A meta-analysis of stated preference studies of noise nuisance

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INTRODUCTION

This paper first provides a brief overview of developments in the valuation of noise nuisance. The challenge of obtaining economic values of noise nuisance has led to an increasing application of stated preference methodologies in recent years. The vast majority of these studies have been in the context of aircraft or road traffic noise nuisance and values obtained exhibit a high degree of variation. It is possible to speculate that these differences could be a result of variation in experimental design and implementation or due to the systematic influence of particular variables.

The main aim of this paper is to provide a rigorous analysis of the available studies through a meta-analysis that should provide insight into the causes of the variation in values and may allow us to alight on a recommended value (or values) derived from this approach.

Issues to be examined from a theoretical, methodological and empirical standpoint include: the context where the noise is experienced; the source of the noise; the representation of noise levels to respondents; the framing of questions in terms of both gains and losses and willingness to pay or willingness to accept; the scale of the changes offered; the time period for noise reduction and the time period for payment; the type of stated preference experiment used; the extent to which data is manipulated or trimmed; segmentation by income; annoyance or other factors with some commonality between studies; the models applied and other issues that may emerge.

NOISE VALUATION CONTEXT

As there is no market for quiet, the classic approach to valuing noise nuisance has been to seek a market within which noise is implicitly valued. If people have a value for quiet then intuitively this would be manifested in a willingness to pay more for houses in quieter areas and conversely less for homes in noisier areas. Typically, then use is made of the housing market where price is a function of a bundle of characteristics of the house and the neighborhood including noise. The value of noise obtained is normally expressed in the form of a Noise Depreciation Index (NDI) or Noise Sensitivity Depreciation Index (NSDI) which indicates the percentage change in house prices that results from a 1 dB change in noise levels. Detailed exposition of the theory and method may be found in Baranzini et al. (2008).

The quantity of hedonic pricing (HP) studies on aircraft noise is such that a number of meta-analyses have been carried out. The most recent by Wadud (2010) included 53 estimates of house price depreciation from aircraft noise concluding that a 1 dBA change in aircraft noise levels leads to a fall in house prices of between 0.45 % and 0.64 %. This estimate is broadly consistent with earlier analysis by Nelson (2004) and the early review by Nelson (1980) though somewhat lower than the estimates of Schipper et al. (1998) of 0.9 % to 1.3 %. There are fewer studies of road traffic noise and no formal analyses have been conducted. Bateman et al. (2001) reviewed 18 studies of road traffic noise mostly from North America finding an average NSDI of 0.55 %. This value is somewhat higher than the 0.40 % identified by Nelson (1982) from nine studies and 14 values all from Canada and the USA. Although the average values are broadly consistent the range of original values is large.

The HP method is attractive because it has a basis in real decisions in the market place and values may be linked to measured or modeled noise levels. However, it may be criticized in that purchasers may not have perfect knowledge of all the attributes of all the houses in their choice set; the housing market is susceptible to other imperfections, most notably transaction costs; explanatory variables suffer from correlation and it is difficult to measure some intangible influences and perceptions of them. HP is also limited in that it can only give a value of disturbance as experienced at home. Additionally the measures of noise used are often quite crude contours. Meta-analysis suggests that this cost may be capitalized through a house price discount of about 0.5 % to 0.6 % per dBA. In order to convert this to a value per dBA per year assumptions must be made about house purchaser's discount rates and the time period over which the values should be discounted. Even then the method cannot tell us what people might be willing to pay now for changes in the noise level experienced or how this might vary by time of day, day of week or season. These are interesting policy questions and for answers another approach was needed.

Stated preference methods (SP) are essentially hypothetical questioning techniques. There are two main forms: Contingent Valuation Method (CVM) and Stated Choice (SC). CVM has a long history in environmental economics whilst SC was more common in other areas including market research and transport studies, SC methods are now being adopted in environmental economics. They offer certain advantages over HP techniques. Firstly, control over the experimental conditions which can ensure: avoidance of correlation between independent variables; sufficient variation in attribute levels; better trade-offs than might exist in the real world; investigation of levels of noise or quiet outside current experience; design can ensure that secondary variables are not dominated; avoidance of measurement error in the independent variables; the ability to "design out" variables by specifying them to be the same for each choice. Secondly, it enables disaggregate analysis relating to individual characteristics but also variation by for example by time period. Thirdly, multiple observations are obtained for each person allowing more precise estimation. Hence, the growing interest in applying such techniques to noise nuisance. The number of studies available is now such as to lend itself to the application of meta-analysis that will hopefully provide insight into the variation in noise values obtained by such studies.

