Integrating noise into government appraisal and cost benefit analysis in the UK

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INTRODUCTION

This paper seeks to explain how noise is being integrated into Government appraisal and cost benefit analysis in the UK. Economic evidence and analysis play a central role in the development of evidence based policy by providing appraisal tools which can quantify the effects of noise. In this way it is possible incorporate noise into decision making along with the other costs and benefits which a particular policy option may involve. The UK government seeks to disseminate these tools as widely as possible so that they are available not only for policy appraisal but also to highlight some key questions for use in further research into the impact of noise.

The first part of this paper gives a brief overview of the UK Government's theoretical and practical approach to creating the noise appraisal tools which we currently use. The second section outlines the results of the latest research into specific impacts of noise and how that work can be integrated into public decision making.

VALUATION METHOD

The Interdepartmental Group on Costs and Benefits Noise Subject Group (IGCB(N)) was established in 2007 with the remit to develop a robust economic methodology to value noise. The IGCB(N) then looks to disseminate these methodologies for use in appraisal across all UK Government policies. The IGCB(N) is an interdisciplinary group of analysts from across most major UK Government departments.

In August 2008 the IGCB(N) published its first report which conservatively valued environmental noise pollution in the UK at £7-10bn per annum (IGCB(N) 2008).

This report also established the 'impact pathway' approach as the central framework for developing appraisal tools for use in the evaluation of UK Government policies. This approach follows noise from its source, through propagation, and through its effect on the ambient noise level, to the final impact on the exposed population, which allows the effect of the additional noise to be quantified, and where possible assigned a monetary value for use in Cost Benefit Analysis.

Noise is commonly defined as any unwanted sound. The individual making the sound (through driving their car) will not view it as noise as such, but third parties in the exposed population able to hear it will. It can be argued that noise is an example of market failure if noise is considered as a negative externality (defined as a cost imposed upon a third party by the producer/consumer of a good or service where the third party had no say in the decision to produce/consume). Noise fits quite well into this aspect of economic theory, as noise is usually generated as a by-product of other economic activity, such as transport used in order to use services. The effects of this noise on the exposed population (third party) effectively amount to a cost which when monetized can be used as an estimate for the cost to society of environmental noise pollution. Figure 1 below shows this concept diagrammatically.

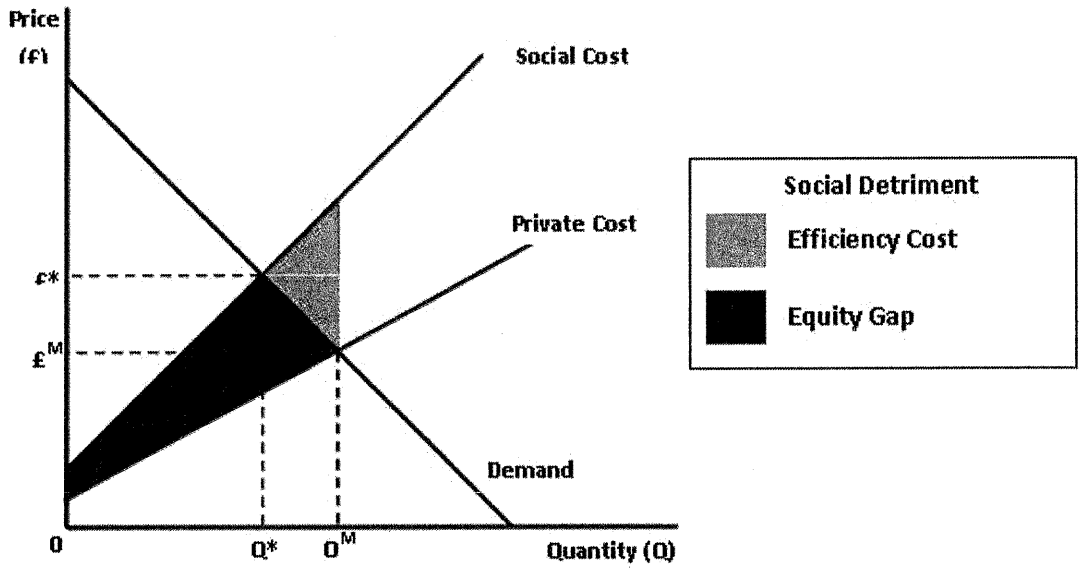

Figure 1: Negative Externality Diagram

The above diagram illustrates a classic negative externality. In this case the social cost of producing/consuming noise creating good/services is greater than the private costs paid by the producer/consumer. This difference between the private cost and the social cost can be seen as the value of noise pollution (the shaded area in Figure 1), this is the cost which is being inflicted on the exposed population. This is an equity problem as it is unfair that these people should bear the cost of an economic decision they were not consulted on. It is also an inefficient use of resources, as when the externality exists, the private cost, and therefore price, of those goods/services is lower than the true cost to society, and demand is consequently higher at that price. This results in overproduction ($Q^* - Q^M$ in Figure 1), as the costs of providing this output exceed the benefits, resulting in deadweight welfare loss (the green area). These resources could be used far more efficiently elsewhere in the economy.

