Airport Noise Footprints Revisited: The Impact of the Cut-Off Value on Noise Costs

VON RONNY PÜSCHEL, DRESDEN UND CHRISTOS EVANGELINOS, BAD HONNEF

1. Introduction

Noise externalities caused by the various transport modes exert considerable social impacts and need to be properly evaluated and internalized. One of the various evaluation methods using stated or revealed preferences is hedonic pricing according to Rosen (1974), Palmquist (1999) and Palmquist (2005), where housing market data is used to isolate the adverse environmental noise effect on property prices.

In Europe, noise footprint data is supplied by the European Environment Agency (2009) based on Directive 2002/49/EC addressing environmental noise. Following the directive's annex VI requirements, noise footprints show spatial noise exposure values caused by road, rail, and air traffic above 55 dB(A) L_{den}[1] respectively 50 dB(A) L_{night}[2]. Both figures can be seen as the assumed background noise level that is caused by typical urban activities.

Within hedonic price studies the background noise level determines the cut-off level of noise impacts. Hence, the application of given noise threshold levels does not allow examination of noise impacts on housing prices below these noise exposure levels. For this reason, the noise depreciation sensitivity index (NDSI)[3] as the key result of a hedonic pricing study may be inaccurate.[4] Furthermore, due to the logarithmic character of noise measurement reductions or increases in the noise level by 1 dB(A) may have different effects at different absolute noise levels. In that case, the noise impact measure NDSI is unable to accurately resemble the non-linear noise impact path.

Anschrift der Verfasser:

Ronny Püschel
Chair of transportation economics and international transport policy
Dresden University of Technology
01062 Dresdem
Ronny.pueschel@tu-dresden.de

Prof. Dr. Christos Evangelinos
Department Aviation Management
International University of Applied Sciences Bad Honnef Bonn
Mülheimer Strasse 38
53604 Bad Honnef
c.evangelinos@iubh.de

1 Day-evening-night noise indicator: Daily average equivalent noise level with penalties for evening and nighttime noise.
2 Night-time noise indicator: Average equivalent noise level during night.
3 Index indicating the relative devaluation of property prices due to a one decibel (A) increase in noise exposure.
4 Thanos et al. (2015).

We examine these two sources of inaccuracy for the region of Düsseldorf, Germany. We address the issue of nonlinearity of noise impacts and test whether the regularly used noise cut-off level of 55 dB(A) L_{den} is econometrically justified. As an indicator of the significance of these measurement issues we compare resulting impact figures, in terms of the number of noise-affected dwellings and inhabitants as well as noise costs in the considered airport region.

Several studies have already picked up this methodology and identified NDSI threshold values and non-linear NDSI values.[5] Recent hedonic price studies use spatial econometric approaches in order to account for spatial autocorrelation. With respect to lower cut-off noise levels and non-linear noise impacts Dekkers and Van der Straaten (2009) use a very similar approach with the one adopted in this paper in order to quantify noise effects for the case of Amsterdam airport and provide arguments in literature for the use of lower cut-off levels. The innovation of this paper lies therefore not much in the used methodology but rather in the verification of existing results for an additional case, notably for the area around Dusseldorf International airport.

2. Data

Our database contains 1370 apartment offers in the region of Düsseldorf from November 2009, obtained from the biggest German property listing website Immobilienscout24. Information on neighbourhood and accessibility attributes as well as noise-related data extends the database. Noise characteristics are represented by strategic noise maps of the year 2007, provided by the European Environment Agency, and maps of noise protection zones.[6] We solely focus on the daily average noise exposure measure L_{den}.[7] The exposure of the apartments concerning the various types of traffic noise is shown in Table 1.

5 Different noise threshold values have been addressed e.g. in Lake et al. (1998), Rich and Nielsen (2004), Cohen and Coughlin (2008), Andersson et al. (2010) as well as Brandt and Maennig (2011). Non-linear noise effects are examined in Pommerehne (1998), Wilhelmsson (2000), Day et al. (2007) and Andersson et al. (2010), Brandt and Maennig (2011), Ahlfeldt and Maennig (2013) among others.

