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Near-airport distribution of the environmental costs of aviation

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ABSTRACT

Aircraft noise, air quality, and climate change damages are spatially and temporally heterogeneous. While policymakers often focus on aggregate cost-benefit analysis to examine tradeoffs in aviation environmental policy, these analyses do not always indicate who bears the costs or who gains the benefits of aviation. We model both the net cost and distribution of environmental damages from one year of aviation operations across the three environmental domains. We find that populations living at airport boundaries face damages of $100–400 per person per year from aircraft noise and between $5–16 per person per year from climate damages (in 2006 dollars). Expected damages from air quality are dependent on the number of operations at the airport and range from $20 to over $400 per person per year with air quality damages approaching those of noise at high volume airports. Mean expected noise and air quality damages decay with distance from the airport, but for noise, the range of expected damages at a given distance can be high and depends on orientation with respect to runways and flight patterns. Damages from aviation-induced climate change dominate those from local air quality degradation and noise pollution further away from the airport. However, air quality damages may exceed those from climate when considering the impact of cruise emissions on air quality.

1. Introduction

Over the past 50 years, the environmental impacts of aviation, particularly noise, air quality, and climate change, have become increasingly important. Aircraft noise can lead to physical and monetary damages such as annoyance, sleep disturbance, and property damage. Primary and secondary aerosols from aircraft emissions lead to increased incidences of premature mortality and morbidity. Aviation impacts the climate through long- and short-lived emissions species such as CO_2, soot, and NO_X, as well as through induced changes in cloud cover.

Technological or operational decisions in aviation can represent tradeoffs across these domains and with economic efficiency. Cost-benefit analyses do not clearly articulate who bears the costs or receives the benefits of a specific policy. This can be especially relevant in aviation where impacts of noise can be concentrated while climate change impacts are spatially and temporally diffuse. When policy impacts are not distributed equally, especially in the spheres of environmental and occupational health and safety, social equity concerns exist. The Environmental Protection Agency (EPA) recommends identifying the burden of policy costs and addressing issues of environmental and social justice (EPA, 2010).

Aircraft noise is the most readily perceived environmental impact of aviation, and the first to be regulated in 1971. Although there has been further regulation since, aircraft noise is still the greatest concern for communities living near airports (Durmaz, 2011). Noise is expected to remain the single largest aviation environmental issue for the foreseeable future (GAO, 2000, 2007). It is important to understand why aviation noise is the most dominant complaint regarding airport expansion and to compare the total environmental costs of aviation noise to the costs of other domains. There are distributional concerns, a problem where one effect like noise is felt more acutely by only a few people while climate change and air quality are more dispersive, and there is the issue of perception and the ability to attribute damages to aviation as opposed to from other sources. An improvement and expansion of aviation environmental impact analyses is necessary to understand these key issues.

This paper calculates how individuals bear the environmental impacts of a year of aviation operations as a function of their distance from an airport. Noise damages to population annoyance and property value loss are related to day-night level noise contours (dB DNL), which measure the average noise over a 24 h period. Human health impacts from air pollution are related to absolute concentrations of particulate matter in the air. In aggregate, primary particulate emissions for a given class of operations scale closely with fuel burn, which scales with the number of aircraft operations at an airport. Therefore, we expect that damages from air quality on a per

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person basis will be more sensitive to airport size, on an operational basis. We quantify the expected burden of environmental costs around an airport as a function of the number of aircraft operations.

Our environmental analysis is limited to the domains of climate change, local air quality degradation, and noise pollution. Aircraft deicing, fuel spills, herbicides to manage aircraft grounds, and surface runoff from ground support can impact the quality of groundwater and waterways surrounding the airport. Air transportation can also effect the environment through bird and surface wildlife strikes and their associated mitigation procedures (Martin et al., 2011) and through direct and induced land use change changes surrounding the airport. These impacts are outside the scope of this analysis.

A number of studies have investigated the air quality impacts of aviation through modeling or field data analysis. However, these studies focus on a limited number of pollutants or pollutant precursors (Farias and ApSimon, 2006) or are limited to a few airports (Diez et al., 2012; Dodson et al., 2009; Unal et al., 2005). Multi-airport studies have either aggregate damages to human health by airport or global region (Barrett et al., 2010; Levy et al., 2012) or are at too coarse a resolution to capture local-scale impacts (Woody et al., 2011). In addition, local studies have focused entirely on primary particulates, ignoring the diffuse impact of secondary particulates.

Noise impacts of aviation on local communities have been estimated using both contingent valuation (Navrud, 2002) and hedonic pricing methods. While most hedonic pricing studies have focused on individual airports, meta-studies including Schipper et al. (1998), Nelson (2004), and Wadud (2009) have examined more generalized relationships between noise exposure and societal damages. He et al. (in this issue) examines US and global noise damages at a global aggregate and per airport basis, but does not directly examine spatial distribution on the local level.

