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Benchmarking the noise-oriented efficiency of major European airports: A directional distance function approach

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ABSTRACT

The EU Environmental Noise Directive (END) requires member states to produce noise action plans for all major airports every five years. Using that data, this paper employs a directional distance function approach to estimate noise-oriented efficiency of 60 European airports between 2006 and 2011. Technical change is calculated using the Malmquist productivity index. The results indicate that European airports have improved their noise efficiency between 2006 and 2011, and some degree of convergence in noise performance across countries is seen. Larger aircraft size is linked to better noise performance. Inefficient airports would also benefit from more stringent night movement limits.

1. Introduction

Aircraft noise is one of the most relevant undesirable outputs of air transport as it affects human health and property values in the vicinity of airports. As the demand for air transport is expected to grow significantly in the coming decades (ICAO, 2013a), the management of aircraft noise has become a main concern for local communities, airport managers, and regulators. In a context of long-term policy development, the European Commission approved a directive in 2002 relating to the management of environmental noise, typically referred to as the Environmental Noise Directive (END, 2002). The END requires member states to produce strategic noise maps for their main sources of environmental noise, including major airports (defined as those serving above 50,000 annual aircraft operations). The Directive also provides a set of guidelines that cover, among other aspects, the process of mapping noise exposure in neighboring areas. The first round of airport noise mapping was completed in 2007 and the second round in 2012, based on the traffic from the preceding years. This paper uses the publicly available data from both mapping exercises in order to benchmark the noise-oriented efficiency and productivity growth of major European airports in the presence of aircraft noise. Results have both policy and management implications.

A Directional Distance Function (DDF) approach is used to estimate noise-oriented efficiency of 60 major European airports between 2006 and 2011. This is the first time an undesirable-output oriented frontier is employed in the airport literature. Technical change and efficiency catch-up are calculated using a decomposition of the Malmquist–Luenberger productivity index (MLPI). The area of the END 55 dB(A) Lden noise contour is defined as a proxy for the total production of noise around each airport. Previous studies on noise-adjusted airport efficiency employed data on noise fees or average sound levels. However, these approaches fail to account for the spatial distribution of noise around the airport, which

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ultimately determines the number of affected residents. A third methodological contribution is the introduction of average length of haul as a non-discretionary output in the DDF model in order to account for heterogeneity in destination mixes across airports. This is also one of the first papers to estimate airport environmental efficiency using a cross-country dataset. A second-stage truncated regression investigates the impact on noise-oriented efficiency of factors such as airport size, aircraft size, share of night flights, population density, and noise abatement procedures.

The rest of this paper is organized as follows: Section 2 reviews the existing literature on the estimation of airport environmental efficiency. Section 3 describes the airport sample and DDF methodology, with special focus on the measurement of aircraft noise. This is followed by Section 4 which analyzes the efficiency results. Several policy implications are discussed. Finally, Section 5 summarizes the main findings and provides suggestions for future research.

2. Literature review

Färe et al. (1989) adapted the standard Farrell approach to efficiency measurement in order to allow for an asymmetric treatment of desirable and undesirable outputs within a non-parametric framework. Adapting their theoretical models to the Directional Distance Function (DDF) structure developed by Chambers et al. (1998) is straightforward. An advantage of these methods is the flexibility to choose between different orientations, depending on the behavioral assumptions of the sample firms (i.e. maximizing output (*Y*), minimizing inputs (*X*) or undesirable outputs (*U*), or any combination of these objectives). These orientations are formalized as vectors in whose direction the distance to the technological frontier is measured. While, in theory, there are an infinite number of directional vectors, they can be grouped attending to the variables included (see Table 1). For example, if undesirable outputs are ignored, one can choose between the output, input, or simultaneous orientations – *Y(X)*, *X(Y)*, and *YX*, respectively. When undesirable outputs are included, the *YU(X)* and *YUX* orientations aim to produce a global efficiency measure that combines several objectives, one of which relates to environmental management.

In the context of this paper, it is also worth reviewing the alternatives that are primarily oriented to reductions in undesirable outputs – also mentioned by Färe et al. (1989), but discussed in depth by Tyteca (1997). These include the U(YX) and U(Y) orientations, which set the model to search for the maximum feasible contraction in undesirable outputs given the observed levels of desirable outputs and inputs, or desirable outputs only, respectively. Stressing the partial nature of these measures, Tyteca (1997) concludes that they provide complementary information and should be all taken into account by decision-makers.

This flexibility in the analysis of environmental performance is not seen in the airport-related literature (see Table 2). DDF has been the most popular methodology, with the exception of Lozano and Gutiérrez (2011) and Lozano et al. (2013), who chose a Slacks-based method (SBM) and a Network-DDF, respectively; and the paper by Martini et al. (2013b) that used a parametric hyperbolic output distance function. In spite of that, all these alternative methods still require an orientation for efficiency measurement. Table 2 shows that all contributions, except Fan et al. (2014), have chosen the typical *YU(X)* orientation along with the basic *Y(X)* in order to measure the change in efficiency and airport rankings when the externalities are considered. In relation to that, Martini et al. (2013a) found *YU(X)* to be a superior choice than *U(YX)* because the latter assumes that (i) airports are already operating at optimal levels of desirable outputs and inputs and (ii) desirable outputs are fixed. For the purposes of this paper, the first argument can be challenged by stating that, as opposed to Martini et al. (2013a) we do not exclusively aim for a global measure of efficiency, rather than a partial, environmentally-focused indicator. The second argument can also be challenged by referring to the large number of airport efficiency studies that have chosen input-orientations in a Data Envelopment Analysis (DEA) context, or cost function specifications in a Stochastic Frontier Analysis (SFA) context (see Liebert and Niemeier, 2013). All of these studies assume outputs (e.g. passenger traffic) to be exogenous to the airport, thus shifting the behavioral objective to cost or input minimization given an output target. We aim to translate this concept to the treatment of undesirable outputs and fill a gap in the literature.

To that end, this paper uses Tyteca's *U(YX)* orientation in a DDF model, with an application to airport operations and the generation of aircraft noise. This is the first undesirable output-oriented efficiency study in the airport literature. From the airports' perspective, this orientation is of interest since it indicates the maximum proportional reduction of noise contour (*U*) that can be achieved at the levels of traffic currently served (*Y*), while taking into account the impact of existing runway infrastructure (*X*) in the generation of said externality. Efficient airports under this orientation will have typically engaged in policies related to aircraft mix, evening/night curfews, or noise preferential routes in order to mitigate the level and spread of noise around the airport. There are indeed other relevant aspects at the time of assessing how airports approach the management of noise, such as geographical location and population density in the area. However, the chosen orientation is consistent with one of the pillars of ICAO's Balanced Approach to Aircraft Noise Management (ICAO, 2008): the reduction of noise at source. With a second-stage regression on the resulting efficiencies, we can further investigate how airports' noise policies relate to that goal.

As seen in Table 2, previous studies have analyzed the impact of noise, delays, and air pollution on airport efficiency, with Scotti et al. (2014) accounting for the three factors simultaneously. Aircraft noise has been proxied by the noise fees paid by airlines (Yu, 2004; Yu et al., 2008) or average noise levels (Martini et al., 2013a). The latter is based on a method developed by Grampella et al. (2012) that combines data on aircraft movements with certified noise levels for each aircraft model. While