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Noëlvia Sedoarisoa, Didier Desponds, Laurent Dalmas, Catherine Lavandier

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ABSTRACT.— **Airports were built on the outskirts of agglomerations, in zones offering large tracts of land. Populations have densified in these areas despite the noise pollution and the constraints of Noise Exposure Plans (NEP) due to the vast array of economic opportunities available. The impact on the price of real estate has been analysed by applying a hedonic pricing method and evaluating the consequences in terms of environmental inequalities and social justice. The results for France's largest airport, Paris – Charles-de-Gaulle, are compared to trends observed in airports both in France and abroad.**

AIRPORT, ENVIRONMENTAL JUSTICE, HEDONIC PRICE, HOUSING MARKET, NOISE POLLUTION

RÉSUMÉ.— **Prix de l'immobilier et proximité de la plate-forme aéroportuaire de Paris – Charles-de-Gaulle (CDG).—**
Les plates-formes aéroportuaires ont été implantées en périphérie des agglomérations, dans des zones offrant de larges disponibilités foncières. Des processus de densification sont en cours dans ces lieux pourtant confrontés aux gênes sonores et couverts par les contraintes du plan d'exposition au bruit (PEB), car les plates-formes offrent de multiples opportunités sur le plan économique. Les effets sur le prix des acquisitions immobilières sont analysées en appliquant un modèle des prix hédoniques et en évaluant les conséquences en termes d'inégalités environnementales et de justice sociale. Les résultats pour la première plate-forme aéroportuaire française, Paris – Charles-de-Gaulle, sont confrontés aux tendances observées sur d'autres terrains, français comme étrangers.

AÉROPORT, JUSTICE ENVIRONNEMENTALE, MARCHÉ IMMOBILIER, NUISANCE SONORE, PRIX HÉDONIQUE

Environmental injustice is defined as an "unequal social situation in the face of nuisances" (Faburel, 2001; Laurian, 2008). This phenomenon has already been observed near several large infrastructures, especially in the United States: "any decision in favor of an infrastructure harmful to the environment leads to the decline of property and real estate values, which attracts poor populations" (Been, 1994).

Although airports are a major asset for metropolitan areas due to the intensity of movements they capture (manufactured products, tourists, etc.) and the activities they contribute to attracting (logistics companies, hotels, business services, etc.), they induce strong noise nuisances that tend to concentrate certain types of households living nearby and to land depreciation.

In France, according to several studies (Faburel, 2003; Faburel, Maleyre, 2007) based around Paris – Orly airport, the noise made by airplanes undermines housing values. In parallel, the renewal of populations does not proceed in a similar way: people arriving are younger and with more modest means than the ones leaving. Environmental inequalities emerge from the interplay between both tendencies. As a result, modest households face more drastic drops in value.

Because of its importance and dynamism, the Paris – CDG airport is a more prominent case than Paris – Orly, Toulouse-Blagnac or Lyon Saint-Exupéry, which were studied using the same approach (Sedoarisoa, 2015). The annual traffic for 2013 is estimated at 62.05 million passengers[1], making it the second most busy European airport behind London Heathrow (72.37 million), and behind Frankfurt regarding cargo volume (with respectively 2,069,200 and 2,094,453 tons of merchandise). This results in a strong employment growth. Taking into account the towns immediately concerned by the airport (Roissy-en-France, Tremblay-en-France and Mesnil-Amelot), Insee counted 14,610 jobs in 1975, 35,424 in 1990 and 90,081 in 2010.

Although public authorities, through multiple constraints[2], attempted very early on to limit new constructions in the areas the most impacted by noise nuisances (whether noise is emitted by airplanes or by repetitive landings and take-offs[3]), it is nevertheless possible to note that the number of inhabitants has significantly increased in these areas, even more recently. If we consider the Noise Exposure Plan (NEP) that came in effect in 2015, we observe a rate of population growth in the IRIS[4] concerned of +7.2% in Paris – CDG, of + 10.3% in Paris – Orly and of +21.6% in Toulouse-Blagnac.

This is the result of residential choices made by households. Although being close to the airport can be a burden, they can find some advantages to it. The intensity of specific residential injustices that are engendered and the appropriate (and possible) level of compensation have to be assessed. Reflections on the implementation of such measures were carried out abroad, in London (Walters, 1975) and in Thailand (Suksmith, Nitivattananon, 2015). They first require the establishment of a link between the level of noise pollution and real estate depreciation.

Our analyses will focus on real estate buyers (houses or apartments) and on the price levels of real estate near Paris – CDG airport. The households concerned are particularly interesting to study because, in a complex system of constraints, they make choices that they cannot withdraw from and that can be considered as bets on the future (Desponds, Bergel, 2013). This approach will allow us to identify territorial specialization according to the social profile of buyers, to observed noise levels and to real estate depreciation, all things being equal. Observed tendencies will have to be interpreted in terms of spatial justice and environmental justice.

1. According to Airports Council International (ACI), see: http://www.aci.aero/News/Releases/Most-Recent/2014/03/31/Preliminary-World-Airport-Trafficand-Rankings-2013—High-Growth-Dubai-Moves-Upto-7th-Busiest-Airport-

2. As early as March 1972, two years before the airport was officially inaugurated, nuisance zones (forecasting the future Noise Exposure Plans) prohibited all new constructions within zones A, the most subject to nuisances, only authorized the construction of utilities in zones B, and limited the expansion of agglomerations in zones C.

3. Unlike Paris – Orly airport for which movements are prohibited between 11.30 pm and 6 am since 1968, Paris – CDG airport is, as of today, not limited by this type of legislation.

4. The IRIS (aggregated units for statistical information) level is the most detailed unit of the territory, used by INSEE. These units respect geographical and demographic criteria and have borders which are clearly identifiable and stable in the long term. See: https://www.insee.fr/en/metadonnees/definition/c1523

The specificities of the Paris – Charles-de-Gaulle airport

A strong demographic pressure in the vicinity of Paris – Charles-de-Gaulle airport

The decision to open an airport to deal with the expansion of air traffic linked to Paris's stable influence and to the predictable saturation of Paris – Orly airport was made by a government decree on January 13th 1964. The airport was inaugurated and immediately made operational on March 13th 1974. The Paris – CDG airport benefited from large land availability and from its proximity with the capital, determining assets for the future development of the platform and for the strategic insertion of the Parisian agglomeration in air transportation networks.