WHY META-ANALYSIS?

Meta-analysis utilizes data from a number of studies to attempt to explain variation in the values of the factor of interest here the value of noise reductions or increases in terms of socio-economic and study specific variables. Key advantages of such an approach are outlined by Abrantes & Wardman (2011) and Nelson & Kennedy (2009) those of most relevance in this context are:

- To provide guidance on "preferred" values, drawing on numerous sources rather than depending on a single study.
- To explain what determines between (and within) study variation. Instead of simply taking a mean value, meta-analysis seeks to identify the variables that

explain such variation. Where these are methodological this may suggest ways of improving future empirical studies.

- To explore aspects such as spatial or temporal variation which are beyond the scope of a single study.

In his 2002 review Navrud concluded that there were still too few SP studies for such analysis. In 2011 this situation has changed, we have identified around 60 such studies covering transportation noise. The aim in sourcing studies was to be as inclusive as possible identifying studies in the grey and academic literature. The current data set contains 252 values from 44 studies across 22 countries. This is still an evolving set of data and we expect to incorporate values from at least 3 or 4 more studies before the data set is finalized – thus the simple models reported here are highly exploratory in nature.

META-ANALYSIS CHALLENGES AND DATA

Key challenges in assembling an appropriate data set were as follows:

- Defining the dependent variable – SP studies tend to value a subjective measure of change in levels of noise or annoyance which varies a great deal between studies.
- Different contexts, not just in the source of the noise but also the location where it is experienced, though the vast majority of studies assess in-home nuisance, several examine noise during a journey.
- Study methodologies, not simply between stated choice and contingent valuation methods, but significant variation within each method, particularly with respect to the treatment of cost.
- Range of study years and countries. The earliest data is from 1968 and the most recent from 2009, a span exceeding 40 years. To date we have data from 22 countries. Standardizing values again poses a challenge.
- Identifying study attributes that are expected to influence the value of noise, ranging from socio-economic factors such as income through to study design features that may induce bias or difference, such as, transparency of design, is it obvious that noise is the focus of the study?, whether the questions are couched in terms of willingness to pay or willingness to accept and similarly, though not identically whether the scenario proposed represents a gain or a loss.

Defining the dependent variable

Studies use of a wide range of methods to present a change in noise levels to respondents. In order to be of greatest use in identifying the value of an objective noise measure the dependent variable here is defined as the annual value placed on a change of one decibel. As few studies report such a value this has required the use of a range of assumptions to convert values expressed in different subjective forms to a decibel value. These assumptions form part of the data set and will be tested for their influence, if any, on the value of noise. These are as follows:

- Where the study adopts assumptions to derive a decibel value these are applied.

- Where a proxy allows a reasonable estimate of the objective change in noise levels to be made, this is used.
- Where a change represents a halving of noise levels a change of 8 dBA is assumed and where a change represents a removal of noise annoyance a change of 10 dBA is used. These two assumptions follow Navrud (2002).

Study year and country

Values need to be converted to a standardized currency and year. Here we have uplifted all values to 2009 using the Consumer Price Index for the study country. These values are then converted to 2009 $US using official exchange rates for 2009 (World Bank 2010). We have deliberately avoided updating the values to allow for growth in incomes over time as income will be used as an independent variable. This is a critical area of interest in indicating a link between income growth and growth in the value of quiet. Cross sectional studies suggest that this elasticity is less than one but there is little consensus on the precise relationship (Bristow 2010).

