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Monetary Valuation of Aircraft Noise

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Monetary valuation of aircraft noise;
a hedonic analysis around Amsterdam airport*

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Abstract

In densely-populated countries and in particular in large metropolitan areas, the presence of so much human activity causes all sorts of negative externalities, for example traffic noise disturbance. These externalities call for corrective measures by the government. Economists have developed a number of procedures that provide reasonable estimates on the monetary value of some amenities and externalities. In this paper we develop a spatially-explicit hedonic pricing model for house prices in order to quantify the social cost of aircraft noise disturbance in monetary terms. While focusing on aircraft noise around Amsterdam airport in the urban fringe of the Amsterdam region, a key point in our analysis is that we account for background noise. We do this by taking multiple sources of traffic noise (i.e. road, railway and aircraft noise) into account simultaneously and by setting threshold values for all three sources of noise above which sound is generally experienced as nuisance. Based on our regression results we conclude that a higher noise level means *ceteris paribus* a lower house price. Air traffic has the largest price impact, followed by railway traffic and road traffic. These model outcomes can subsequently be used to estimate the marginal and total benefits of aircraft noise reduction in the studied area around Amsterdam airport. We find a marginal benefit of 1 dB noise reduction of 1,459 Euro per house, leading to a total benefit of 1 dB noise reduction of 574 million Euros.

Keywords: aircraft noise, GIS, hedonic price theory, noise reduction, valuation

*This paper is based on the authors' contribution to Lijesen et al. (2006).

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1. Introduction

Sound disturbance or noise nuisance is a negative externality of transport, especially occurring near main transport arteries. People respond differently to noise nuisance, but in general when noise levels reach a certain threshold, they tend to be affected negatively. In this paper we examine the effect of transport noise on house prices, using the hedonic pricing method to estimate the benefits of noise reduction in a second step. More in particular, we focus on aircraft noise near airports. A relatively new approach in this analysis is that we take multiple sources of transport noise into account, combining road, railway and aircraft noise in one analysis. This is important since the presence of traffic background noise influences people's perception of aircraft noise (see Johnston and Haasz, 1979, for an overview of studies on this issue). To our knowledge, the study by Bateman et al. (2001) is the only hedonic pricing study on aircraft noise that actually takes more than one noise source into account. Amsterdam airport is an interesting case, since it is one of Europe's largest airports situated within the urban fringe of the Amsterdam region, a highly urbanised area. In this study we measure people's perception of the sound charge level of various modes of transport. Sound charge is an objective measure for sound level expressed in decibels. As soon as people are negatively affected by any sound charge level, this sound charge is called noise. Our focus is on the latter issue, therefore we will from this point onwards use the term transport noise or noise nuisance most of the time instead of transport sound charge.

When also the costs of aircraft noise reduction are determined, the optimal size of government intervention in case of noise nuisance near airports can be calculated. This is done by Lijesen et al. (2008). The presented study is part of this broader study. We start with a literature review of hedonic price studies on the effect of noise nuisance in general (Section 2). This review will help us to select the proper model specification in Section 3. Then, some remarks are made on the calculation of noise (Section 4). Next, the study area and the (spatial) data are described in Section 5. Subsequently, the regression results are discussed in Section 6. The presence of spatial dependence in the dataset is investigated in Section 7. Further, in Section 8 the results are used to calculate marginal and total benefits of noise reduction. And finally, we end with some conclusions in Section 9.

2. Literature review

Quite a few international studies have focused on the effect of transport noise on house values. Most studies focus either on noise from road and/or railway transport or on aircraft noise. The bulk of the studies have been carried out in the United States and Canada and use the Hedonic Pricing Method (HPM). Results are often expressed in the form of a Noise Depreciation Index (NDI, also known as Noise Depreciation Sensitivity Index (NSDI)). The NDI represents the average house value decrease caused by a 1 decibel (dB) increase in aircraft carrier noise. Table 1 gives an overview of (meta-) analyses on transport noise including the found NDI-values. The analyses show that the NDI for aircraft noise varies between 0.10 and 3.57.

Table 1. Overview of NDI-values found in studies on transport noise

Study	Source	NDI	Period	Study area	Remarks
Bateman et al. (2001)	Road	0.08-2.2	1950-1990	Australia, Finland, Norway, Sweden, Switzerland & USA	Overview of 28 studies
	Air	0.29-2.3	1960-1996	Australia, Canada, UK & USA	Overview of 30 studies
Nelson (2004)	Air	0.5-0.6 0.8-0.9	1969-1993	Canada and United States	Meta-analysis (33 NDIs)
Schipper (1999)	Air	0.83	1967-1996	Australia, Canada, UK & USA	Meta-analysis (30 NDIs)
	Air	0.10-3.57	1967-1996	Australia, Canada, UK & USA	Overview of 30 studies
Udo (2005)	Road	0.21-1.6	1974-2003	Australia, Canada, Denmark, Japan, Norway, Scotland, Sweden & Switzerland	Overview of 14 studies
	Air	0.4-2.3	1979-1996	Canada, UK and USA	Overview of 7 studies

