Airport noise pollution: how to regulate efficiently by confronting victims and polluters?

par

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Abstract

Noise-induced pollution constitutes a hot and topical societal problem for all major airports. This paper discusses various issues in the implementation of a market for noise licenses as a solution to solve the noise externality between the residents located around airports and the aircrafts moving in and to airports.

Résumé

La gestion de la pollution sonore autour des aéroports est un problème important. Un marché de permit de bruit pourrait solutionner le problème d'externalité entre résidents et avions en mouvement autour d'un aéroport. Cet article discute la mise en oeuvre d'un tel instrument.

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I. Introduction

Noise pollution around airport is probably one of the most salient environmental and societal issues in large cities. Because of the variety of stakes, noise pollution constitutes a crucial management and political problem for urban and regional policy makers. Regarding airport authorities, the main problem is to cope with local residents' resistance. Regarding the public authority, the problem is to implement a fair and efficient regulation of aircraft activity around the airport. At the implementation level, a key issue is the spreading of aircraft movements over different geographical zones (the choice of routes). However, the implementation of any solution must first solve of the problem created by the absence of residents' revealed preferences about noise pollution.

In practice, current noise regulations use command-and-control instruments. Local governments negotiate with airport authorities about the aircraft movement activity and the geographical design of the aircraft routes. However, such regulations are usually disconnected from local residents' subjective perception of noise damages. Many discussions have focused on technological improvements or on the definition of noise standards. For instance, governments have exerted pressures for airports to operate quieter airplanes and adopt less noisy land-off and kick-off procedures. Recent history has clearly shown that much improvement can be achieved thanks to such technological improvements. Other policies have limited the amount of noise around airport by setting noise quotas. In such policies, the airport is allocated a number of noise quotas that it grants, or possibly, auctions to airline companies. In most cases, the number of quotas fixed by local governments usually attempts to set the noise damage to its historical level. Surprisingly, none of those policies are able or designed to set the level of noise damage to what would coincide with a socially optimal level, neither for the global activity level, nor for the distribution of noise around the airport. This is merely due to the fact that those policies do not rely on an evaluation of residents' actual noise disutility. In other words, given the absence of information about noise disutility, one cannot judge whether the above technological efforts are insufficient or excessive, whether airport activity is above or below its socially optimal level, whether aircraft movements produce too much noise or not, and finally whether the noise level is acceptable or not by residents.

In this paper we present a novel policy instrument for noise regulation around airports. It simply consists in giving the right for silence to the residents located around the airport, and allowing them to sell the related tradable noise licenses to airlines companies. By doing so, residents reveal their preferences (i.e. their disutility due to noise pollution) and the market for noise licenses, when adequately designed by the regulator, implements an efficient flight activity and spreading over the routes. Furthermore, because the rights are given to residents, local acceptability is also met. Finally, the market provides the airline companies with an incentive to adopt quieter aircrafts.

Such a solution consists in defining property rights on quietness and allocating them to residents. Coase (1960) has clarified the role and limitations of property rights in the efficiency of economic situations between several economic agents. Montgomery (1972) has further explained how a market for pollution licenses can achieve efficiency. Since then, such instruments have been implemented in various environmental contexts. The present solution for airport noise is a natural extension of those views. In addition, the allocation of quietness rights to residents has strong similarities with the allocation of land property rights to landowners. The social acceptability of the former and latter might be similar.

The purpose of this paper is to explain how such market can work from a micro-economic viewpoint. The paper presents a rather simplified analysis for readers acquainted with usual economic notions. The general and more technical analysis is presented in Bréchet and Picard (2010) and practical implementation issues are analyzed in detail in Bréchet and Picard (2011). Our aim is not only to outline the properties of a well-designed market that solves the noise externality issues around airport, but it is also to point out that an efficient solution for airport noise should take the resident's subjective damage into consideration. Any discussion in that direction is welcome.

The paper is organized as follows. Section II briefly summarizes the economic literature on the topic. Section III explains how markets for noise licenses work. Section IV concludes.

II. Economic context and related literature

Our approach departs from the institutional approach of noise management. In 2001, the International Civil Aviation Organization (ICAO) Assembly endorsed the concept of a « balanced approach », to aircraft noise management. It promotes the four policy approaches: (i) reduction at source (quieter aircraft), (ii) land-use planning and management, (iii) noise abatement operational procedures and (iv) operating restrictions. This ICAI's declared objective is to address the noise problem in the most cost-effective manner. Nevertheless, it does not really refer to the residents' damage. The European Commission also advocates a similar « balanced approach », to aircraft noise management (Directive 2002/30/EC, European Commission, 2002). Its objectives are however broader than those of ICAO as the Commission seeks to limit or reduce the number of people significantly affected by the harmful effects of noise, and to achieve maximum environmental benefit in the most cost-effective manner. The cost-effectiveness of the policy is clearly claimed, but the residents' damage minimization is also part of its objective. Yet, the choice of the instrument to implement the policy remains open.

