VALUING NOISE IMPACTS USING HEDONIC PRICING AND STATED PREFERENCE METHODS: WHAT DOES THE EVIDENCE TELL US?[1]

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Abstract: Estimates are presented from both Australia and overseas of the value of traffic noise reductions. These estimates were sourced from both hedonic price and stated preference applications. A similar range of estimates was found using both techniques. However, the number of studies available is relatively limited given the importance of noise impacts within the economy, and there is substantial variability in the estimates generated using both techniques. The variability appears to be primarily an artefact of methodological differences rather than differences in cultural perspectives regarding the cost of noise.

1. INTRODUCTION

One of the main negative externalities arising from road traffic is noise impacts. Noise impacts arise from a vehicle's power train, from rolling noise and from electronic equipment. Actual traffic noise is a function of quite a few different factors. These include traffic volume, the type of vehicles using the road, the road surface, the distance of properties from the road and geography (ie the existence of natural mounds, bluffs and vegetation).

Traffic noise is measured using several indexes. The most common of these is the $L_{Aeq,T}$ index. $L_{Aeq,T}$ stands for "Equivalent Continuous A-Weighted Sound Pressure Level". This is the average (logarithmic) noise level (expressed in dB) that would occur if traffic flow were uniform, within a specified time interval *T*.

Noise is considered to be a negative externality because it is unwanted, and affects people other than those directly involved in the use of the motor vehicles. Some of the most apparent impacts are on sleeping patterns and general amenity. But there are other impacts. Noise can affect stress levels and people's ability to communicate [1].

The existence of negative externalities is a cause of market failure, and provides a rationale for government intervention within the market. This intervention typically takes one of two forms. The first is modifications to roads to minimise noise impacts. This might involve the construction of barricades to block noise, or modifications to road surfaces. Alternatively compensation may be required, particularly if property prices are affected by road widening and subsequent increases in traffic. The critical question for policy makers in either of these circumstances is "what value should be given to noise impacts?" Answers to this question are needed to determine when the control of noise is warranted, and/or the appropriate level of compensation that should be paid.

Some information about the value of noise can be derived from existing market data. This typically involves looking at changes in damage costs or preventative expenditures [2]. For example, information about expenditure on double glazing windows or other modifications to the design of houses provides an indication of the benefits of reduced noise. However, the benefits of noise reductions are more typically deduced by using related or hypothetical market data. Using these techniques, it may be possible to estimate the 'non-market' value associated with changes in noise levels.

The purpose of this paper is to review the existing literature pertaining to the valuation of road traffic noise. Specifically, the results from hedonic price studies and stated preference studies conducted both in Australia and overseas are reviewed and compared. In Section 2, these two approaches are briefly described. Then, in Section 3, the results from applications of the hedonic price method are reviewed and, in Section 4, the results from the stated preference applications are reviewed. Conclusions are offered in Section 5.

2. METHODS FOR VALUING NOISE IMPACTS

The most commonly used method for valuing noise impacts is the hedonic price method, which in the economics literature is described as a "revealed preference technique". Revealed preference techniques use information from related markets to impute a value for non-market goods [3]. A related market is one that indirectly reveals values for environmental goods.

The hedonic price method uses differences in property prices to impute a value for changes in environmental quality such as noise, air quality, water quality or river health. In most (single stage) hedonic price studies a regression equation is estimated where property prices are a function of all of the attributes of the property, including environmental quality. The effect of marginal changes in environmental quality on property prices can then be quantified. However, to estimate demand (which is required for valuing non-marginal changes) for an externality such as noise is more complicated. Estimating demand requires data from multiple, distinct mar-

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kets, as well as information on the individual purchasers of the differentiated commodity [4, 5]. With distinct markets, the value of noise can then be calculated at different levels of supply, thus identifying the demand curve. This is known as a second stage hedonic function.

Economists tend to have greater trust in the results from revealed preference studies because they are based on existing market data. However, the results from the non-market valuation literature indicate that the variation associated with estimates derived using revealed preference techniques is often very great (and typically larger than the other class of techniques, which will be described shortly) [6]. Moreover, value estimates are subject to the judgement of the researcher. Value estimates can be affected by the attributes selected, the accuracy of measurement of the pollutants involved and the functional form used [7, 8].