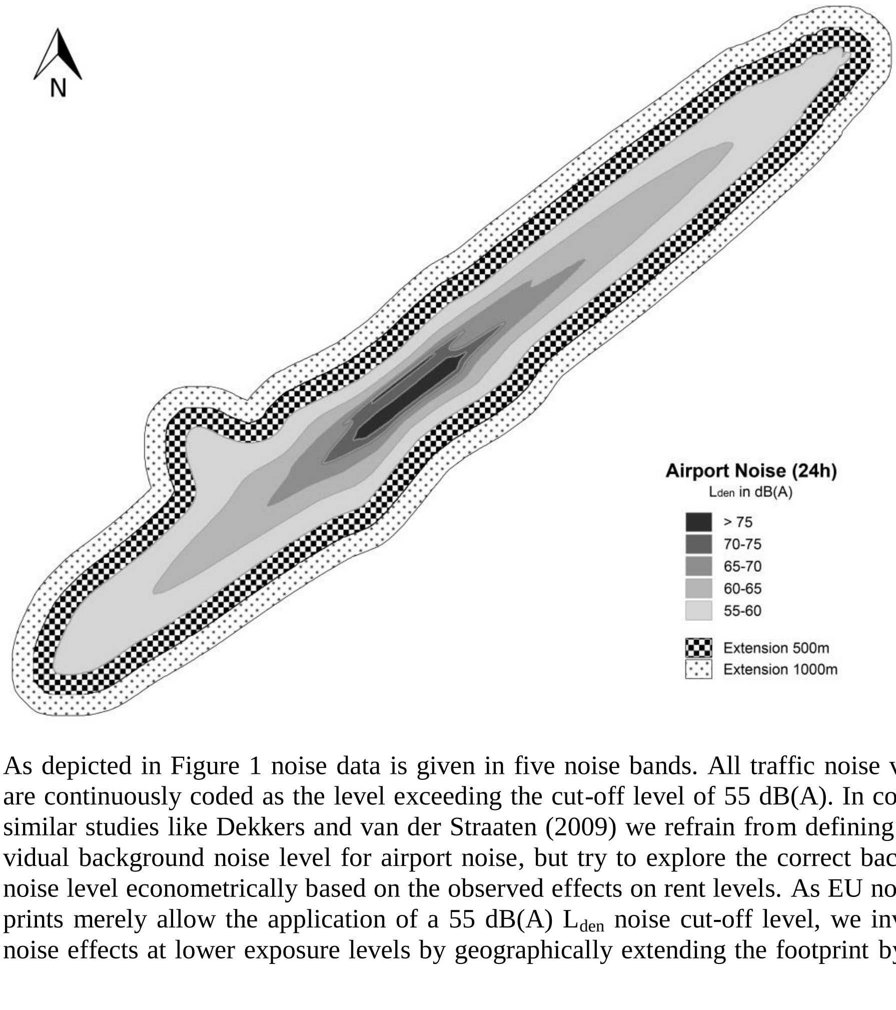
6 In Germany, landlords are eligible to apply for noise protection measures and monetary compensations if the respective housing unit is located within a specific noise zone according to the Aircraft Noise Act (FluLärmG). As respective noise level threshold values are given in the Leq measure, the noise zone is not equivalent to a specific noise exposure band of the EEA noise footprint.

