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TRAFFIC RELATED NOISE AND AIR QUALITY VALUATIONS: EVIDENCE FROM STATED PREFERENCE RESIDENTIAL CHOICE MODELS

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Abstract
This paper reports on research which has estimated valuations of changes in traffic related noise levels and air quality and which contributes to the body of knowledge and to methodology in this area. There are several novel aspects of this research. Firstly, there have been relatively few stated preference studies of the monetary valuations of traffic related noise and air quality. A feature of this analysis is the examination of variations in values according to the size and sign of the environmental change, the currently experienced level of the attribute and various socio-economic factors. Secondly, the important issue of presentation is addressed, with two different methods used in the valuation of air quality and links made between valuations and physical measures. Thirdly, the results from stated preference and the contingent valuation method are compared. Finally, we bring together evidence from other studies and compare them with the findings obtained here.

Keywords: stated preference, traffic noise, air quality, valuation, appraisal

1. INTRODUCTION

In recent years, there has been increasing interest in the use of stated preference (SP) methods to value environmental externalities from traffic (Nelson, 1998; Sælinsminde, 1999; Daniels and Hensher 2000; Hunt, 2001; Ortúzar and Rodríguez, 2002; Arsenio et al., 2002; Eliasson et al. 2002; Galilea and Ortúzar, forthcoming). In part this stems from a relatively recent appreciation of the contribution that this long available technique can make in the area of environmental valuation, but a further stimulus has been worsening environmental problems and a corresponding increased concern to evaluate the welfare implications.

This paper reports on research which has estimated valuations of changes in traffic related noise levels and air quality and which contributes to the body of knowledge and to methodology in this area. There are several novel aspects of this research. Firstly, there have been relatively few SP studies of the monetary valuations of traffic related noise and air quality. A feature of this analysis is the examination of variations in values according to the size and sign of the environmental change, the currently experienced level of the attribute and various socio-economic factors. Secondly, the important issue of presentation is addressed, with two different methods used in the valuation of air quality and links made between valuations and physical measures. Thirdly, the results from SP and the competing contingent valuation method (CVM) are compared. Finally, we bring together evidence from other studies and compare them with the findings obtained here.

2. BACKGROUND

A wide range of methods have been used to derive environmental values (Pearce and Markandya, 1989; Garrod and Willis, 1999). Hedonic pricing has been widely used to value noise from the impact on willingness to pay in the surrogate housing market. A large number of studies have used this method to assess the impacts of noise from transport (Schipper et al.,1998; Nelson, 1980) and to a lesser extent air pollution (Smith and Huang,1995). The method has been questioned on several counts, including imperfect knowledge of the attributes of each location and other market imperfections, correlation of explanatory variables, and the difficulty of measuring intangible influences and individuals' perceptions of them.

Alternative cost approaches seek to value implied expenditure or costs incurred. One method is to examine the costs of averting behaviour (Nero and Black, 2000), whether incurred by the individual (eg, double glazing, behavioural change) or other bodies (eg, noise barriers, noise regulations). A related approach, used in the context of air pollution, is consequential cost (Bickel et al., 1997) which examines the health and other damage costs. However, a value of life has to be determined external to the approach, and values of an acute death brought forward exhibit a large range making their application problematic. The limitations of these methods led researchers in the field of environmental economics to investigate the potential of more disaggregate survey based approaches centred upon individual willingness to pay.

The contingent valuation method (CVM) was the first of the hypothetical questioning techniques used to value environmental factors and since the 1970's it has been extensively applied to a wide range of environmental attributes (Mitchell and Carson, 1989; Bateman and Willis, 1999). In the context of transport externalities, examples include studies of: noise (Pommerehne, 1988; Soguel, 1994; Navrud 2000; Barreiro et al., 2000); air pollution (Carlsson and Johansson-Stenman, 2000; Bateman et al. 2002); the health impacts of air pollution (Navrud, 2001) and nuisance and intrusion from traffic (Walker, 1997; Bateman et al., 2000).

SP has its background in mathematical psychology in the 1960's and has been extensively used in a wide range of contexts (Wittink and Cattin, 1989; Louviere et al., 2000) but it is only recently and on few occasions that it has been used for the valuation of environmental attributes. In the specific context of the environmental impacts of transport, SP studies have been conducted of road traffic noise valuations (Arsenio et al., 2002, Garrod et al., 2002; Galilea and Ortúzar, Forthcoming), air traffic noise valuations (Baarsma, 2001), a range of impacts including traffic noise (Daniels and Hensher, 2000), the intrusion effects of transport (Eliasson et al., 2002), air quality valuations (Nelson, 1998; Ortúzar and Rodríguez, 2002) and both noise and air quality valuations (Sælinsminde, 1999; Hunt, 2001).

3. SURVEY METHODS

Two related survey methods have been used. The main objective was to apply the SP method given its suitability, a number of attractions compared to established methods and the few examples of SP application in this area. The more conventional CVM was also used for comparison purposes.

3.1 Why Stated Preference?

SP experiments offer the decision maker hypothetical scenarios and the preferences expressed indicate the relative importance of the attributes that characterise the scenarios. The most common form of evaluation is choice, although ranking exercises are sometimes employed, and typically just two alternatives are compared with between nine and twelve comparisons involved and usually between four and six attributes characterising each alternative. There has been a gradual appreciation of the advantages of SP methods and a movement towards their application in environmental valuation (Department for Transport, 2002).

The CVM usually takes one of two forms, depending on the response scale used. Open-ended CVM asks directly for a maximum willingness to pay whilst what is termed referendum or iterative bidding CVM asks the respondent whether they would be willing to pay a series of different amounts. The main shortcoming of the open-ended method is that the respondent finds it more difficult to state the maximum amount that would be paid. However, the iterative bidding procedure requires more questions and there is convincing evidence that starting point bias is a problem whereby the valuation obtained depends on the initial price in the iterative bidding process (Mitchell and Carson, 1989).

Discussion of the merits of CVM and SP often view them as widely different approaches to valuation. It is fair to say that their spheres of application have been quite distinct and that their differences have tended to be exaggerated. CVM can be seen as a special case of SP where there are only two attributes, one of which is typically money and the other is a single change in environmental conditions (Boxall et al, 1996). In most cases, the main differences between SP and CVM can be summarised as follows:

- SP examines several attributes simultaneously whilst CVM tends to look at attributes in isolation. SP therefore has an important advantage since the purpose of the study will be less obvious and a lesser incentive to strategic bias can be expected (Bohm, 1971; Wardman and Whelan, 2001). Zero willingness to pay 'protest' responses are common in CVM whilst values based on willingness to accept compensation tend to be far higher than willingness to pay values (Mitchell and Carson, 1989; Horowitz and McConnell, 2002). In addition, SP can examine interaction effects and package effects and is also more useful when the scenario under consideration is multi-dimensional.

- SP examines different levels of attributes, whereas CVM generally does not, and hence the SP approach supports detailed and controlled analysis of the functional relationship between the valuation of an attribute and its level as well as sign and size effects.

- SP tends to ask for the order of preference whilst CVM tends to ask for the strength of preference. Although CVM is less tedious where it involves a single question, and the information content of the single response is in principle high, SP responses can be expected to be more reliable for two key reasons. Firstly, it is simpler to indicate the order than the strength of preference. Secondly, individuals routinely make choices but are rarely required to establish the strength of preference in real life decision making.

- SP is a behavioural model from which values are implied, whereas CVM is a direct valuation model. Whilst SP is more suited to forecasting applications, CVM can avoid the problems involved in the development of choice models. For example, CVM obtains values for each individual, thereby avoiding problems of preference and functional form heterogeneity in SP models which typically pool data across individuals, and assumptions about how individuals make decisions are not needed. In general, CVM data is easier to analyse.