The residents located around an airport incur a considerable damage from the noise created by aircraft movements. Such damage may have an impact on the residents' willingness to pay to locate, and therefore on house prices, in the noisy airport environments. The economic literature offers many evaluations of the impact of airport activities on property values in residential areas using hedonic prices models (see e.g. McMillen, 2004; Nelson, 2004; Schipper, 2004). The medium value of environmental costs in a set of 35 European airport areas is $0.0241 (0.0201 Euro) per passenger-km. In this figure, the noise costs counts for 75 per cent (Schipper, 2004). Roughly speaking, this implies an environmental cost of $2,400 (2,000 Euros) per 100-seat aircraft flight over 1,000 km. Numerous empirical studies have confirmed that aircraft noise influences property values around airports. Hedonic price approaches uses housing market data to infer the noise impact on housing rents. In average, they report a noise impact on housing rents of 1 per cent per acoustic decibel (e.g. Baranzini and Ramirez, 2005). Interestingly, such measure does not significantly change with noise measuring procedures and with the institutional structure of the housing market (private versus government ownership). According to this information, the price of a house would diminish by 15% if it is located in a noisy airport environment that increases the average decibel (dBA) by 15% compared to quiet locations. A recent study by Bréchet *et al.* (2009) confirms such values in the case of the Brussels' airport. In addition, this study highlights the fact that the noise damage is highly unequally shared among the residents. It shows that a strong perceived damage (equivalent to a house rent discount of 1,200 Euros per year) is concentrated in a small residential place close to the airport. By contrast, a small perceived damage (equivalent to 220 Euros per year) is spread over a much larger set of residential locations.

Local economic benefits of airports are also significant, covering profit, tax revenues and direct and indirect employment opportunities. In the case of the last Chicago O'Hare airport extension, McMillen (2004) has assessed that the benefits outweighed the social costs (including noise damage). The issue of airport expansion is particularly tricky because it takes place in suburban areas. The opening of new runways typically exacerbates the dilemma between noise concern and economic benefits. According to the US Federal Aviation Administration, 18 of the 31 large hub airports in the US plan to add runways in the next decade. Brueckner (2003) estimates that the O'Hare expansion would raise service related employment in the Chicago area by 185,000 jobs. In the case of Brussels' airport, one may remember the information campaigns about job implications of airport extension and/or DHL relocation. Of course, the inclusion of job opportunities in the welfare gains of an airport extension depends on how such jobs substitutes for other jobs that are not related to the airport. For instance, such job opportunities would add nothing to the wealth of a region in a hypothetical world with full employment, perfect labor market and elastic labor demands. The welfare valuation of the related jobs can only be made by taking into account the existing imperfections in the labor market.

There exists nevertheless a strong presumption that the socio-economic benefits of the airport exceed its costs. Indeed, Brian and David Pearce, researchers at the University College of London, estimated that a very low tax (less than 2%) on air fares would suffice to compensate for the whole set of environmental effects (noise pollution, air pollution, etc.) caused by activity at Heathrow Airport. A back-to-the-envelop calculation shows that, in 2004, a tax of 12.5 Euros per passenger would yield a revenue equivalent to the rental cost of the whole residential area under one of the two air corridors used by Brussels National before 1999 (Picard, 2005). Bréchet *et al.* (2009) are more precise about the costs and benefits for Brussels' airport. In that study, the social damage of aircraft noise is evaluated at about 10 million Euros in 2005, which can be compared with the revenues and profits generated by the airport: 324 and 161 million Euros, respectively. The revenues and benefits of indirect activities should be added. A main question is then to assess by how much residents should be compensated to make aircraft noise acceptable. A cost and benefit analysis would help answering this question, but it would not address the problem of internalization of the noise externality between aircrafts, airports and residents.

