 1,\ldots,N$). For given parameter values

and characteristics, let β_i^r be the corresponding vector of preference weights β_{ki}^r given by (3), replacing ω_{ki} by ω_{ki}^r. Estimation by simulated maximum likelihood (SML) proceeds by maximizing the following criterion:

$$(4) \quad SLL = \sum_{i,s,j} d_{isj} \ln \hat{P}_{isj}$$

where $d_{isj} = 1$ if individual i chooses j in scenario s, and zero otherwise, and

$$(5) \quad \hat{P}_{isj} = \frac{1}{R} \sum_r \left[\frac{\exp[X'_{isj}(\beta_i^r)]}{\sum_h \exp[X'_{ish}(\beta_i^r)]} \right]$$

is the simulation estimator of the unconditional probabilities obtained by the draws. Lee (1992) derives the asymptotic distribution of the estimator when the number of replications increases with sample size. Under certain regularity conditions the estimator is consistent and asymptotically normal and if the number of replications rises faster than the square root of the number of observations, the estimator is asymptotically equivalent to the maximum likelihood estimator.

Our code for this estimator was written in GAUSS and was tested by comparing the results of appropriate models against the estimates obtained using LIMDEP and using a program for mixed logit estimation downloaded from Kenneth Train's website.

V. Model specification

Both the consumer and the plumber utility maximization problems are characterized using the standard Random Utility Model (RUM); see, e.g., Louviere et al. (2000). Below we describe the structure of the models for the consumers and for the plumbers. Descriptions of the individual variables are given in Table 1.

A. Consumer's random utility function

It is assumed that the choices of consumers are determined by: water heater attributes, price, running cost, plumber's advice, financing options, and variables that capture plumber characteristics and the plumber-consumer relationship. In each of eight choice tasks, the

consumer is asked to choose between three different alternatives. Two of the water heater/plumber alternatives constitute hypothetical situations (j = 1 and 2), while the third alternative (j = 0) allows the consumer to choose neither of them.

In the survey this third alternative was described as their current heater. There was an expectation that we would be able to exploit this revealed preference (RP) data within our estimation procedure. Consumers would be comparing attributes of the SP alternatives with characteristics of the heater that they recently purchased. Unfortunately, the consumers did not know many of the heater characteristics so that there was considerable missing data associated with these variables and hence little explanatory power in the RP data.The utility of the RP alternative was assumed to be determined by a linear combination of a restricted set of observed characteristics of the current heater and a consumer specific intercept that depends on household income as well as a random unobserved heterogeneity component.

The utility that consumer i receives from alternative j in scenario s is given by:

$$(6) \qquad U_{isj}^{c} = (1 - RP_{ij})(X'_{1isj}\beta_{1i} + X'_{2isj}\beta_{2i}) + RP_{ij}(X'_{3i}\beta_{3} + \beta_{4i}) + \varepsilon_{isj}^{c}$$

where the dummy variable, RP, represents the current water alternative; i.e. RP_{ij} = 1 if j = 0, and RP_{ij} = 0 otherwise. All variables relating to the revealed preference alternative, X_3, are constant across all the eight choice tasks faced by the consumer. Hence this alternative can be seen as the consumer's reference alternative. The coefficients β_{1i}, β_{2i} and β_{4i} are treated as random coefficients, see (3). Variables manipulated in the choice experiment have been divided up according to whether they also appear in the plumber's indirect utility function, X_1, or only in the consumer's, X_2. The components of β_{1i} and β_{2i} are all assumed to follow independent normal distributions with means and variances that do not depend on consumer characteristics. Given the consumer's household income, the coefficient β_{4i} is assumed to follow a normal distribution, independent of β_{1i} and β_{2i}, but with a mean that depends on the reported household income category. In order not to lose too many observations, those with missing income are treated as a separate income category.

There were a number of interactions that were allowed for in the design and in the modelling. For

example, in the consumer model income was initially interacted with price. But in preliminary testing none of these proved to be significant and hence they have been omitted.