- CVM is relatively straightforward to design. In contrast, there is no unique SP experimental design, even in a tightly defined choice context, and the SP design procedure is somewhat more complicated and surrounded by greater uncertainty.

Although SP does not dominate CVM from a theoretical perspective, we regard the former to be, on balance, preferable.

3.2 SP Experimental Design

The SP exercise was set in the context of choosing between two houses (A and B) which differed in terms of travel accessibility, environmental quality and local council tax. The latter instrument is appropriate given that the SP exercise is property based. The environmental variables were traffic related noise and air quality whilst accessibility covered travel times around Edinburgh by car and bus. Other attributes were specified to be the same for the two alternatives. Table 1 presents the levels associated with accessibility and environmental quality.

An important issue to address when using survey techniques to value environmental attributes is that of presentation. Possible approaches are categorical scales, proportionate changes, pictures and verbal descriptions, simulation and locational proxies. A novel feature of this study was that air quality was presented using the two most common methods: the proportionate change method, which is denoted AirP, and the location method, which is denoted AirL. The latter offered respondents five locations with poor air quality and five with good air quality and one was selected from each which, alongside the air quality currently prevailing at their home, was presented to them in the SP exercise. A number of locations were offered so that respondents could select those which they were most familiar with.

TABLE 1 ABOUT HERE

In principle, the location method could also have been used to present different noise levels. However, we did not proceed with this on the grounds that respondents might well be familiar with noise levels at different locations but these would generally be outdoor noise levels. Subsequent research has extended the location means of presentation to the valuation of noise levels (Arsenio et al., 2002).

A feature of the SP design is that an attribute difference can be composed as alternative A worse than the current situation with alternative B held constant, alternative B better than the current situation with alternative A held constant or simultaneous deterioration in alternative A and improvement in alternative B. This allows testing of whether gains and losses are valued the same or not.

We felt it important to restrict the percentage changes to those to which individuals are expected to most easily relate. The 100% improvement was represented to respondents as ‘twice as good as now’, being the opposite of the ‘twice as bad as now’ which was used to represent a 100% deterioration. We subsequently realised that this had not been an appropriate representation and that, with hindsight, it is not sensible to specify noise and air pollution to be completely removed. Inspection of respondents’ ratings of twice as good indicated that there was wide variation in its interpretation and it had certainly not been interpreted as intended. Given these concerns, we therefore removed from analysis those observations where the 100% improvement level occurred.

Where a given difference between the two alternatives could be composed in different ways, one form of difference was randomly selected by the computer program used to administer the SP exercise. An exception was that improvements to air quality and noise were not permitted where the respondent reported their current level to be good or very good.

A fractional factorial design was used to combine the attribute differences. The monetary variable, which took the form of a weekly council tax payment, was originally set at four levels of difference between the two alternatives. However, we departed from orthogonality in order to obtain a more satisfactory range of trade-offs against cost. In part this was driven by our uncertainty as to the likely monetary valuations that households might possess and in part because more variation in cost would lead to a more precise cost coefficient estimate. As a result, seven cost differences were presented ranging from 25 pence per week through to £10. The cost difference was, in a random fashion, presented either as an increase on the reported council tax level or a reduction in it.

Prior to implementation, the experimental design was subjected to simulation testing to ensure its adequacy. This involved the creation of synthetic choice data using known utility functions, parameters and random error which mimics how households could respond. The coefficients obtained from calibration of choice models to data sets based around the anticipated sample size can be assessed in terms of how closely they correspond with the parameters used to create the choice data and how precisely they are estimated. It was this procedure that led us to increase the range of the cost differences so that more precisely estimated cost coefficients would be obtained. The simulation tests also confirmed that the design would allow size and sign effects to be reliably estimated.

The experimental design involved 16 comparisons of alternatives A and B. The pilot survey examined whether it was preferable to offer a random subset of 12 comparisons but it was concluded that respondents had little difficulty with the full set of comparisons. The respondent was asked to answer on behalf of the household as a whole so that the valuations represented what a household would be prepared to pay for environmental improvements.

3.3 CVM and Other Survey Issues

Following on from the SP exercise, the CVM was used to elicit direct willingness to pay values for separate 50% improvements to noise levels and air quality. Those who offered a zero willingness to pay were asked why this was so.

Information was collected about a range of variables to facilitate analysis and interpretation of the valuation data and to set respondents' preferences in a broader context. Respondents provided a rating of noise levels currently experienced around the home on a scale of very noisy, noisy, quite noisy, fairly quiet, quiet and very quiet whilst air quality was rated as very good, good, fair, poor or very poor. Information was also collected on the most important sources of noise and, where appropriate, of poor air quality whilst attitudes towards improvements in air quality and noise levels were set against other possible quality of life improvements. The latter covered: improved road safety; reductions in local crime; more local play facilities; better quality of health care; improved appearance of the neighbourhood; more local shops; improved educational quality and low council tax. Questions were also asked about: whether alleviating measures had been taken to reduce the impact of traffic noise; household size, structure and income; employment status, gender, and age group for each household member; and length of residency.

4. FINDINGS

Computer assisted interviews were completed with 403 individuals in their homes between September and November 1996 in Edinburgh. Of these, five were removed since the residence was a business.

4.1 Current Conditions and Priorities

Table 2 summarises respondents' perceptions of current levels of noise and air quality. The sample of 398 who answered these questions represents a reasonable spread of different current experiences.

Very few respondents regarded the environment around their home to be quiet or very quiet. Whilst over half regarded the situation to be quite noisy or fairly quiet, surprisingly around a fifth of respondents felt the situation to be very noisy and a further fifth stated it to be noisy. Road traffic was cited as the principal source of noise by 87%, the second largest source by 7% and the third largest source by the remainder. Around a quarter of the sample felt that the second most important cause of noise was planes, with the same proportion regarding it to be people outside and 18% regarding it to be children playing outside. Around 20% of households had installed double glazing with the aim of reducing noise and a small proportion had installed or altered hedges and fences to reduce noise impacts.

TABLE 2 ABOUT HERE

Only small proportions felt air quality to be either very good or very poor, with the largest proportion of around a third regarding air quality to be fair. 88% cited road traffic as the main cause of poor air quality, with 7% citing industry as the main source. The second most important cause of poor air quality was deemed to be trains by 32% of the sample, other sources by 32% and industry by 21%, with road traffic forming a further 8%.

Table 3 summarises preferences towards reduced noise levels and improved air quality in the broader context of a range of measures that could improve quality of life. The most important priorities fall into three categories. Firstly, road safety is by far the most frequently mentioned first choice. This is followed by improved air quality, lower council tax, reduced noise levels and reduced local crime which have very similar priorities. The remaining improvements were regarded as the most important priorities by small proportions of the sample. In terms of overall mentions, improved road safety is the most important priority but noise levels and air quality also feature highly alongside reductions in council taxes. Whilst the responses only provide a broad indication of relative importance, it seems reasonable to conclude that air quality and traffic noise are quite serious concerns for most households.

TABLE 3 ABOUT HERE

4.2 Stated Preference Results

Of the possible 6368 SP observations from 398 completed interviews, 4175 (66%) were analysed. There were 179 cases where the respondent had not expressed a preference between the two alternatives and 2014 observations where the 100% improvement for either noise or air quality occurred and which were removed for the reasons set out in section 3.2.

The SP choice data has been analysed using a binary choice logit model. In order to allow for what is termed the repeat observations problem, whereby correlations amongst the errors within individuals' multiple answers lead to the standard errors associated with the coefficients being too low, we have used a jack-knife procedure. This is a repeat sampling method (Cirillo et al., 2000) which provides revised standard errors of coefficient estimates but rarely has any appreciable impact on the coefficient estimates themselves. In all cases, the jack-knife procedure was specified to take 30 samples from the SP data set[1].