Very few hedonic price studies that aim at measuring the price effects of transport noise have been performed in the Netherlands. Recently, Van Praag and Baarsma (2005) have carried out a stated preference study on the valuation of aircraft noise around Amsterdam airport. In this study, the well-being of people is defined as a function of income, family size, age, the presence of sound insulation in people's homes and their perception of noise[1]. The perception of noise depends on family size, monthly expenses on housing, how much of their time people spend at home during daytime hours, presence of a balcony or a garden and the real noise level (expressed in Ke). The results show that the perception of noise negatively influences the general sense of well-being. The shadow price of sound depends both on the percentage change of the noise level as on the income level of a household: a household with a monthly net-income of 1,500 Euro needs to receive a compensation of 2.24 percent (or 33.60 Euro) when the noise level increases from 20 to 30 Ke. When the noise level increases from 30 to 40 Ke, the compensation needs to be 1.58 percent. Since we use Lden (Level day-evening-night) as the unit for transport noise, representing the average sound charge during a whole year expressed in decibels (dB), it is worthwhile to mention that 20 Ke is approximately equal to 53 Lden, 30 Ke approximately to 55 Lden and 40 Ke approximately to 58 Lden (NLR, 2005).

Next to the overview of meta-analysis studies presented in Table 1, Udo (2005) has estimated the value of quietness in the villages Baarn and Soest for the period 1996-2000. The sources of transport noise in this study are highways, busy municipal roads and a railway. The results show that the decrease in house prices depends on the chosen threshold value above which an increase in noise is assumed to negatively influence house values. An increase in noise of 1 dB at a threshold value of 55 dB leads to a house price decrease of 1.7 percent (at an average house price of 146,000 euro this is equal to 2,500 Euro). When the threshold value is chosen to be 45 dB, the decrease is equal to 1,600 Euro. This result shows us that we must carefully choose the threshold value in our analysis.

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[1] The model is also estimated in an alternative form with calculated sound charge in Ke-units. In that estimation, the Ke-variable did not differ significantly from 0.

3. The model

As written in the introduction, the effect of the transport noise level on the price of a house can be calculated using the Hedonic Pricing Method. The first step in the analysis is to estimate a hedonic price function with the house price as the dependent variable. Next, the individual demand curve for each separate explanatory variable can be calculated. The basic regression model used in this analysis is formulated as follows:

$$P = \alpha + \beta S + \gamma L + \tau G + \varepsilon \qquad (1)$$

where P is an (n x 1) vector of house prices, S is an (n x i) matrix of transaction-related characteristics (e.g. free of transfer tax, year of sale), L is an (n x j) matrix of structural characteristics (e.g. number of rooms, quality of inside maintenance), G is an (n x k) matrix of spatial characteristics (e.g. accessibility, neighbourhood ethnicity, level of urban facilities), α; β, γ and τ are the associated parameter vectors and ε is a (n x 1) vector of random error terms. For this analysis, we choose to estimate a log-linear model, since this functional form is widely used in similar studies and, thus, allows for a straightforward comparison of results (Section 6). Furthermore, we tested the model for the presence of spatial dependence in the dataset (Section 7).

Figure 1 shows two possible relations between noise reduction and house prices. Line A shows a linear relationship between noise reduction and house prices, which means that when the noise reduction increases (i.e. when the absolute noise level decreases), house prices increase at a constant rate. Another possible relation (Line B) is that when the noise reduction increases, house prices increase at a decreasing rate. Which relationship is more appropriate in the urban fringe around Amsterdam airport remains to be seen.

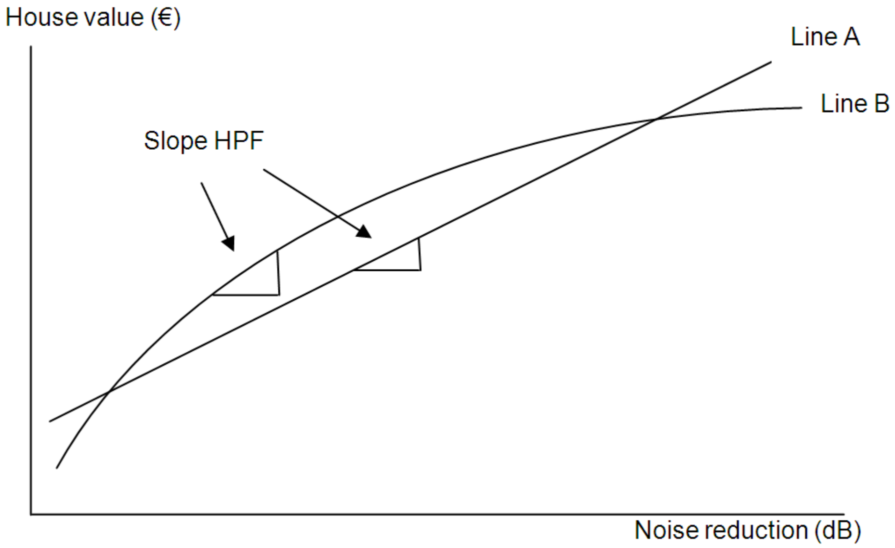

Figure 1. Possible relations between house prices and noise reduction.

4. Calculation of noise nuisance

We briefly mentioned in Section 3 that we use Lden (Level day-evening-night) as the unit for transport noise. Lden represents the average sound charge during a whole year, expressed in decibels (dB). A twenty-four hour weighting factor is applied to calculate Lden. This weighting factor depends on the time of day an aircraft causes noise: Noise nuisance during the night weighs ten times stronger than day-time noise. Because of this methodology, we cannot say anything about the valuation of noise on different times during the day. The Lden unit has a logarithmic scale, which means that an increase in sound of 3 dB is equal to a doubling of the sound intensity.

