ARTICLE IN PRESS

Transport Policy ∎ (∎∎∎∎) ∎∎∎–∎∎∎

Contents lists available at ScienceDirect

Transport Policy

journal homepage: www.elsevier.com/locate/tranpol

Estimation of the global impacts of aviation-related noise using an income-based approach

Qinxian He [a,*], Christoph Wollersheim [b], Maryalice Locke [c], Ian Waitz [a]

[a] Department of Aeronautics and Astronautics, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, MA 02139, USA
[b] Booz Allen Hamilton, Inc., 22 Batterymarch Street, Boston, MA 02109, USA
[c] United States Federal Aviation Administration, Office of Environment and Energy, 800 Independence Avenue, S.W., Washington, DC 20591, USA

ARTICLE INFO

Keywords:
Aircraft noise
Hedonic pricing
Willingness to pay
Aviation noise impacts
Cost-benefit analysis

ABSTRACT

Current practices for assessing the monetary impacts of aviation noise typically use hedonic pricing methods that estimate noise-induced property value depreciation. However, this approach requires detailed knowledge of local housing markets, which is not readily available at a fine resolution for most airport regions around the world. This paper proposes a new noise monetization method based on city-level personal income, which is often more widely available. Underlying the approach is a meta-analysis of 63 hedonic pricing studies from eight countries, conducted between 1970 and 2010, which is used to derive a general relationship between average city-level personal income and the Willingness to Pay for noise abatement. Applying the new model to income, noise, and population data for 181 airports worldwide, the global capitalized monetary impacts of commercial aviation noise in 2005 are estimated to be $23.8 billion, with a Net Present Value of $36.5 billion between 2005 and 2035 when a 3.5% discount rate is applied. Comparison with previous results based on real estate data yields a difference of −34.2% worldwide and −9.8% for the 95 US airports in the analysis. The main advantages of the income-based model are fewer data limitations and the relative ease of implementation compared to the hedonic pricing methods, making it suitable for assessing the monetary impacts of aviation noise reduction policies on a global scale.

1. Introduction

The demand for commercial aviation is expected to rise steadily in the coming years, with annual growth estimated to be 5% over at least the next two decades (FAA, 2009b; Metz et al., 2007; Schäfer and Waitz, this volume). With this anticipated growth comes increasing concerns regarding the potential environmental impacts of aviation, which include aircraft noise, air quality degradation, and climate change. Of these issues, aircraft noise is of chief concern, as it has the most immediate and perceivable impact on surrounding communities (GAO, 2000; Schipper, 2004; Wolfe et al., this volume). These impacts can include annoyance, sleep disturbance, interference with school learning and work performance, and physical and mental health effects (McGuire, 2009; Swift, 2009). In addition to the physical effects, policy-makers, researchers, and aircraft manufacturers are also interested in the monetary impacts of aviation noise, such as housing value depreciation, rental loss, and the monetary value of lost work or school performance. The quantification of these monetary impacts provides tangible measures with which to conduct cost–benefit analyses of various policy options for aviation.

The objectives of this paper are two-fold. First, the paper introduces a method to assess the monetary impacts of aviation noise in order to evaluate policy alternatives and inform decision-making. The proposed method is termed the income-based noise monetization model, and estimates individuals' Willingness to Pay for noise abatement based on city-level personal income, which differs from conventional approaches that rely on detailed real estate data. The second objective of the paper is to describe how such a monetization model can be implemented within the framework of an aviation policy assessment tool, such as the United States Federal Aviation Administration's APMT-Impacts Noise Module, to estimate the worldwide economic impacts of aviation noise.[1]

* Corresponding author.
E-mail addresses: qche@alum.mit.edu (Q. He), iaw@mit.edu (I. Waitz).

[1] The US Federal Aviation Administration (FAA) is developing a comprehensive suite of software tools that can characterize and quantify a wide spectrum of environmental implications and tradeoffs, including interdependencies among aviation-related noise and emissions, impacts on health and welfare, and industry and consumer costs under various scenarios (Mahashabde et al., 2011). This effort is

http://dx.doi.org/10.1016/j.tranpol.2014.02.020

Please cite this article as: He, Q., et al., Estimation of the global impacts of aviation-related noise using an income-based approach. Transport Policy (2014), http://dx.doi.org/10.1016/j.tranpol.2014.02.020

The organization of the paper is as follows: Section 2 presents an overview of valuation methods used for aviation noise and motivates the need for a new monetization approach. Section 3 details the development of the income-based noise monetization model, with particular emphases on meta-analysis and econometric estimation. Section 4 frames the context for model application by presenting an overview of the APMT-Impacts Noise Module. Section 5 describes the use of the model to perform benefit transfer using a realistic aviation noise scenario; the results of this section not only demonstrate model applicability but also give a benchmark measure of convergent validity. Finally, Section 6 provides some concluding remarks.

2. Background and motivation

In environmental economics, quietness is viewed as an amenity that has an associated economic value. However, because there are no explicit transaction costs associated with this public good, it is necessary to employ non-market valuation methods in order to discern its value to the community (Hanley et al., 1997). The two general categories of non-market valuation methods are revealed preference and stated preference (EPA, 2000).

The most common approach for assessing the monetary impacts of aviation noise is hedonic pricing (HP), a revealed preference technique that uses statistical methods to identify differences in housing markets between noisy and quiet areas to determine the implicit value of quietness (or conversely, the cost of noise) (Wadud, 2009). Typical metrics used in HP are housing value depreciation and rental loss. These real estate-related damages are used as surrogate measures for the wider range of interdependent noise impacts that are difficult to assess separately, although it is recognized that such estimates may undervalue the full impacts of noise.