In the towns concerned by levels at least equal to Lden 55[5] (see the definition in box 1), populations strongly grew between 1968 and 2010 (fig. 1), leading to increasing densities from 1,093 to 1,287.6 inhabitants per square kilometer, particularly south of the airport, near the Parisian agglomeration. These dynamics may seem paradoxical given the noise pollution created by the airport and the urban planning constraints imposed by the Noise Exposure Plan. During the recent 1999-2010 period, the population grew by 5.5% within the Lden 55 zone, and the number of jobs increased by 42.6%.

How to evaluate the impact of transportation infrastructures on noise pollution?

Noise is one of the most significant aspects of environmental impacts made by air transportation. Noise exposure is a real public health issue, as noise can have a considerable impact on health. Other than hearing problems, noise can affect an individual and lead to diverse forms of disorders: inconvenience, sleep disturbances, cardiovascular diseases, learning disability, etc. (Babisch, 2002). Nowadays, in Europe, for exposure that does not reach a critical stage, long-term noise pollution and the effects on sleep at night are the most significant effects of transportation noise on health. Characterizing noise pollution in an environment implies using an indicator. This is one of the reasons why the European Directive (2002/49/CE) makes the use of Lden and Ln indicators compulsory while leaving scope for the use of other indexes such as LAmax.

Noise pollution requires taking different elements into account: sound energy produced by planes flying over; the different perception of noise during daytime and nighttime (it is common to consider that a night flight engenders as much discomfort as that provoked by ten day flights). The result is expressed in Lden: the higher this index is, the more discomfort there is. By linking the dots with the same Lden value, we obtain curves of Lden noise levels[6] that illustrate the levels of noise considered as discomforting. Lden index measures the noise level of a source, airplanes for instance, but does not take into account the phenomenon of multiple noise exposures (trains, cars, industry, etc.).

In France, numerous curves are used (box 1): Curves of Environmental Noise (CNE) based on the traffic observed during the previous year, Noise Pollution Plans that help define the eligibility

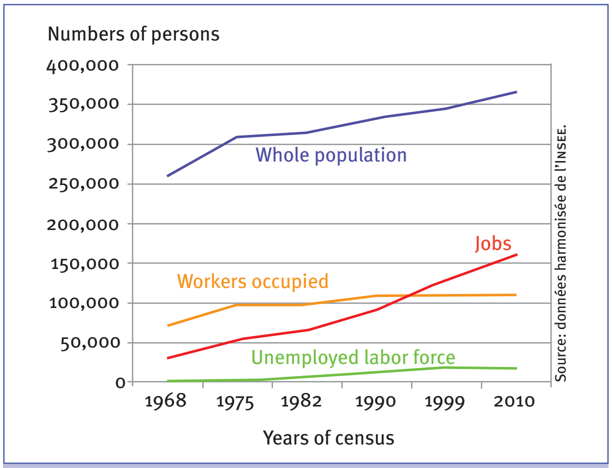

Fig. 1/ Evolution between 1968 and 2010 of the population, number of jobs and the resident active population (employed or not), in the zone delineated by Lden 55 (2005)

5. Because of the proximity between Roissy – CDG and Bourget (dedicated to business aviation) airports, the zones concerned by each of these two platforms that observe levels reaching at least Lden 55 have been merged. In total, there are 36 towns concerned.

6. See the legifrance website: http://legifrance.gouv.fr/affichCode.do?idSectionTA=LEGISCTA000006175741&cidTexte=LEGITEXT000006074075&dateTexte=20010331. In the case of Roissy – CDG, zone A in the NEP is defined by Lden 70, zone B by Lden 65, zone C by Lden 56 and zone D by Lden 50.

Box 1/ How to evaluate noise pollution and limit its impact

• Measuring indicators.

• dB(A): it corresponds to the decibel level perceived by a human ear. Lden is expressed in dB(A).

• The *Level Day Evening Night* (Lden): it is an indicator recommended by the European Union to consider noise pollution. It is calculated in the following way: a day is divided into three periods (daytime, from 6 am to 6 pm, evening between 6 pm and 10 pm, and nighttime between 10 pm and 6 am). To compensate for noise discomfort unequally endured during each of these phases, they are weighted differently: +5 for the evening and +10 for nighttime. Lden is defined as the average noise level on a 24 hour period. Penalties can be applied to the sub-periods (5 dB(A) for evenings, 10 db(A) for nighttime), according to the following formula:

Lden = 10log[(12/24)*10^(Lday/10)+(4/24)*10^((Levening+5)/10)+(8/24)*10^((Lnight+l0)/l0)].

• Curves of Environmental Noise: these curves are not based on hypotheses, but rather on the traffic actually observed during the previous year. These curves are made with 1 dB(A) steps over Lden 50. They aim at regularly monitoring the evolution of noise pollution throughout time.

• Noise Pollution Plans contain three zones: zone I, within the Lden 70 curve; zone II, between Lden 70 and Lden 65 curves; zone III, between the external limit of zone II and the Lden 55 curve. These zones are based on an estimated traffic, on air traffic procedures and on equipment that will be operating the year following the order approving the Noise Pollution Plan.

• Noise Exposure Plans: they were made compulsory with the 85-696 law of July 11th 1985. They define four noise areas: zone A, denoting a very high level of noise pollution within the Lden 70 contour, zone B, denoting a high level of noise pollution between Lden 70 curve and Lden 65 or Lden 62 curves; zone C, denoting a moderate level of noise pollution between the external limit of zone B and Lden 57 or 55 curves; zone D, denoting a low level of noise pollution between the external limit of zone C and Lden 50 curves. Moreover, based on the 2002/49/CE European Directive, France has a threshold value of Lden 55 before it engages protection measures. These plans are not conceived according to acoustic recordings that allow to measure the noise levels that truly affect inhabitants, but rather according to the possibilities of airports developing before 15 or 20 years. These documents are established by State services, are subject to a public consultation for the towns concerned and benefit from the expertise of the Airport Noise Nuisance Control Authority (ACNUSA). In view of the evolution of airports, they require constant reviews. In the case of Paris – CDG, two Noise Exposure Plans were validated by public authorities. The most recent one was endorsed on April 3rd 2007*; it concerns 127 towns and prohibits any construction over 22,339 hectares.