However, if there is no aircraft noise present on the ground, this does not mean the background noise level is also zero dB. In an urban environment, the background noise level approximates 50-60 dB during day-time and 40 dB at night according to Nelson (2004). Morrison et al. (1999) mention a normal background noise level of 44-55 dB during the day. To take the presence of background noise into account, we use multiple sources of sound in one hedonic pricing model simultaneously and use various threshold values for the different sound sources. The Netherlands Environmental Assessment Agency (MNP) applies in her EMPARA[2]-model for the measurement of background noise a threshold value of 55 dB (MNP, 2005; Dassen et al., 2001). Internationally, there is agreement on a threshold vale of 55 dB for noise from road transport and 60 dB for noise from rail transport (Vermeulen et al., 2004; ECMT, 1998). These values are also applied in this analysis. The reason for a difference in threshold value between different transport modes is that for an equal sound charge the sound of a train passing by is in general experienced as less disturbing (see, for instance, Fields and Walker, 1982). To correct for this difference, the threshold value for rail transport noise is increased by 5 dB (Vermeulen et al., 2004).

For the hedonic price analysis of the influence of aircraft noise on house prices we choose a threshold value of 45 dB, arguing that this type of noise is experienced as more disturbing (see, for instance, Miedema and Oudshoorn, 2001, or Taylor et al., 1987)[3]. In our analysis this threshold value means that, for instance, for a house that experiences an aircraft noise level of 55 dB, the aircraft noise variable in the model equals 10 dB. We have performed some tests to see whether sound charge levels below the chosen threshold value influence house prices in any way. The test results do not confirm any presence of noise nuisance below the chosen threshold value, although we must admit that the test results are not very robust. This might be caused by the fact that the observations are unequally distributed, both over the various sound charge levels and over the study area, see Figure 3 and Table 5.

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[2] For its Nature Outlook publications, MNP use the model EMPARA (Environmental Model for Population Annoyance and Risk Analysis). This model is a new and improved version of the Landelijk Beeld van Verstoring (LBV)-model (Vermeulen et al., 2004).

[3] These authors conclude based on empirical research that noise annoyance for aircraft noise is consistently higher than for road transport noise. Passchier et al. (2002) report an outdoor day and night aircraft noise annoyance threshold level of 42 dB based on research by the Health Council of the Netherlands (1999).

We estimated several different specifications of noise and looked which specification fitted the model best. The results show that a linear specification of the sound charge gives the best explanation of the relation between the house price and noise level (remember Line A in Figure 1). Figure 2 shows the corresponding linear relation between house prices, threshold value and sound charge levels.

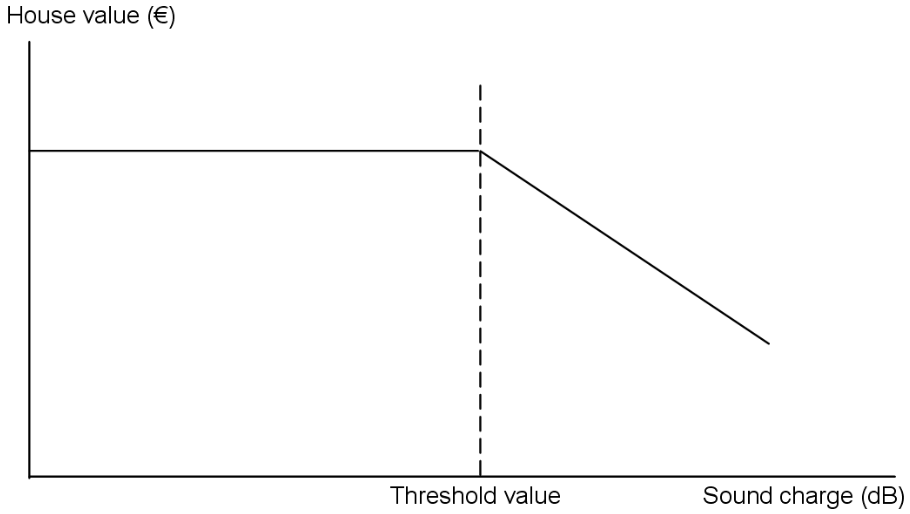

Figure 2. Influence of sound charge on house price.

5. Exploratory Data Analysis

We use various (spatial) data sources in the analysis. First, we have data on house transactions: Price, date of sale (period 1999-2003) and structural house characteristics (e.g. floor area, volume, number of rooms, different types of isolation[4]). This data is provided by the Dutch Association of Real Estate Agents (NVM) and includes all houses sold by the NVM during this period[5].

Second, after having geocoded the transactions, many variables on the housing environment are constructed and included in the analysis. For each neighbourhood, the following characteristics are included: population density (Source: CBS Statline), the normalised number of retail outlets, the distance to the nearest railway station and the distance to the nearest highway ramp (Source: Netherlands Environmental Assessment Agency, MNP).