Uncertainty about the capacity of the hedonic price method to accurately value noise provides a rationale for using other non-market valuation techniques. The other main class of non-market valuation techniques are those based on the stated preferences of individuals. Stated preference techniques involve the use of surveys from which estimates are derived of the non-market benefits of different resource use alternatives.

The most widely used stated preference technique for estimating non-market values is the contingent valuation method (CVM) [9]. CVM questionnaires contain several well-defined elements including a description of the study site, details of the proposed changes (including a method of payment), an elicitation question and a series of socioeconomic and attitudinal debrief questions. State-of-the-art applications of the CVM generally utilise the 'referenda' format for the elicitation question, an example of which is shown in Table 1.

Under this format, respondents are asked whether they support a project given that they are required to pay a certain amount towards it, with the payment amounts being varied between respondents. The responses to the elicitation question are then regressed against several variables including the payment amount, respondents' attitudes, and socioeconomic characteristics such as income, age, education etc.. This equation is then used to estimate mean and median willingness to pay.

The CVM has the advantage of being recognised by respondents as a standard public choice instrument (as it is similar to a referendum). However, despite its wide usage, the CVM has

Table 1: The dichotomous choice CVM format

Do you support the proposal to reduce noise at a cost of $50 per household, or do you oppose the proposal? (*tick one box*)	
I support the proposal at a cost of $50	☐
I oppose the proposal at a cost of $50	☐

several limitations. It is relatively costly to use, provides limited information about people's preferences and is arguably prone to various biases [10, 11]. In Australia, it has become controversial since its use by the Resource Assessment Commission to estimate the environmental costs of mining at Coronation Hill [12]. Similar controversy was experienced in the USA where contingent valuation was used in the Exxon-Valdez oil spill case [13].

A second stated preference technique that has been used to estimate the value of improved water quality and could be applied to valuing the improved environmental quality resulting from the control of noise is conjoint analysis. Conjoint analysis has been widely used in transport economics in predicting market share for transportation options and valuing travel-time savings [14, 15].

Conjoint questionnaires are similar to CVM questionnaires in that they contain background information about the non-market good, an elicitation question, and debrief questions. The main difference between the two methods is in the form of the elicitation question. In conjoint questionnaires, respondents are presented with a series of alternatives that they are asked to evaluate. This evaluation could involve rating, ranking or choosing one of the alternatives. An example of the choice version of conjoint analysis is shown in Table 2. From each choice set, respondents are asked to choose their preferred alternative. The alternatives in the choice sets are defined using a common set of attributes (ie effective speed limit, reduced noise level from road traffic, reduced length of waiting time for pedestrians to cross road, annual cost per household in terms of increased local taxation etc.), the levels of which vary from one alternative to another.

Table 2: Example of one choice set in a choice modelling questionnaire

Please indicate the alternatives you prefer most by ticking one of the boxes below:

	Alternative 1	**Alternative 2**	**Alternative 3** (the status quo)
Speed limit	50 km/h	60 km/h	60 km/h
Noise level	60 dB	70 dB	80 dB
Waiting time to cross road	1 minute	3 minutes	3 minutes
Increased rates	$90	$30	$0
	☐	☐	☐

In conjoint applications goods are decomposed into a set of 'attributes' or characteristics. For example, a car could be considered to be simply the sum of its component parts ie 4 wheels, a chassis, an engine etc. The trade-offs respondents make when choosing between alternatives are quantified using statistical techniques. Where one of the attributes involves a monetary payment, the resulting trade-offs can be used to estimate the value of each of the environmental quality attributes. This can be conceptualised in the case of purchasing a car. Existing market data might show that on average people may be willing to pay $1000 extra for air conditioning — this implies that air conditioning is worth this amount of money.

Conjoint analysis has several advantages over contingent valuation. It provides much greater information about people's preferences for noise reductions. This extra information is particularly useful for benefit cost analysis where multiple alternatives are typically evaluated. Often the full range of policy alternatives may not have been identified before the non-market valuation exercise has taken place. With contingent valuation it may be necessary to undertake a new exercise if a new policy option is identified. In contrast, the results from a CM application can be used to value any alternative within the space of attributes used in the exercise. This provides the decision maker with much greater flexibility. However, conjoint applications do involve a greater level of complexity than is involved with contingent valuation. In subsequent sections, estimates are provided of the value of noise generated using both revealed preference and stated preference techniques.