4.2.1 Model Specification

Ideally, the independent variable representing air quality in the choice model should be an objective measure rather than simply the percentage change offered or dummy variables denoting different locations. The locations in themselves mean little whilst a given percentage change will imply a different absolute change and hence a different value according to the base level to which it relates. More importantly, conversion to an objective measure is needed so that we can compare the results from the two different means by which air quality was presented whilst it also produces a wider range of air quality measures which will facilitate more detailed analysis of functional form issues.

[1] Trials indicated that the revised coefficient standard errors had settled down at 30 samples.

A novel feature of the study was an attempt to link environmental valuations with actual environmental conditions. There is no single representative measure of air pollution from traffic. Nitrogen Dioxide (NO_2) levels in the air in $\mu g/m^3$ was selected since it has adverse health impacts, making it one of the key pollutants in the UK government's air quality strategy (Department of the Environment, Transport and the Regions, 2000), and it is easy and cheap to measure. NO_2 measures were taken over a period of one week on some residential streets and at all the sites that were used in the presentation of different levels of air quality.

Matters are complicated because we do not have air quality measures for all residences. We therefore specify the following four air quality variables in our models, distinguishing between whether a measure (M) or no measure (NM) was available as well as means of presentation:

- $AirL_M$ denotes that the location method was used to present air quality and that a measure of air quality was available. The variable is therefore specified as NO_2 in $\mu g/m^3$.
- $AirP_M$ indicates that the proportionate method was used to present air quality and that an air quality measure was available. This variable also enters the model as NO_2 in $\mu g/m^3$.
- $AirL_{NM}$ denotes that the location method was used but that no measure of air quality was available for the residence. Dummy variables were therefore specified to represent the air quality at the better ($AirL_{NM\text{-}G}$) and worse ($AirL_{NM\text{-}L}$) locations relative to the residence. The sample is not large enough to further distinguish between the different locations.
- $AirP_{NM}$ denotes that the proportionate method was used but that no measure of air quality was available. The variable is therefore specified as a percentage change.

Of the SP responses obtained, 21% related to $AirL_M$, 21% to $AirP_M$, 28% to $AirL_{NM}$ and 30% to $AirP_{NM}$.

Noise is typically measured in dB(A) and a similar procedure to that adopted for air quality could have been followed. 18 hour noise measurements were taken at house facades for some residences but inspection of the data indicated that it would not provide a reliable account of the indoor noise levels and indeed the use that was made of it in analysis did not prove fruitful.

Some environmental studies have explored for the presence of what are termed sign, size and level effects (Bateman et al., 1997; Bateman et al., 2000; Arsenio et al., 2002; Horowitz and McConnell, 2002). The ***sign*** effect denotes an asymmetry between the valuations of gains or improvements in the level of an attribute and losses or deteriorations in the level of an attribute. A ***size*** effect is present where the unit value of a change in an attribute depends upon the size of the change. The ***level*** effect indicates that the sensitivity to a change in an attribute depends upon the level from which the attribute varies. There are a number of reasons why we might expect size, sign and level effects but it is essentially a matter for empirical testing.

There are two ways in which we can explore these effects depending upon whether the variable enters the utility function as a continuous or categorical term. We can treat cost, $AirL_M$ and $AirP_M$ as continuous variables (X). In this instance, we can specify the utility function as:

$$U = \alpha_1 d_G X^{\lambda} + \alpha_2 d_L X^{\lambda} + \beta_1 d_G (X - X_{base})^2 + \beta_2 d_L (X - X_{base})^2 \quad (2)$$

The terms d_G and d_L are dummy variables respectively denoting whether X is a gain on the current situation or a loss. The expressions for the marginal utility of X in the case of gains (MU_{XG}) and losses (MU_{XL}) are:

$$MU_{XG} = \frac{\partial U}{\partial X} = \alpha_1 \lambda X^{\lambda - 1} + 2\beta_1 (X - X_{base}) \quad (3)$$

$$MU_{XL} = \frac{\partial U}{\partial X} = \alpha_2 \lambda X^{\lambda - 1} + 2\beta_2 (X - X_{base}) \quad (4)$$

Comparison of these marginal utilities indicates the extent to which there is a ***sign*** effect. The parameter λ allows the sensitivity to changes in X to depend upon the ***level*** of X. If λ is greater (less) than one then households become more (less) sensitive to changes in X at higher levels of X. With regard to ***size*** effects, if β_1 is greater (less) than zero, and given that the marginal utility is negative and X is less than X_{base}, larger gains will lead to increases (reductions) in the absolute value of the marginal utility. If β_2 is greater (less) than zero, larger losses will lead to reductions (increases) in the absolute value of the marginal utility.

Where a measure of the current situation is unavailable or unreliable, as with noise and $AirP_{NM}$, it is a straightforward matter to specify dummy variables to represent the different categories which enter at the four levels of +100%, +50%, 0% and –50%. We could therefore specify the utility function as:

$$U = \gamma_1 d_{+50} + \gamma_2 d_{+100} + \gamma_3 d_{-50} \quad (5)$$

where, for example, d_{+100} is a dummy variable denoting whether the variable in question is specified as a 100% increase on the current situation. The arbitrarily omitted category against which the estimated coefficients are interpreted is the current situation. Comparison of γ_1 and γ_3 provides a test of ***sign*** effects whilst comparison of γ_1 and γ_2 indicates whether a ***size*** effect is present. By definition, we cannot here examine ***level*** effects.

The results of testing for size, sign and level effects are given in Model I of Table 4. Model II retains those effects that are justified by theoretical reasoning and empirical testing. This model is then enhanced by analysis of how the values of noise and air quality vary according to socio-economic characteristics and this is represented by Model III.

TABLE 4 ABOUT HERE

4.2.2 Level Effects

The effect of the attribute level on the sensitivity to changes in it is, for $AirL_M$, $AirP_M$ and cost, discerned by the λ parameter in equation 2. A search procedure was used across different values of λ in intervals of 0.1 to identify the best fitting model. The results were similar in indicating that the level of the variable did not materially affect the sensitivity to changes in it.

The λ providing the best fit for cost turned out to be 1.0. Whilst higher council taxes might lead to greater sensitivity to changes in cost, those paying higher council taxes tend to be wealthier and should therefore be less sensitive to cost. The λ coefficients for $AirL_M$ and $AirP_M$ that provided the best fit to the data were 0.9 and 1.2 respectively. Since these imply only slight variations in marginal utility with respect to the level of the variable, the default λ value of unity has been retained. In addition, we also estimated a simpler form of model where λ is constrained to be one but the α parameter is allowed to vary across a number of categories of the levels of $AirL_M$, $AirP_M$ and cost in order to allow the sensitivity to changes in these variables to depend upon their levels. In each case, various categorisations were examined but no clear relationships were apparent.

We can also allow the sensitivity to changes in $AirL_M$ and $AirP_M$ to depend upon perceived levels as represented by respondents' ratings of the current situation. However, these ratings are not purely an objective assessment of the physical environment but will, to some unknown extent, reflect the degree of annoyance with the experienced levels. Nonetheless, we were unable to obtain convincing and statistically significant relationships between the values of $AirL_M$ and $AirP_M$ and the ratings.

4.2.3 Size Effects

In order to examine whether the size of the change in a variable impacts on its marginal utility, it is necessary that the variable exhibits a range of changes of different sizes. For $AirL_M$, the size of the changes is bound by the worst and best sites and the residences tend to have broadly similar air quality. However, the absolute size of changes in air quality can be large when the proportionate method is used, as it can also be for cost. We first discuss size effects where equation 2 was used prior to discussing the use of equation 5.