Third, with regard to aircraft noise, we use data from the Netherlands Institute for Health and the Environment (RIVM). In the RIVM-model, aircraft noise is computed by the National Aerospace Laboratory (NLR, 2005) using modelled flight paths. Noise in Lden is expressed in dB and then the average is computed for houses on CBS neighbourhood-level. In 2002, 2003 and 2004 the modelled area was approximately 70 by 55 kilometers. In 1999, 2000 and 2001 the area was approximately 55 by 55

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[4] This variable includes, for example, double glazing, roof isolation and floor isolation. Unfortunately the data did not allow us to separate different types of isolation (i.e. noise isolation versus warmth isolation).

[5] Of all the houses sold in the Netherlands, 65-70 percent are sold by NVM real estate agents.

kilometers. The missing neighbourhood noise values for these latter years (caused by the smaller modelling area) are calculated using interpolation. We choose to follow this definition of the study area in our analysis. See for a detailed description MNP (2005). Analogous to what is mentioned in Section 2, the Hedonic Price Method (HPM) measures the perception of households with regard to sound charge levels. In our model we assume that the perception of households equals the sound charge levels as computed by NLR.

Fourth, next to aircraft noise we take into account noise from main roads and railways. Few studies on aircraft noise simultaneously include these other transport noise sources. Navrud (2002, p.27) says: "In a situation where individuals are exposed to *multiple sources of noise*, measures to reduce one dominating source (especially if the decibel level is below 65 dB) or one out [of] two equal noise sources will have little effect on the level of annoyance as the other sources will take over and dominate (e.g. shutting down an airport makes people at some distance from the airport more aware of and annoyed by nearby roads traffic noise). Therefore, action plans towards noise must consider all noise sources (especially when the noise level is below 65 dB); at higher noise levels there is a more significant effect of reducing one noise source, and they may be treated source by source." Noise of main roads and railways is included in the analysis on six-digit zip code level.

Fifth, because the house transaction dataset covers a period of multiple years during which house prices increased significantly, we use annual dummies to correct for this and other temporal effects.

Sixth, also municipal dummies are included to correct for other differences on municipal level that explain house price differences.

Furthermore, several choices are made with regard to the type of houses analyzed: Because the rental market is highly regulated in the Netherlands, we disregard rental houses and houses that are sold by auction and we only include houses that are permanently occupied (no recreation houses).

Table 2 contains the summary statistics of the variables used in the analysis. Finally, Figure 3 displays the aircraft noise per CBS neighbourhood in 2003. The dots represent the locations of the house transactions that are analysed. The figure also shows that our analysis does not include house transactions in the urban area above the North Sea Channel, due to the fact that we did not obtain any data for this region.

Table 2. Summary statistics of all model variables in the study area (1999-2003)

Variable	**Min.**	**Max.**	**Average**	**Std. Dev.**
Transaction price (x 1,000 Euro)	16	3,450	235	152
Transaction price per square meter (x 1,000 Euro/ m^2)	0.2	13.4	2.1588	0.7181
Transaction characteristics				
1999			0.1716	0.3770
2000			0.1925	0.3943
2001			0.2052	0.4038
2002			0.2099	0.4073
2003			0.2208	0.4148
Free of transfer tax (0=no/1=yes)			0.0029	0.0535
Leased land (0/1)			0.1700	0.3730
Structural characteristics				
Building age in ranges: <1906; 1906-1930; 1931-1944; 1945-1959; 1960-1970; 1971-1980; 1981-1990; >1990	-	-	-	-
Surface area (m^2)	26	530	100.5	1.461
Number of rooms	1	10	3.776	1.436
Presence of two or more types of isolation (0/1); Types: roof, wall, floor, double-glazing, partly double-glazing, double window frame, no cavity wall, eco-built			0.3366	0.4726
Presence of garage (0/1)			0.1037	0.3049
Presence of carport (0/1)			0.0328	0.1780
Presence of garden(0/1)			0.5376	0.4986
Quality of inside maintenance excellent to good (0/1)			0.8870	0.3285
Quality of inside maintenance fair to mediocre (0/1)			0.1075	0.3098
Quality of inside maintenance moderate to bad (0/1)			0.0155	0.1236
House type (indicating any of the 16 possible types)	-	-	-	-
Spatial characteristics				
Sound charge (aircraft) > 45 dB	0	20	2.0485	3.1259
Sound charge (railway) > 60 dB	0	18	0.1154	0.9085
Sound charge (road) > 55 dB	0	23	1.8588	3.0073
Distance to nearest railway station > 2 km (0/1)			0.3922	0.4882
Distance to nearest motorway ramp > 2 km (0/1)			0.4529	0.4978
Population density (x 1,000)	0.008	28.398	8.3666	5.7885
Density retail outlets (normalised in 500 meter grid cells)	0	0.4	0.0635	0.0830
Municipality (indicating any of the 27 municipalities)	-	-	-	-

Figure 3. Lden in 2003 per CBS neighbourhood, Amsterdam Airport and house transactions.

6. Regression results

After constructing all the variables and cleaning the data, the regression-analysis includes over 66,000 complete house transactions. We choose to use a log-linear model, in which the dependent variable is equal to the natural logarithm of the transaction price. Since we are mainly interested in the results with regard to noise, we will focus in our discussion of the results on that particular part of the analysis. Table 3 gives the results of our log-linear regression model.