B. Plumber's random utility function

In each of sixteen choice tasks, the plumber is asked to choose between two water heater/consumer situations and to recommend one of them (j = 1 and 2). Plumbers can also decide that they can't recommend either of the two alternatives (j = 0). In making their recommendations, it is assumed that the plumbers will look at their own interests as well as those of the consumers. In particular, in the short term, they will be concerned with the profits they will make from the project. But there is also a longer-term interest in building up a good relationship with the consumer since this may lead to future jobs.

The main variables affecting the plumber's choices are: water heater attributes, cost variables, job-related variables and variables that capture consumer characteristics and the plumber-consumer relationship. The choice of the "can't recommend either" alternative is treated as a constant reference alternative across all choice sets and its utility function contains only the alternative-specific intercept and the random error term.

The utility that plumber i receives from alternative j in scenario s is given by:

$$(7) \qquad U_{isj}^{p} = (1 - CR_{ij})(X'_{1isj}\alpha_{1i} + X'_{4isj}\alpha_{2i}) + CR_{ij}\alpha_{3i} + \varepsilon_{isj}^{p}$$

where the dummy variable, CR, represents the "can't recommend either" alternative; i.e. $CR_{ij} = 1$ if $j = 0$ and $CR_{ij} = 0$ otherwise. The coefficient α_3 is treated as a random coefficient (see (3)), which is constant for the sixteen choice tasks faced by each individual plumber, but which varies across plumbers. Thus the plumbers are assumed to have individual-specific reference points for evaluating the hypothetical alternatives. Variables denoted by X_4, represent those that only appear in plumber's indirect utility function, whereas the variables in X_1 also appear in the consumer's indirect utility function (see Table 1).

Among the job-related variables is the variable "profit", which is the difference between the plumber's quote for the job and the purchase cost to the plumber of the water heater. This

variable is treated as exogenous in the present analysis. When one considers that the plumber is likely to include a similar profit margin when quoting for both hypothetical water heaters in each choice task, exogeneity is not an unreasonable first assumption. However, the approach that plumbers take to quoting for jobs, and the relationship of quotes to recommendations, is of considerable independent interest and we intend to explore this topic in future work.

VI. Estimation results

A. Overview of results

Estimation results are presented for consumers in Table 2 and for plumbers in Table 3. In both cases, results are presented using a standard multinomial logit (MNL) model and for the corresponding mixed logit model.

Note that comparisons of the MNL and mixed logit estimates require some care. If, in fact, the latter is the more appropriate specification, then the parameter estimates and standard errors are not comparable because those in the MNL model will be inconsistent. With respect to the coefficient estimates, the MNL results are typically smaller in magnitude. This is to be expected since, in the mixed logit model, the parameter estimates are normalized relative to the extreme value part of the disturbance term, that is, net of the error component introduced by the random coefficients. Since the disturbance in the MNL specification captures both sources of error, it will have a larger variance and hence normalization relative to this variance will lead to estimated parameters that can be expected to be smaller than those of the mixed logit.

Because the stochastic portion of utility has different variances in the two models, it is difficult to compare the magnitude of coefficient estimates, but signs can be compared. Coefficient estimates typically have expected signs that are consistent across models. Many of the standard deviations estimated in the mixed logit framework are large and statistically significant. This indicates the presence of considerable preference heterogeneity and vindicates the move away from the basic MNL model. While the models are nested, the hypothesis tests are non-standard because the parameter space is restricted under the alternative. In such situations the LR test statistic does not have the usual chi-square asymptotic distribution; see for example Andrews (1998). However, a comparison of fit as measured by the pseudo R^2 statistics clearly indicates that the mixed logit represents an improvement over MNL.

In moving from the MNL to the mixed logit models the improvement in fit is due to allowing for heterogeneity, accounting for the panel nature of the data. An intermediate model with a random intercept as the only random coefficient captures the panel nature of the data in a more common way, adding a random individual effect. For the consumer data the pseudo R^2 for this panel mixed logit model with only β_4 random is 0.2408. The pseudo R^2's for the mixed logit model and the MNL model are 0.0815 and 0.2600, respectively. Thus most of the improvement in fit here is due to adding the random individual effect β_4. For plumbers this intermediate model with only α_4 random has a pseudo R^2 of 0.1841, compared to a pseudo R^2 of 0.1441 for the MNL model and 0.2306 for the mixed logit. For plumbers, adding the random individual effect thus accounts for less than half of the improvement of the fit.