The idea of tradeable licenses is not new[3]. Tradeable licenses have been promoted as policy instruments for environmental issues since Dales (1968). Initially, they were regarded as impractical despite their theoretically attractive properties (cost-efficiency). Yet, since the 1990s, markets for tradeable licenses have been implemented for sulfur dioxide pollutants in the US power industry, and for carbon dioxide in the EU. Those market experiences where inspired by Montgomery (1972) who formally showed that, under a global emission constraint, competitive markets of tradeable licenses yield cost efficient allocations of pollution abatement whatever the distribution of licenses amongst polluters. In such a market, the global emission cap coincides with the total number of emission licenses, those being emitted by the regulator (grandfathered or auctioned) and trade occurring among polluters.

The environmental economic literature generally discusses the efficiency properties of the allocation of pollution licenses in a secondary market where a government has no information about the firms' cost structure. Designing rules for initial allocations of pollution licenses (or quotas) has remained a critical issue of information revelation until the particular auction mechanism recently proposed by Montero (2007). However, such mechanisms cannot be applied to our context because the government has no information about individual's noise damage function, and no information about each airline company' business structure. By contrast, we here explain the design of a primary local market for noise licenses between the local victims (the residents) and the polluters (the aircraft companies). We give a particular focus on a design that makes the airport activity acceptable to neighboring

3. We use the word « license », but « permits » or « quotas » can be found in the literature. In all cases, one permit gives the right to the polluter to emit one unit of pollution.

residents. Since the latter are victims of aircraft noise disturbances, it seems natural to grant the property rights on noise (or quietness) to those residents. They are then free to sell those rights to aircraft companies by the means of noise licenses. Hence, the regulator does not impose any arbitrary global noise quota.

In this paper, our aim is to provide a contribution that is both policy-oriented and methodological. We propose a new application of the concept of tradeable licenses to the issue of noise exposure, with an emphasis on the spatial dimension of the problem.

III. The micro-economics of a market for noise licenses

The starting point of the discussion about airport noise licenses lies in several observations about residents, airlines and airport spatial structure. First, residents incur a disutility from aircraft noise that positively affects their preferences for a residential location away from airports. This has been reflected in both surveys (Van Praag, 2004) and hedonic price models of property values (Nelson, 2004). Second, airports host a set of airline companies that offer air connections between city pairs with various profitability levels. Some city pair connections are highly profitable while others are less. In equilibrium, the least profitable air connection will naturally have (almost) zero

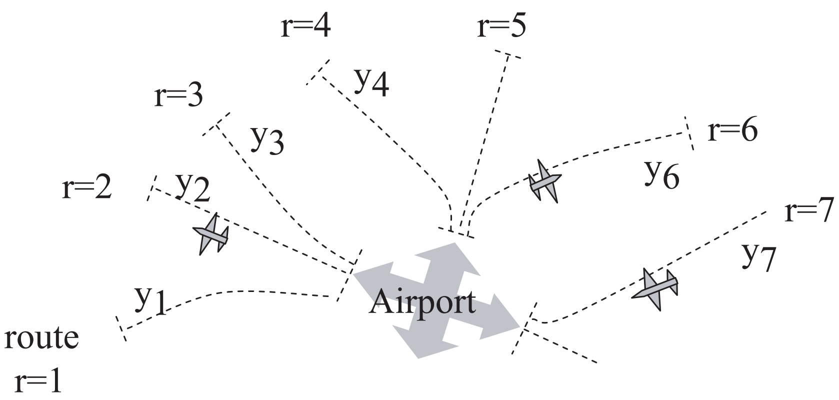

Figure 1: Feasible routes from an airport.

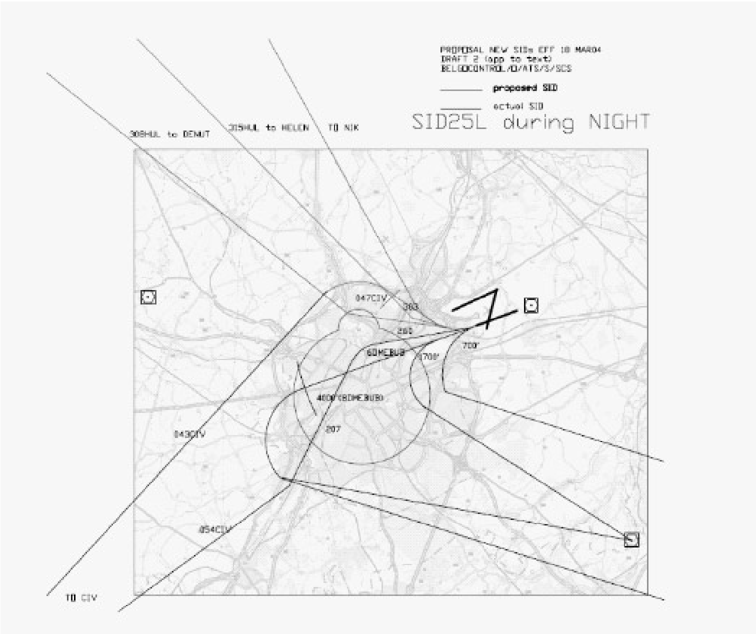

Figure 2: Actual and proposed routes from Brussels airport.