While this demonstrates the detriment from noise, in order to inform decisions it is necessary to assess the evidence on the scale of the problem. If the detrimental effects of noise can be quantified and monetized, we can essentially estimate the value of the colored area in Figure 1. For presentational reasons the IGCB(N) first report split noise pollution down into four key effects which could then be analyzed separately in detail. These effects were on:

- Public amenity, reflecting the public's conscious reaction from noise exposure (both positive and negative), this was estimated at £3-5bn per annum.
- Health, including long term health effects such as changes in mortality and temporary health effects such as acute myocardial infarction (AMI), the value of these effects was estimated at between £2-3bn.
- Productivity, which largely concerns sleep disturbance due to noise causing next day fatigue, or sleep deprivation leading to an increase in accidents in the work place, leading to health costs, this pathway, was estimated at approximately £2bn per annum.
- Environmental impacts, such as impacts on breading patterns and damage to natural ecosystems.

Estimation and valuation of the public amenity costs of noise has been considered in transport appraisal since 2005. Monetization has been carried out using a hedonic pricing model which estimates the difference between house prices as a result of different noise levels. The Department for Transport (DfT) uses this methodology to calculate its Webtag valued, which are used in the appraisal of road and rail projects (Department of Transport 2011). This methodology assigns values for a per decibel change in noise levels per household, making it relatively simple to quantify the amenity effect of a given project which is expected to lead to a change in noise levels of a given amount (these values are shown below in Table 1).

Table 1: Valuation of Amenity and Health effects of noise (Mid-point marginal values are used for each volume range (there is a full list of per decibels in the IGCB(N) second paper)

Volume L_{aeq}, 18hr dBA	Cost per household per dB change	
	Health value	Amenity/Annoyance costs
55-60 dB	£2.70	£40.00
60-65 dB	£10.47	£53.20
65-70 dB	£15.71	£66.40
70-75 dB	£29.62	£79.60
75-80 dB	£41.01	£92.80
80-85 dB	£53.60	£98.00

In its first report IGCB(N) prioritized the investigation of health effects. Defra, on behalf of the IGCB(N), commissioned experts Dr Bernard Berry and Dr Ian Flindell to undertake a review of research into the links between noise and health (Berry & Flindell 2009). The report produced several key findings: Quantifiable empirical evidence was found linking noise to Acute Myocardial Infarction (AMI) (heart attacks), and other cardiovascular illnesses. Evidence was identified linking noise with other health effects such as; annoyance, mental health, hypertension (high blood pressure), cognitive development in children, and hearing impairment, though monetary valuation of these impacts was not judged to be sufficiently robust to include these effects in appraisal methodology at present.

In response to this work the IGCB(N) published its second report (IGCB(N), 2008). This paper incorporates Acute Myocardial Infarction (AMI) into the monetary valuation methodology of noise using the Babisch does-response function (Babisch 2006) recommended by Berry and Flindell. This was a major step forwards in the valuation of environmental noise, and this relationship was also formalized into an appraisal tool valuing the effect per household of a per decibel increase in environmental noise levels, which can be used together with the amenity appraisal tool. These values are shown in Table 1 below. The IGCB(N) second paper also agreed dose response functions linking environmental noise with hypertension and sleep deprivation: For each 1 dBA L_{den} increase in exposure per household above 55 dB, there is an expected increase in hypertension of around 16 new cases per 1,000 households. For sleep disturbance, an increase in night time noise levels from 70 dB to 71 dB, would lead to 22 additional cases of sleep deprivation per 1,000 households. At the time we did not have the methodology for using these relationships to estimate the monetary value of these changes.

Once this was agreed amongst IGCB(N) members, these appraisal values became supplementary departmental guidance, and are now classified as appraisal best practice guidance. This represents significant progress over the past three years in

which IGCB(N) has existed. However, the IGCB(N)'s remit is to ensure that appraisal is based on the best available evidence, and seeks to keep up to date with advancements in academic work on noise.