B. Consumer results

Consider the coefficient estimates produced by the mixed logit model for consumers presented in Table 2. Note that the signs of mean coefficients are typically sensible and a large number of these effects are precisely estimated. The magnitudes of the estimated standard deviations are also sensible. Whenever, mean coefficients are precisely estimated the associated standard deviation is typically less than the estimated mean coefficient. This implies that the estimated distributions for our random parameters have only relatively small probabilities associated with parameter values that have signs different from the mean. Alternative specifications were tried, such as assuming a truncated normal distribution that constrains the entire distribution to have the same sign. However, similar to the experiences of Revelt and Train (1998) with their use of lognormal distributions, we often had convergence problems with this approach. Also, for some attributes, having the flexibility of both negative and positive effects is desirable.

Consumers value more capacity and longer warranty and both the mean and standard deviation coefficients are significant for these two attributes. Consumers are also very conscious of price and running costs. Both mean coefficient estimates are negative and precisely estimated. While the running cost standard deviation points at substantial heterogeneity in consumer's valuation of running costs, the same is not true for price. The price standard deviation is small and has a standard error that exceeds the point estimate, indicating little heterogeneity in the way consumers react to price changes. In some previous work, the price effect is assumed to be fixed

a priori; see for example Revelt and Train (1998) and Layton and Brown (2000). The rationale is usually to simplify willingness-to-pay (WTP) calculations or to avoid distributions of price effects that include positive responses.

Table 2: Estimation results for consumers

	Multinomial logit		**Mixed logit**			
Variables	Coefficient	Standard error	Mean coefficient	Standard error	Standard deviation	Standard error
cap	0.4445	0.0777	0.6879	0.1312	0.7420	0.1905
warr	0.9058	0.1563	1.3185	0.2555	0.6989	0.2576
price	-1.3116	0.1696	-2.0446	0.2562	0.0910	0.2017
run	-0.3328	0.0345	-0.6427	0.0707	0.5092	0.0744
rebate	0.0849	0.0799	0.1260	0.1358	0.4993	0.2283
fstpay	0.0407	0.0761	0.1008	0.1273	0.4468	0.2206
cash5	0.2122	0.1053	0.3861	0.1718	0.5978	0.2611
loan5	0.0167	0.1058	0.0695	0.1656	0.6481	0.2265
loan10	-0.1278	0.1097	-0.2437	0.1875	1.0833	0.2080
certb	0.6952	0.1214	1.4242	0.2106	0.8918	0.3039
certgr	0.4519	0.1218	0.9232	0.2044	0.8880	0.3154
certgo	0.5952	0.1220	1.1883	0.2325	0.1625	0.4207
ratesat	-0.1977	0.1122	-0.2456	0.1827	0.3458	0.2943
ratevg	0.0563	0.1074	0.1856	0.1599	0.3946	0.3082
rateex	0.2862	0.1037	0.5278	0.1677	0.2436	0.2774
pldkn	-0.0905	0.0847	-0.1365	0.1626	0.0151	0.3019
plchrg	-0.0505	0.0839	-0.1644	0.1714	0.6088	0.2825
type	-0.7602	0.1096	-1.2775	0.2162	1.3438	0.1873
type*typeRP	1.1747	0.1499	1.6927	0.2845		
RP	-0.0009	0.2989	-0.3011	0.5524	3.0163	0.2347
RP*inclt50	0.3225	0.1159	1.5703	0.5013		
RP*incgt90	0.1431	0.1118	0.0513	0.4509		
RP*mincome	0.1548	0.1194	0.2575	0.4582		
RP*typeRP	0.7105	0.1111	1.2128	0.3540		
RP*mtype	-0.0381	0.3578	1.5959	1.9345		
Pseudo R^{2} [a]	0.0815		0.2600			
Log-likelihood	-2154.78		-1736.10			

Note: [a] Pseudo R^2 is defined as $1 - (LL/LL_0)$, where LL is the value of the (simulated) log-likelihood function evaluated at the estimated parameters while LL_0 is the value of the log-likelihood function for a base model that only contains a non-random RP intercept.

