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AIRCRAFT NOISE: ANNOYANCE, HOUSE PRICES AND VALUATION

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INTRODUCTION

"Nobody wants to buy your house. It's the aircraft noise. You'll have to reduce the price a lot."

Aircraft noise around airports causes annoyance, and tends to reduce the price of affected properties. Can annoyance be 'costed' by examining house price reductions? Are there other ways of valuing annoyance in monetary terms? This short paper summarises key research results and poses some questions.

BACKGROUND

A previous paper (Brooker 2004) reviewed UK Government sponsored studies to determine what index should be used to assess aircraft noise disturbance near major airports. This Aircraft Noise Index Study (ANIS) included extensive social surveys and noise measurements around these airports, plus detailed statistical analyses. The main result of the study was that Leq (A-weighted) would be an appropriate index, and government made the decision to use the 16-hour Leq for the UK aircraft noise index.

But people's expressed annoyance is not the only way of assessing the impact of aircraft noise. Increasingly, research studies and government policy have tried to 'cost' the disturbance caused by noise. Current UK Government policy states (DfT, 2003):

> "…we will work to ensure that aviation meets its external costs, including its environmental and health costs. The aviation industry has a responsibility to reduce its impacts under the 'polluter pays' principle."

Valuation of aircraft noise's external costs is a vital component of environmental impact assessment. If, say, Heathrow airport's runways are operated differently, or if new runways are built, then what are the corresponding environmental costs? What are aviation's 'external costs' for noise disturbance?

Very accessible general guides to environmental economics are the King and Mazzotta website (2006) and the early chapters of Bateman et al (2001). Environmental economics starts with the concept of 'human well-being'. Environmental costs decrease this well-being. They usually occur because the activities of firms and individuals affect third parties. Airlines flying people to and from airports produce aircraft noise, which disturbs nearby residents, ie reduces their well-being. But these residents generally do not have what are termed ‘property rights’: they do not own some specific level of peace and quiet; and they cannot take legal action against the airport, the airlines, the passengers, the local planning body that permitted the airport to be built, or the Government. These particular kinds of property rights were specifically removed under various UK Government civil aviation acts during the last century.

The absence of these property rights means the absence of a direct commercial market for peace and quiet, so how can costs be estimated? Economists have developed ways of inferring these costs by indirect means (see HM Treasury (2003)). Figure 1 compares some of these methods with the measurement of annoyance and gives some aircraft noise examples. Some context is needed to understand Figure 1. Well-being is determined by the kinds of things that people prefer (‘dislike’ is a negative preference). There are two basic ways of measuring preferences:

> Preferences are revealed through actual choices/market behaviour or are stated through questionnaire (ie market research) procedures.
>
> Quantitative measurement of a preference is found from the individual's willingness to pay (WTP) for the avoidance of a cost, or their willingness to accept compensation for tolerating a cost.

For aircraft noise, the most important Revealed Preference method is known as 'Hedonic Pricing’; while the two most common Stated Preference (SP – or WTP) techniques are known as Contingent Valuation and Contingent Choice – see Figure 1. It is important to note that the results of these methodologies must represent the responses of large numbers of typical individuals exposed to aircraft noise. The results from the research literature are examined in turn.

HEDONIC PRICING

The name Hedonic Pricing (HP) is an unfortunate product of economists’ liking for Greek words. Hedonic is the adjective from hedonism, ‘pleasure’: it and merely refers to people wanting to make decisions that deliver the most pleasure, taken as a whole. The decision of most relevance to aircraft noise is that of buying a home near – or not near – to an airport. All other things being equal, houses tend to cost less near to an airport; the major reason for this being that most people prefer quite environments to noisy ones – a revealed preference. These are obvious statements, but turning the obvious into something quantitatively usable has led to a considerable body of research work.

The earliest HP research that successfully combined theoretical economics and empirical data about property was Walters (1975). Since then, there have been many HP studies on the effect of airports on property prices, but the basic methodology proposed by Walters is still in place. The empirical model is:

$$\text{Log } V = A_0 + A_1 (\log \mathbf{Z}) + A_2 \text{ Leq}^* + U$$

Here:

V = house price

Z = vector of house factors, eg size, quality of area

Leq* = Noise index, generally Leq-based, measured in dB

A_0, A_1, A_2 = constants to be determined by statistical means, usually multiple regression fitting

U = error term, assumed to vary ‘randomly’

Some economic researchers incorrectly say that Leq* ‘is’ annoyance, rather than being a metric used to measure annoyance. The key result from statistical analyses is the value of A_2. Multiplied by 100, it is the Noise Sensitivity Depreciation Index (NSDI):

NSDI = Percentage decrease in property price / Increase in Leq* value

Thus, if the NSDI is 1%, a property exposed to 65 dB Leq* sells for 10% les than the same property located at 55 dB Leq*.