7 Further information on data is shown in Püschel and Evangelinos (2012).

Table 1 Traffic Noise Exposure of Apartments

Trafic Noise Source	*>55-60 dB(A)*	*>60-65 dB(A)*	*>65-70 dB(A)*	*>70-75 dB(A)*	*> 75 dB(A)*	*Total*
Road noise	230	208	183	60	1	682
Rail noise	338	117	44	10	8	517
Airport Noise	34	16	1	0	0	51

Figure 1 Noise Footprint and Extension Zones



As depicted in Figure 1 noise data is given in five noise bands. All traffic noise variables are continuously coded as the level exceeding the cut-off level of 55 dB(A). In contrast to similar studies like Dekkers and van der Straaten (2009) we refrain from defining an individual background noise level for airport noise, but try to explore the correct background noise level econometrically based on the observed effects on rent levels. As EU noise footprints merely allow the application of a 55 dB(A) L_{den} noise cut-off level, we investigate noise effects at lower exposure levels by geographically extending the footprint by adding two zones of 500 meter width around the noise band of 55-60 dB(A). The necessity for using the 500 m zones originates from the fact that noise exposure data below the threshold of 55 dB(A) are not available for the whole area of investigation.

In addition we also test our data for non-linearity in the airport noise variable by introducing dummy variables for the different noise bands and both extension zones.

Table 2 presents a complete overview of variables.

Table 2 Data

Variable		Description	Mean	St. Dev.
Dependent variable				
Rent		Base rent in €	547.40	304.67
Structural attributes				
Size		Living space in square meters	70.380	27.46
Type of Apartment	Type_Loft	1 if apartment is a loft or penthouse	0.011	0.10
	Type_Duplex*	1 if apartment is a duplex apartment	0.043	0.20
Location of Apartment	Loc_Base*	1 if apartment is located in basement	0.013	0.11
	Loc_Ground*	1 if apartment is located in ground floor	0.119	0.32
	Loc_Top*	1 if apartment is located in top floor	0.250	0.43
Quality of Facilities	QoF_deluxe	1 if quality of facilities in apartment is deluxe	0.018	0.13
	QoF_upscale	1 if quality of facilities in apartment is upscale	0.240	0.43
	QoF_basic*	1 if quality of facilities in apartment is basic	0.014	0.12
Flooring	Floor_Par	1 if parquet flooring present in apartment	0.157	0.36
	Floor_Lam	1 if laminate flooring presen in apartment	0.320	0.47
SecBathroom		1 if apartment is equipped with second bathroom	0.177	0.38
Kitchen		1 if apartment is equipped with built-in kitchen	0.224	0.42
Cellar*		1 if apartment is equipped with cellar storage unit	0.702	0.46
Garden*		1 if apartment is equipped with a garden	0.099	0.30
BalconyPatio		1 if apartment is equipped with a balcony or patio	0.640	0.48
HeatingOven*		1 if apartment is oven heated	0.005	0.07
Parking		1 if reserved parking is available	0.275	0.45
Condition of Building	QoB_new	1 if apartment is newly built	0.075	0.26
	QoB_ren	1 if apartment is renovated	0.349	0.48
	QoB_need	1 if apartment is in need of renovation	0.019	0.14
Construction Period	Bef1914	1 if apartment has been constructed before 1914	0.052	0.22
	1915_45*	1 if apartment has been constructed between 1915 and 1945	0.050	0.22
	1946_89	1 if apartment has been constructed between 1946 and 1989	0.335	0.47
Levels		# of floors in apartment building	2.996	2.25
Neighborhood attributes				
Schools*		# of schools within 1 km distance	4.559	2.85
Playgrounds		# of playgrounds within 1 km distance	7.986	4.01