The variable "rebate" measures the "green" effect as the rebate itself has been accounted for in the price. Its estimated mean coefficient is positive, but small and insignificant. The associated standard deviation is large relative to the mean coefficient and precisely estimated. Apparently

there is considerable heterogeneity amongst consumers regarding the green rebate. While on average there is a positive green effect, a large proportion of consumers do not seem willing to pay for environmentally friendly water heaters.

There is a similar pattern of diversity with the financing options. Apart from the cash discount, the mean effects of the different loan options are all insignificant but have large and precisely estimated standard deviations. Consumers are divided in their views of these attributes. Even in case of the cash discount where the mean coefficient is positive and significant, the large standard deviation indicates considerable heterogeneity in how consumers value this option. This general result is consistent with Revelt and Train (1998) who find substantial variation in how consumers respond to loans for high efficiency refrigerators.

Consumer choices are influenced by positive plumber recommendations although only a rating of "excellent" has a statistically significant impact. It is also the case that the standard deviations associated with each of the ratings are not significantly different from zero. Thus there is no evidence of heterogeneity with respect to these ratings.

Plumber certificates have a much greater impact on consumer choices than plumber recommendations. Both green and gold certificates influence choice, although the impact of the latter is greater. Having both certificates has an even greater impact but the difference relative to having just one of the certificates is relatively small. The standard deviations for both certificates and a green certificate are large, in contrast to the standard deviation for the gold certificate. All of this is expected as the gold certificate already exists in the market and people are going to be more certain of its value relative to the green certificate, which exists in other countries but not Australia.

That consumers put a high value on certificates is consistent with previous empirical studies on the economics of advertising and information provision. For example, Laband (1986) and Mixon (1995a,b) provide support for the proposition that suppliers of experience or credence goods, such as water heaters, provide more informational cues, such as licenses and certificates, than do suppliers of search goods.

Whether or not the consumer knew the plumber is not important. The estimated mean is insignificant, and the estimate of the standard deviation is small and imprecise. Whether the plumber charged a standard installation rate also has an insignificant mean effect but the associated standard deviation is much larger, indicating substantial heterogeneity.

Water heater type refers to whether the SP alternatives are electric or gas. This impact is allowed to vary according to "typeRP", which represents whether the consumer's current water heater is electric or gas. Clearly, consumers have a strong preference for their existing heater type. Consumers currently with a gas heater are likely to choose hypothetical heaters that are also gas and similarly for those people currently with electric heaters. These mean effects are quite significant. However, the standard deviation for "type" is large as well, which indicates that there is considerable heterogeneity around these mean tendencies to prefer gas or electricity. To illustrate the effect of the difference in preferences between electricity and gas consumers, we calculate the probability of "switching" preferences. According to the estimated random coefficient distributions, the probability that an electric consumer (one who currently has an electric water heater) would prefer gas is 0.379, while for a gas consumer (one who currently has a gas water heater) there is a probability of 0.171 that they'd prefer an electric water heater. The finding that the tendency to switch is substantially different across consumer types is consistent with the churn rates in our sample of consumers where 12.2% of people who previously had an electric water heater switched to gas for their latest purchase while only 1.0% of people who previously had gas switched to electricity.

Current water heater type is also interacted with the RP dummy. Here the results indicate that consumers, who have electricity as their RP type, are less likely to make an SP choice than people with gas as their RP type. (This is the conditional probability, and hence corrects for the fact that there are more respondents with electric water heaters.) Consumers, who are in the lowest income category, are also less likely to make an SP choice in preference to their current water heater. There is no significant difference between the highest income group and the middle-income group that serves as the base category.