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*See the website of the Prefecture of Val-d'Oise: http://www.val-doise.gouv.fr/Politiques-publiques/Environnement-risques-naturels-et-technologiques/Bruit/PEB

conditions for grants to soundproof one's house or apartment, and Noise Exposure Plans which are urban planning regulatory documents imposed on local stakeholders when urban planning projects are conceived and building permits are delivered[7]. In this study, we chose curves of environmental noise that enable us to measure more precisely the real impact on populations.

The profile of real estate buyers near Paris – Charles-de-Gaulle airport: an indicator of social specialization?

The utility of data on real estate acquisitions (BIEN database)

Acquiring property (house or apartment) for a primary residence is both the result of the wish to settle in the area and a form of real estate investment. The mechanisms to access property make it more complex to meet the conditions to purchase real estate and to initiate a sale and resale process. Access to property therefore leads to strong residential

7. ACNUSA website explains the methods implemented when elaborating NEP, such as Noise Pollution Plans: http://www.acnusa.fr/fr/lebruit-et-la-cartographie/lacartographie/peb-plandexposition-au-bruit/14

inertia (longer time spent in the same dwelling, or shorter duration of rotation within a given house or apartment) than with the private rental sector or with social housing. Data on real estate transactions, compiled in the notarial economic database (BIEN)[8], provide access to complementary information on the profile of buyers and sellers, on the specific qualities of the good and on transaction prices. They allow us to open a window on the social dynamics at stake in the territories as well as on the contrasted evolution of local real estate markets (Desponds, 2005; Guérois, Le Goix 2009; Boulay, 2011; Desponds, Bergel, 2013, 2014)[9]. Yet, the data from the BIEN database present some weaknesses: certain variables are insufficiently informed (dwelling size, for instance), and can even be unstable in time. Although this information sheds light on the transformations that progressively affect territories through the selling and acquisition of real estate, they do not provide elements on the specific stocks available at a given point in time for each of the two processes.

The volumes of transactions and their type (house or apartment) also vary strongly. Those made within the Lden 55 curve of environmental noise are significant: 3,977 houses and 7,733 apartments in transaction in the Val-d'Oise département. They are rarer in the zones directly neighboring the airport, due to its initial situation, to its establishment on agricultural lands sparsely populated, as well as the land planning rules applied as early as 1972 and reinforced by the 1989 and 2007 Noise exposure plans.

Some observations on the social profile of active residents and real estate buyers

With Insee's harmonized data, we were able to analyze the socio-economic profiles of workers (actually working or not) living in the towns located in the same Lden 55 zone. Blue collars represented 29.3% of the workforce in 1990, 28.1% in 1999 and 25.4% in 2010. Managers and professionals represented 9.7%, 8.5% and 9.8% of the workforce on those same years. The ratio of the former category over blue collars, these two socio-professional categories being on the two ends of the spectrum, was 0.33 in 1990, 0.30 in 1999 and 0.39 in 2010 in the Lden 55 zone.

Because of the conditions for accessing property, the average profile of buyers tends to overrepresent the wealthiest categories; several towns under study (Gonesse, Goussainville, Sarcelles, Villiers-le-Bel) are nevertheless characterized by high levels of social housing in which working-class households are much more present.

The use of the same ratio (managers and higher intellectual professionals/blue collars) for real estate buyers, houses and apartments being analyzed separately, demonstrates strong patterns of social specializations in the Lden 55 zone (fig. 2), with certain nuances nevertheless. With regards to old houses[10], with the exception of the western part of Montmorency, blue collars are much more numerous than managers and higher intellectual professionals. Apartments seem to be less characterized by this strong social specialization.

Exploring the acquiring market through gross prices

Although there are significant differences in transaction prices from one town to another, it is also necessary to distinguish the contrasts likely to appear within a town[11]. Comparing the recorded prices per square meter with the average level of the two départements directly concerned by the Paris – CDG airport, Seine-Saint-Denis and Val-d'Oise, allows us to obtain a first map segmentation (fig. 3). If we exclude the rural areas where the prices are relatively low, the lowest levels are recorded near Paris – CDG. Moreover, strong spatial correlations appear between buyers' social profiles and the level of transaction prices.

8. These data are exploited by the Notary Chamber of Paris (Paris Notaires Services: http://basebien.com/PNSPublic/front/f_basebien.php?rub=1) and are made available, under certain conditions, to economic and social sciences researchers.

9. The data were exploited for a study dealing with dynamics in Val-d'Oise, entitled *Tendencies and ruptures: a Val-d'Oise in transition: what consequences for the future?* It was carried out in 2010 in the framework of a contract with the General Council of Val-d'Oise.

10. The goods considered as new in the BIEN database have been excluded from the study; their price and VAT conditions are not comparable with those of old real estate.

11. In order to reduce the number of IRIS with a small number of transactions, it was decided to do the calculation over a period of two years, to smooth out the data by taking into account for each Iris the transactions made by their immediate neighbors and to exclude those who would have made less than five transactions. This helps limit the main biases without totally excluding them.