Kindergarten	# of kindergartens within 1 km distance	5.539	2.76
Attractions*	# of touristic attractions within 1 km distance	2.597	4.03
Culture*	# of cultural facilities within 500 m distance	0.498	1.27
Gastronomy	# of gastronomy facilities within 500 m distance	8.409	13.76
Hotels	# of accommodation facilities within 500 m dist.	0.904	2.27
Parks	# of parks within 1 km distance	2.970	2.87
Riverbank*	1 if riverbank within 1 km distance	0.317	0.47
ApartmentDens	# apartments per residential building in urban district	5.677	2.61
BuildingDens	# Residential buildings per square kilometer in urban district	523.39	258.05
Seniors*	Share of people aged 60+ years in urban district (%)	24.450	3.92
Unemployment	Share of unemployed residents in urban district (%)	5.400	2.20
Accessibility attributes			
PubTransAccess	# Public transit access points within 500m dist.	8.012	6.23
DistAutobahn	Distance to nearest Autobahn ramp in km	2.429	1.21
DistAirport	Distance to airport terminal in km	9.009	4.10
DistCenter	Distance to city center of Düsseldorf in km	6.470	5.00
Environmental attributes			
NoiseProtZone	1 if property is located within noise protection zone	0.023	0.15
NoiseRoad	Road traffic noise level in Lden above 55 dB(A)	5.255	6.31
NoiseRail	Rail traffic noise level in Lden above 55 dB(A)	2.861	4.51
NoiseAir	Airport noise level in Lden above 55 dB(A)	0.252	1.37
NoiseAir55-60	1 if apartment is exposed to 55-60 dB(A) airport noise	0.001	0.03
NoiseAir60-65	1 if apartment is exposed to 60-65 dB(A) airport noise	0.012	0.11
NoiseAir65-70	1 if apartment is exposed to 65-70 dB(A) airport noise	0.025	0.16
NoiseAir500	1 if apartment is located within 500 m airport noise footprint extension	0.055	0.23
NoiseAir1000	1 if apartment is located within 500 to 1000 m airport noise footprint extension	0.036	0.19

* eliminated during regression process

3. Methodology

The hedonic pricing method uses secondary markets such as the housing market to evaluate price effects of a good’s tangible and intangible attributes. Thus, the impact of noise exposure as one of the various attributes of an apartment on its price can be indirectly examined.[8] According to Rosen (1974) the price p of housing units can be described by a vector Z of structural, neighbourhood, accessibility, and environmental attributes:

$$\boldsymbol{p} = \beta \mathbf{Z} + \varepsilon.$$

Parameters β reflect coefficients respectively implicit prices, ε is the normally distributed error term with mean zero and constant variance. Furthermore, spatial autoregression as well as autocorrelation can be addressed by introduction of spatial lag respectively spatially distributed error terms. As the Lagrange multiplicator test indicates existence of spatial autocorrelation, the model incorporates a spatially adjusted error term:

$$\boldsymbol{p} = \beta \boldsymbol{Z} + \lambda \mathbf{W} \varepsilon + \xi$$

where W represents the spatial weights matrix[9] and ρ respectively λ the parameters of the spatial lag respectively spatial error. ξ contains the remaining, spatially uncorrelated error.

In total, three models are estimated: Model 1 incorporates linear noise variables, while models 2 and 3 use the binary coding of airport noise in order to test non-linear noise effects. Model 3 further elaborates on rent price effects in the two airport noise extension zones.

4. Results and Discussion

Regression results displayed in Table 4 are obtained by multi step generalized moments (GM) estimations of a linear Cliff and Ord type of model based on Kelejian and Prucha (1999) and, thus, lack traditional model quality indicators. However, the underlying models discussed in Püschel and Evangelinos (2012) show satisfactory results with respect to the goodness of fit (adjusted rho-squared of 0.866).

Table 4: Regression based estimates

	1 Linear Noise Variables	**2 Dummy Noise Variables**	**3 Dummy Noise Variables, Noise Footprint Extension**
Constant	5.426 ***	5.428 ***	5.432 ***
Structural attributes			
Size	0.012 ***	0.012 ***	0.012 ***
Type_Loft	0.098	0.096	0.094
QoF_delux	0.090 **	0.091 **	0.090 **

[8] More information on existing studies may be found in Schipper (2001) and Wadud (2009).
[9] Row-standardized 60 nearest neighbors matrix.