3. HEDONIC PRICE ESTIMATES

Hedonic price studies have primarily been used as a basis for deriving estimates of the value of noise impacts in Australia. For instance, the Roads and Traffic Authority (p.8.2) "estimated that property values depreciate on average by a rate within the range of 0.8% to 1.28% for every decibel over 50 dB(A)" [16]. This finding was based on report commissioned by the Resource Assessment Commission [5], who in turn primarily based their findings on a review by Pearce and Markandya [17], who primarily based their findings on a review by Nelson [18] which was published in the Journal of Transport Economics and Policy. In Nelson's study, he reviewed nine studies published between 1974 and 1980, and identified a range of adjusted NDSI's[2] of 0.08-1.05%, with a weighted mean of 0.40%.

The use of all of these nine studies in calculating this mean estimates has been questioned by NSW EPA [1]. They comment that:

> *The sample size appears inadequate in some estimates such as Hall et al. (1978) who have a final sample size of 21; and Bailey (1977), who have a sample size of 90. The environmental good is not carefully measured in several estimates...who do not measure noise levels. Bailey (1977) uses the natural log of distance to highways which Nelson (1982) suggests is an 'excellent alternative' but it ignores the potential effect of topography on noise levels...Also, many of the noise measurements cover a very short time period. In Vaughan and Huckins (1975), noise measurements were taken for only 5 minutes at each site...*

Further criticisms could also be made of these studies. Apart from being fairly old, they used only single stage regression analysis and have specification problems such as from collinearities [19]. They also only examined the impacts of highway noise. NSW EPA [1] reported that when the studies that are seen to have less reliability are excluded, the mean of the more reliable estimates is approximately 0.25% per dB.

Several hedonic price studies of road traffic noise have been conducted in Australia. The first two were rudimentary single stage hedonic price models with relatively few regressors. McCalden and Jarvie [20] in a study in Newcastle estimated that the NDSI was 0.20%. In another study conducted in Sydney, Holsman and Bradley [21] estimated that the NDSI was 1.80% for main roads where noise levels were generally higher, and 0.70% for parallel streets.

A third study was conducted by Williams [22], who examined the effect of noise impacts on property prices along the South East Freeway in Brisbane. While using only a single stage hedonic model, the study was more robust than the previous ones. The study was based on a sample of 218 houses within one kilometre of the freeway. The initial model included 13 regressors that were subsequently factor analysed to produce a set of five uncorrelated regressors. This is a fairly novel approach, in the non-market valuation literature, for dealing with problems due to multicollinearity. Williams [22] found that the cost of proximity to the freeway was $4.48 per metre ($872 for an average house or 3% of average house price) in A$1978. Williams [22] suggests that this impact is primarily due to noise impacts, however noise levels were not measured at each of the housing sites. Hence it is not possible to determine the impact on house prices for changes in noise levels.

A final and more recent Australian study identified by Renew [23], that was conducted in streets throughout Brisbane, estimated a NDSI (L_{eq}) of 1.00%. The data set included 350 houses (across 36 streets) with sales occurring over a three year period. Noise levels were measured for 24 hours at a representative site in each street. A linear regression model was estimated, and ten attributes (including noise levels) were used to explain variations in house prices.

Thus the Australian evidence shows considerable variance, with the NDSI ranging from 0.20% to 1.80%. It is possible that the divergence could reflect the different nature of the towns (Newcastle being a rural centre). However, there may be other explanations such as the differences in when the studies were conducted (ie changing tastes), or differences in methodology.

Given the lack of convergence of the Australian estimates, it is appropriate to consider other estimates derived in North America and Europe. Since Nelson's [18] study, several other studies have been conducted to value the impacts of traffic noise, some of which are reported in Table 3. Overall, there appear to be relatively few studies conducted on the value of traffic noise compared to the relatively broad literature where the hedonic price method has been used to value aircraft noise

2. Noise Depreciation Sensitivity Index. This gives the average percentage change in property prices per decibel.

Table 3: Overseas estimates of the value of traffic noise impacts

Study	Location	NSDI
Grue et al [27]	Oslo, Norway	0.21-0.54%
Hall et al [28]	Toronto, Canada	0.42-0.52%
Iten and Maggi [29]	Zurich, Switzerland	0.9%
Pommerehne [30]	Basel, Switzerland	1.26%
Hidano et al [31]	Tokyo, Japan	0.7%
Sougel [32]	Neuchatel, Switzerland	0.91%
Vainio [19]	Helsinki, Finland	0.36%
Wilhelmsson [33]	Stockholm, Sweden	0.6%
Bateman et al [34]	Glasgow, United Kingdom	0.2%

and air pollution. The studies reported in this table show a similar variation in estimates to the Australian studies, with the NDSI ranging from 0.21% to 1.26%, with a mean of 0.71%.