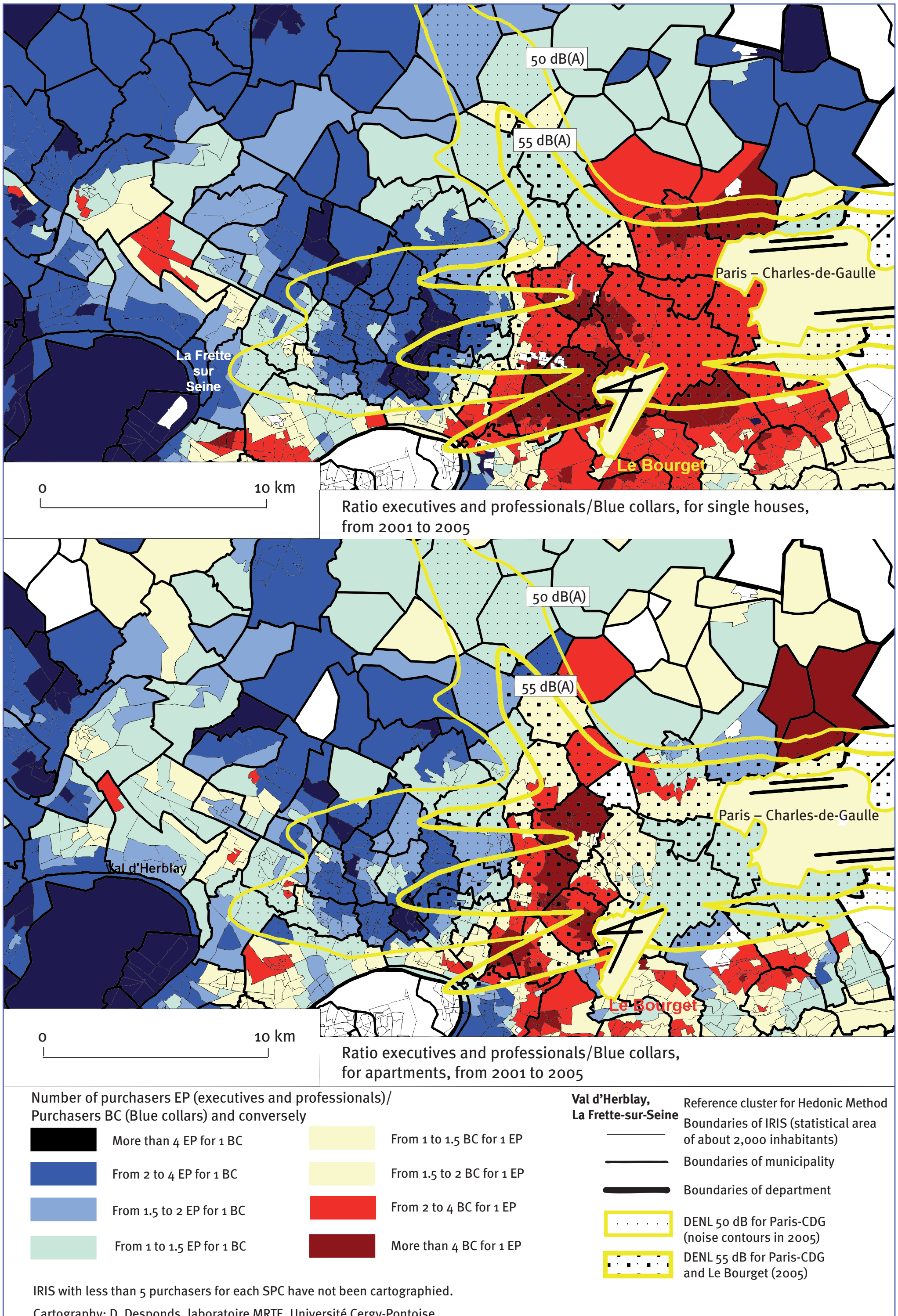

Fig. 2/ Ratio of buyers that are managers and professionals over blue collar buyers, for old houses and apartments, in the vicinity of the Paris - Charles-de-Gaulle airport

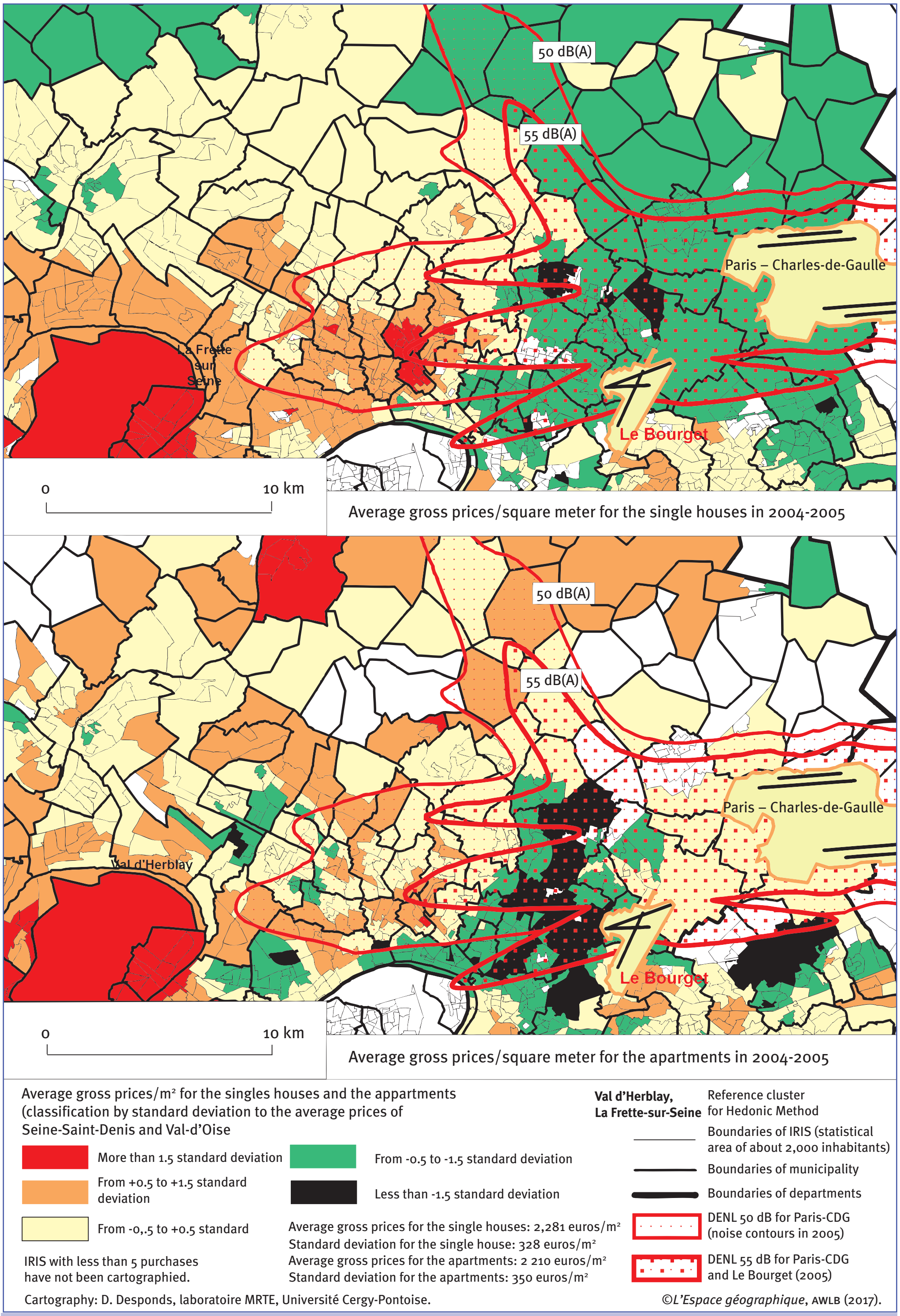

Fig. 3/ Differences between average prices in Val-d'Oise, average gross prices per meter square for the purchase of old houses and apartments in 2004-2005

Where the “managers and higher intellectual professionals/blue collar” ratio is favorable to the former category, prices are higher, for both houses and apartments, and vice-versa in the cases where blue collars are in the majority. The towns that neighbor the airport are not characterized by an emerging gentrification process.