The coefficients associated with the quadratic terms in equation 2 (β_1 and β_2) indicate whether there is a size effect. For $AirP_M$ and both gains and losses there is no statistical support for a size effect. This is also so for increases in cost but not for cost reductions where the coefficient is significant at the 5% level. The latter implies that the sensitivity to cost is less for larger reductions in council tax. Whilst this is consistent with both conventional diminishing marginal utility and with reference dependent preference theory (Tversky and Kahneman, 1991), for even a modest reduction in council tax of £4.25 per week the marginal utility would implausibly become zero. It may be that tax reductions are simply not believable and are given less weight in decision making. However, the result could also stem from the large correlation of 0.84 between the coefficient estimates for $Cost_G$ and $(Cost_G\text{-}Base)^2$, and a likelihood ratio test (χ^2=2.7) indicates that including this squared term does not provide a significant improvement in fit.

Turning to the use of equation 5 to explore size effects, it can be seen that the unit utility effect for a 50% deterioration in air quality ($AirP_{NM+50}$) of -0.014 is not greatly different to the unit effect for a 100% deterioration ($AirP_{NM+100}$) of -0.011. Similarly, a 50% increase in noise ($Noise_{+50}$) has a unit utility effect of –0.012 compared to the unit effect for a 100% increase ($Noise_{+100}$) of -0.010.

Whilst there is some support for a diminishing marginal effect as the size of a change increases, and this is in line with reference dependent preference theory for both gains and losses and with conventional economic theory for gains, it is not strong. Subsequent models therefore do not make allowance for size effects.

4.2.4 Sign Effects

Once the size effects for cost were removed, the coefficients for $Cost_G$ and $Cost_L$ were –0.0011 and –0.0013 respectively which, according to a t test (t=0.80), were far from significantly different. There is no support for a sign effect for cost and hence a single generic cost coefficient is used.

For the location method, the coefficients for gains ($AirL_{M\text{-}G}$) and losses ($AirL_{M\text{-}L}$) were marginally insignificant. As a result, they are not significantly different from each other and a single term is therefore specified ($AirL_M$). The coefficient for the latter is significant at the 5% level. When the insignificant size effects were removed from $AirP_{M\text{-}L}$ and $AirP_{M\text{-}G}$, a sign effect is apparent since losses in air quality were found to have a significant influence upon choice but the gains had a far from significant effect.

The $AirL_{NM}$ coefficients for the worse locations ($AirL_{NM\text{-}L}$) and the better locations ($AirL_{NM\text{-}G}$) cannot directly give evidence on the sign effect since the specification of these terms as dummy variables results from the absence of an air quality measure for the residence. However, they can shed light on the issue if we take the air quality measures at the residences where we have measures as typical of those residences where we have no measures. The average level of NO_2 in $\mu g/m^3$ is 28. This compares with the mean levels of 17 and 41 for the better and worse locations. The $AirL_{NM\text{-}L}$ coefficient therefore implies a utility change per unit of NO_2 of –0.011 whereas it is 0.010 for $AirL_{NM\text{-}G}$. Thus $AirL_{NM\text{-}L}$ and $AirL_{NM\text{-}G}$ indicate that there is no difference between gains and losses.

The remaining sign effects are obtained from the dummy variables specified for noise and $AirP_{NM}$ as set out equation 5. With regard to air quality, comparison of $AirP_{NM+50}$ and $AirP_{NM\text{-}50}$ indicates that losses are valued more highly than gains but the difference is only slight and, after accounting for the sign, it is not significant (t=0.7). Given the absence of any convincing size or sign effects, a single term ($AirP_{NM}$) was specified denoting the percentage change in air quality presented.

Comparison of $Noise_{+50}$ and $Noise_{-50}$ indicates that increases in noise are valued much more highly than reductions. A single term relating to the proportionate increases in noise ($Noise_L$) was specified, since no size effect was apparent, and the noise reduction was specified in terms of the proportionate change ($Noise_G$). Although the coefficients associated with these two terms were not significantly different (t=1.3), they were retained as separate effects on the grounds that they are quite dissimilar and because of the large and significant (t=2.3) difference at the same proportionate change between $Noise_{+50}$ and $Noise_{-50}$. However, subsequent analysis indicated that, for most of the population, gains and losses in noise would be valued the same.

4.2.5 Socio-Economic and Taste Variation Effects

Model III is an enhancement of model II with relevant socio-economic effects. The approach adopted combines theoretical reasoning and statistical testing and involves the specification of dummy variable terms to determine whether a particular household category has a different sensitivity to air quality, noise or cost. If, for example, it is hypothesised that the sensitivity to noise depends upon whether noise alleviation measures, such as double-glazing, have been taken, whether there are children in the household and whether the household contains one adult, two adults or more than two adults, the utility function with respect to noise would be specified as:

$$U = \beta Noise + \gamma_1 d_1 Noise + \gamma_2 d_2 Noise + \gamma_3 d_3 Noise + \gamma_4 d_4 Noise \quad (6)$$

d_1, d_2, d_3 and d_4 are dummy variables denoting respectively whether alleviating measures have been taken, whether there are children in the household, whether there are two adults in the household and whether there are more than two adults in the household. The β coefficient should be negative and applies to all households. If there are n categories of a socio-economic variable, n-1 dummy variables are specified and their coefficients indicate how a particular category deviates from the arbitrary base category. Thus we would expect, given that noise is a bad, that γ_2 is negative on the grounds that households with children would, other things equal, be more concerned about noise levels. The marginal utility of noise for a household with no children, one adult and where noise alleviation measures have not been taken is simply β whereas it is $\beta+\gamma_1+\gamma_3$ for households with no children, two adults and where noise alleviation measures have been implemented.

We might expect the $AirP_{NM}$, $Noise_L$ and $Noise_G$ coefficients to vary according to the current situation, since these are all specified as proportionate changes and a given proportionate change should be more highly valued when it applies to situations which are noisier or where the air quality is poorer. However, we were unable to discern a monotonic relationship between the valuations and the various categories of current noise levels and air quality.

The valuation of air quality and noise might be expected to vary with the length of residency since residents become more accustomed to noise and poor air quality over time. However, various forms of segmentation by length of residency failed to detect a significant effect.

Those who have undertaken noise alleviation measures, such as the installation of double glazing, can be expected to have higher values of noise. This could be because they live in noisier areas, whereupon a given proportionate change will be more highly valued, or simply because their greater sensitivity to noise causes them to undertake alleviation measures. The incremental coefficient (Noise-Allev) is the same for gains and losses and, although it was not quite significant at the usual 5% level, it does indicate a quite large impact on noise valuations.

Segmentations by household size and structure proved to be the most fruitful. As a result of segmenting according to whether there were two or more adults in the household, the noise reduction coefficient ($Noise_G$) became far from significant. As expected, households with more than one adult had larger values of noise. For a loss, the noise coefficient for households with more than one adult is –0.0081, somewhat higher than the –0.0048 for single adult households. A gain in noise has no estimated value for single adult households, possibly because they live in quieter areas. However, for households with more than one adult, the noise coefficient for a gain is –0.0071 which is little different to the value for a loss. Thus for the vast majority of households, gains and losses effectively have the same value.

If there are children in the household, the valuation of noise is higher, with the same incremental effect for gains and losses. It is not surprising that these households have higher valuations, which is around 50% higher for households containing more than one adult. Variations in values due to the precise number of children were not discerned.

Incremental effects for air valuations were estimated jointly for $AirL_M$, $AirP_{M-L}$ and $AirP_{NM}$ since these coefficients have broadly the same magnitude. Households which contain children value air quality around twice as much as households without children. This is by far the strongest incremental effect detected, presumably due to the health concerns raised by poor air quality. Various segmentations were conducted by age group, gender and employment status, in part proxying for time spent at home, but no remotely significant effects were apparent.