The signs of most of the variables are as expected. The coefficients of the year dummies are positive and increasing, meaning the house transaction price was higher in 2003 than in 1999. Possible explanations for the house price increase are the interest rate developments and demand pressure on the housing market during this period. The surface area and number of rooms both have a positive sign. Also a house with better inside maintenance is more expensive according to the model outcome, and a house with a garden is more expensive than one without a garden. A house which is built on leased land is cheaper then a house on owned land. What is striking is the fact that the level of urban facilities has such a large positive influence on house prices. This variable seems to capture very well the price variance *within* municipalities.

The different noise variables all have a negative sign, as to be expected: a higher noise level means *ceteris paribus* a lower house price. Aircraft noise has the largest price impact (NDI = 0.77), then railway noise (NDI = 0.67), then road noise (NDI = 0.16). We have to consider though that, given the chosen threshold values, air- and road transport already have a price impact on lower absolute sound charge levels compared to railway transport.

The NDI's we find in our analysis generally correspond well with the values in other studies, see again Table 1. The reported air traffic NDI's in that overview range between 0.10 and 3.57. For railway transport we mentioned one other study carried out in the Netherlands by Udo (2005) in which he simultaneously analyzes the effect of railway and road noise nuisance and finds an NDI of 1.7. This is clearly higher than the NDI's we find. For road transport, the NDI's reported in Table 1 vary between 0.08 and 1.6, which does correspond with our findings that are to be put in the lower parts of this range.

Table 3. Results hedonic pricing model

Variable	Coefficient	(Std. Err.)	Variable	Coefficient	(Std. Err.)
(Constant)	8.4106**	(0.0174)			
Transaction characteristics			Spatial characteristics		
Year 2000	0.1185**	(0.0025)	Noise (aircraft) > 45 dB	-0.0080**	(0.0004)
Year 2001	0.1903**	(0.0025)	Noise (railway) > 60 dB	-0.0072**	(0.0009)
Year 2002	0.2232**	(0.0025)	Noise (road) > 55 dB	-0.0014**	(0.0003)
Year 2003	0.2226**	(0.0024)	Dist. railway stat. >2km	-0.0392**	(0.0021)
Free of transfer tax	0.1186**	(0.0141)	Dist. motorw. ramp>2km	-0.0309**	(0.0018)
Leased land	-0.0330**	(0.0025)	Pop. density (x 1,000)	-0.0097**	(0.0002)
			Density retail outlets	1.3327**	(0.0145)
Structural characteristics			Municipality		
Building age (<1906)	0.0411**	(0.0038)	Abcoude	0.0892**	(0.0110)
Building age ('06-'30)	-0.0035	(0.0033)	De Bilt	-0.0823**	(0.0193)
Building age ('31-'44)	-0.0200**	(0.0037)	Breukelen	-0.0964**	(0.0087)
Building age ('45-'59)	-0.1100**	(0.0041)	Loenen	0.1242**	(0.0132)
Building age ('60-'70)	-0.1808**	(0.0032)	Maarssen	-0.2740**	(0.0053)
Building age ('71-'80)	-0.1469**	(0.0033)	Utrecht	-0.2613**	(0.0027)
Building age ('81-'90)	-0.0763**	(0.0030)	Aalsmeer	-0.0331**	(0.0081)
Ln(surface area)	0.7795**	(0.0036)	Amstelveen	0.0722**	(0.0044)
Ln(number of rooms)	0.0112**	(0.0008)	Diemen	-0.0817**	(0.0115)
≥2 types of isolation	0.0183**	(0.0021)	Haarlemmerliede c.a.	-0.0902**	(0.0229)
Garage	0.1250**	(0.0028)	Haarlemmermeer	-0.1475**	(0.0039)
Carport	0.0607**	(0.0044)	Ouder-Amstel	0.0374**	(0.0091)
Garden	0.0395**	(0.0026)	Uithoorn	-0.0573**	(0.0066)
			Alkemade	-0.1273**	(0.0150)
House type			Leiden	-0.2291**	(0.0033)
Simple terraced house	-0.0091	(0.0052)	Leiderdorp	-0.1143**	(0.0062)
Canal side house	0.1667**	(0.0113)	Oegstgeest	-0.0166**	(0.0062)
Mansion	0.1572**	(0.0030)	Voorschoten	-0.1281**	(0.0064)
Farm	0.5031**	(0.0202)	Wassenaar	0.1082**	(0.0075)
Bungalow	0.3829**	(0.0076)	Woerden	-0.0827**	(0.0210)
Villa	0.4507**	(0.00560	Zoetermeer	-0.2673**	(0.0091)
Country house	0.5854**	(0.0174)	Zoeterwoude	-0.1688**	(0.0131)
Estate	0.7270**	(0.0967)	De Ronde Venen	-0.1035**	(0.0065)
Ground-floor flat	0.0626**	(0.0035)	Rijnwoude	-0.1684**	(0.0128)
Upstairs flat	0.0470**	(0.0036)	Wijdemeren	0.5086**	(0.0562)
Maisonette	0.0310**	(0.0047)	Leidschendam-Voorburg	-0.1637**	(0.0063)
Porch flat	0.0452**	(0.0037)			
Gallery flat	-0.0076	(0.0042)	Inside maintenance		
Old people's home	-0.6654**	(0.0167)	Excellent to good	0.1738**	(0.0062)
Ground-floor and upstairs flat	0.0794**	(0.0120)	Reasonably well to moderate	0.0714**	(0.0065)
Nr. of observations	66.636		Mean dependent var.	234,883	
Adjusted R^2	0.83		S.D. dependent var.	152,193	