Although the analysis of gross prices contributes to drawing a first spatial segmentation, it faces the risks linked to the diversity of acquired goods. Real estate prices can indeed be affected by multiple qualitative variables (age of the property item, proximity to urban equipment or transportation infrastructures, quality of life,). The BIEN database does not include all the intrinsic characteristics of a dwelling[12], but it nevertheless opens the possibility to implement a methodology of hedonic prices to measure the specific impact of the quality of a given item and what this implies on the making of prices. Moreover, this methodology aims at measuring in the most objective way possible the impact of the airport on real estate prices. It has already been applied on operations of urban renewal (Barthélémy et al., 2007) or on industrial wastelands (Letombe, Zuindeau, 2001). Numerous research works have also been dedicated, since the 1960s, to the evaluation of transportation noise pollution, including noise pollution from air traffic. These studies were mainly carried out in the United States (Mc Millen, 2004; Cohen, Coughlin, 2007; Pope, 2008 for example), more marginally in Canada (Mieszkowski, Saper, 1978; Mac Millan et al., 1980) and in Australia (Abelson, 1979, among others). Very few studies took place in Europe (Dekkers, Van der Straaten, 2009; Salvi, 2009, for example). Two studies dealing with Paris – Orly were published in France (Haut Comité de l'Environnement, Noise and vibration Committee, 1978; Faburel, Maleyre, 2007). There are reviews of the works undertaken in this domain (Nelson, 1980, 2004, 2007; Shipper et al., 1999). Although the findings are quite disparate, the majority of the studies concludes with a depreciation of the value of dwellings exposed to airplane noise, in comparison with an identical but unexposed dwelling (generally exposed to a Lden inferior to 55).

The hedonic approach to real estate prices to counterbalance structural effects

The Hedonic Pricing Method (HPM) to consider the specific qualities of real estate

The Hedonic Pricing Method consists in explaining by using statistics the price of real estate according to its characteristics (Rosen, 1974). To do so, an appropriate functional form has to be selected to represent this relation. The HPM does not provide theoretical arguments allowing to choose between different specifications. It leaves the choice of the most appropriate functional form to the modeler[13]. Several functional forms are available: linear, semi-log, log-log and Box-Cox transformation. The Box-Cox transformation seems more adequate, but when an explanatory variable is a binary variable, the Box-Cox transformation of this variable does not make sense (Linnemann, 1980). The linear form is the simplest to estimate and to interpret, but it is generally not adapted. In this study, as most explanatory variables are binary variables, only the semi-log and log-log forms were tested, as in most studies (Nelson, 2004). We kept the log-log form which produced better results: for houses, the adjusted R^2 is 0.58 for the semi-log form and 0.61 for the log-log form; for apartments, it is 0.70 for the semi-log form, whereas it is 0.73 for the log-log form. Box 2 presents the applied model.

12. No information is provided on the level of sound insulation of the dwelling, a criteria that can have an impact on the price of the property in the area under study. The same applies to the orientation with respect to the runways.

13. There are two big families of functions: “flexible” and “restrictive” functions. The latter include linear, semi-logarithmic, log-linear, log-log and Box-Cox transformation, which are nothing else but special cases of the flexible forms such as quadratic, semi-log quadratic, translog and Box-Cox quadratic functions. Maureen Cropper et al. (1988) base themselves on observed data to see which form of functions provides the smallest error when estimating the marginal prices of characteristics.

Box 2/Presentation of the methodology implemented

The model we are going to estimate therefore uses the logarithm of the price per meter square of transactions as an explanatory variable. It is composed of explanatory variables of characteristics that are measured either in the form of continuous variables (in log), or in the form of binary variables (see below). Two types of models have been estimated: a model in which the airplane noise variables are introduced in continuous forms (model 1) and a model in which airplane noise variables are introduced in the form of binary variables representing different zones (model 2); other variables are still present in a continuous form or in a binary variable form. The second model is presented below. The model is represented as such:

$$Ln(p_i) = \alpha_o + \sum_{j=1}^{j} x_{ij}\,\beta_j + \sum_{k=1}^{k} Ln(z_{ik})\gamma_k + \varepsilon_i$$

$\ln(p_i)$: hedonic price function,
p_i: property prices,
α_o: consistent term,
ε_i: stochastic error term,
x_{ij} et z_{ik}: observation matrix of characteristics. The *xij* matrix concerns characteristics (structural, temporal, environmental and housing location) that are introduced in the form of binary variables, and the zik matrix represents the characteristics introduced in the form of continuous variables (living space, surface area).

The coefficients are interpreted in the following way: for a continuous variable, the coefficient γ_k corresponds to the elasticity of the selling price in relation to the *k* characteristic. The selling price changes by *k*. % when the *j* characteristic increases by 1%. For binary variables, the interpretation of the coefficients nevertheless requires a small mathematical manipulation. Suppose we want to study the impact of an environmental externality (airplane noise in zone j for instance) on the price of houses; if *xij* = 0.
it means that house i is located outside the noise zone *j* and if *xij* = 1 the house is located within the noise zone *j*. A percentage estimation *g* of the impact of this variable on the explanatory variable (the price of houses) is given with the formula: $g = 100\ (e^{\beta}j\text{-}1)$
in which β_j s the coefficient relative to the binary variable taken into consideration.

For sets of binary variables, we must define (arbitrarily) the category of reference against which we measure price differentials. In this study, we chose to use the most frequent category as a reference. For IRIS variables, the reference is the one in which the average price corresponds to the median price of the sample as a whole.

Property items of reference

House: House: house bought in 2006, 6 rooms, 1 bathroom, 1 garage, 2 stories, plot of 466 m² period of construction (1914-1947), located in the "La Frette-sur-Seine" IRIS, unexposed to airplane noise (or to noise <50 dB(A))(see figures 2 et 3).
Apartment: standard apartment bought in 2003, 3 rooms, located on the 3rd floor, period of construction (1948-1968), 1 bathroom, 1 garage, located in the "Val d'Herblay" IRIS, unexposed to airplane noise (or to noise <50 dB(A))(voir fig. 2 et 3).