Study contexts and explanatory variables

The majority of studies address noise nuisance experienced at home. Since few studies provide income segmentations or even average incomes of respondents, we therefore use per capita Gross Domestic Product as a proxy. Most of the defined variables relate to study methodology and include:

- Basic descriptive information relating to publication year, study year, type of publication, country and sample size.
- Basic information on method: stated choice or Contingent valuation or other; method by which noise is represented, context, noise source, time period when noise is changed.
- More specific information on method including: who pays; transparency, willingness to pay (WTP) or willingness to accept (WTA); gain or loss for CVM the type of cost presentation and whether zeros or extremes are trimmed; payment vehicle and time period for payment and where appropriate the largest change in cost offered.
- Information on any noise measurement or modeling.
- Some studies segment values by key attributes, for example annoyance level or income these are included here.

INITIAL MODELS

The initial models were run with the log of the per dBA value as the dependent variable. This means that the coefficients of variables expressed in logarithmic form denote elasticities, representing the proportionate change in valuation after a proportionate change in the variable in question, whereas the coefficients of dummy variables when exponentiated indicate the proportionate change in value from being at that level of a variable relative to the omitted category.

The initial tests included dummies for: method (CVM, SC); source of the noise (air, road, rail, combined); log GDP; payment period (weekly, monthly, annual, perjourney and house price); context (home, journey); combinations of WTP/WTA and gain and loss; was the noise change measured in the study or estimated (real; estimated in study; estimated for analysis); was the purpose transparent or not; presentation of noise; type of CVM relative to SC; type of publication; type of survey; whether CVM data had been trimmed or not and finally how zeroes had been treated in CVM. Variables that were not significant at 90 % were removed one by one and levels combined where appropriate (note that sets of dummies are retained where one or more is significant and there is no logical case for merging insignificant variables). Unfortunately the dummy variables defined for type of CVM and to a lesser extent presentation had a number of levels that were study specific and have been dropped for this reason. The next step in the modeling process will be to allow effectively for study specific and random effects. It is possible that these may be the dominant effects. A model run solely on study dummies indicated that many were significant. At this early stage we report a simple regression based a number of key potential explanatory variables excluding study effects, see Table 1. Variables not significant at 95 % are indicated in italics.

Table 1: Exploratory Regression Model (dependent variable = log of value per year for a change of 1 decibel, in US$2009)

Variable	Coefficient	T-statistic	Effect or elasticity
Constant	1.921	3.632	
Method			
SC	Base	Base	
CVM	-1.030	-4.016	-64 %
Log GDP	0.341	2.767	0.341
Noise source			
Road traffic	Base	Base	
Air	1.045	4.851	+184 %
Rail	-0.579	-2.713	-44 %
Combined source	*0.832*	*1.174*	*+130 %*
Payment period			
Annual	Base	Base	
Monthly	0.597	2.558	+82 %
Weekly	1.556	4.821	+374 %
Per journey	*-0.388*	*-0.662*	*-32 %*
Houseprice	2.815	5.716	+1569 %
Gain/loss and WTP/WTA			
WTP for a gain	Base	Base	
WTP to accept a loss	*0.445*	*1.003*	*+56 %*
WTA to forgo a gain	*-0.177*	*-0.262*	*-16 %*
WTA to compensate for a loss	1.707	5.284	+451 %
Both combined in one model	*0.558*	*1.524*	*+75 %*
Neither (WTA for current)	2.011	3.108	+647 %
dBA real or estimated			
dBA estimated	Base	Base	
dBA estimated within study	0.786	2.126	+119 %
dBA real	*-0.347*	*-1.702*	*-29 %*
Adjusted R^2 sample size	0.652	252	

This preliminary model has a respectable adjusted R^2 explaining variation in the data well. The negative and significant coefficient on CVM indicates that these studies yield values 64 % lower than SC studies. There is some supportive within study evidence from seven studies that open ended CVM provides lower or similar range values than SC (Bristow 2010).

A key finding is that the elasticity of values to income is 0.341 this is in line with values estimated in individual cross sectional studies (Bristow 2010), but on the low side when compared with evidence on other factors such as the value of time where there is no reason to expect a diversion from a unitary effect.

The values with respect to noise source indicate higher values for aviation noise and lower values for rail noise compared to road. This finding is in line with the weight of evidence in annoyance studies which indicates that a given measured level of noise is more or less annoying depending on the source. Aviation noise is most annoying, rail noise the least annoying with road lying somewhere in between (Miedema & Oudshoorn 2001).