Hedonic pricing studies typically derive a Noise Depreciation Index (NDI) for one airport region, which represents the percentage decrease in property value corresponding to a one decibel (dB) increase in noise level in the area. Numerous such studies have been conducted for various airports in North America, Europe, and Australia, though few studies exist for other regions. Several meta-analyses have summarized the HP literature, showing that typical aviation NDI values for owner-occupied properties range between 0% and 2.3%, with median estimates between 0.60% and 0.70% (Nelson, 2004; Schipper et al., 1998; Wadud, 2009). Furthermore, NDI values tend to be similar across countries and stable over time (Nelson and Palmquist, 2008).[2]

In addition to quantitatively integrating literature pertaining to a specific topic, meta-analyses also enable researchers to identify trends and make inferences (Stanley and Jarrell, 1989; Rosenberger and Stanley, 2006). In the context of aviation noise, the goal of a meta-analysis is to derive a generally valid relationship between noise level and community impact in order to enable benefit transfer from one location to another. Such transfers are of critical importance to environmental policymaking; because of the broad (potentially global) scope of aviation policies and limited time and resources to perform new valuation studies, it is desirable and necessary to generalize the results from “study sites” to “policy sites” where limited or no data exist (Rosenberger and Loomis, 2000; Navrud, 2004). To date, there has been only one study which uses HP-derived NDI values to estimate the global economic impacts of aviation noise (Kish, 2008). The Kish (2008) study was conducted using a previous HP-based version of the APMT-Impacts Noise Module, which employed an NDI of 0.67% (derived by Nelson, 2004) to perform benefit transfer across 181 airports around the world. These 181 airports are part of the 185 Shell 1 airports in the FAA's Model for Assessing Global Exposure to the Noise of Transport Aircraft (MAGENTA), and comprise an estimated 91% of total global aviation noise exposure.[3] The study concluded that at 2005 noise levels, commercial aviation noise resulted in a total of $21.4 billion in capitalized housing value depreciation in year 2006 US Dollars (USD), and an additional $800 million per year in lost rent.[4] In terms of physical impacts, Kish (2008) estimated that there were over 14.2 million people exposed to at least 55 dB DNL of commercial aviation noise; of that group, 2.3 million were estimated to be highly annoyed based on surveys that related annoyance to noise level (Miedema and Oudshoorn, 2001).[5]

As the Kish (2008) study estimated monetary impacts in terms of depreciation in real estate value, it required detailed data for house prices and rental costs around all 181 airports. However, except for the United States and the United Kingdom, these data were generally not readily available at the required resolution. Instead, a statistical model was employed based on US data, which estimated house price as a function of distance from an airport, number of enplaned passengers at the airport, county-level population density, and state GDP per capita (ICF International, 2008). While this real estate model enabled the APMT-Impacts Noise Module to perform global estimates of aviation noise impacts, it had several limitations: it was derived solely from US property value data, verification tests for three UK airports revealed discrepancies of up to 70% between predicted and observed house prices, and additional estimation models were required to obtain all the necessary inputs (He, 2010). In order to be a practical and reliable tool to support policy analysis and decision-making, a new version of the APMT-Impacts Noise Module was desired, one which does not suffer from the same data constraints and delivers comparable or greater accuracy and robustness for global applications. The development of such a model is the subject of the following sections.

(*footnote continued*)
known as the Aviation Environmental Tools Suite, and was motivated by a report made to the US Congress on aviation and the environment that underscored the need to develop a set of tools and metrics that can be used to assess and communicate the environmental impacts of aviation, as well as inform policy-making decisions (Waitz et al., 2004). The Tools Suite consists of five main components, one of which is the Aviation environmental Portfolio Management Tool for Impacts (APMT-Impacts). The various modules within APMT-Impacts evaluate the physical and socio-economic impacts of policy alternatives as they relate to climate, air quality, and aircraft noise. This paper pertains to the APMT-Impacts Noise Module. For more information on the Aviation Environmental Tools Suite and APMT, see Mahashabde et al. (2011).

[2] An alternative to HP is contingent valuation (CV), a stated preference approach that uses survey methods to explicitly determine individuals' Willingness to Pay (WTP) for noise abatement, or alternatively, Willingness to Accept (WTA) compensation for noise increases. However, the accuracy of CV is often questioned (Diamond and Hausman, 1994), and CV-based studies of aviation noise impacts are very few and yield no consistent results (for example, Navrud (2002) summarizes a handful of such studies, which predict WTP values ranging between €8 per dB per household per year to almost €1000). For these reasons, CV studies for aviation noise will not be discussed further in this paper.

[3] MAGENTA is an FAA-developed model used to estimate the number of people exposed to aviation noise worldwide. The model's database includes 1700 world civil airports that handle jet traffic, which are divided into two sets: Shell 1 includes 185 airports, and Shell 2 the remainder (FAA, 2009a). The base year of the noise exposure estimates is 1998.

[4] An NDI of 0.67% was used to estimate both housing value depreciation and rental loss.

[5] The Day-Night average sound Level, or DNL, is the 24-h A-weighted equivalent noise level with a 10 dB penalty applied for nighttime hours. A similar measure, the Day-Evening-Night average sound Level (DENL), is commonly used in Europe; DENL is very similar to DNL, except that it applies a 5 dB penalty to noise events during evening hours.

Please cite this article as: He, Q., et al., Estimation of the global impacts of aviation-related noise using an income-based approach. Transport Policy (2014), http://dx.doi.org/10.1016/j.tranpol.2014.02.020