FURTHER RESEARCH

Despite this progress there remain notable gaps and uncertainties in the evidence of the impacts of noise. One of the main criteria when selecting research areas is the potential impact of noise in that area, as it makes sense to estimate the areas with the largest impact, so that the most important effects are included first. In September 2010 Defra commissioned research on some key gaps in the evidence base relating to; health, amenity, and productivity. Most of this work seeks to quantify impacts to so that they can be compared to the other impacts to determine their magnitude, and then incorporated into appraisal guidance. The impacts that were researched and the findings are explained in more depth in the following sections.

Quantifying the link between health effects and environmental noise related hypertension

The IGCB(N) second paper introduces the dose-response relationship between environmental noise and hypertension, for example, a 1 dBA rise in noise levels affecting 1,000 households would lead to 16 new cases of hypertension in the exposed population. This methodology can be used to estimate the quantitative (but not monetized) impact of noise on hypertension. However, to determine how large the impact of hypertension is relative to other health effects it is useful to monetize these effects. The impact pathway approach functions by identifying end points of emissions to which monetary values can then be ascribed. In the case of hypertension, these end points are the additional risks of secondary health outcomes that arise from or can be exacerbated by hypertension. These final health outcomes can then be quantified and monetized to provide an estimation on the marginal impact of noise on health in this pathway.

This project was undertaken by the Health and Safety Laboratory and was completed in April 2011 (Harding et al. 2011). After conducting a literature review the main health effects from hypertension were; stroke, ischaemic heart disease, chronic renal failure/end-stage renal disease, dementia, pregnancy complications, eye conditions, and sexual function. It was necessary to prioritize three health effects to move forwards for monetary valuation, this decision was based on the strength of the evidence on the relationship between the health effect and hypertension, and the likely cost of the health effect monetized. Ischaemic head disease, stroke, and dementia were prioritized.

The final health effects were quantified in terms of Quality Adjusted Life Years (QALY), the Department for Health's recommended figure in appraisal of health effects, this QALY has a value of £60,000 ($97,000), which was then multiplied by the risk of hypertension associated with environmental noise and the risk of each health outcome associated with hypertension. This was then applied to data collected during Round 1 noise mapping (a requirement of the Environmental Noise Directive (2002/49/EC)), to estimate the impact of road and rail traffic noise. The total impact of road traffic noise was valued at £1,023m (£277m for AMI, £300m for stroke, and £446m for dementia). However, this only covers approximately 40 % of the UK popu-

lation as mapping was only done for the 23 largest agglomerations in England, although this is the 40 % of the population most exposed.

IGCB(N) are currently in the process of developing a response to this research to suggest how and if this evidence will be reflected in appraisal guidance. Furthermore, this work has also highlighted some further gaps in the methodology. Most significantly, the current methodology only considers the impact of noise on the exposed population without hypertension (by estimating the additional number of cases of hypertension due to noise), and if the effect of noise causing increased blood pressure on those with pre-existing hypertension was included the estimate of the impact would be more accurate. This, however, would require more research on the relationship between environmental noise and systolic blood pressure. Also, this report only values the cost of morbidity/mortality to the individual due to these health effects. The costs to society in terms of health and social care in 2008 were estimated to be £8bn for coronary heart disease, £5bn for stroke, and £23bn for dementia, so a proportion of these costs should be included at this level.

Quiet areas

Having access to somewhere quiet is important: a 2009 ICM Poll found that 91 % of respondents in the UK thought that existing areas of quiet need protecting. Furthermore, the Environmental Noise Directive stipulates that member states must protect existing quiet areas in urban agglomerations. Much of the literature on noise focuses on the detrimental effects of noise rather than on the benefits of quiet, which may be greater than avoiding the costs of high noise levels. This piece of work attempts to assess the relative importance of quiet against other issues through attempting to estimate the monetary value to society of quiet areas.

Defra commissioned URS Scott Wilson Ltd to undertake the project, and the final report was completed in April 2011 (Rowcroft et al. 2011). The project's ultimate aim was to produce a methodology for valuing quiet areas. This is difficult because many areas that are considered quiet are often parks or other urban open spaces where quiet is just one of a number of benefits drawn from the space. Moreover, many of the benefits are not easy to separate from quiet (e.g. an escape from hustle/bustle or a place for rest/relaxation). The key question to answer is therefore how much greater is the value of an area which is quiet, relative to an identical area which is not? Disaggregating the benefits (and hence value) of quiet areas is a key challenge, as people typically do not pay for access to these places. The paper also sought to investigate how people's valuation of a particular area changed in response to increasing environmental noise levels through asking how their usage of an area would alter in response to changing noise levels.