Income is expected to be the principal cause of variations in the sensitivity to cost. Those with higher incomes are expected to be less sensitive to cost and thus to have higher monetary values. Household income data was collected in bands of £10,000 with a maximum level of £70,000 or over. Six income categories were specified, including one representing cases where information on household income had not been supplied. A strong monotonic relationship of the expected form was apparent between the coefficients and the level of household income they represented. It was therefore decided to analyse income effects in more detail by specifying an actual income level based on the mid-point of the income category[2]. This allows the examination of whether income per household member provides a better account of households' willingness to pay. The cost variable was entered into the utility function as:

$$U = \alpha \frac{C}{Y^{\lambda}} \tag{7}$$

The marginal utility of money will fall and monetary values will increase as income increases, and λ denotes the elasticity of a monetary value with respect to income. It emerged that household income provided a somewhat better fit than household income per person. The search process identified the best fitting model to have an income elasticity of 0.7, and the cost coefficient is more precisely estimated than the comparable model which does not contain the income effect.

4.2.6 Internal Assessment

There are a number of encouraging features of the findings. Whilst the ρ^2 goodness of fit measure is low, it is in line with values typically achieved in more routine SP models of travel behaviour despite the choice exercise here being one which will be less familiar and involve more difficult choices. The coefficients for the environmental attributes and cost are generally significant and are correct sign, and we have uncovered a number of variations in valuations according to households' socio-economic characteristics which are consistent with expectations. As far as the absolute money values are concerned, these vary with a number of factors but they generally appear reasonable.

Given the linear-additive utility function of Model II, a money value is obtained as the ratio of the coefficient of the relevant attribute and the cost coefficient. In Model III, the denominator term is instead, from equation 7, equal to α/Y^{λ}. The value of air quality obtained by Model II using the location method of presentation ($AirL_M$) is 12.2 pence per week for a unit change in NO_2. Where there was no measurement of the air quality for the residence, the difference between the best ($AirL_{NM-G}$) and worst ($AirL_{NM-L}$) scenarios is valued at 310.7 pence per week. Given mean levels of air quality at the best and worst sites used of 17 and 41, the value per unit of change in NO_2 is 12.9 pence per week

[2] The average income level was used for those who did not supply their income level. Removal instead of those who did not supply income data did not materially alter the results

which is very similar to the value based on $AirL_M$. Contrast these values with the valuation of air quality based on the proportionate change method where actual air quality measures were available ($AirP_M$). In this latter case, only the value for deteriorations in air quality was significant and this implies a value of 17.6 pence per week for a unit change in NO_2. Note, however, that when no measure of air quality is available ($AirP_{NM}$), gains were valued the same as losses.

The difference between the mean air quality levels at the worst and best sites used would be valued at £2.93 per week per household using $AirL_M$ and it is £3.11 using $AirL_{NM-L}$ and $AirL_{NM-G}$ together. In contrast, it is £4.22 per week using $AirP_{M-L}$ whilst, taking the mean level of NO_2 where a measure is available of 28, the mean of the best sites is 39% better and the mean of the worse sites is 46% worse and these are valued at £4.37 and £5.16 respectively using $AirP_{NM}$.

Given the appreciable difference in air quality between the worst and best sites, these monetary values seem reasonable even though they cover quite a large range. This large range is, however, the result of differences in values according to the means of presentation and is a cause for concern, particularly regarding the proportionate method given that it is less realistic and more difficult than the location method.

Model II implies that, on average, households are prepared to pay 9.3 pence per week to avoid a 1% increase in noise and 6.3 pence per week to achieve a 1% reduction. A 50% variation in noise is therefore valued between £3.15 and £4.65 per week per household. These figures seem reasonable.

Table 5 provides values of air quality and noise in pence per week for a range of household characteristics for the average income level of £20618 (Inc2) and for income levels half (Inc1) and double (Inc3) that amount. Its purpose is to illustrate the relative importance of air quality and noise as well as variations in values across households. The values relate to a 1% change in air quality and to 1% improvements and deteriorations in noise levels. The values of air quality are most readily compared with the noise values given the same method of presentation ($AirP_{NM}$). Although the absolute values corresponding to any percentage change depend upon the conditions to which the change applies, there is clear evidence that for most households air quality is valued somewhat more highly than noise with the largest differences amongst households with children. The similarity of gains and losses for households with two or more adults is apparent whilst the strong variations according to income are also evident.

TABLE 5 ABOUT HERE

4.2.7 CVM Results

Two questions were asked concerning willingness to pay additional council tax in return for 50% reductions in noise levels and 50% improvements in air quality. Given that zero responses to willingness to pay questions are common, the interview probed the reasons behind them. Those who offered a zero response were asked whether this was because: the improvements were not worth paying for or they were not bothered about them; noise and air quality could not be improved through increases in council tax; they were not prepared to pay more council tax; or some other reason.

Table 6 indicates households' responses. It can be seen that only a minority of respondents expressed an actual willingness to pay, whilst around a fifth stated that they were not bothered about improvements. By far the main reason for a zero response was an aversion to paying more council tax. The other category largely represents protest responses. 81% of respondents had a positive value for both air and noise or a reported zero valuation of both attributes.

TABLE 6 HERE

The estimated money valuations will clearly depend on whether those with zero willingness to pay are included or not. The differences between the valuations based on all respondents and just those with a positive willingness to pay can be seen in Table 7. The issue therefore becomes one of deciding the extent to which those with zero responses are excluded. Our view is that those who stated that noise levels or air quality could not be improved through a process of raising council tax should be removed from the calculations since they have supplied a zero valuation because we have not offered an appropriate surrogate market. Those who are not bothered about improvements should be retained since their zero valuation is valid. The issue is less straightforward for those who would not be prepared to pay increased council tax, which is unfortunate given the size of this group. It is certainly the case that those with true zero valuations will not be prepared to pay additional council tax even if it secured improvements in noise and air quality levels, but such respondents could have stated that they were not bothered about improvements. It is likely that there may be an element of protest here. Nonetheless, a useful feature of these supplementary questions relating to CVM is that protest responses can be identified.

TABLE 7 ABOUT HERE

Table 8 contains weekly household valuations and associated 95% confidence intervals for 50% improvements of noise and air quality obtained from both the CVM and SP. The first set of CVM results omits just those who stated that noise levels and air quality could not be improved in this way whilst the second set additionally removes those who are not prepared to pay more council tax and the other category. The SP values are taken from Model II of Table 4, with the same means of presentation used for air quality ($AirP_{NM}$). The CVM values for the whole sample are considerably lower than the SP values. Even after making use of evidence relating to possible biased responses, the CVM values are still lower, appreciably so for air quality. We take this as symptomatic of greater strategic bias and protest response in CVM data.

TABLE 8 ABOUT HERE

Finally, we developed regression models to explain variations in willingness to pay across households. The results are presented in Table 9 for all the responses except those who stated that noise or air quality could not be improved in this way (Model I) and for all the non zero values (Model II). For both the noise and the air quality models, only three independent variables were found to have a statistically significant influence on willingness to pay. These were annual household income (*INC*), the number of people in the household (*NHH*) and whether the current noise or air quality conditions were poor or very poor (*POOR*).

As expected, households are prepared to pay more for a proportionate improvement in noise or air quality when this is applied to current conditions which are poor or very poor. Income and household size are expected to be amongst the principal influences upon willingness to pay and they have the expected positive effect. Attempts were made using non-linear least squares regression to determine whether the effect of income on willingness to pay was proportional or not but reliable estimates could not be obtained. Whilst it is encouraging that each of the independent variables have the expected sign, it is disappointing that only a very small proportion of the variation in willingness to pay can be explained and the responses apparently contain significant random error. In addition, the correlation between air and noise valuations was 0.87, increasing to 0.95 when the zero responses were removed. Even though rounding error will have contributed to these large correlations, they do raise concerns about the quality of the responses supplied.

TABLE 9 ABOUT HERE

5. Comparisons with Other Studies

Our results can be compared with the findings of other studies along a number of different dimensions. These are: means of presentation; size, sign and level effects; the values obtained from SP and CVM; variations in values; and the overall values obtained. In each case, we summarise briefly the results obtained here, compare them with studies of traffic related environmental values and, where appropriate, refer briefly to the results of valuations studies in other areas.