The dependent variable is the natural logarithm of the transaction price
For the dummy variables the remaining categories (e.g. year = 1999) act as reference values
** = significant at 1%; * = significant at 5%

In our analysis, we defined aircraft noise as a continuous variable. This makes the marginal benefit curve a continuous function, which makes a comparison with a marginal cost function easier. But in many other studies on the house price effects of aircraft noise, the variable on aircraft noise is defined as a dummy variable or defined in several separate classes above a certain threshold value. In order to analyse the effect of different noise levels on house prices, we also estimate a model using six separate noise classes, of which four in the value range above the chosen threshold value (Table 4). The results show that values of houses with an aircraft noise level of 35-40 dB do not differ significantly from houses with an aircraft noise level lower than 35 dB. When the absolute noise level increases, house values decrease at an increasing pace. This effect is visible up to the class 50-55 dB. In the final two classes (between 55-60 dB and over 60 dB) the value decrease is less than in the class 50-55 dB. A possible explanation for this is the low number of houses in these classes, respectively 1,397 houses (2.1 percent of our dataset) and 273 houses (0.4 percent) (Table 5).

It has to be noted that changing the threshold value influences model outcomes. This effect corresponds with the findings of Udo (2005). When we for instance choose a threshold value of 48 dB, the coefficient of aircraft noise in the continuous model is less negative (-0.005). At a threshold value of 50 dB and 55 dB, the coefficient is not significant. Therefore, one has to be careful with interpreting and using the model outcomes.

Table 4. Results hedonic pricing model using sound charge classes

Variable	**Coefficient**	**(Std. Err.)**
Noise (aircraft) range 35-40 dB	0.0064	(0.0049)
Noise (aircraft) range 40-45 dB	-0.0172 *	(0.0073)
Noise (aircraft) range 45-50 dB	-0.0778 **	(0.0076)
Noise (aircraft) range 50-55 dB	-0.1312 **	(0.0079)
Noise (aircraft) range 55-60 dB	-0.1139 **	(0.0095)
Noise (aircraft) range >60 dB	-0.0703 **	(0.0142)
Adjusted R^2	0.83	

Houses with a noise level lower than 35 dB act as a reference value
** = significant at 1%; * = significant at 5%

Table 5. Number of houses (x 1,000) in the study area and number of houses (x 1,000) in the dataset classified according to aircraft noise disturbance

	Dataset		**Study area**	
Noise disturbance	**# Houses**	**Share (%)**	**# Houses**	**Share (%)**
Total	66.6	100.0	1,422	100.0
Below 35 dB	12.2	18.3	150	10.5
35-40 dB	5.9	8.8	161	11.3
40-45 dB	17.8	26.8	509	35.8
45-46 dB	3.7	5.5	117	8.2
46-47 dB	4.1	6.1	113	7.9
47-48 dB	3.5	5.2	105	7.4
48-49 dB	3.9	5.8	85	6.0
49-50 dB	3.7	5.6	38	2.7
50-55 dB	10.3	15.4	132	9.3
55-60 dB	1.4	2.1	11.6	0.8
60 dB or higher	0.3	0.4	0.4	0.0

7. Spatial dependence

A necessary step in spatial regression analysis is to test the data for spatial dependence. The presence of spatial dependence can cause model estimates to be (spatially) biased or inefficient. There are two types of spatial dependence: lag and error dependence. The former, also known as structural dependence, means there is a price correlation for neighbouring houses. A spatial lag model therefore tries to control for this dependence between the explanatory variables. The latter means that the error term for neighbouring houses is mutually dependent. A spatial error model estimates the effect of this heteroskedasticity (Anselin, 1988a). Various standard global and local dependency tests are available. In our case, we use global tests for both types of spatial dependence.

Reformulating our basic model (Eq. 1), we can describe both types of spatial dependence as follows:

$$P = \rho WP + \alpha + \beta S + \gamma L + \tau G + \varepsilon \qquad \text{where } \varepsilon \text{ is equal to:} \qquad (2)$$

$$\varepsilon = \lambda W\varepsilon + \mu \qquad \text{and } \mu \sim N(0, \sigma^2) \qquad (3)$$

In this model, W represents a row-standardized spatial weight matrix, while ρ and λ are spatial-econometric coefficients that describe the importance of the spatial lag and spatial error component respectively. For computational reasons tests for spatial dependence had to be performed on a sub sample of around 11,000 observations (±30% of the total sample). The tests show the presence of spatial error in the HPM-model (Table 6[6]), however the estimation of a spatial error model for the sub sample did not yield substantially different results with regard to our noise nuisance variables (i.e. for aircraft noise a coefficient of -0.0077 instead of -0.0080 in the regression model, see Table 7).

Table 6. Results of Moran's I and Lagrange Multiplier tests for spatial dependence

Test	MI/DF	Value	Prob.
Moran's I (error)	0.154	138.1	**
LM (lag)	1	154.8	**
Robust LM (lag)	1	21.6	**
LM (error)	1	13,461.4	**
Robust LM (error)	1	13,328.2	**
Nr. of observations		10,901	

MI denotes the Moran's I test-value, DF indicates the degrees of freedom in the Lagrange Multiplier (LM) test.
** = significant at 1%; * = significant at 5%

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[6] For technical details on the LM test and the model specification, see Anselin (1988b), Bera and Yoon (1993) and Anselin et al. (1996).