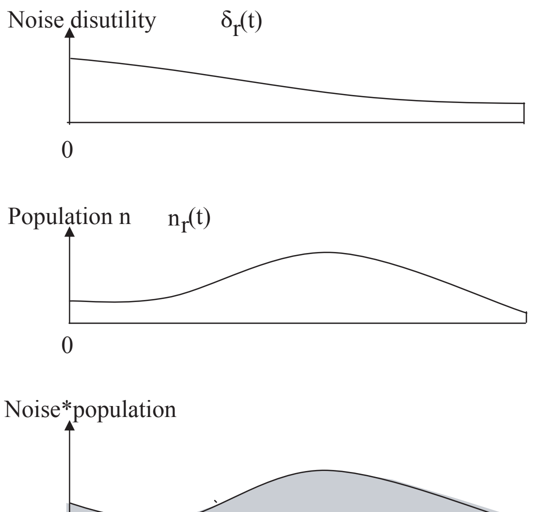

Figure 3: Distribution of noise disutility on route r and design of zones.

profit. Third, airports operate aircraft movements on one or several runways, and each runway can be associated with several aircraft routes. Air traffic is organized along several routes that airplanes may take when they land and take off. Landing and take-off routes are determined by exogenous technical characteristic, for instance by the direction of wind. Yet, within the same set of technical parameters there exist several route possibilities. An aircraft route includes the path, the altitude and the engine power taken by an aircraft for takeoff or landing. As shown in Figure 1, a West-runway may for example direct the planes to a South-West, West or North-West route some miles after takeoff. Figure 2 displays no less than six actual routes and three additional proposed routes from the South-West runway of Brussels airport.

For expositional purposes, we make the three following simplifying assumptions in this paper[4]. First, we assume that only one type of aircraft operates in the airport, so that the residents have the same noise disutility for every aircraft flight. Second, to emphasize spatial design issues we suppose that residents are homogenous with respect to their disutility for noise pollution, but that they differ according to their distance from the airport. Finally, there is only one relevant time period, say 8:00-20:00, during which aircrafts operate.

We focus therefore on the relationship between space and the market for noise licenses. Each aircraft gives rise to noise disutility ?(t) to each resident living on ground at the distance t from the airport. The intensity of the noise disutility varies with the altitude and the engine power of each aircraft, which depends on the aircraft position on its route. As shown in Figure 3, the total disutility hence depends on this noise intensity and the number of residents harmed by the noise, and it is different on each point of the aircraft route.

Let us begin with the simple (but probably unrealistic) case of a single route (Figure 2).

A. The case of a single route

It is rather easy to understand how markets for noise licenses work when there exists only a single route. In this case, a noise license is defined as the right for one aircraft to fly over the route and to emit noise. This right is given to the residents, who are represented by a single

4. Those assumptions are relaxed and discussed in Bréchet and Picard (2010, 2011).

representative acting on their behalf. As a consequence, noise licenses must be purchased by each aircraft flying over the route. The demand for noise licenses is given by the profitability of city pair connections. If each city pair connection *x* makes a profit $\pi(x)$, and if the price of the noise license to flight the route is denoted by *P*, then the demand for noise license is equal to $y^D(P)$, the number of city pair connections that make a profit at a noise license price *P*. At a positive noise license price, the lowest profitable connection is no longer viable and must close. In Figure 3, this is shown by the curve $y^D(P)$ Mathematically, it is defined as $y^D(P) = \#\{x: \pi(x)-P\}$. On the other hand, noise licenses are granted by the representative of the residents under the unique route. This representative organizes the compensation for aircraft noise. If she is utilitarian, she will consider the aggregate disutility over the route, *d(y)*, which depends on the number of flights and on a measure of aggregate disutility B. That is, she sums the numbers *n(t)* of residents at every distance t from the airport on the route with the intensity of the noise disutility that is perceived by the residents at distance *t*, $\delta(t)$. This yields :

$$B = \int_0^T n \cdot (t) \cdot \delta \cdot (t) \; dt$$

Note that the parameter $\delta(t)$ measures the resident's noise subjective perception, i.e. their disutility. It is not a technical measure of noise exposure, such as the dBA index. The key of noise license markets is to allow residents to reveal their true disutility.