QoF_up	0.068 ***	0.068 ***	0.068 ***
Floor_Par	0.081 ***	0.081 ***	0.080 ***
Floor_Lam	0.022 **	0.021 **	0.019 **
SecBathroom	0.028	0.028	0.027
Kitchen	0.035 ***	0.036 ***	0.035 ***
BalconyPatio	0.083 ***	0.082 ***	0.083 ***
Parking	0.040 ***	0.040 ***	0.038 ***
QoB_new	0.126 ***	0.127 ***	0.128 ***
QoB_ren	0.041 ***	0.041 ***	0.041 ***
QoB_need	-0.071 ***	-0.070 ***	-0.070 ***
Bef1914	0.058 ***	0.058 ***	0.059 ***
1946_89	-0.017 *	-0.017 *	-0.015 *
Levels	-0.007 ***	-0.007 ***	-0.006 ***
Neighborhood attributes			
Playgrounds	-0.007 ***	-0.007 ***	-0.007 ***
Kindergarten	-0.001	-0.001	-0.002
Gastronomy	0.001	0.001	0.001
Hotels	-0.006 **	-0.006 **	-0.006 **
Parks	0.008 **	0.008 **	0.007 **
ApartmentDens	0.009 **	0.009 **	0.009 **
BuildingDens	0.000	0.000	0.000
Unemployment	-0.031 ***	-0.031 ***	-0.031 ***
Accessibility attributes			
PubTransAccess	0.002 **	0.002 **	0.002 **
DistAutobahn	0.020 ***	0.020 **	0.018 ***
DistAirport	-0.004	-0.004	-0.006
DistCenter	-0.008 **	-0.008 **	-0.006
Environmental attributes			
NoiseProtZone	0.099 *	0.094	0.092
NoiseRoad	-0.002 **	-0.002 **	-0.002 **
NoiseRail	-0.001	-0.001	-0.001
NoiseAir	-0.010 *		
NoiseAir55-60		-0.067 *	-0.086 **
NoiseAir60-65		-0.084	-0.102
NoiseAir65-70		-0.174 **	-0.203 ***
NoiseAir500			-0.057 **
NoiseAir1000			0.008
Spatial Error	Yes	Yes	Yes
Residual St. Error	0.161	0.161	0.161

* Significance at 90% level, ** Significance at 95% level, *** Significance at 99% level.

Due to the application of a log-linear regression function estimates reflect semi-elasticities; to correctly interpret parameters of dummy variables the conversion

$s = e^r - 1$ based on Halvorsen and Palmquist (1980) needs to be applied, where s denotes the semi-elasticity and r is the parameter estimate.

All parameter estimates show the expected sign. However, an interesting result is the statistical insignificance of distance to the airport terminal. Usually proximity to the airport, notwithstanding the corresponding noise exposure, is seen as an amenity due to ease of travel or accessibility to workplaces at the airport grounds. Our results do not confirm this in the case of Düsseldorf airport. Although not directly addressed in this paper, this result may be explained by the general proximity of the airport to the city-center of Dusseldorf and/or its ease of access by private car and public transport.

4.1 Linear Noise Effects

Model 1 confirms the findings in Püschel and Evangelinos (2012). Here, street and airport noise show significant negative effects on rent prices, NSDI values are 0.2 respectively 1. As in all other model setups rail traffic noise seems not to affect rent prices. Location within the noise protection zone, which can be assumed to be equivalent to the realization of noise protection measures, leads to a rent increase of about 10%.

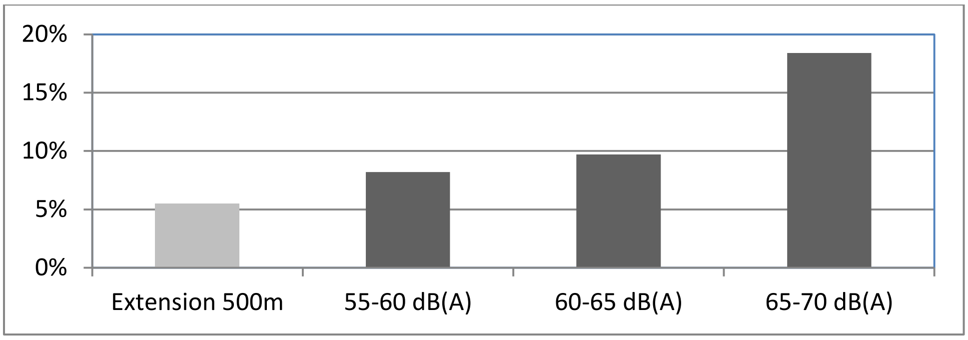
4.2 Non-linear Noise Effects

While the NDSI value of model 1 assumes a constant noise impact along the range of airport noise exposure values, both models 2 and 3 take into account non-linear airport noise effects by introducing dummies for the three relevant noise bands. Estimation results confirm the findings of model 1. However, they provide more detailed information concerning noise impacts.