Table 7. Estimation results corrected for spatial dependence (error-models)

Model	**Full model OLS**		**Sub sample OLS**		**Spatial error model**	
Variable	**Coeff.**	**(St.Err.)**	**Coeff.**	**(St.Err.)**	**Coeff.**	**(St.Err.)**
Noise (aircraft) > 45 dB	-0.0080**	(0.000)	-0.0073**	(0.001)	-0.0077**	(0.002)
Noise (railway) > 60 dB	-0.0072**	(0.001)	-0.0071**	(0.003)	-0.0067**	(0.002)
Noise (road) > 55 dB	-0.0014**	(0.000)	-0.0027**	(0.001)	-0.0016*	(0.001)
λ					0.9327**	(0.007)
Nr. of observations	66,636		10,901		10,901	
R^2	0.910		0.830		0.866	

OLS means Ordinary Least-Squares and signifies the type of regression analysis used
** = significant at 1%; * = significant at 5%

8. Marginal and total benefits of noise reduction

The outcomes of the hedonic price analysis can be used to estimate the marginal and total benefits of aircraft noise reduction in the area around Amsterdam airport. This is done by taking the model coefficient for aircraft noise and multiplying the related house price impact by the house value of each house for which noise reduction is accomplished. The marginal costs of noise increase can be calculated in a similar way. We include these calculations in the results, but in the discussion we pay more attention to the benefits of noise reduction.

The marginal benefits depend on the house value. As a consequence of our choice for a linear specification of the relation between noise and house prices, for each (absolute) noise level the marginal benefits are equal (i.e. the marginal benefit of a decrease of one dB is equal for houses with a noise level of, for instance, 60 dB and, for instance, 48 dB). These can be calculated by taking the derivative of the abbreviated regression-function with only the aircraft noise variable included. This function is:

$$Ln(P) = C + \beta_i(Lden) \qquad \text{and its derivative is:} \tag{4}$$

$$MB = \beta_i P \tag{5}$$

in which *P* represents the average house price in the dataset, *C* is the constant in the model, β_i is the coefficient of the aircraft noise variable (Lden) and *MB* are the marginal benefits. When we take the average house value from the dataset (234,883 Euro), the marginal benefit of 1 dB noise reduction is 1,872 Euro per house that has an aircraft noise level greater than or equal to 45 dB. When we take the average house value (tax-value per 1 January 1999) of all CBS neighbourhoods with an aircraft noise level greater than or equal to 45 dB, the marginal benefit of 1 dB noise reduction is 1,459 Euro per house. Using an interest rate of 7 percent (4 percent basic interest plus 3 percent risk compensation) this is equal to a marginal benefit of 102 Euro per dB per house per year[7].

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[7] The EU Working Group on Health and Socio-Economic Aspects (2003) recommends calculating with 25 Euro per dB per household per year.

For the calculation of the total benefits of reductions in aircraft noise in the Amsterdam region, we use the tax-value since this value is known for all neighbourhoods. We do not only observe noise reduction alongside landing tracks and/or approach routes, we look at the whole study area. In order to measure the total benefits of the 1 dB noise reduction, we multiply the marginal benefits of an average house by the total tax-value of all the houses with an aircraft noise level greater than or equal to 45 dB. It has to be noted that we aggregate all the houses in the CBS neighbourhoods around Amsterdam airport, meaning both owned and rented houses, because of the fact that not only home owners but also renters experience the benefits. Supposing that in 2007 a policy will be introduced that realises an aircraft noise reduction in residential areas of 1 dB in 2008 (thus disregarding interest rates), the total benefit amounts to 574 million Euros. When we want to know the benefits per year and we use an interest rate of 7 percent, this means 40 million Euros per year, the assumption being that the amount of houses in this area remains equal.

In case of an increase in aircraft noise, some houses that first did not have a noise level at or above 45 dB now have a noise level at or above the threshold value, and thus a negative effect on their house prices. The more the noise increases, the more of the houses that were under the threshold value will now have a value equal to or higher than the threshold. Table 8 displays the total benefits and costs and the marginal benefits and costs per year for a decrease respectively increase in noise nuisance. It shows that there are decreasing marginal benefits per dB noise reduction. The first dB noise reduction has a marginal benefit of 574 million Euros or, at an interest rate of 7 percent, 40 million Euros per year. The fifth dB only adds 172 million Euros to the total benefits, or 12 million Euros per year. Similarly, we see increasing marginal costs per dB noise increase. Figure 5 displays the curve of the marginal costs and benefits per year.