The resident's representative is allowed to issue noise licenses and to sell them to the aircrafts that fly over her route. She is willing to issue and sell noise licenses. Her supply curve for noise licenses will be upward sloping. Under the assumption that the noise of the first flight during the time period implies no noise disutility, this supply curve will have a zero intercept. This is shown by the curve $y^S(P)$ in Figure 4. When there exists only one route and many independent airline companies, the representative will exert monopsony power and set the number of noise licenses that maximizes the aggregate utility of the residents located under the route. That is, she will supply noise licenses until her aggregate marginal disutility from noise exceeds her marginal revenue from noise licenses. Her revenue is thus equal to $Py^S(P)$. Any additional license brings her a marginal revenue equal to $Py^S(P)$', which is represented in Figure 4 by a curve higher than the price under her supply curve $y^S(P)$. The marginal revenue rises faster than the price determined by the supply curve because every additional noise license must compensate for a higher noise damage, which makes this license and all the other ones more expensive. Then, the equilibrium is given by the equality between marginal revenues and demand: $(Py^S(P))' = y^D(P)$. As a result, the residents located below the route constrain the number of flights to y^M. Because the number of flights is equal to $y^o > y^M$ in the absence of noise licenses, the requirement to purchase noise licenses from residents reduces the airport activity by eliminating the least profitable flights.

As in any market, a rise in the supply curve must raise the equilibrium price and reduce the activity level. The difference with a usual market is that residents here collect a share of the airline activity rents in addition to the strict compensation for their noise disutility. Residents are represented by a representative that has monopsony power. The latter collect more than what would be necessary to accept the noise related to the flight activity. Nevertheless, residents do not cancel the airport activity (as it is sometimes feared by airport advocates). Indeed, airline companies face a situation similar to the one the manufacturing firms face with union monopsonies: the latter constrains the firms' activities and profits but do not call for their shutdown. It is probably interesting to push the present analysis a bit further. For instance, defendants of airport economic activity sometimes claim that the impact of noise pollution is much less than what residents' associations state. Under this claim, both the supply and marginal revenue curves should have relatively flat slopes. As a consequence, the introduction of a market for noise licenses should imply a quite low price for noise license, which would be of no threat for the airport activity.

The main point of this exercise is to show that noise licenses allow residents to reveal their preferences about their noise disutility below the route and allow airline companies to reveal their willingness to pay to operate from the airport. This is typically what Coase (1960) would advocate: to give property rights over noise either to local victims (the residents) or to polluters (the aircraft companies). Since the residents are victims of aircraft noise pollution, this naturally implies that property rights on noise (or quietness) are granted to those residents. They are then free to transfer those rights to aircraft companies by the means of noise licenses. Hence, the regulator does not need to arbitrage between residents and airline companies for the noise externality.

What would be the size of this rent to residents in practice? That depends on the shapes and elasticities of supply and demand curves, and on the equilibrium reached once the noise license market is implemented. For a linear supply curve (as shown in Figure 4), the price under marginal revenue is known to be double of the price under the supply curve. So, if we set the airport traffic level to the one existing without noise licenses, the noise damage cost per 100-seat aircraft asked by residents would be evaluated at about 55 Euros for the Brussels' airport according to Bréchet *et al.*'s (2009) study. That would be what the residents should receive to make the aircraft noise acceptable. However, the monopsony power of residents would yield an additional rent of the same amount. At this traffic level, the price for a noise license of a 100-seat aircraft would amount to the double of the above cost to 55 Euros; that is, 110 Euros. This amount is unlikely to alter the airlines' decision to operate their city-pair connections. By contrast, in Schipper (2004), the environmental cost is evaluated at about 2,000 Euros, so that the total