Based on the effective impacts, it is possible to calculate the Noise Depreciation Index (NDI) for each noise zone, in relation to the zone of reference, the zone exposed to a level of noise inferior to Lden 50. Given their specificities, houses and apartments are analyzed separately[14].

Four categories of variables are taken into account in this model: structural characteristics (surface area, number of rooms, number of bathrooms, the presence of a garden, etc.), temporal characteristics (year and month when the transaction was made), location characteristics (binary variable attributed to each IRIS, to the exception of the IRIS of reference[15]), environmental characteristics (noise made by air, road and train traffic).

14. A new indicator was tested and suggested, based on the exploitation of the data found in this article, the Real Estate Tolerance Level (RETL) (see Lavendier et al., 2016).

What incidence does the "noise" variable have on real estate prices?

The determination coefficient (adjusted R^2) indicates the proportion of the variance in the dependent variable (the prices of houses or apartments), which can be explained by regression. The more this coefficient is close to 1, the best the statistical estimation can be.

For each type of property, the two types of models reveal the same significant variables and the coefficient values are close. Given the closeness of the results, only the ones in the second model are presented here (tables 1 and 2). The characteristics inherent to real estate (number of rooms, number of bathrooms, of garages, etc.) play a prominent role in determining the price of both houses and of apartments. The time when the transaction occurred (year and month to a lesser extent) also has an impact on the price. Extrinsic variables, represented by the IRIS, enable us to integrate other price determinants that are difficult to observe and that are linked to the neighborhood. The variable rates induced by the IRIS show big gaps from one IRIS to another: between -50% and +83% in comparison with the IRIS of reference for houses and between -62% and +52% in the case of apartments. In line with the results of past studies on this issue, the variables linked to transportation noise play a negative and statistically significant role on the price of dwellings. Road and train noise[16] nevertheless has little impact on real estate prices. Being exposed to a level of road noise superior to Lden 55 diminishes the price of houses by 1.54%. These effects are much inferior to those observed in the case of air traffic noise pollution. However, being exposed to train noise of the same intensity increases the price of an apartment by 2.07%[17].

To explore in more depth the relationship between the decrease of real estate prices and the increase of airplane noises, we subdivided noise zones as thinly as possible (in graduations of 1 dB(A)) and used real data for noise measurement, based on Curves of Environmental Noise (model 2). The results obtained are presented in figure 4. The diminution of the price for each increase of a unit of the noise variable is not linear.

When applying the HPM to the noise made by airplanes, results are often presented in the form of NDI (Walters, 1975), which represents the percentage of depreciation of the selling price for a marginal variation of one sound unit (one decibel). For this, we only need to divide these obtained percentages by the difference of noise nuisance for each zone in relation to the zone of reference. It results with the NDI varying between 0.96% and 1.54% (unweighted average: 1.27%) for houses and between 0.57 and 2.6% for apartments (unweighted average: 1.29%). We must note that with the model in which the noise variable of airplanes is integrated in the form of a continuous variable (model 1), being exposed to a level of airplane noise superior to 50 dB(A) diminishes the price of houses by 1.5% per decibel and that of apartments by 1.1% per decibel. These results converge with those obtained in several past studies because they are located within a range of values (between 0.10 and 3.57%)[18] found through a meta-analysis carried out by Shipper et al. (1998) based on thirty studies in Australia, Canada, United-Kingdom and United-States. In France, Guillaume Faburel and Isabelle Maleyre (2007) also demonstrated that one decibel higher undermines the value of a dwelling by 0.96% around Paris – Orly airport. Jasper E.C. Dekkers and J. Willemijn Van der Straaten's study (2009) on the Amsterdam airport, which takes into account the multiple exposures to noise, also proved that noise from air traffic has the most impact on the price of houses (NDI=0.77), followed by train noise (NDI=0.67) and road noise (NDI=0.16).

15. This study covers all transactions made in the Val-d'Oise *département* and located within a radius of 35 km of the Paris – CDG airport barycenter, totaling 19,891 houses and 23,264 apartments.

16. These data are from noise strategic maps made by the Val-d'Oise Equipment and Agriculture Authority.

17. This increase can result from the advantage of living close to a train station, considered an asset rather than a nuisance. The effect of the train noise variable is not statistically significant for houses and the same goes for the effect of the road noise variable on apartments.

18. For other meta-analyses, see Nelson 1980 and 2004.

Table 1/ Results for houses of the estimations of hedonic price models on Paris – Charles-de-Gaulle

House single					
	Variables	B	t	Impact in percentage	
	Constant	6.882	303.56	303.56	
	Plot	0.180	61.47	0.18	
Year	2002	-0.501	-87.63	-39.43	
	2003	-0.400	-68.56	-32.97	
	2004	-0.279	-47.56	-24.33	
	2005	-0.131	-23.19	-12.25	
	2008	0.076	12.83	7.91	
Age of the construction	‹ or = 1913	0.031	2.88	3.13	
	1970-1980	0.066	7.85	6.80	
	1981-1991	0.075	8.81	7.74	
	› or = 1992	0.102	9.31	10.72	
	Unknown	0.027	4.60	2.73	
Numbers of rooms	Number ‹ or = 2	0.296	31.98	34.49	
	Number = 3	0.172	29.02	18.74	
	Number = 4	0.094	20.48	9.90	
	Number = 6	-0.107	-20.14	-10.10	
	Number › or = 7	-0.280	-43.59	-24.46	
Bathroom	No bathroom	-0.191	-22.49	-17.35	
	Number › or = 2	0.087	20.05	9.06	
Garage	No garage	-0.049	-12.41	-4.75	
	Number › or = 2	0.051	6.73	5.21	
Number of floors	One floor	-0.052	-11.04	-5.05	
	Number › or = 3	0.019	3.55	1.91	
Swimming pool	One	0.141	5.61	15,09	
	Unknown	0.007	2.02	0,69	
Sensitive area (ZUS)	In ZUS	-0.051	-2.50	-4.96	
Traffic noise	Road noise	-0.016	-1.86	-1.54	
	Railway noise	0.002	0.24	NS	Number of transactions
Aircraft noise	[50-51[	-0.010	-1.12	-0.96	1,420
	[51-52[	-0.018	-1.79	-1.80	1,348
	[52-53[	-0.033	-2.72	-3.21	1,122
	[53-54[	-0.039	-2.93	-3.80	1,145
	[54-55[	-0.060	-4.22	-5.85	1,178
	[55-56[	-0.096	-6.05	-9.12	896
	[56-57[	-0.114	-6.60	-10.77	744
	[57-58[[	-0.130	-6.82	-12.22	580
	[58-59[	-0.126	-6.04	-11.84	367
	[59-60[	-0.151	-6.70	-14.04	258
	[60-61[	-0.159	-6.58	-14.70	440
	[61-62[	-0.158	-5.96	-14.58	342
	[62-63[	-0.188	-6.27	-17.18	163
	› ou = 63	-0.243	-6.71	-21.56	89