Studies examining aviation damages across environmental domains on a common scale are limited. Lu and Morrell (2006) investigated the environmental impact of noise and engine emissions at five European airports on a monetary cost basis. Their analysis focused on per-flight marginal damages and airport level aggregation, and did not investigate the spatial distribution of damages. Furthermore, they do not differentiate between climate and air quality emissions damages, only consider cruise impacts for one species (NO_X), and valuate impacts by emission species and not by pollutant concentration. They similarly find that, in aggregate, the costs from engine emissions exceed those of noise. Mahashabde et al. (2011) examined the difference in expected monetized environmental benefits for climate, air quality, and noise for several NO_X stringency policies at a national aggregate level.

2. Methodology

This section lays out how expected damages per person are calculated as a function of distance from an airport for a year of aviation operations across three environmental spheres of interest: noise, air quality, and climate. The domain is limited to US airports. We quantify the expected burden of environmental costs around an airport as a function of the number of aircraft operations.

2.1. Noise

The contribution to monetized damages from aircraft noise is calculated using the APMT-Impacts Noise Module (He et al., in this issue). The APMT-Impacts Noise Module overlays noise contours and population data and then applies a monetization formula based on willingness-to-pay for noise abatement. This monetization is derived from a meta-analysis of residential housing hedonic pricing surveys that correlates willingness-to-pay per dB of noise reduced to citywide income levels. We take expected damages from the APMT-Impacts Noise Module and map them to the airport region being considered. Noise contours for 2006 are taken at a 50 m × 50 m resolution from AEDT/MAGENTA (Roof, 2007). Noise levels are generated in contours at 5 dB DNL resolution, with an estimated contour uncertainty of ±2 dB (He, 2010). Population data are taken at the US census block group level.

The APMT-Impacts Noise Module does not monetize the impact of aviation on noise on areas with low background noise levels, such as national parks (Gramann, 1999; Lim et al., 2008). These areas may be susceptible to damage from overhead flights, and are considered critical research areas (Eagan et al., 2011). There are some limitations to utilizing the APMT-Impacts Noise Module for estimating geographic distribution of damages. While sensitivity analyses performed by He (2010) show code robustness and comparable results to an alternative valuation model described by Kish (2008), no comparison has been performed to show sensitivity on a grid distance level basis. Furthermore, traditional noise damage indices may not be applicable for noise contours above 75 dB DNL, leading to underestimation of damages at very near airport locations (Feitelson et al., 1996). Finally, because the APMT-Noise model was developed using a limited set of airport noise studies, there is the opportunity for generalization error in benefit transfer to airports with a high degree of dissimilarity from the airports in the meta-analysis.

2.2. Air quality

We use the Community Multiscale Air Quality (CMAQ) modeling system (Byun and Schere, 2006) to model aviation emission-attributable $PM_{2.5}$ in the continental United States. CMAQ is a high-resolution regional air quality model used by the EPA to support regulatory impact assessment. Total anthropologic and biogenic emissions not including aviation are compiled from the EPA 2005 National Emissions Inventory (NEI) database. The meteorological input for CMAQ modeling is generated by MM5 (Grell et al., 1994). The CMAQ domain is a Lambert conformal projection of the continental United States and parts of Canada and Mexico consisting of 112 × 148 square grid cells at 36 km × 36 km resolution.

The aviation emissions are derived from the FAA's Aviation Environmental Design Tool (AEDT). AEDT calculates aircraft fuel burn and emissions in 2006 on a flight-by-flight basis, covering the majority of civil aviation. A procedure similar to that applied by Barrett et al. (2012) is used to modify AEDT output for use in our analysis. We apply the three-dimensional model of tropospheric chemistry driven by 2006 meteorological observations from the Goddard Earth Observing System of the NASA Global Modeling Assimilation Offices (GEOS-Chem) to provide boundary conditions to CMAQ simulations (Bey et al., 2001).

While CMAQ provides the average particulate matter concentration over a grid cell, its coarse resolution fails to capture local peak concentrations. A rapid dispersion code (RDC) is applied to efficiently calculate the long-term mean concentration at a receptor point a given distance away from an area source (Barrett and Britter, 2009). The RDC requires dispersion parameters, shapes and locations of the area source, as well as the emission rates. The dispersion parameters are calculated from AERMOD with its preprocessor (AERMET). The 2006 upper-air soundings are obtained from the National Climatic Database Center (NCDC) Integrated Global Radiosonde Archive (IGRA). Hourly surface meteorology comes from the NCDC Integrated Surface Database (ISD).

Emissions data for the RDC are obtained from the same AEDT model used in the CMAQ modeling (Barrett et al., 2010). Only ground-level primary PM emissions are included in the RDC simulations. Ground-level emissions are summed for each airport for all 365 days and assigned to either taxiway or runway sources

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