With respect to the payment period the overall value falls with the time period for payment – so if people are asked to pay weekly their value is higher than if asked for an annual payment. This may be influenced by the range of values offered within studies. It also appears that where a payment is rolled up into the house price the value is much higher, this maybe because it represents a relatively small proportion of the whole or because the likelihood of payment is remote or a reflection of the small number of studies using this payment mechanism.

Another key finding is that with respect to whether respondents are asked to pay or accept compensation and whether this is for a gain or a loss. The most common formats are WTP for a gain and WTA compensation for a loss. If WTP for a gain is the base then WTA for a loss yields higher values as does the special case of WTA compensation for the current situation the rest are not significantly different from WTP for a gain. Although the difference looks very large with WTA values being five and a half times the WTP values, the review by Horowitz & McConnell (2002) found WTA values to be ten times higher across 46 studies of goods without a market price. The key difference is in the WTP or WTA framing as only the WTA a loss is significantly different from the other formulations rather than a difference in the valuation of gains and losses. This has also been identified within studies (Wardman & Bristow 2008).

It appears that where the change in decibels is estimated whether within study or for this analysis the value is higher than where a measured change in noise levels is used.

As stated above this is a very preliminary analysis and whilst the initial findings are of interest a more sophisticated approach will be required to see if these effects are stable once any additional explanatory variables are considered and individual study effects and random effects are allowed for. The next step will be to test random parameters on the constant to allow for varying constants (ie values) across studies.

CONCLUSIONS

We are constructing a large data base of noise valuation studies using CVM and SC techniques. At present it is difficult to draw firm conclusions on the key explanatory variables. However across model iterations we found that the GDP and WTP/WTA effects remained broadly consistent. Whilst findings may be related to study specific attributes and clearly require further analysis, where within study evidence exists it is broadly supportive.

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An update on research to guide United States policy on aircraft noise impact

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INTRODUCTION

Aircraft noise is a major environmental concern and can constrain aviation growth. Over several decades, United States policy has promoted actions to reduce the impact of aircraft noise on people around airports. The number of Americans living in areas of significant aircraft noise exposure has been reduced from 7 million in the mid-1970's to less than 300,000. Looking forward, the goal is to continue to reduce people exposed to significant noise despite aviation growth, and provide additional measures to protect public health and welfare and national resources (e.g., national parks). Measures to reduce noise impact—including aircraft source noise reduction, noise abatement flight procedures, airport configuration changes, land use controls, funding for noise mitigation—are guided by the level of the cumulative noise impact using the Day-Night average sound Level (DNL) and whether land uses are deemed incompatible with that level. Determinations rely on studies that were last reexamined in the U.S. in the early 1990's. There have been changes in aircraft technology, operations, public expectations, and scientific knowledge. New software tools under development will have the capability to quantify interdependencies among aviation-related noise, emissions and fuel burn both at the source level and through changes in health and welfare endpoints.

This paper provides a synthesized review of major considerations related to aircraft noise impact and research being conducted to guide U.S. policy.

AVIATION NOISE IMPACTS ROADMAP

In 2009, the Federal Aviation Administration (FAA) Office of Environment and Energy began the process of developing a comprehensive research roadmap to address noise impact research needs (Girvin 2009). In 2009-2010, the FAA conducted three workshops focused on noise impacts on health, annoyance, and sleep disturbance. During the workshops, the knowledge gaps were discussed and research projects were proposed to address the gaps. Following recommendations from experts in the field, the FAA funded several studies on the relationship of noise to annoyance and sleep disturbance, which are described in this paper. Workshop attendees expressed an interest in conducting regular meetings to coordinate and communicate research activities and findings, advance collective scientific knowledge, and develop optimal mitigation solutions.

The first Meeting on the Aviation Noise Impacts Roadmap was held in April 2011 in Washington DC. The FAA, National Aeronautics and Space Administration (NASA), Department of Defense (DoD), Department of Housing and Urban Development, National Park Service, Centers for Disease Control and Prevention, National Institutes of Health, National Oceanic and Atmospheric Administration and other federal agencies, international organizations, industry, academia, and the public met to discuss ongoing activities and future noise impacts research needs. Based on presented material, discussion and responses to knowledge gaps questionnaires, the Aviation