C. Plumber results

Results for the mixed logit model for the plumbers are presented in Table 3. As in the case of the

consumers, the signs of the coefficients are typically sensible and a large number of effects are precisely estimated. Similarly the estimates of the standard deviations are also sensible and precise.

Extra capacity, longer warranty, lower running costs and cheaper price, impact on plumber recommendations with the same signs as they affect consumer choices. All of these mean effects are significant as are the associated standard deviations. The standard deviations are at most a similar magnitude to the estimated mean effects. Thus, there is significant heterogeneity but the random coefficient distributions only produce relatively small probabilities for signs different from the estimated mean effects.

Table 3: Estimation results for plumbers

	Multinomial logit		**Mixed logit**			
Variables	Coefficient	Standard error	Mean coefficient	Standard error	Standard deviation	Standard error
cap	0.9680	0.0715	1.2357	0.1334	1.2779	0.1355
warr	1.1753	0.1501	1.5624	0.1959	0.9709	0.2266
price	-1.1841	0.1920	-1.7267	0.2525	1.0369	0.2347
run	-0.4641	0.0338	-0.6525	0.0651	0.5584	0.0687
avail	0.1829	0.0729	0.2182	0.1090	0.4338	0.1752
inst	-0.2058	0.0749	-0.1813	0.0992	0.0108	0.1951
rebate	0.0369	0.0877	0.0424	0.1377	0.2439	0.2663
profit	0.5923	0.2826	1.2368	0.5780	1.7862	0.3800
sub	-0.1584	0.1554	-0.2576	0.2497	0.1242	0.4252
othbids	-0.0305	0.1552	-0.0094	0.2683	0.2551	0.4468
mag	0.0349	0.1585	0.1573	0.2890	0.7770	0.3095
bef	-0.0153	0.1556	0.1701	0.3072	0.7254	0.3311
fut	0.1288	0.1569	0.2728	0.2598	0.3851	0.3556
type	-0.5170	0.0724	-0.6479	0.1213	0.6367	0.1319
CR	-2.7596	0.2899	-4.2849	0.4881	1.4855	0.2943
Pseudo R^2 [a]	0.1441		0.2306			
Log-likelihood	-1616.17		-1452.98			

Note: [a] Pseudo R^2 is defined as $1 - (LL/LL_0)$, where LL is the value of the (simulated) log-likelihood function evaluated at the estimated parameters while LL_0 is the value of the log-likelihood function for a base model that only contains a non-random CR intercept.

Several characteristics related to the nature of the job impact significantly on the plumber's recommendations. Plumbers are more likely to recommend a water heater that is readily available and less likely to recommend one that is difficult to install. While both these mean effects are

precisely estimated, the standard deviation for ease of installation is small. On the other hand the standard deviation for availability is large relative to the estimated mean effect. Thus there is considerable heterogeneity with regard to the impact of availability. The situation is similar with profit. The more profitable the water heater is to the plumber the more likely it is that plumbers will make a positive recommendation. However, the associated standard deviation is large and precisely estimated. According to the estimated random coefficient distribution 24.4% of plumbers do not assign profit a positive weight in determining their recommendations.

Like consumers, plumbers are not overly influenced by environmental concerns. The mean and standard deviation associated with whether there was a green rebate of any kind were both small and insignificant.

Factors related to reputation and the relationship between the plumber and the consumer also have small and insignificant mean impacts. Presumably repeat business is not an important characteristic of the plumber's market.

The estimated mean coefficient associated with "type" is negative, indicating that plumbers prefer gas to electricity. This coefficient is precisely estimated, as is the associated standard deviation. Both estimated parameters are similar magnitudes indicating there is considerable heterogeneity in preferences but nonetheless a clear majority of plumbers have a very strong preference for gas. A possible explanation is that a plumber is typically also a gas fitter, and, unlike with electricity, plumbers don't have to engage another tradesman to connect the water heater to the gas grid.