There have been dozens of studies to estimate NSDI values for particular airports, published in journals of economics, (real) estate finance, banking and urban studies. Most studies are for the USA, Canada and Australia. Recent review articles are by Schipper et al (1998), Navrud (2004 – work initially reported in 2002); and the most recent by Nelson (2004). These are complex statistical exercises, given the need to control for several effects, in particular the positive house price effects of accessibility to an airport and its employment opportunities (eg see Tomkins et al, 1998). Nelson estimates a weighted-mean NSDI of 0.58% per decibel for pooled USA and Canadian data, using L_{dn} as the noise index.

Results from more recent USA/Canada work than the studies in Nelson’s dataset, eg Cohen and Coughlin (2005), McMillen (2004), Gillen (2004), are generally consistent with these values. There is also some interesting work on Amsterdam airport by van Praag and Baarsma (2005), which is discussed later here. Typically, 55 L_{dn} is used as the lower cut-off value for aircraft noise effects, although there is considerable debate about this (eg see Navrud, 2004).

There has been limited UK HP work on airport effects, but the NSDI values are similar to Nelson’s statistical estimates, eg Gautrin (1975), London Heathrow: 0.62; Pennington et al (1990), Manchester: 0.47; Tomkins et al (1998), Manchester: 0.78. In some studies, aircraft noise was a component of a mainly road traffic environment (eg Bateman et al, 2001).

STATED PREFERENCE

In contrast to HP studies, there are few aircraft noise SP studies. There is not complete agreement on the right methodology to use, so some effort is required to put the results into some common form. Navrud (2004) critically reviewed European SP studies published up to 2002, but found just two of reasonable quality that used an Leq* base. Pommerehne’s 1988 study at Basel, Switzerland, produced a 43 € WTP/dB/hh/year. Thune-Larsen 1995 work at Oslo Airport Fornebu, Norway produced a 190 - 959 €WTP/dB/hh/year. Here, WTP/dB/hh/year is Willingness-to-pay (WTP) per decibel (dB) per household (hh) per year, reported in national currencies in the year of the study and converted to 2001-value euros.

Feitelson et al (1996) carried out SP studies near an undisclosed airport. The key question is shown in Figure 1. The house price effect was about four times that of a typical HP analysis. However, this was in the context of a major airport expansion, with a very noise exposure – of the order of 75 Leq.

Since 2002, three other SP studies have been published: Bristow and Wardman et al (2003) [Manchester, Lyon and Bucharest]; Carlsson et al (2004) [Stockholm]; and Van Praag and Baarsma (2005) [Amsterdam].

Bristow and Wardman et al (2003) studied three airports, in different countries, for the Eurocontrol Agency. The study is well documented, and they stress that this was very much exploratory work to test methodologies – for both CV and CC – and to estimate order-of-magnitude numbers. Three different types of SP experiment were used: embedding aircraft noise nuisance within a broader quality of life context; offering changes in aircraft movements by aircraft type within specific time periods; and offering changes in generic aircraft movements by time of day. Figure 1 shows an example of the kind of question used.

Bristow and Wardman et al's (2003) Key Conclusions include estimates of the relative value per week of removing/adding flights during different periods of the day. Respondents in Manchester value a change of one aircraft per hour in the daytime at €0.87 and a change of one aircraft per hour in the evening at €0.31. The corresponding figures for Lyon are €1.10 and €1.26.

Carlsson et al analyzes the marginal WTP for changes in noise levels related to changes in the volume of flight movements at a city airport in Stockholm, Sweden, by using a choice experiment:

> "When estimating marginal WTP for different times of the day and days of the week, we find that these vary with the temporal dimensions: mornings and evenings have higher marginal values… A large proportion of people are satisfied with the current level of flight operations at the airport and are not prepared to trade off any change for monetary compensation or payments."

This is consistent with Bristow and Wardman's results, shown here for Manchester in Figure 2, which show the variety of reasons that people give for <u>not</u> participating in a CV exercise. Unfortunately, Carlsson et al's acoustics content is negligible – there is no analysis in terms of Leq or any other noise index – so it has little general value here.