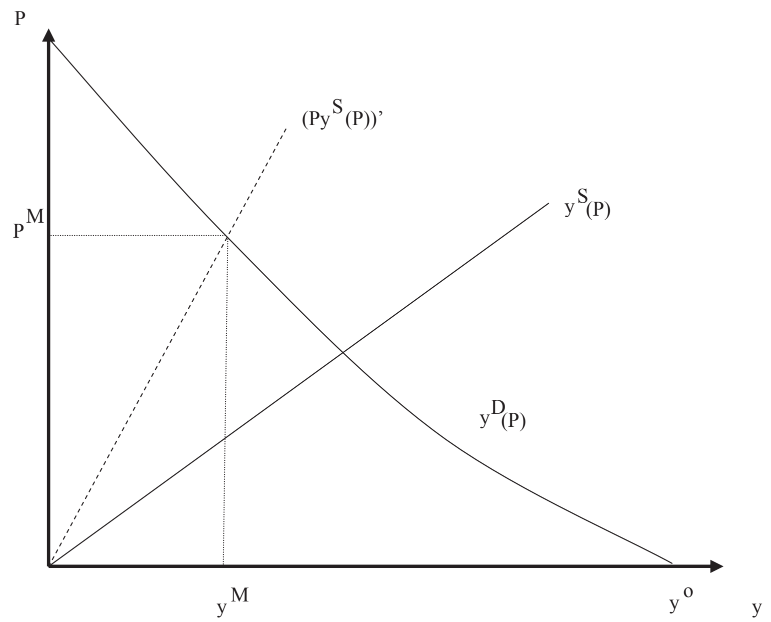

Figure 4: Market equilibrium with monopsony route

price at the current traffic level would be 4,000 Euros, which is high. The point of a market for noise licenses is to entice residents and firms reveal the price that will reflect their marginal damage and loss.

The rent to residents has an impact on aircraft movements and noise market prices. Indeed, higher rents will cause higher noise license prices, which will entice airlines to consider shutting down the non-profitable connections. To assess this, we must again stress that the answer does depend on the shapes and elasticities of supply and demand functions. We know that passenger demands have elasticities roughly around one (see Gillen *et al.* 2007). This means that a 10% increase in ticket price diminishes travel demand by 10%. For the sake of the exercise, we may consider that, in addition to the above assumption of linear supply, the demand for noise licenses has a unitary elasticity (a heroic assumption). In this case, one can show that the presence of monopsony rent decreases aircraft movements and increases the price by the factor $\sqrt{2} = 1.4$

In such an example, the residents' monopsony power would have a significant impact on the price of noise licenses and on the airport activity. The design of the noise license market must therefore reduce this market power of residents on a specific route by introducing additional routes, which we explain now.

B. The case of several routes

Suppose now that air traffic controllers can direct flights over several routes. In this (more realistic) case, a noise license is defined as the right for one aircraft to fly and emit noise over a specific route. So there are as many types of noise licenses as there are routes. As the reader will understand, the main feature of a market for noise licenses is now its spatial dimension. Residents are distributed over the space under aircraft routes and airline companies are required to buy the licenses to take a route. In addition, each route is associated with an independent representative who is responsible to issue noise licenses in exchange for a monetary compensation. The competition between representatives is meant to reduce the monopsony rents described above. Each representative i infers her supply of noise licenses $y_i^S(P)$ from the aggregate noise disutility of the residents dwelling under her route. The representative is in charge of redistributing the compensation and the possible rent to each individual according to the local noise conditions.

From the air controllers' viewpoint, routes are generally good substitutes. For instance, under good weather conditions, routing an aircraft to West or North-West routes a couple of miles after takeoff does not present technical and safety challenges. Figure 2 offers a good example of a handful of routes from Brussels airport. Because routes are substitutes, aircraft are enticed to choose the routes offering the noise licenses with the lowest price. In equilibrium, the noise license prices of all routes must equalize and the equilibrium number of flights, $y^R(P)$, is given by the aggregation of each route's supply, $y^S(P)=\Sigma_i\, y_i^S(P)$ and the total demand for noise licenses, $y^D(P)$. This is shown in Figure 5.

As above, the residents' possibility to sell noise licenses entices them to reveal their disutility. The intervention of the regulator is not needed after the setup of a noise license market. In addition, dividing the space surrounding the airport into several routes has two important properties. First, it permits the noise disutility to be spread over more individuals. When individuals are increasingly harmed by additional noise events,