5.2.1 Means of Presentation

This study has used both the location and proportionate change methods to present variations in air quality to individuals. With the exception of the zero valuation for improvements when an air quality measure is available, the proportionate change method yields appreciably higher values. This difference, and the implausible zero valuation for improvements, is a cause for concern. Given this difference, our preference is for the location method on the grounds that individuals can be expected to relate more readily to air quality variations between familiar locations than to proportionate changes.

5.2.2 Size, sign and level effects

Taking our results as a whole, and for analysis of the utility effects of variations in air quality, noise levels and cost, we have not uncovered any convincing evidence to support the existence of size, sign, or level effects.

Results relating to size, sign and level effects from other studies of transport externalities are mixed. In SP analysis of noise valuations, Arsenio et al. (2002) found a sign effect, that larger gains are valued less per unit but not that larger losses had different unit values, and some evidence for level effects. Nonetheless, most of the effects were relatively small, particularly the sign effects, and some level effects were confounded with self-selectivity stemming from those with higher valuations selecting quieter home locations. Similarly, Eliasson et al. (2002) found that intrusion values were up to 70% lower for people who had chosen to live near roads and railways. In contrast, level effects were apparent in Pommerehne (1988) and Vainio (2001) whereby households with lower levels of noise, due to insulation or triple glazing, had lower willingness to pay for noise reductions.

Hunt (2001) explored the impact of the scale of the change for both air pollution and noise. For air pollution, the three levels were bad one day per year, bad one day per month and bad one day per week. The coefficients were –0.2446, -0.5092 and –0.9796 respectively, in each case approximately doubling as the level increased. The reduction in the unit value seems implausible, and there may have been a ‘halo’ effect apparent whereby some respondents infer that if air quality is bad one day per year then it will be worse than currently the remainder of the time. A categorical scale was used for noise and the levels and utility weights were no noise (0), occasionally just noticeable noise (-0.1694), constant faint hum (-0.7165), sometimes disturbing (-0.5348) and frequently disturbing (-1.3500). Although the results are open to differing interpretations, they do not point to strong non-linearities.

Bateman et al. (2000) examined four welfare measures using CVM in the context of the disamenity effects of roads and traffic. These four welfare measures covered willingness to pay and to accept compensation and increases and losses in consumption of the externality. Whilst the usual differences between willingness to pay and willingness to accept were apparent, there were no significant differences between the valuations of gains and losses in consumption. It was concluded that, “…. the survey provided no serious evidence of reference dependent preferences”.

In summary, the evidence relating to size, sign and level effects in the SP based valuation of transport related externalities is far from convincing. This does contrast with a wealth of evidence in environmental valuation in general (Mitchell and Carson, 1989; Sugden, 1999; Horowitz and McConnell, 2002), particularly relating to sign effects where the empirical findings largely concur with the assertion of Tversky and Kahneman (1991, p1047) that, “The basic intuition concerning loss aversion is that losses loom larger than corresponding gains”.

There are, however, several observations that can be made. Firstly, environmental valuation has been dominated by CVM, and it may be that this technique is more susceptible to the biases that lead to, in particular, sign effects. There is little SP based evidence on size, sign or level effects in this area. Secondly, there is some, albeit weak, evidence that the sign effects in our results are more apparent where the proportionate change method rather than the location method has been used. This may be because the former method places more emphasis on changes and thereby induces sign effects in what is an artificial setting[3]. Thirdly, recent work (Bateman et al., 2000) indicates that the loss aversion is more of an issue for cost than for other aspects of utility. Fourthly, most of the work has focussed upon sign effects, with much less evidence relating to size and level effects. Finally, there may be under-reporting of empirical studies which 'failed' to detect sign, size or level effects

5.2.3 SP and CVM

We found open-ended CVM values to be lower than SP values for both air quality and noise. This was so even when protest zero responses were removed from the CVM data. Little of the variation in the CVM values across individuals could be explained, with only two socio-economic variables having significant yet weak influences. These findings confirm other research in this and related areas.

Arsenio (2002) also found values of noise from open-ended CVM to be lower than those obtained from a corresponding SP model. In addition, a greater number of significant influences from socio-economic factors were discerned in the SP model than CVM models and the explanatory power of the latter, as in this study, were very poor (R^2<0.1).

In cases where actual markets exist, assessment of the findings obtained from hypothetical questionning against actual behaviour is both possible and desirable. There is now a large body of such evidence in transport markets (Louviere et al., 2000; Wardman, 1988, 2001a; Wardman and Whelan, 2001) and this indicates that the performance of SP varies, with variations in incentives to strategic and protest responses seemingly a contributory factor. In the context of traffic related environmental impacts only surrogate markets exist, but nonetheless comparing values based on hypothetical questions with those obtained using hedonic pricing (HP) has obvious attractions. Pommerehne (1988) found that HP values exceeded CVM values of traffic noise by around 8%, although for aircraft noise the CVM values exceeded the HP values by 44%. Vainio (2001) found HP noise values to be around three time higher than CVM values and a very similar result was obtained by Brookshire et al. (1982) in the case of air quality. On the other hand, Eliasson et al. (2002) estimated SP intrusion values to be around twice as high as HP values.

Taking this evidence as a whole, the findings do seem to point to CVM providing lower values than SP in the area of traffic related externalities. This is consistent with evidence in the broader area of environmental valuation where there have been many more studies that have compared different methods (Bishop and Heberlein, 1979; Brookshire et al., 1982; Boxall et al. 1996; Carson et al., 1996; Foster et al., 1997; Adamowicz et al., 1994, 1997, 1998, Hanley et al., 1998a, 1998b, 2002). As Hanley et al. (2001) point out, the evidence is clear that the values obtained from and the intended payments of CVM are generally less than the values and payments of actual behaviour. On the other hand, the findings of SP models have generally compared favourably with equivalent RP results (Adamowicz et al., 1994, 1997; Boxall et al., 1996; Hanley et al., 2002). Whilst it is therefore surprising that where SP and CVM have been compared (Boxall et al., 1996; Adamowicz et al. 1998; Hanley et al., 1998a, 1998b) the SP values are not always greater, it is noticeable that the iterative bidding form of CVM was used where the CVM values were higher and this tends to give higher values than the open ended variant (Bateman et al., 1995).

5.2.4 Variations in Valuations

We have found household values of noise and air quality to vary with the level of household income and whether there are children in the household whilst noise valuations additionally vary with the number of adults and whether alleviation measures have been taken.

In the general area of environmental valuation, most of the empirical evidence suggests that the income elasticity is less than one (Pearce, 1980; Kristrom and Riera, 1996**;** Hökby and Söderqvist 2001). In the area of travel choice analysis, a significant amount of research indicates a cross-sectional

[3] Decision science posits that gains and losses rather than final states are the true carriers of value, in which case SP or CVM designs based on changes to the current situation would not induce artificial sign effects but would instead simply be doing part of the conversion task that the respondent would otherwise have to perform.

income elasticity of around 0.5 (Gunn, 2001; Wardman, 2001b). In the specific context of air quality and noise valuations, Carlsson and Johansson-Stenman (2000) found an income elasticity of 0.4 for air quality improvements whilst income elasticities for the willingness to pay for noise reductions have been estimated to be 0.9 by Pommerehne (1988), and 0.5 by Arsenio et al. (2002). The evidence would suggest that the cross-sectional income elasticity is less than one. Most studies identify some form of income effect, although income elasticities are not always estimated or reported.

The income elasticity here estimated to the SP data was 0.7. This is both plausible and consistent with a large amount of evidence for the valuation of environmental attributes in general and noise and air quality values in particular.