D. Comparing consumer and plumber results

In order to investigate more formally the extent to which plumbers mimic consumer preferences in their recommendations, we look more closely at the variables common to the indirect utility functions of both consumers and plumbers. Table 4 collects the mixed logit estimates of the mean coefficients and standard deviations of the relevant variables. Recall that the consumer and plumber models have been separately estimated and in each case the scale is normalized on the GEV errors. There is no reason why the degree of heterogeneity reflected in the errors should be the same for plumbers and consumers so that even if consumers and plumbers make similar tradeoffs, the actual coefficient estimates may still differ by a fixed proportion because of scaling

effects.

In the first instance we construct a joint Wald test for the null hypothesis that the ratios of consumer and plumber mean coefficients are the same for all four common attributes. The resultant chi-square test statistic with 3 degrees of freedom is 8.18, yielding a p-value of 0.042 and hence rejection of the null at a 5% but not 1% level. Visual inspection of the individual mean coefficient estimates in Table 4 indicates that, while those for warranty, price and running cost are quite similar between consumers and plumbers, the mean coefficients for capacity are quite different. If the Wald test for proportionality is repeated without capacity, then the test statistic is only 1.43 with an associated p-value of 0.489, enabling us to accept the hypothesis of proportionality.

Table 4: Parameter estimates and tests of differences for attributes common to indirect utility functions of plumbers and consumers

	Consumers		**Plumbers**		**Wald tests of difference**	
Variables	Mean coefficient	Standard deviation	Mean coefficient	Standard deviation	Mean coefficient	Standard deviation
Capacity	0.6879	0.7420	1.2357	1.2779	8.57*	5.26*
Warranty	1.3185	0.6989	1.5624	0.9709	0.57	0.63
Price	-2.0446	0.0910	-1.7267	1.0369	0.78	9.34*
Running cost	-0.6427	0.5092	-0.6525	0.5584	0.01	0.24

* Indicates difference in coefficient is significantly different from zero at the 1% level.

A similar pattern emerges if we test for proportionality among all eight parameters; four mean coefficients and four standard deviations. The Wald chi-square test statistic with 7 degrees of freedom is 18.87 yielding a p-value of 0.009. Repeating the test without the two capacity parameters gives a test statistic of 10.75 and associated p-value of 0.057. So again, the hypothesis of proportionality is rejected at the 5% level if we include the two capacity parameters, but it's accepted if we repeat the test without them.

In view of the fact that several of the proportionality factors when comparing the estimated parameters for consumers and plumbers are close to unity, Table 4 also presents the individual Wald tests for the null hypothesis that each pair of consumer and plumber parameters is the same.

These individual tests of differences confirm the distinct situation with regard to capacity; for capacity the Wald statistic for testing for equality between the mean responses of consumers and plumbers is very significant, while for the other attributes the Wald statistics are quite small.

While, on average, both consumers and plumbers value capacity (see Tables 2 and 3), compared to other attributes plumbers clearly place much more weight on capacity than consumers do. On the other hand, the standard deviation for capacity is also much larger for plumbers, suggesting that the percentage of plumbers who do not attach much value to capacity is similar to that for consumers.

With the exception of the price standard deviation, which is very small for consumers but much larger for plumbers, the remaining individual tests indicate a remarkable similarity between the estimated plumber and consumer coefficients.

"Type" was also a common attribute, but because plumbers' recommendations did not control for the current water heater of their customers, it is difficult to formally test differences between preferences of plumbers and consumers for water heater type. However, like the situation with capacity, there are indications of substantially different preferences. For a gas consumer the mean coefficient for the variable "type" is –1.28 while for an electric consumer the mean coefficient is 0.41. This indicates a preference for the existing water heater fuel type for both electricity and gas customers, but for existing gas customers this preference is much stronger than for electricity customers. Taking a weighted average across these two classes of consumers (43.6% of our sample had gas), the resultant coefficient for "type" is –0.33 indicating an overall preference for gas. By comparison the mean coefficient for "type" for plumbers is –0.65, indicating an even stronger preference for gas.