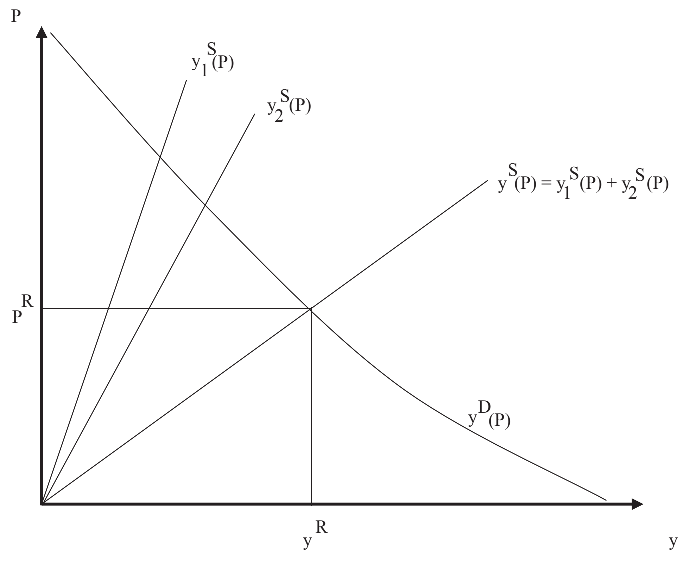

Figure 5: Market equilibrium with two routes

they are less hurt by an aircraft noise event at low traffic levels than at high levels. As a consequence, it is more efficient to rebalance flight activity from routes with high flight activity to ones with low activity. The market for noise licenses achieves this dispersion property. Second, by setting up several routes, the routes' representatives lose market power over aircraft and get lower rents. Formally, the importance of the rent reduction depends on the number of routes that can be opened to aircraft movements. Hence with a large enough number of routes the above rents can be significantly reduced.

The existence of rents is no surprise. Rents are features of any markets with heterogeneous buyers and sellers. The market is here used to reveal the preferences of both residents and airline companies about the aircraft noise emissions.

The use of markets for pollution licenses to regulate pollution is typical in the environmental economics literature. Montgomery (1972) indeed inspired the use of tradeable permits or licenses as policy instruments for environmental issues. Since the 1990s, many examples of markets for tradable permits have been successfully implemented, most notably for sulfur dioxide pollution in the US power industry (Ellerman *et al.*, 2000) and for carbon dioxide in the European Union (see Ellerman *et al.*, 2010). All these markets, nevertheless, are cap-and-trade systems in the sense where the global supply of pollution licenses is set by the regulator (this is the cap on pollution), and polluters are then allowed to trade these permits among themselves. In our setting, the supply of licenses is endogenous, and it is based on residents' preferences. By contrast to cap-and-trade systems, our market allows to reveal preferences on both sides of the market[5].

C. Several zones, with one route

We finally consider the last case where aircrafts must follow a unique route, but where this route is divided into several contiguous zones. A zone is defined as a land strip below a route where residents are represented by a single representative. There may be many zones and representatives below the same route. Those zones can be municipalities, districts, communities or residents' associations. Figure 6 depicts a case where the route is divided into two zones. A noise license is thus defined as the right for one aircraft to fly over one zone

5. See Ellerman (2005) for a broad introduction to markets for tradeable pollution permits.

and to emit noise in that zone. So, to fly the entire route an aircraft ought to purchase a noise license for every zone. On the route, the licenses supplied by different zones' representatives are thus perfect complements for airline companies. Noise pollution is therefore a complementary bad for all zones on a single route.

Typically, this may lead to a tragedy of the anti-commons where the agents do not internalize the global effect of their decisions on the route traffic. The usual tragedy of the commons (Hardin, 1968) explains why people overuse shared resources: it happens when too many owners can have a privilege to use a given resource, and no one has a right to exclude another. The tragedy of the anti-commons (Heller and Eisengerg, 1998) happens when a resource is prone to underutilization because too many owners can block each others, and no one has an effective privilege of use. In our context, each residents' representative owns the right to issue noise licenses and does not internalize the benefits that other zones bear. One may conjecture that the number of licenses and flights is inefficient. Another way to see this is to observe that noise licenses offered by the different zones are complementary