The similarity in the spread of values to the Australian studies is somewhat surprising, given the differences in cultural context and time periods over which the various studies were conducted. This implies either that (1) noise is valued similarly across cultures or (2) that differences in methodology are part of the reason for the convergence. Given what is known about how sensitive hedonic price estimates are to methodological variations, the latter explanation is likely to be important. This suggests that it would be prudent to conduct a meta-analysis to determine the value of noise, once allowance has been made for differences in methodology and culture.

4. STATED PREFERENCE ESTIMATES

Several stated preference studies have been conducted in Europe to value traffic noise. This includes the use of both contingent valuation and conjoint analysis. The first two of these studies by Vainio [19] and Barreiro, Sanchez and Viladrich-Grau [25] used the contingent valuation method. The latter application, by Garrod, Scarpa and Willis [26] used conjoint analysis. Given that only a few stated preference applications have been conducted to value traffic noise impacts, they will be reviewed in greater detail.

The study by Vainio [19] paralleled an application of the hedonic price method that was reported in the previous section. Vainio [19] sent a survey to 700 households in Helsinki, Finland and received back 421 valid responses (60%). In the survey they asked the following question to estimate respondents' willingness to pay to reduce noise in a street where they felt noise was a particular nuisance:

The purpose of this equation is to estimate how much people would be willing to pay for the elimination or considerable reduction of traffic nuisance.

Let's consider the idea that the road/street that is causing the harm could be calmed be eg diverting the traffic elsewhere or into a tunnel so that the street would be converted to a "residential street". The residents of the street could still use it but the through passage would be prohibited. This would incur costs which need to be distributed in some way.

How much would you be willing to pay for the traffic volume to diminish considerably ... [the noise] nuisance?

Thus Vainio [19] used an open-ended elicitation format for estimating willingness to pay. This type of format is no longer regarded as state of the art. The referenda format, which is used by Barreiro, Sanchez and Viladrich-Grau [25], is now preferred because it is less susceptible to strategic behaviour.

The data from this study were analysed using ordinary least squares (linear) regression. The coefficients of several important explanatory variables were significant, including noise, income and work status, which provides some confidence in the validity of the results generated. However the explanatory power of the regressions was relatively low (adjusted R^2 ranging from 0.05 to 0.27). Willingness to pay for a change in noise levels from Leq 65 to Leq 55 was estimated to be $1032 ($US) per year or $10,320 (annualised using a 10% discount rate). This contrasts with an estimate made using the hedonic price method of $2662. At first glance it appears that the contingent valuation estimates are substantially greater than the hedonic price estimates, which is suggestive of yea-saying behaviour. However, the arbitrary selection of a 10% discount rate has probably affected the comparability. Empirical evidence indicates that discount rates in contingent valuation studies are typically far higher than this, often being 30% or higher. If a more appropriate discount rate were selected, then there would most likely be greater convergence between the estimates.

The second study, by Barreiro, Sanchez and Viladrich-Grau [25], was another application of the contingent valuation method to value reductions in traffic noise in the city of Pamplona in northern Spain. Pamplona is a moderately sized city with a population of about 200,000 inhabitants. Pamplona is a relatively noisy city, with 59% of measurements throughout the city being about 65 dB(A) and an average noise level of 67.1 dB(A).

Barreiro, Sanchez and Viladrich-Grau [25] described to respondents three projects that the local government could implement to reduce traffic noise. These included: (1) a noise control campaign, (2) a program of surveillance that would include fines for infringements and (3) modifications to road surfaces. A double bounded dichotomous choice format was used to determine willingness to pay. With this format, respondents were first asked if they were willing to pay a given amount. If they answered positively they were asked if they were willing to pay a higher amount, and if they answered negatively they were asked if they were willing to pay a lower amount. The sample size for this study was 600 respondents.