What do these comparisons indicate about the plumber/consumer relationship? For some water heater attributes, including warranty, price and running costs, our estimation results indicate plumber and consumer preferences are closely aligned. The two attributes where this is not the case are capacity and whether the water heater is gas or electric. One might want to argue that the plumbers are exploiting their information advantage to extract more profit from their consumers. Profit margins are likely to be greater for gas water heaters and for higher capacity heaters, and,

unlike say warranty; these attributes have credence and experience characteristics. Consumers would find it difficult to know beforehand, or to determine afterwards, whether their newly purchased, high capacity water heater was appropriate for them or not.

However, in our experiment we independently vary the cost and hence are able to control for the profit received by plumbers in the plumber model. Thus an explanation for the difference is not that larger capacity water heaters are more profitable for the plumber; unless perhaps there are some characteristics that are not reflected in the plumbers' quotes or in the other variables used, but which are correlated with capacity and lead to different levels of profitability for water heaters.

Another plausible explanation is that plumbers might have inaccurate perceptions of the preferences of consumers leading them to put undue weight on excess capacity when making recommendations. Anyone familiar with water heating advertising in Australia knows that this is a key element of the advertising program of the country's major brand. It is possible that plumbers have been more influenced than consumers by this campaign.

As has been explained, plumbers are likely to prefer gas because, unlike with electricity, they don't have to engage another tradesman to connect the water heater to the gas grid. While we have controlled for any extra profitability associated with these different arrangements it is still likely that plumbers would prefer to avoid involving an electrician in the water heater installation.

The differences in the tradeoffs made by consumers and plumbers need to be interpreted with some care. In the health economics literature, where the doctor-patient relationship parallels our plumber-consumer relationship, the concept of the "perfect agent" has been introduced. According to Culyer (1989), the perfect agent chooses/advises as the patient/consumer would choose if the patient/consumer possessed the full information held by the doctor/plumber. This suggests that we need to take account of, not only a possible difference between the preferences of the two types of agents, but also the difference in the amount of information each may have. A well-intentioned plumber might recommend a particular type of water heater, despite the fact that the plumber knows that it is not the consumer's preferred choice, because the plumber has more

information, and they believe that based on this information, their recommendation is the best choice for the consumer.

VII. Conclusion

In many countries water heating is one of the two most important uses of gas in the home, and a study by the International Energy Agency (IEA, 1989) found that water heating was one of the top three residential uses for electricity in each of six OECD countries studied. In the state of New South Wales in Australia, water heating accounts for over 50% of residential gas consumption and over 30% of residential electricity consumption (Fiebig and Woodland, 1994). Moreover, there are new technologies, like high-efficiency instantaneous gas water heaters and electric heat pump water heaters, which could have a major impact on the energy requirements of water heating (Rollin and Beyea, 1985). The results presented here provide a better understanding of the decision processes underlying the choice of water heater, and they provide useful information for any policy aimed at reducing energy consumption or CO_2 emissions in the residential sector.

Unlike previous studies of appliance choice we have attempted to account for the role of experts who potentially influence the purchase decisions of consumers. In the absence of revealed preference data, the econometric analysis has been made possible by the collection of stated preference data on a sample of consumers and plumbers. The results indicate that stated preference surveys can be usefully employed to elicit statistically significant and economically reasonable preferences for both.

For the particular case of water heaters, our results indicate that key attributes of water heaters such as capacity and warranty are important determinants of water heater choice. Price and running costs are also important but consumers do not seem to value the different financing options that were included in our experiment. Green initiatives by themselves seem to be unattractive to both consumers and plumbers. If the government wants to influence choices then price levers are needed.

For some water heater attributes, including warranty, price and running costs, our estimation results indicate plumbers tend to mimic the preferences of consumers. But this is not the case with capacity and whether the water heater is gas or electric. These differences could very well be a reflection of the ability of plumbers to exploit their superior knowledge regarding water heaters. A plausible explanation exists for why plumbers would want to shade their recommendations in

the case of the type of water heater. A possible explanation is given for why capacity is rated more highly by plumbers, but this explanation is more speculative.

Overall, the approach and resultant analysis has provided useful insights into the behaviour of consumers and their relationship with experts such as plumbers. We feel we have provided a potentially useful template for applications to other areas of modelling where there is interaction between agents involved in making choices.

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