Model 2 translates the constant airport NDSI result of model 1 into three semi-elasticities. While location of an apartment within the noise band of 55-60 dB(A) reduces rents by 6.5%, exposure to 60-65 dB(A) yields a discount of about 8.1%, although not statistically significant. Finally, exposure to levels of 65-70 dB(A) airport noise leads to rent reductions of 16%. The non-linear increase of noise impacts clearly shows disproportionally growing airport noise effects with increasing noise level. Model 3 confirms these findings, however at a slightly higher level of rent discounts (8.2%, 9.7%, and 18.4%). A lower noise threshold level increases respective noise discounts, as Thanos et al. (2015) have shown. Furthermore, we observe a statistically significant noise discount of 5.5% in the smaller extension zone (0 to 500 meters), but none in the wider (500 to 1000 meters) one. Non-linear noise impacts are visualized in Figure 2.[10]

[10] Note that the parameter of noise band 60-65 dB(A) is statistically insignificant in models 2 and 3. However, the estimates' magnitude seems to be correct and in line with the other estimates.

Figure 2 Non-linear airport noise discounts (Model 3)



4.3 Impact on Derived Airport Noise Effects

As estimation results of model 3 have shown, the application of a 55 dB(A) background noise level does not properly reflect present adverse economic effects. In order to highlight the importance of this issue we calculate the additional impact of this result (the number of dwellings and the number of inhabitants affected) as well as the airport noise costs according to all model specifications.

Noise impact analysis figures, i.e. the number of people affected by airport noise above 55 dB(A) L_{den}, are mandatory to be reported to the European Commission (according to Directive 2002/49/EC, Annex VI). Figures for the agglomeration of Düsseldorf can be found in Table 5. Since econometric evidence indicates that noise effects are also present below the threshold of 55 dB(A) L_{den} we further approximate the number of people living within the 500 meter extension.[11]

Table 5 Impact analysis figures

	L_{den} > 55 dB(A)	**L_{den} > 65 dB(A)**	**L_{den} > 75 dB(A)**	**Within extension (500 m)**
Population	38,300	3,400	0	Ca. 58,000
Number of dwellings	18,772	1,113	0	Ca. 29,700

European Environment Agency (2009), own calculations.

While about 38,000 people are affected by airport noise of 55 dB(A) L_{den} or higher, we find additional 58,000 people within the 500 meter extension zone. Focusing on airport noise-

[11] We derived respective figures by calculating respective populated land areas and applying housing density figures in GIS.

affected dwellings, we discover a similar growth of almost 150% in the number of houses affected by devaluations.

Noise costs are represented by house devaluations or rent reductions due to airport noise exposure as stated in Wadud (2009). The hedonic approach may not reflect total noise costs since it is arguable if long-term health effects are properly priced in into apartment rents. Nevertheless, in our case rent revenue losses by landlords can be seen as a measure at least of noise annoyance costs.

Table 6 displays noise costs according to the three modeling approaches. We find the lowest cost when calculations are based on linear noise effects of model 1. Costs increase by 50% when taking into account non-linear airport noise effects. However, noise annoyance costs increase by about 1 million euros per months when including information on adverse economic effects within the 500 meter noise footprint extension.[12]

Table 6 Airport noise costs

	Euro per month	Euro per year
Model 1	600,000	7,200,000
Model 2[a]	940,000	11,280,000
Model 3[a]	2,050,000	24,600,000

[a] About 350 apartments are located in noise exposure zone of 70-75 dB(A), where no discount rate could be estimated. Here, the discount rate of noise exposure zone 65-70 dB(A) is applied.