Although we have not discerned any of the expected effect from length of residency on noise and air quality valuations, we are only aware of one study (Arsenio et al., 2002) which has. We found that those who had undertaken noise alleviation had higher values, which is presumably a self selectivity effect similar to that apparent in Arsenio et al. (2002) and Eliasson et al. (2002) whereby those with higher values tend to choose less noisy home locations. However, Vainio (2001) and Pommerehne (1988) both find that the installation of insulation depresses the willingness to pay for further noise reductions.

Although there will be a tendency for larger households to have larger valuations simply because they have higher incomes, we would also expect a household with a given income to have higher values where it contains more members. We have uncovered relatively strong effects from household size. A noticeably strong and almost proportional effect was apparent from the number of household members on the valuation of noise in Galilea and Ortúzar (Forthcoming). This could have been because the SP exercise was conducted as a household activity rather than the usual method of focussing on a single respondent. We also found that the presence of children increases the valuation, especially in the case of air pollution. Elsewhere, Pommerehne (1988) and Soguel (1994) find that the presence of children has a positive influence on the willingness to pay for noise reduction, while Vainio (2001) finds the opposite.

In general, studies valuing noise and air quality find that there are only a limited number of socio-economic variables which have a significant influence on values, with income being the key variable, followed by household size and composition and factors related to self-selectivity. This is broadly in line with our findings.

5.2.5 Absolute Values

Comparison of noise and air quality values across studies is not a straightforward task, in part because of the different units in which they are expressed. Tables 10 and 11 present noise and air quality valuations. Where possible, valuations of a 50% change are presented to enable direct comparison, but there are other cases where the values are estimated in units which do not allow this. Values have been converted to 1999 US$ by adjusting for gross domestic product (GDP) and purchasing power parity (Nellthorp et al. 2001). Values were adjusted to the base year 1999 using GDP deflators and assuming a GDP elasticity of 1 and then converted to US$ at 1999 rates (Organisation for Economic Cooperation and Development, 2002a). Values were adjusted to allow for differences in purchasing power (Organisation for Economic Cooperation and Development, 2002b, Criminal Intelligence Agency, 2002). We cannot of course adjust for other variations in the studies.

In general, there seems to be an encouragingly high degree of correspondence between the noise valuations derived in different locations. The same cannot be said of the air quality values. This could reflect the inherently greater difficulties involved in presenting air quality and variations in individuals' perceptions of air quality and understanding of its impacts. Nonetheless, some of the variation may be explained by variations in air pollution levels between locations, as is the case between Santiago (Ortúzar and Rodríguez, 2002) and Edmonton (Hunt, 2001).

The values for traffic noise and air pollution are broadly consistent with our findings that SP values exceed those obtained using CVM. However, the CVM noise values of Pommerehne (1988) and Soguel (1994) are more in line with SP studies. The Soguel study applied iterative CVM and so is expected to be higher. The survey used by Pommerehene offered a move to a neighbouring street where noise levels were halved, which is a highly realistic scenario. Moreover, the Pommerehne study is the oldest in the tables, and in converting the values for comparability we have assumed that the elasticity of the values to GDP is one which may have inflated the values from early studies somewhat. The low SP values for air pollution found by Nelson (1998) could be partly a function of the payment vehicle which was annual road tax and a small number of levels. CVM studies not included in the tables because they valued a reduction in traffic nuisance overall (Walker, 1997; Bateman, 2000) also yielded lower values than those in SP studies for noise and air pollution effects.

Our study and Sælinsminde (1999) estimate values to both noise and air quality. Both studies indicate that variations in air quality are valued more highly than variations in noise. The figures reported by Hunt (2001) are less comparable, but we would argue that air quality variation would be more highly valued if it related to ‘frequently bad’ levels, to correspond with the ‘frequently distracting’ noise that was valued, rather than ‘bad one day per week’. Taking the values in Tables 10 and 11 as a whole, the impression is that air quality is valued more highly.

TABLES 10 AND 11 HERE

6. CONCLUSIONS

This study has contributed to the relatively small body of empirical evidence relating to the valuations households place upon variations in traffic related noise and air quality. It has applied SP methods to estimate households’ valuations of noise and air quality within the broader context of residential choice and also including local accessibility levels by car and bus. The monetary values obtained were generally plausible and varied in a largely sensible manner. Although comparison is not straightforward, variations in air quality appear to be valued somewhat more highly than variations in noise. Relatively large proportions of Edinburgh residents experience a noisy environment or poor air quality, and attitudinal questions indicated that improvements in noise and air quality are quality of life priorities.

The principal causes of variations in monetary values were found to be income and household size. The cross-sectional income elasticity was estimated to be 0.7 and is consistent with other evidence both in environmental valuation and travel choice analysis. The finding that only a few variables influence household values is consistent with most studies of traffic related externalities.

A novel feature of this study has been the comparison of different means of presenting air quality. The differences in the values obtained according to the means of presentation were taken to confirm our theoretical preference for the location method over the proportionate change method. Another novel aspect of the study was relating the variations in air quality to an actual measure of air quality which was taken as Nitrogen Dioxide (NO_2). This facilitates the use of estimated values in practical cost-benefit appraisals.

Tests were conducted for the presence of sign, size and level effects. Taking our results as a whole, our conclusion is that such effects are relatively minor and that this is also the case in other SP based studies of traffic related externalities. Our findings are not in line with a wealth of evidence supporting sign, and to a lesser extent size and level effects, in the general area of environmental valuation. However, we note that much of that evidence is based on CVM and there is a need for a controlled comparison of whether such effects are more or less prevalent in CVM values than in values derived from SP.

We have compared the SP approach with the open-ended form of CVM. The results here confirm evidence from environmental studies in general that open-ended CVM provides lower values than SP, even when the large proportion of protest zeros common with the former are removed. Our view is that the reduced emphasis on cost and the lesser transparency of the purpose of the study means that there is a lesser incentive to bias willingness to pay in SP studies. Whilst we conclude that the SP method is preferred to CVM, there is nonetheless scope to exploit the information contained in CVM responses, particularly protest responses, to potentially enhance the SP model.

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Table 1: Accessibility and Environmental Quality Attribute Levels

	Noise		AirP		AirL		Car Times		Bus Times	
	A	B	A	B	A	B	A	B	A	B
1	Current	Current	Current	Current	Current	Current	Current	Current	Current	Current
2	Current +50%	-50% Current	Current +50%	-50% Current	Worse	Current	Current +10%	-10% Current	Current +20%	-20% Current
3	Current +50% +100%	-100% -50% Current	Current +50% +100%	-100% -50% Current	Current	Better	Current +20%	-20% Current	Current +33%	-33% Current
4	+100%	-100%	+100%	-100%	Worse	Better	-	-	-	-

Table 2: Perceptions of Local Noise Levels and Air Quality

Noise		Air	
Very Noisy	21%	Very Poor	7%
Noisy	17%	Poor	27%
Quite Noisy	27%	Fair	34%
Fairly Noisy	26%	Good	24%
Quiet	5%	Very Good	8%
Very Quiet	4%		

Table 3: Three Most Important Priorities for Improvement

	1st	2nd	3rd	%mentioning
Improved Road Safety	25%	13%	11%	49%
Reduced Local Crime	13%	12%	10%	35%
More Local Play Facilities	6%	10%	9%	25%
Improved Air Quality	14%	15%	9%	38%
Improved Health Care	4%	5%	8%	17%
Reduced Noise Levels	14%	16%	12%	42%
Improved Neighbourhood Appearance	3%	7%	7%	17%
More Local Shops	4%	9%	7%	20%
Improved Education Quality	3%	4%	7%	14%
Lower Council Tax	14%	9%	20%	43%