The study by van Praag and Baarsma (2005) into the effects of Schiphol airport introduces a novel method. It is not an SP technique, but as it relies on questionnaires rather than HP techniques, it is included as such. The authors say that a SP approach would have considerable difficulties, because it implies the risk of strategic behaviour, for example, people overestimating noise and/or boycotting surveys. Amsterdam and Schiphol airport's noise nuisance are quoted as 'hot issues' and a 'playing field for environmental activists'.

Van Praag and Baarsma use a survey questionnaire to find individuals' 'ordinal life satisfaction' – or 'happiness' – measured on a (1–10) scale originally developed by Cantril. A person's answers depend on income/family size/age/etc, exposure to aircraft noise and other variables. In essence, this data, analysed by a complex form of multiple regression analysis, produces a best-fit equation explaining happiness as a function of income, noise and these other variables. It is then possible to estimate the change in income that would be necessary to compensate for a specified change in noise exposure.

The main van Praag and Baarsma result is that the net income compensation needed to neutralise an increase in noise from 20 to 35 Kosten Units (Ku – the old Netherlands noise index) is about 3% of net annual household income or about 9% of housing costs. For a noise-insulated house, the compensation needed is much less, about one-third of those percentages. [20 and 35 Ku correspond approximately to 53 and 58 L_{den} respectively.]

ISSUES

The increasing use of valuation techniques opens up some important questions. Do the techniques broadly do what they are intended to do? If so, are they accurate? Do they complement or conflict with annoyance results? A selection of these kinds of issue is discussed below.

Are HP studies concerned with aircraft noise annoyance?

There are some misunderstandings about HP studies for aircraft noise. Consider the parliamentary answer below:

> ***"Hansard 17 July 2003: Property Prices (Heathrow Flight Path)*** [125824]:
>
> ***Mr. McNulty:*** House prices around Heathrow vary and are affected by many factors, as elsewhere. Both the economic benefits of the airport and the environmental disbenefits will affect property prices in a wider area than under the flight paths. There is already extensive worldwide literature on the effect of aircraft noise on house prices although the literature largely concerns day time noise and it is difficult to isolate aircraft noise (or any other single factor) as a discrete influence on house prices."

The reference to 'day time noise' misses the point. Most HP studies use L_{dn} or L_{den}, both of which contain a night-time component. House prices are affected by the total noise effects that people 'know' about, including daytime/evening annoyance; and perceived sleep disturbance. They may even encompass the possible effects of learning impairment at local schools – families often move house to be nearer to 'better' schools. But note also that house prices are affected by other airport-related issues, eg air pollution levels and the associated road traffic.

Do HP studies estimate somebody's 'well-being'?

The use of phrases such as 'well-being' and 'willingness-to-pay' do not spell out whose beliefs and decisions are being examined. They are not those of the 'average person' summed over time. There is comparatively high housing mobility in the UK, so people who are very perturbed by aircraft noise – who find it 'unacceptable' – will tend to move away from high Leq areas; to be replaced by people who generally are less perturbed, and who may indeed work for airport-related firms. HP analyses will compare these kinds of people with generally 'less perturbable' people living in much lower Leq areas. The price differentials would therefore tend to underestimate the loss of 'well-being' felt by a 'typical' person in a low Leq location exposed to much higher noise exposure.

Are SP CV studies accurate?

CV has been widely used for 20+ years, but there is considerable controversy over whether it properly measures people's willingness-to-pay for environmental quality. King and Mazzotta (2006) list sixteen issues and limitations of CV (compared with four advantages), finishing with: "Many people, including jurists, policy-makers, economists, and others, do not believe the results of CV". This is mainly since SP surveys are hypothetical in both the payment for and provision of the economic good in question. This so-called hypothetical bias is reviewed in Murphy et al (2005), which suggests that the average bias is about 2.5 to 3 times greater than actual cash payments, and also that this covers considerable variations.

Does Annoyance 'equal' Valuation?

If simultaneous annoyance and SP valuation exercises were to be carried out on the same people, would Annoyance 'equal' Valuation (using capitals to indicate that these are the best measures of their kind)? Are the two highly correlated statistically? Are they in reality measuring essentially the same thing? To reiterate, authors of valuation studies quite often say that their results are correlated with annoyance, but in practice they match valuation results against an indicator of annoyance – shown here as Leq*. Two more analytical questions are:

> Are the core noise variables the same, ie are both Annoyance and Valuation specified by some appropriate 'core' function of weighted noise energies?
>
> Is Valuation directly proportional to some kind of strictly monotonically transformed function of Annoyance?