The case study clearly shows how the noise cut-off value affects derived noise effects. Thus, for the evaluation of noise abatement policy this value has to be chosen very carefully.[13] As we have shown, the default cut-off value of 55 dB(A) L_{den} used in EU-conform strategic noise maps may not be the precise trigger value for airport noise annoyance in terms of economic effects, at least not in our case study region.[14]

Our result may contradict medical and acoustic research evidence, but might be explained based on the following reasons. First, research evidence points to the fact that airport noise is systematically perceived as being more annoying than other transport modes.[15] Thus, people may perceive airport noise as annoyance at even lower noise exposure levels. Second, the L_{den} measure reflects a daily average of noise exposure. However, air traffic

[12] Noise cost amount to 1.5 million euros per month respectively 18.5 million euros per year when assuming linear airport noise effects starting at 50 dB(A). These costs are in line with noise costs resulting from the model 1.II.

[13] See Lijesen et al. (2010) for an example of application.

[14] We can imagine deviating trigger values also for street and rail traffic noise. However, we cannot test this hypothesis due to the lack of appropriate noise data available to the authors.

[15] see Giering (2010) for an overview of research evidence.

movements may occur at certain peaks during the day while in off-peaks less noise is produced. As a result, people are exposed to a temporally unevenly distributed noise pattern where a daily average can underestimate actual annoyance during airport operating times. Night flight bans, as is the case in Düsseldorf, and temporally concentrated arrivals and departures at hub airports may cause noise peaks and off-peaks. Hence, noise annoyance may be significant even if averaging noise exposure indices do not indicate so.

5. Conclusions

We analyzed airport noise effects on apartment prices in the region of Düsseldorf. By performing spatial hedonic regression analysis with linear and non-linear noise effects we identified local airport noise discount rates. We also find noise discounts for apartments located just outside the airport noise footprint designed according to a cut-off level of 55 dB(A) L_{den}.

We conclude that a cut-off value of 55 dB(A) L_{den}, usually applied in strategic noise mapping, does not properly reflect adverse economic noise effects in the case of Düsseldorf. In the local setting resulting impact figures and noise annoyance costs substantially increase when considering a lower cut-off value. The resulting underestimation of noise costs may typically be high for city airports and low for airports in remote areas.

We gained evidence that from an economic point of view a cut-off level lower than 55 dB(A) L_{den} might reflect airport noise annoyance effects appropriately. To exactly display and analyze noise impacts of all transport modes in Europe a more detailed noise mapping procedure may be necessary.

Acknowledgements

We would like to gratefully thank Bernhard Wieland and Georg Hirte at the Institute for Transport and Economics Dresden as well as anonymous referees for their critical and helpful comments and remarks on earlier versions of this paper. All remaining errors are ours.

Abstract

This study examines linear and non-linear airport noise effects in the airport region of Düsseldorf, Germany and extends existing findings with regard to threshold values of airport noise effects. By applying spatial hedonic regression we estimate a linear NDSI value of 1.0. However, rent devaluations due to airport noise exposure appear to be non-linear. Furthermore we discover statistically significant adverse effects of airport noise exposure in a 500-meter-wide zone extending the standard noise footprint defined by a cut-off value of 55 dB(A) L_{den}. Airport noise impacts are consequentially underestimated when calculated on the basis of the standard cut-off value defined in Directive 2002/49/EC.

Keywords: Airport noise externalities, housing markets, airport environment, cut-off values, airport noise costs.

References

Ahlfeldt, G. M. und Maennig, W. (2013), External Productivity and Utility Effects of City Airports, *Regional Studies* 47(4), 508-529.

Andersson, H., Jonsson, L. und Ogren, M. (2010), Property Prices and Exposure to Multiple Noise Sources: Hedonic Regression with Road and Railway Noise. *Environmental and Resource Economics* 45, 73–89.