All coefficients are significant at 1%, to the exception of stories [50-51[and [51-52[which are significant at 5%. The explanatory variable is Ln of the price per meter square (see Box 2). Source: BIEN database.

Tabl. 2/ Results for apartments of the estimations of hedonic price models on Paris – Charles-de-Gaulle

	Apartment				
	Variables	**B**	**t**	**Impact in percentage**	
	Constant	7.377	612.06		
Year	2002	-0.114	-19.30	-10.79	
	2004	0.154	28.04	16.68	
	2005	0.349	63.71	41.81	
	2006	0.521	89.92	68.40	
	2008	0.622	99.49	86.20	
Age of the construction	< or = 1913	0.053	5.76	5.48	
	1914-1947	0.015	2.18	1.54	
	1981-1991	0.051	7.81	5.22	
	1992-2000	0.125	17.02	13.36	
	> or = 2001	0.119	4.72	12.63	
Number of rooms	Number = 1	0.138	23.67	14.83	
	Number = 2	0.063	14.05	6.52	
	Number = 4	-0.059	-13.81	-5.70	
	Number = 5	-0.100	-13.56	-9.54	
	Number > or = 6	-0.186	-9.38	-16.98	
Bathroom	No bathroom	-0.082	-11.64	-7.83	
	Number > or = 2	0.038	4.41	3.83	
Garage	No garage	-0.044	-10.46	-4.30	
	Number > ou = 2	0.029	4.04	2.90	
	Unknown	-0.049	-4.20	-4.75	
Floor	One floor	-0.033	-6.58	-3.26	
	> or = 6	-0.037	-4.96	-3.60	
Garden	With garden	0.050	5.71	5.12	
Terrace	With terrace	0.029	3.38	2.92	
Sensitive area (Zus)	In ZUS	-0.100	-5.35	-9.49	
	In a buffer zone close to a Zus (750 m)	-0.042	-5.30	-4.09	
Traffic noise	Road noise	0	0,04	NS	
	Railway noise	0,021	2,16	2,07	Number of transactions
Aircraft noise	[50-51[	-0,021	-2,37	-2,09	706
	[51-52[	-0,053	-5,18	-5,20	514
	[52-53[	-0,037	-3,35	-3,65	373
	[53-54[	-0,063	-5,24	-6,11	318
	[54-55[	-0,068	-5,09	-6,53	272
	[55-56[	-0,070	-5,02	-6,80	180
	[56-57[	-0,055	-3,64	-5,35	110
	[57-58[	-0,116	-6,67	-10,98	122
	[58-59[	-0,140	-7,58	-13,05	70
	[59-60[	-0,120	-5,19	-11,33	66
	[60-61[	-0,124	-4,01	-11,68	116
	[61-62[	-0,112	-3,04	-10,60	78
	[62-63[	-0,138	-3,13	-12,86	22
	> ou = 63	-0,084	-1,76	NS	9

All coefficients are significant at 1%, to the exception of stories [50-51[and [51-52[which are significant at 5%. The explanatory variable is Ln of the price per meter square (see Box 2). Source: BIEN database.

The HPM enables us to take more effectively into account specific depreciations linked to the impact of an exogenous factor, airport noise nuisances in this case, than with the method limited to gross prices. With the first method, we are able to integrate the characteristics of the local real estate market. The second method could be applied if all properties had strong similarities (in terms of age, size, surface area, etc.) over the whole territory, which is not the case. Comparing the two methods[19] applied on old houses (fig. 5) and on old apartments (fig. 6) confirms that the HPM tends to rather soften the impacts.

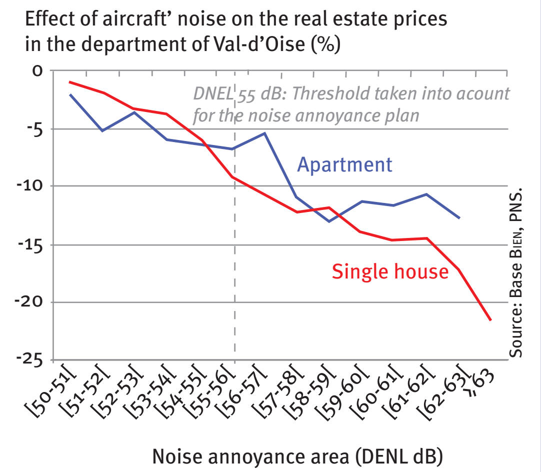

Fig. 4/ Impact of airplane noise on real estate prices in Val-d'Oise compared to the zone of reference (Lden < 50 dB(A))

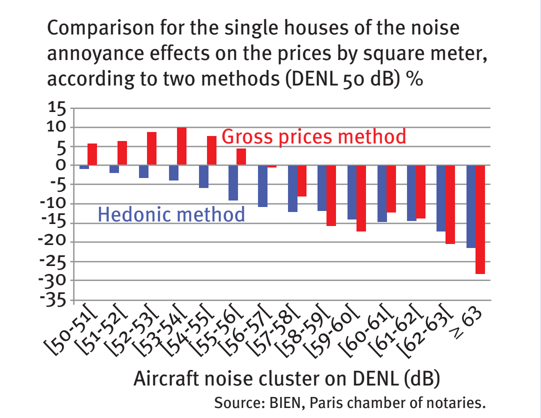

Fig. 5/ Comparison between the impact of airplane noise and the price of house in Val-d'Oise

The impact is obtained by using the hedonic pricing method and the difference between gross prices for each noise zone and the zone of reference.