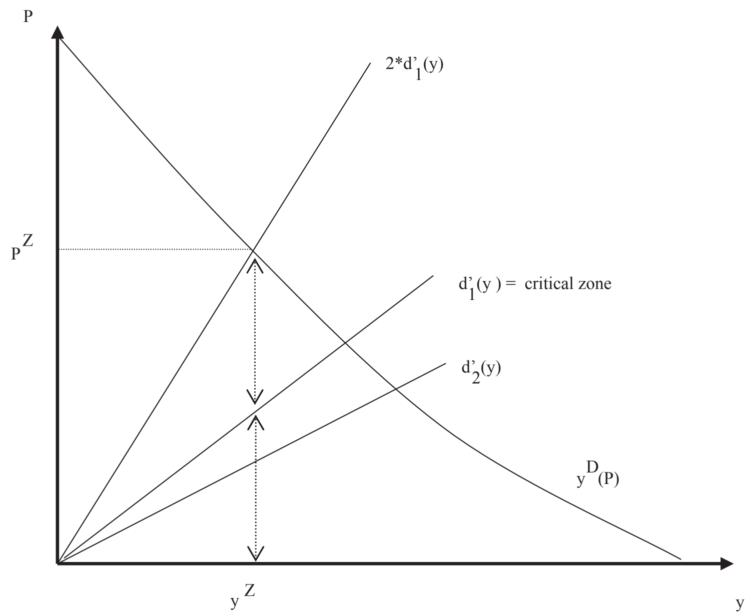

Figure. 6: Market equilibrium with two zones

goods. Therefore the market for noise licenses may be suspected to be subject to under-provision of complementary goods. Independent suppliers of complementary goods would set inefficiently low output levels because they would not internalize the effect of the benefit of a larger supply of their goods on the other suppliers. Bréchet and Picard (2010) show that those effects do exist, but that they can nevertheless be under the control of the market designer. In sum, the market itself does not work properly but it can be adequately designed by the regulator to match the socially optimal situation.

Bréchet and Picard (2010) propose to organize the market with a neutral auctioneer who collects the noise license price bids supplied by the zone representatives and who sell to each aircraft the bundles of noise licenses on all zones at a price equal to maximum bid price times the number of zones. This means that the zone offering the bid with the highest noise license price (which is also the one that bears the highest noise damage) receives exactly what it bids. This zone is called the critical zone because it determines the price to fly over the whole route. The other zones receive more than what they bid. Such a situation corresponds to a standard market equilibrium where the marginal transaction gives no rent to the marginal supplier, but a positive rent to the infra-marginal suppliers.

In this context, the equilibrium in the noise license market can be represented as in Figure 6 (for two zones). Let $d_i(y_i)$ be the aggregate noise disutility over the zone *i* for a traffic level y_i over the zone *i*. This is the disutility that zone *i*'s representative considers in deciding its price bid for a noise license. The bid price of a zone i's representative is then determined by her marginal disutility $d_i'(y_i)$. The market auctioneer picks the largest bid price $(\max_i d_i'(y_i))$ and sets the price of the route $P^Z=2\max_i d_i'(y_i)$. The resulting number of flights is then given by the aircraft demand to fly on the route $y^Z = y^D(P^Z)$. The zone *j* with the lowest marginal disutility gets a rent. In Figure 6, this rent is given to zone 2 and equal to $d_1'(y^Z) - d_2'(y^Z)$.

The key point here is to consider that the market designer is able to tune the level of this rent by altering zones' spatial design. Indeed, if she reduces the size of the critical zone, aircraft noise will affect fewer residents in this zone. It will therefore reduce the aggregate disutility and the marginal disutility over this zone, which in turn will reduce the critical zone's bid price, and therefore the rents given to other zones. The important point is that the tragedy of the anti-commons can be neutralized in this setup by an appropriate design of the zones.

IV. Conclusion

Noise pollution is a sensitive issue for all major airports. Many airport authorities try to manage this problem using aircraft noise limitation, aircraft movement procedures and land planning. They do not use instruments that make airline activities internalize the noise disutility of the residents located below the takeoff and landing routes, and it is also easy to understand that a fee on noise would not solve the distribution of aircraft movements across the available routes. By contrast, in this paper we explain how to implement local markets for noise licenses as a way to allow both airlines internalize their harm on residents and residents reveal their disutility due to noise pollution. In such a market the supply of noise licenses is made by residents who are organized in geographical zones under the aircraft routes (e.g. municipalities, districts, communities, associations) and who are allowed to emit and sell noise licenses to airline companies. In equilibrium of the market for tradeable noise licenses, the price of noise licenses will reflect both the marginal noise disutility of residents and the smallest profit made by the aircrafts moving in and out the airport. An adequate design of the market (by defining the zones) implements the socially optimal situation.

The combination of noise licenses given to residents with an appropriate spatial design of aircraft activity around airports is thus an appealing solution for the management of noise pollution around airports. The market for noise licenses yields an efficient allocation of flights across routes, a solution that airport charges on aircraft movements could not achieve. By increasing the number of routes the market designer can spread the noise disutility where it has the lowest social cost and she can reduce the residents' rents in eliciting their information about noise disutility. By creating appropriate zones the market designer can delegate the revelation of noise disutility to smaller spatial groups of residents and limit the problem of the tragedy of anti-commons.

At this stage of the discussion, we acknowledge that, because of its novelty, the present economic theory of noise licenses may let the stakeholders involved in airport noise management issues rather dubious. However the economic instruments that allow polluting parties to internalize the harm on the victims are shown to have superior efficiency properties. Noise license markets are such instruments. To our opinion, they deserve a dedicated attention by policy makers as well as further research in the field of air transport management.

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