Brandt, S. und Maennig, W. (2011), Road noise exposure and residential property prices: Evidence from Hamburg. *Transportation Research Part D* 16, 23-30.

Cohen, J. P. und Coughlin, C. C. (2008), Spatial Hedonic Models of Airport Noise, Proximity, and Housing Prices. *Journal of Regional Science* 48(5), 859–878.

Day, B., Bateman, I. J. und Lake, I. (2007), Beyond Implicit Prices: Recovering Theoretically Consistent and Transferable Values for Noise Avoidance from a Hedonic Property Price Model. *Environmental and Resource Economics* 37, 211-232.

Dekkers, J.E.C. und van der Straaten, J.W. (2009). Monetary valuation of aircraft noise: A hedonic analysis around Amsterdam airport. *Ecological Economics* 68(11), 2850-2858.

Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise - Declaration by the Commission in the Conciliation Committee on the Directive relating to the assessment and management of environmental noise, Official Journal L 189 , 18/07/2002, p. 12-26.European Environment Agency, 2009. EIONET Central Data Repository. URL: http://cdr.eionet.europa.eu/de/eu/noise/colsz1lpw/envsuwwa.

Giering, K. (2010), Lärmwirkungen. Dosis-Wirkungsrelationen. Texte 13/2010, Umweltbundesamt.

Halvorsen, R. und Palmquist, P. (1980), The Interpretation of Dummy Variables in Semilogarithmic Equations. *American Economic Review* 70(3), 474-475.

Kelejian, H.H. und Prucha, I.R. (1999), A Generalized Moments Estimator for the Autoregressive Parameter in a Spatial Model. *International Economic Review* 40(2), 509-533.

Lake, I. R., Lovett, A., Bateman, I. J. und Langford, I. H. (1998), Modelling Environmental Influences on Property Prices in an Urban Environment. Computers, *Environment and Urban Systems* 22, 121–136.

Lijesen, M., Straaten, W.V.D., Dekkers, J., Elk, R.V. und Blokdijk, J. (2010), How much noise reduction at airports? *Transportation Research Part D: Transport and Environment* 15(1), 51-59.

Palmquist, R.B. (2005), Property value models, in: Mäler, K.G., Vincent, J. (Eds.), *Handbook of Environmental Economics*. Elsevier, Amsterdam, 763-819.

Palmquist, R.B. (1999), Hedonic models, in: Van den Bergh, J. C. J. M. (Ed.), Handbook of *Environmental and Resource Economics*. Edward Elgar, Aldershot, 765-776.

Pommerehne, W. W. (1988), Measuring the Environmental Benefits: A Comparison of Hedonic Technique and Contingent Valuation. In Bos, D., Rose, M., Seidl, C. (eds.), *Welfare and Efficiency in Public Economics*. Berlin: Springer-Verlag, 363–400.

Püschel, R. und Evangelinos, C. (2012), Evaluating noise annoyance cost recovery at Düsseldorf International Airport. *Transportation Research Part D: Transport and Environment* 17(8), 598-604.

Rich, J. H. und Nielsen, O. A. (2004), Assessment of Traffic Noise Impacts. International Journal of Environmental Studies 61, 19–29.Rosen, S., 1974. Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition. *Journal of Political Economy* 82(1), 34-55.

Schipper, Y. (2001), Environmental Costs and Liberalization in European Air Transport: A Welfare Economic Analysis, Edward Elgar, Aldershot.

Thanos, S., Bristow, A. L. und Wardman, M. R. (2015), Residential Sorting and Environmental Externalities: The Case of Nonlinearities and Stigma in Aviation Noise Values. *Journal of Regional Science* 55(3), 468-490.

Wadud, Z. (2009), A Systematic Review of Literature on the Valuation of Local Environmental Externalities of Aviation. Omega - Aviation in a sustainable world, University of Cambridge, UK.

Wilhelmsson, M. (2000), Impact of Traffic Noise on the Values of Single-Family Houses. *Journal of Environmental Planning and Management* 43, 799-815.