Table 8. Total and marginal annual benefits and costs due to changes in noise level

Noise decrease (dB)	**Marginal benefits per year (mln Euros)**	**Total benefits (mln Euros)**	**Noise increase (dB)**	**Marginal costs per year (mln Euros)**	**Total costs (mln Euros)**
– 5	12	1,732	1	-49	-697
– 4	15	1,560	2	-57	-1,505
– 3	23	1,339	3	-67	-2,465
– 2	31	1,015	4	-77	-3,558
– 1	40	574	5	-87	-4,798

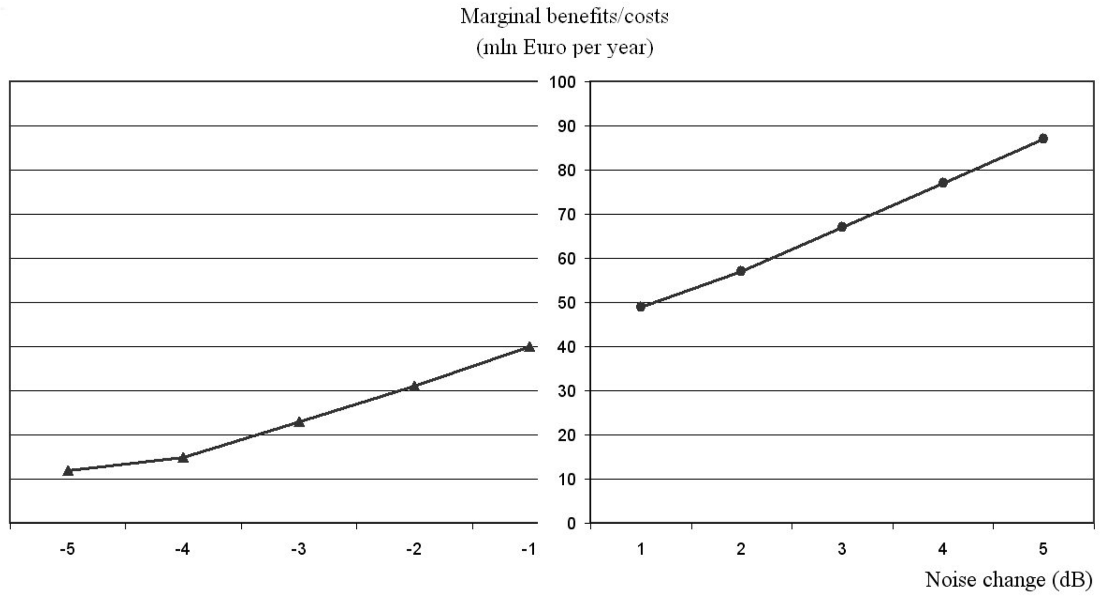

Figure 4. Marginal benefits and costs per year of noise level changes.

In the report on mainport developments for the evaluation of the Amsterdam airport policy, De Wit et al. (2006) analysed various external effects of an increase in aircraft noise. This also included an analysis of the increase in noise per household. For this analysis the results of the stated-preference investigation carried out by Van Praag and Baarsma (2005) were used. In the report the monetary compensation for the year 2008 and 2012 for people living around Amsterdam airport is calculated. Because for the latter year the compensation is calculated using an increase in aircraft noise of 1 dB, those results are compared with our model outcomes, although we have to remark that there are differences in methodology (stated preference versus revealed preference) and differences in the noise unit used (Ke versus Lden). De Wit et al. (2006) find that the average compensation per household in 2012 equals 33.25 Euro per year. This amount is multiplied by the number of houses in the area where there is an increase in aircraft noise. The total compensation then amounts to 18.5 million Euros per year. In our calculation we estimate the total costs of an increase of 1 dB in aircraft noise to be 697 million Euros, which is 48.8 million Euros per year (interest rate 7 percent). This means that the total costs following our method are approximately 2.5 times higher than the total costs according to De Wit et al. (2006).

9. Conclusions

This paper examined the effect of transport noise on house prices in the highly urbanized area around Amsterdam airport. Based on the regression results, total and marginal benefits of noise reduction were calculated, indicating that a 1 dB sound charge reduction will lead to a total house value increase of 574 million Euros, or 40 million Euros per year.

The benefits as we calculate them are on the low side compared to other international hedonic pricing studies. A point of discussion is the choice for a threshold value of 45 dB. This choice up to a certain point is arbitrary and the chosen model is sensitive to the threshold value. Relative little is known about the relation between sound charge and noise experience on lower sound charge levels. Navrud (2002, p. 31) rightfully states that “ERFs [Exposure- Response Functions], level of noise annoyance and economic values at noise levels below 50 Lden are very uncertain, and more empirical studies are needed to be able to set a lower cut-off point and avoid *underestimation* [curs. by ed.] of social benefits of noise reducing measures affecting low noise levels”. What this means for our model results is unclear at this moment. We recommend further research in this direction.

Another recommendation we would like to make is to include more house transactions in the model, specifically on the north-side of Amsterdam airport. The airport opened a fifth runway on the first of January 2003. It would be interesting to examine whether we can find a timing-effect of the announcement of the construction of this runway in the data and to see what the house price impact of this fifth runway on houses north of Amsterdam airport is, in particular in areas where people did not previously experience any serious aircraft transport noise nuisance.

The increase in house prices in case of a noise level reduction, the so-called willingness-to-pay (WTP) for noise reduction, is only one point on the demand curve of households. This means that the individual demand curve cannot be computed. That can only be done using extra information or with the assumption that the demand curves of all households are completely identical (Johansson, 1987, 1993). In general however, households will differ in many ways, for instance with respect to income and preference for environmental quality. In order to analyze the demand structure under these circumstances, we need to assess how the marginal WTP relates to income and other household characteristics. Next to the fact that this data is often unavailable at the desired level-of-detail, the estimation of the demand curve is hard due to identification and endogeneity problems (see Palmquist, 2003, and Ekeland et al., 2002, for a more elaborate discussion on this issue.) It would be interested however to investigate how the WTP for noise reduction relates to income, other households characteristics and preferences for environmental quality.

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