The data in Barreiro, Sanchez and Viladrich-Grau's study were analysed using a binary logit model with a very simple model specification that included no socio-demographic or attitudinal regressors. While this basic model appeared to be relatively robust, and generated fairly tight confidence intervals, the lack of detail reported makes it difficult to assess the validity of the estimate. Mean willingness to pay was estimated to be about 39 euros per year. This represents about 0.19% of total annual income, which is much lower than the results of the previous contingent valuation study where willingness to pay was 4.84% of total annual income[3].

The final study is a conjoint application by Garrod, Scarpa and Willis [26]. The objective of their study was to estimate the benefits of traffic calming procedures, such as warnings about speed restrictions, road humps, chicanes and visual warnings. They used the choice version of conjoint analysis, where respondents were presented with three alternatives (one of which represented the status quo) and asked to choose their preferred alternative. The alternatives presented to respondents were described using the following attributes:

- Effective speed limit (20 or 30 mph)
- Reduced noise level from road traffic (60, 70 or 80 dB)
- Reduced length of waiting time for pedestrians to cross the road (1 minute or 3 minutes)
- Overall appearance of the traffic calming scheme ("basic" or "improved")
- Annual cost per household of the traffic calming scheme in terms of increased local taxation (£10, £20, £30).

About 400 surveys were conducted at three locations in England where noise from main roads was a problem. The data from the choice experiments were analysed using conditional logit and other model specifications. Note that in the basic model specification, the coefficient for appearance was not significant. However, it did become significant when variable interactions were included in the model. Hence no willingness to pay figure has been reported for appearance. Results from the basic model specification indicate that respondents are willing to pay:

- £0.45 per mile per hour for reductions in the effective speed limit
- £1.95 per dB per annum for reduced noise
- £3.75 per minute per annum for reduced waiting time

Household income in Britain in 1997/98 was £9405 per year. Willingness to pay of £19.50 for a 10 dB decrease in noise is equivalent to 0.21% of annual household income. Thus the results from the conjoint analysis indicate a comparable willingness to pay to the contingent valuation study by Barreiro, Sanchez and Viladrich-Grau [25]. One possible explanation for the much lower value estimate compared to the study by Vainio [19] is that the elements of the traffic reduction programme have been decomposed into attributes in this study, of which noise is just one attribute. In hedonic price studies, noise would most likely be a proxy for changes in several attributes including noise.

The next relevant question is how well do the stated preference generated estimates compare with the hedonic price estimates? This is perhaps easiest understood in the Australian context. Given the previously reported NDSI's that ranged from 0.20-1.26%, a 10 dB(A) decrease in noise would imply a 2.0-12.6% increase in prices. Assuming a median house price in Australia of $145,200 [24], this is equivalent to an increase in price of $2904-$18,295.

Now let's compare this with the stated preference estimate. Household individual income in Australia was found to be $47,326 in the 1996 census. Willingness to pay, based on the results of the stated preference studies, was 0.19-4.84% of annual household income, which is equal to about $79-$2004 per year for a 10 dB decrease in noise levels. Assuming a discount rate of 10% over 25 years, the present value of willingness to pay is equal to $714–$18,187. Thus there is a fairly similar range of estimates generated using both the stated preference and hedonic price techniques.

This result is similar to the findings of Button [2]. Button conducted a rudimentary meta-analysis of noise valuation studies and included a variable that represented the use of willingness to pay techniques (as opposed to property value techniques). The coefficient for this variable was not found to be significant, indicating that stated preference and hedonic price generated value estimates converge.

5. CONCLUSION

The results from this review indicate that there is considerable uncertainty regarding the value for noise. Both hedonic price and stated preference generated estimates differ by up to an order of magnitude. The wide range in these estimates appears to be driven primarily by methodological differences, however cultural differences may also be contributing.

Noise is particularly important economically. Button [2] reported estimates of the cost of noise ranging from 0.02 to 11.18% of GDP. Given the importance of noise to policy decisions, it is surprising that such little attention has been given to establishing the value of this negative externality, in Australia and elsewhere. For more accurate and informed decision making, there is a case for undertaking further studies to establish the value of traffic noise in Australia.

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3 The lower figure for willingness to pay could be a function of the choice of the bid vector. The bid vector was based on the actual costs of the noise mitigation projects rather than on likely willingness to pay. There may also be a cultural explanation, as about a third of the sample indicated a zero willingness to pay for the noise reduction schemes.

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