The real time monitoring of the effects of airports

The impact of noise nuisances on the real estate market allows us to better understand noise nuisances around the airport, to quantify the impact on the quality of life and to analyze the way these impacts are distributed between the different zones (Bréchet, Picard 2007; Dobruszkes, 2007; Bréchet et al., 2009). This type of issue can be analyzed in terms of environmental justice. This concept developed in the United-States in the late 1970s to designate both inequalities in the exposure to environmental risks (pollution, waste, floods) and the exclusion of racial minorities from the design and implementation of environmental policies (Environment Protection Agency, 1998; Laurent, 2009). In Europe, including in France, this concept has led to the implementation of public policies aiming for sustainable development and social justice (Stec, 1998; Bélier, 2002; Laurian, 2008). Among the possible measures are first and foremost compensation actions (Walker et al., 2005). Although they take different forms, the depreciation of real estate prices due to noise nuisances can constitute an estimation of the amount of the financial compensation to be paid to residents enduring noise pollution (Walters, 1975). Considering the average acquisition amount in 2008 of real estate in our database (303,642 euros for houses and 166,782 euros for apartments), the amount of the compensation to be given to each household in the different zones of noise would vary between 2,915 and 65,465 euros per household for houses and between 366 and 2,289 euros per household living in apartments (table 3). In annualized terms, these amounts would vary between 307 and 6,885 euros per household for houses and between 366 and 2,289 euros per household for apartments. The compensation modalities could take different forms among which better sound insulation in dwellings, liable of also contributing to their thermal insulation. These amounts are therefore much higher than the soundproofing grants given in

19. In order to do the comparison, gross prices were deflated according to INSEE's old housing price indexes (index base 100 in 2008).

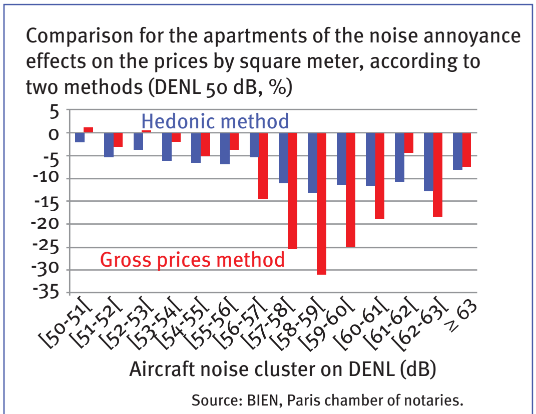

Fig. 6/ Comparison between the impact of airplane noise and the price of apartments in Val-d'Oise

The impact is obtained by using the hedonic pricing method and the difference between gross prices for each noise zone and the zone of reference.

France. For individual housing located in zone III with five main rooms and a kitchen, the works to be done are limited to 15,575 euros for a rate of 100% (a maximum of 12,460 euros for a rate of 80%). The acoustic diagnostic of the dwelling is limited to 778 euros for which Aéroports de Paris (2013) pays a maximum of 778 euros for a rate of 100% (623 euros for a rate of 80%). The grant will amount to a maximum of 16,353 euros.

Conclusion

The aim of this article was to contribute to the evaluation of the effect of airplane noise on real estate prices around Paris – CDG airport. For this, the gross price method, followed by the hedonic pricing method, were successively applied to the data on real estate transactions from the BIEN database. The hedonic pricing method reveals that airplane noises negatively and significantly affect the price of houses and apartments, but this influence is not linear. This depreciation is the result of decisions made by households when acquiring property (apartment or house). Airplane noise lowers the price per meter square of houses by 1.1 to 21.6% and that of apartments between 1.8 and 17.1%. The results converge with those obtained in other areas in France, such as

Table 3/ Price decline due to noise and loss of wellbeing per household, according to the type of property item and the noise zone

Aircraft noise cluster based on LDEN dB (A)	House			Apartment		
	Depreciation in %	Depreciation in euros	Constant annuity	Depreciation in %	Depreciation in euros	Constant annuity
[50-51[	-0.96	2 914.96	306.61	-2.09	3 478.36	365.87
[51-52[	-1.80	5 465.56	574.89	-5.20	8 673.84	912.36
[52-53[	-3.21	9 746.91	1 025.23	-3.65	6 087.76	640.34
[53-54[	-3.80	11 538.40	1 213.66	-6.11	10 182.28	1 071.02
[54-55[	-5.85	17 763.06	1 868.40	-6.53	10 890.47	1 145.51
[55-56[	-9.12	27 692.15	2 912.79	-6.80	11 346.42	1 193.47
[56-57[	-10.77	32 702.24	3 439.78	-5.35	8 928.26	939.12
[57-58[	-12.22	37 105.05	3 902.89	-10.98	18 311.46	1 926.09
[58-59[	-11.84	35 951.21	3 781.52	-13.05	21 768.37	2 289.70
[59-60[	-14.04	42 631.34	4 484.17	-11.33	18 903.94	1 988.41
[60-61[	-14.70	44 635.37	4 694.96	-11.68	19 486.06	1 049.64
[61-62[	-14.58	44 271.00	4 656.64	-10.60	17 674.56	1 859.09
[62-63[	-17.18	52 165.70	5 487.04	-12.86	21 446.11	2 255.80
> or = 63	-21.56	65 465.22	6 885.94	-8.05	13 425.10	1 412.12

Source: BIEN database, Paris Notaires Service, 2002-2008 (except 2007).

Toulouse-Blagnac airport (Sedoarisoa, 2015), or elsewhere (Shipper et al., 1998; Navrud, 2002; Nelson, 2004; Dekkers, Van der Straaten, 2009). Certain limits nevertheless need to be underlined. The correlation between sound level variables and planes flying over did not enable the simultaneous analysis of their respective influences. Moreover, prevention measures should also be taken into account: double glazing can be installed to reduce the impact of noise. However, these data are not available in the BIEN database, and another approach would be needed to take them into consideration. The obtained results nevertheless allow us to objectify the effect of noise pollution on real estate value and lead us to suggest the implementation of a compensation plan to face the observed situation of environmental injustice, as is the case in other European contexts. In order to confirm the results, this study based on a quantitative approach should however be completed with a qualitative approach to clarify the choices that households make (real estate buyers or not) when they decide to live near an airport, especially where noise pollution is at its highest. Can the latter be counterbalanced by advantages caused by the economic dynamism boosted by airports? We would then be able to further deal with and clarify the tendencies obtained by analyzing real estate prices (gross prices, but especially hedonic prices).

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