Valuation results specified in £s or $s may tempt people into believing that Valuation figures have somehow been demonstrated to have 'cardinal' properties, eg that two individuals' one (SP) £ 'equals' another individual's two £s (see discussion on Scale properties in Brooker (2004) and Stevens (1946)).

Are Valuation results from other countries applicable to the UK?

The Bristow and Wardman (2003) results already suggest that Manchester and Lyon have markedly different SP ratings for day and evening aircraft noise. Van Praag and Baarsma (2005) attempted to carry out a HP study for people living near Schiphol, but say they failed totally. They comment that: "…house prices in the Greater Amsterdam Area do not significantly depend on noise nuisance. Undoubtedly, this has to be explained by the chaotic situation in the Amsterdam housing market." This is diagnosed as the product of long-term housing shortages, government regulations and comparatively large transactional costs for moving between properties.

The Netherlands housing market is probably actually more typical of European countries than is the UK's. Figure 3 is from van Ommeren and van Leuvensteijn (2003). It shows on the vertical axis how frequently people move and on the horizontal axis the costs of housing transactions as a percentage of the property value. The high transaction costs in most of these countries imply that the economic assumptions necessary for HP calculations, eg see Bateman et al (2001), will be largely absent.

Can SP CC Results help to create better noise indices?

The European Commission endeavours to have a high reputation in environmental matters, but its introduction of L_{den} for aircraft noise disturbance has not been supported by large-scale Europe-wide quantitative evidence (Brooker, 2004). The major methodological problem in substantiating L_{den} is the intercorrelation between Leq values in different time periods. Can CC help to provide support for L_{den} (or otherwise)? Some Bristow and Wardman (2003) results are developed below, with several simplifying assumptions, to illustrate the ideas.

L_{den} is a variant of Leq. L_{den} adds an artificial extra number of decibels to aircraft noise levels occurring in the 4-hour evening (5 dB) and 8-hour night (10 dB). In the following equation: ** denotes 'to the power of'; * is times; the i subscript denotes the i^{th} noise event; SEL_i is the noise energy in the i^{th} aircraft noise event adjusted so that it lasts for one second; d, e and n are day, evening and night; W_e = 5 and W_n = 10; and T is 24 (hours).

$$L_{den} = 10 \log \{ T^{-1} [\Sigma_{di}\ 12*10**(SEL_{di}/10)$$
$$+ \Sigma_{ei}\ 4*10**((SEL_{ei} + W_e)/10)$$
$$+ \Sigma_{ni}\ 8*10**((SEL_{ni} + W_n)/10)]\}$$

What do Bristow and Wardman's estimated values for changing the number of flights in the day and evening periods, noted above, say about day and evening weightings? Suppose that SP CC and Annoyance have the same core functional form in noise terms (which still allows for one being a mathematical function of the other). Assume that Bristow and Wardman's daytime and evening match the L_{den} periods (precise definitions were not used). For Manchester, twelve fewer daytime aircraft are worth €0.87 and four fewer evening aircraft are worth €0.31, so one aircraft over the day period is priced at 0.87 / 12 = €0.0725, and one aircraft over the evening period is priced at 0.31 / 4 = €0.0775. <u>If</u> the core functional forms are the same, ie sum the SEL values as in L_{den}, <u>and</u> if the respondents are judging day and evening aircraft to have the same average SEL value, then the ratio 0.0775 / 0.0725 = 1.069 should equal 10**(W_e/10). This gives the evening weighting W_e = 10 log 1.069 = 0.3 dB for Manchester. In contrast, the Lyon results give W_e = 10 log 3.44 = 5.4 dB. The Manchester 0.3 dB and Lyon 5.4 dB values compare with L_{den}'s (European) 5 dB weighting.

CONCLUSIONS

The sketch above indicates that valuation techniques appear to be a useful complement to annoyance estimates. However, the apparent precision of £, $ and € outputs can obscure the economic, psychological and statistical modelling assumptions that are being made. Contingent choice methods may well be helpful in providing (eg) some quantitative basis for evening and night weightings – but this would require further studies with sufficiently large statistical samples.