Table 4: Stated Preference Models

	Model I	Model II	Model III
$AirL_{M-L}$	-0.0093 (1.6)		
$AirL_{M-G}$	-0.0086 (1.5)		
$AirL_{M}$		-0.0110 (2.7)	-0.0114 (1.9)
$AirL_{NM-L}$	-0.1408 (3.2)	-0.1469 (4.6)	-0.1391 (4.2)
$AirL_{NM-G}$	0.1097 (3.2)	0.1327 (4.7)	0.1257 (4.5)
$AirP_{M-L}$	-0.0277 (2.2)	-0.0158 (5.4)	-0.0163 (5.7)
$(AirP_{M-L} – Base)^2$	0.0002 (0.4)		
$AirP_{M-G}$	-0.0120 (0.9)		
$(AirP_{M-G} – Base)^2$	0.0011 (0.3)		
$AirP_{NM+50}$	-0.6996 (4.8)		
$AirP_{NM+100}$	-1.1109 (6.5)		
$AirP_{NM-50}$	0.5457 (2.4)		
$AirP_{NM}$		-0.0100 (6.8)	-0.0082 (5.5)
$Noise_{+50}$	-0.5800 (6.3)		
$Noise_{+100}$	-0.9756 (8.1)		
$Noise_{-50}$	0.2265 (2.4)		
$Noise_{L}$		-0.0084 (9.1)	-0.0048 (2.2)
$Noise_{G}$		-0.0057 (3.4)	
CarTime	-0.0007 (2.3)	-0.0014 (1.8)	
$Cost_{G}$	-0.0017 (2.6)		
$(Cost_{G} – Base)^2$	-0.000002 (2.9)		
$Cost_{L}$	-0.0015 (2.8)		
$(Cost_{L} – Base)^2$	-0.000003 (0.7)		
Cost		-0.0009 (8.2)	
$Cost/Income^{0.7}$			-0.7606 (9.3)
Incremental Effects			
Air-Child			-0.0109 (2.7)
Noise-Child			-0.0038 (2.3)
$Noise_{L}$-Adults			-0.0033 (1.8)
$Noise_{G}$-Adults			-0.0071 (4.2)
Noise-Allev			-0.0029 (1.8)
ρ^2	0.07	0.05	0.08

Notes: Costs are expressed as pence per week. A gain is denoted by the subscript G and a loss by the subscript L except where a percentage change is concerned and the three levels (+50, +100 and –50) are used as subscripts. The incremental effect Air-Child relates to all the air coefficients except $AirL_{NM-L}$ and $AirL_{NM-G}$. Average income is £20618. CarTime denotes the proportionate change in car journey times but changes in bus times had no significant influence.

Table 5: Household Values of Air Quality and Noise

	$AirP_{NM}$			$Noise_L$			$Noise_G$		
	Inc1	Inc2	Inc3	Inc1	Inc2	Inc3	Inc1	Inc2	Inc3
One Adult and No Children	6.9	11.2	18.2	4.1	6.6	10.7	0.0	0.0	0.0
One Adult and Children	16.1	26.1	42.3	7.3	11.8	19.1	3.2	5.2	8.4
Two Adults and No Children	6.9	11.2	18.2	6.9	11.1	18.0	6.0	9.7	15.7
Two Adults and Children	16.1	26.1	42.3	10.1	16.3	26.4	9.2	14.9	24.2

Table 6: Nature of Households' Willingness to Pay Responses

	Noise		Air	
Not worth paying/not bothered about improvements	71	(17.8%)	62	(15.6%)
Cannot improve noise/air quality in this way	26	(6.6%)	25	(6.3%)
Not prepared to pay more council tax	123	(30.9%)	112	(28.1%)
Other	33	(8.3%)	38	(9.6%)
Willing to Pay	145	(36.4%)	161	(40.4%)

Table 7: Households' Willingness to Pay Valuations (£ per week)

	Obs	Mean	SD	SE	10%	25%	50%	75%	90%
Noise (All)	398	1.39	3.21	0.16	0.00	0.00	0.00	2.00	5.00
Noise (Non Zero)	145	3.80	4.38	0.36	1.00	1.00	2.50	5.00	7.00
Air (All)	398	1.50	3.29	0.17	0.00	0.00	0.00	2.00	5.00
Air (Non Zero)	161	3.71	4.33	0.34	1.00	1.00	2.00	5.00	10.00

Note: SD and SE denote the standard deviation and the standard error respectively, and the % terms denote percentiles.

Table 8: Noise and Air Quality Valuations for 50% Improvements

	CVM 1	CVM 2	SP
Noise	£1.48 (±0.34)	£2.55 (±0.54)	£3.17 (±1.94)
Air Quality	£1.60 (±0.36)	£2.68 (±0.54)	£5.56 (±1.90)

Table 9: Weekly Willingness to Pay Regression Models

	Noise I	Noise II	Air I	Air II
Constant	-0.238 (0.6)	1.182 (1.3)	-0.207 (0.6)	0.966 (1.0)
INC	0.00003 (2.7)	0.00004 (2.0)	0.00002 (2.0)	0.00002 (1.0)
NHH	0.331 (2.4)	0.553 (2.0)	0.440 (3.1)	0.648 (2.2)
POOR	0.767 (2.3)	0.313 (1.4)	0.922 (2.5)	0.362 (1.5)
Adj R^2	0.06	0.07	0.06	0.04
Obs	372	145	373	161

Table 10: Values of Traffic Noise in US$ 1999, WTP per month

Author	Location/Year	Values	Change in impact valued
			50% changes in noise levels
This study	Edinburgh 1996	33.55 (loss) 22.75 (gain)	**SP**
Sælinsminde 1999	Oslo & Akershus 1993	33.33 – 66.66	**SP** attributes (i) in-vehicle time and (ii) fuel cost (relating to a specific journey, % change in (iii) noise and (iv) local air pollution caused by traffic
This study	Edinburgh 1996	10.63 – 18.33	**CVM** WTP for 50% reduction in traffic noise levels
Pommerehne 1988	Basle 1983/4	56.60	**CVM** WTP to halve traffic noise exposure
Soguel 1994	Neuchâtel 1992	32.15 – 38.47	**CVM** "what increase in your monthly rent would you agree to pay in order to halve your housing noise level"
Vainio 1995 & 2001	Helsinki 1993	5.08 – 7.53	**CVM** WTP, only for households where noise exceeded 55dBA
			Other changes
Hunt 2001	Edmonton 1996	148.45	**SP** change from "no noise" to "frequently distracting" traffic noise"
Barreiro et al 2000	Pamplona 1998/9	4.23	**CVM** WTP to reduce traffic noise from daytime to night-time levels
Navrud 2000	Oslo, Ullensaker 1999	8.74	**CVM** WTP for to eliminate indoor noise and a 50% reduction and outdoor noise annoyance and to eliminate noise nuisance in parts of a nearby forest recreation area.

Table 11: Air Pollution from Traffic Values, in US$ 1999, WTP per month

Author	Location/Year	Values	Change in impact valued
			50% change in air pollution levels
This study	Edinburgh 1996	39.91	**SP**
Sælinsminde 1999	Oslo & Akershus 1993	94.78 – 188.52	**SP** attributes (i) in-vehicle time and (ii) fuel cost (relating to a specific journey, % change in (iii) noise and (iv) local air pollution caused by traffic
This study	Edinburgh 1996	11.49 – 19.30	**CVM** WTP for a 50% reduction in traffic related air pollution
Carlsson & Johansson-Stenman 2000	Sweden 1996	17.84	**CVM** WTP for a 50% reduction in the "concentration of harmful substances" in the air where respondents live and work.
			Other change
Hunt 2001	Edmonton 1996	107.8	**SP** change in frequency of bad air from "never bad" to "bad one day per week"
Nelson 1998	Bedford 1995	8.00	**SP** "50% less vehicles pass your house in the morning peak time"
Ortúzar and Rodríguez, 2002	Santiago 2000	495.6	**SP** WTP for a one day reduction in air pollution alert days