The report began by conducting an extensive literature review on the available evidence in order to build on the existing valuation studies in this area. This is a relatively new area of research (although now rapidly gaining in prominence) so there was a relatively small number of valuation studies found suitable for use. In light of this, the report suggested three ways in which to use the available information to value the benefits of quiet: using a range of green space values as a proxy for quiet areas to identify an upper range estimate of the value of quiet areas, estimating the opportunity costs of maintaining undeveloped sites, and making use of existing values for noise disturbance in the home (using DfT's WebTAG values which are derived from a study on house prices). Some primary research conducted as part of the project

found that one third of respondents would vacate an open space if continually subjected to loud traffic noise. An illustrative case study on a park in Westminster, used both willingness to pay figures available for parks offering similar amenities and primary survey data to estimate the value of quiet within the green space. This was estimated to lie between £284,130 and £1,782,660 per year (this range in value is principally driven by the willingness to pay estimates used). Applying this approach on a national scale, the total value of quiet in open spaces could be up to £1.4bn per annum. Whilst quiet is only one component of the total economic value of these open spaces, this result implies that the value of all the open spaces in the 23 agglomerations would be very large, with quiet being a significant component in that value.

This report, on what is essentially a new area of study, makes a clear step forwards, as not only does it move us to the frontier of the available evidence, it has also identified a methodology, and also filled some important evidence gaps. This is a relatively unresearched area, and this report makes a very useful contribution to the literature. Furthermore, the paper makes some recommendations for further work including: identification of the criteria/attributes that define different types of 'quiet areas' or spaces people value specifically because they are quiet, assessing the value or ranking of quiet relative to other properties that characterize 'quiet areas', better defining the relationships between the different types of quiet areas and the value of benefits obtained (i.e. is there a threshold of noise beyond which the benefits of quiet are lost?), determining the willingness to pay for quiet areas and how this changes in response to changing noise levels, and conducting trial studies of quiet areas using noise mapping/sound measurements and data on user numbers to identify empirical relationships. In sum, more work is needed to improve the consideration of acoustic factors when assessing the value of open spaces, as quiet is an implicit feature in how people value open spaces which needs to be done before a more formal appraisal tool can be created.

Estimating the productivity impacts of noise

The IGCB(N) first paper estimated that the productivity costs of environmental noise were roughly £2bn per year, however, this indicative estimate was based on a single link through sleep disturbance. However, noise can affect productivity through several different pathways such as: Noise causing sleep deprivation leading to tiredness, causing lower next day effectiveness. Higher noise near schools can lead to reduced academic performance, resulting in lower lifetime earnings. Also, the health effects of noise may lead to absence from work, which results in lower productivity as output falls. Defra commissioned Transport Research Laboratory (TRL) to conduct a literature review to assess the available evidence (Morgan et al. 2011). The main pathways which noise affects productivity are shown below:

- Noise → Sleep Disturbance → Tiredness → Accident/Inefficiency
- Noise → Stress → Short-Term Health Effects → Absence from Work
- Noise → Distraction → Lower Educational Attainment → Lower Lifetime Earnings
- Noise → Distraction in Workplace → Reduced Output

The report found that it would be possible to produce an appraisal tool linking sleep deprivation to a loss in productivity, though there are some issues with the dose-response relationship employed, as much of the evidence is based around self reported sleep disturbance which does not always correlate well with lab based

measures of sleep quality. Also, noise events rather than L_{den} measures of noise have been shown to be a more accurate measure of awakenings. Productivity loss through sleep deprivation has been estimated at 0.8 % of GDP in Australia in 2004, and in Japan in 2003 it was estimated to cost the economy $30.7bn per year, these reports suggest that it would be possible to produce a high level estimate for the UK, and the results may be quite significant relative to the existing monetized impacts of noise.

The report also highlighted the potential loss in productivity from noise induced health effects. For example, if someone was affected by noise induced hypertension then they may be less productive and absent from work which would result in a productivity cost. At present we value the cost to the individual of noise in terms of QALYs but not the cost of the lost output that worker has not produced due to the illness.

CONCLUSIONS

While the evidence base which underpins noise appraisal has developed rapidly a number of notable gaps and uncertainties remain before it can be fully reflected in policy decisions. The next step for IGCB(N) is to produce a response paper which will determine what can be taken from these research projects and integrated into our existing appraisal tools.

This evidence has however identified a wide range of additional areas and questions to continue to develop this area. The key areas where future work/research would, in our view, add the most value are:

- The relationship between noise and systolic blood pressure, so that the effect of noise on those with pre-existing hypertension can be estimated.
- Quantification of the link between sleep disturbance and reduced next day productivity, and also the link between lower academic attainment and lifetime earnings.
- Determination of consumers' willingness to pay for quiet areas, and how this changes in response to increased noise levels.
- The effect and final impact of hypertension (caused by noise) on End-stage Renal Disease.

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