Method	General Description	Aircraft Noise Example
Annoyance *(or Disturbance)*	Ask people directly, in a survey, how much aircraft noises disturbs them and/or how much they are annoyed at their activities being disturbed	How much does aircraft noise bother or annoy you: Very much? Moderately? A little? Not at all? (eg Brooker, 2004)
Hedonic Pricing HP *(Revealed Preference RP)*	People may be willing to live in an area that is subject to aircraft noise, but only if they receive a discount on the price. The size of the discount measures their aversion to aircraft noise exposure.	How much did they pay for their house and when? How many bedrooms and/or bathrooms has it got; how far is it from the airport; how big is the garden, etc, etc? (eg Cohen and Coughlin, 2005).
Contingent Valuation CV *(Stated Preference SP)*	Ask people, in a survey, how much they would be willing to pay (WTP) for an aircraft noise environment; or the amount of compensation they would be willing to accept to give it up. Thus, WTP is *contingent* on a specific hypothetical scenario.	What would you pay for this kind of house in any area with no noise; and then how much if there was frequent aircraft noise; and then how much if there was severe noise? (eg Feitelson et al, 1996)
Contingent Choice CC *(Stated Preference SP)*	Like contingent valuation, it asks people to make valuation choices based on a hypothetical scenario. But it does not ask people to state their values directly. Values are inferred from the hypothetical choices or tradeoffs that people make.	An individual currently facing 10 daytime flights per hour, 6 evening flights per hour and paying €20 per week in tax, is asked to state which is preferred and second preferred of a reduction in daytime flights of 2 per hour, a reduction in evening flights of 2 per hour and a 2€ per week reduction in tax. (eg Bristow and Wardman, 2003)

Figure 1. Comparison of Annoyance and Stated Preference Measures

Question: "Overall what is the most that you would be willing to pay in additional council tax PER WEEK to HALVE the overall number of flights"
In the day time (ie every day)
In the evenings (ie every day)"

Response	**Day %**	**Evening %**
No answer	6.5	10.0
Zero	68.0	64.5
Willing to pay	25.5	25.5

Zero Willingness to Pay	**%**
Not bothered about aircraft and a reduction is not worth anything to me	28.3
I am bothered by aircraft, but believe the benefits of the airport outweigh the cost in terms of noise	13.0
I am bothered by aircraft, but do not believe that any changes would take place	26.1
I am bothered by aircraft, but not willing to pay because I have a right to a quiet environment	33.3
Other	2.9

Figure 2. Manchester CV questions (adapted from Bristow and Wardman (2003))

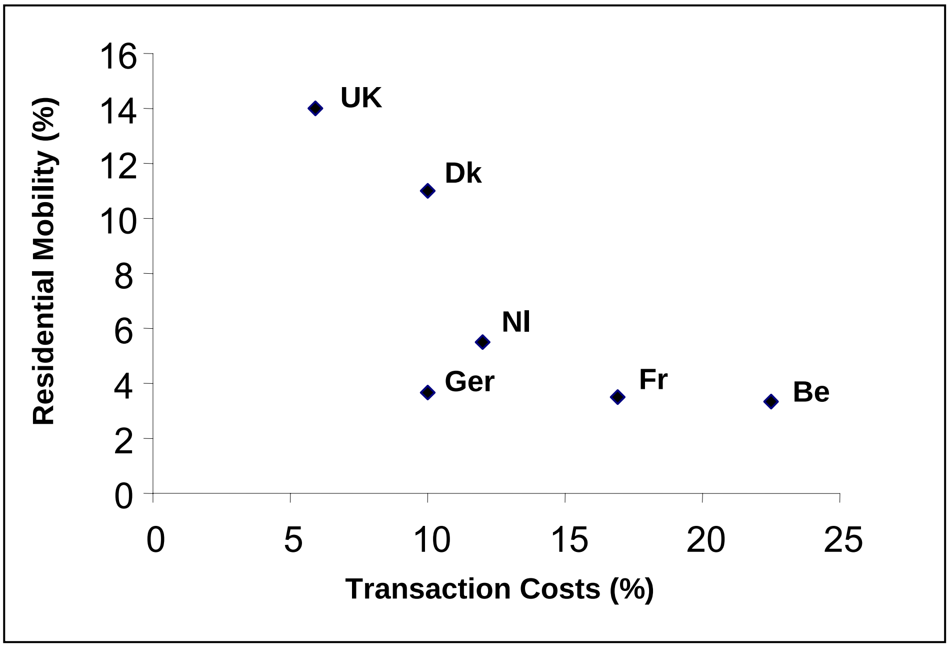

Figure 3. Residential Mobility (%) and Transaction Costs (%) (adapted from van Ommeren and van Leuvensteijn (2003) [Be = Belgium, Dk = Denmark, Fr = France, Ger = Germany, Nl = the Netherlands, UK = United Kingdom]

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