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THE INFLUENCE OF NOISE ON NET REVENUE AND VALUES OF INVESTMENT PROPERTIES: EVIDENCE FROM SWITZERLAND

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Keywords: Hedonic prices, investment property, Switzerland, noise nuisance, GAM, spline.

ABSTRACT

In this study we use hedonic models to measure the influence of noise nuisance on rents, costs and values of investment properties in Switzerland. Countrywide data is provided by institutional real estate investors. The effects are measured for aircraft noise, road traffic noise and railroad noise. We show that negative effects appear between lower and upper tresholds which vary between different noise types and across residential and non-residential properties. Rents, costs and values are affected below the administrative tresholds given by the LSV and the negative impact ceases at an upper threshold. However high noise nuisance might influence investment decisions, i.e. offices are built instead of housing etc. These important effects are not given account in the data. In addition, directly measured reductions on market values are lower than the expected reductions based on empirical effects on rents and costs. The reasons for the different market value reductions may be found in the Swiss tenancy law. Rents for dwellings within existing rental agreements can only be adjusted in accordance with the change of the "reference interest rate" (Referenzzinssatz) and the CPI. The analysis shows that the average contract duration is dependent on the noise nuisance, which leads to a significant reduction of noise-induced losses within periods of increasing market rents.

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1 INTRODUCTION

In Switzerland, road and rail traffic as well as aircraft noise are important sources of nuisance in settlement areas. The fact that real estate markets value traffic noise has been shown by many different empirical studies, e.g. Andersson et al. (2009), Day et al. (2007) and Kim et al. (2007). Nelson (2008) published a meta analysis of studies assessing the impacts of aircraft and road traffic noise. Most of the existing studies explore noise effects on prices of private properties and market rents for apartment.

So far, there is little knowledge on the effect of noise on investment properties. This part of the building stock contains multi-family houses as well as office buildings, shopping malls, mixed-used properties and others. With a house owner quota of only about 40 per cent, the major part of Swiss households rents a flat. In addition to the general importance of the rental market, the question of the impact of noise on investment properties becomes important because of deadlines for noise remediation. In a couple of years Cantons and railway companies will have to compensate house owners for losses due to excessive noise nuisance.[1] Today there is only compensation for private properties and multi-family houses affected by aircraft noise around Zurich airport.

Estimating hedonic models for investment properties is a challenge, since noise nuisance can affect market rents, contract rents and owner side costs as well as risk assessments (discounting factors in DCF appraisal). In addition there is no database with detailed and harmonised transaction data. For this study a uniquely large and well-described dataset of institutional properties has been compiled. It contains comparable information across all appraisal-relevant components of investment properties as well as the market values of these properties.

This study is based on the theory that noise affects both the gross revenue (reduction of rental income) as well as the owner-side costs (increased owner costs due to higher fluctuation, vacancies and maintenance costs). With the available data, noise effects can be measured on both the gross revenue as well as the owner-side costs. In addition, the data allow estimating the influence of noise nuisance directly on the market values.

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[1] According to the federal "Lärmschutzverordnung" LSV (Bundeskanzlei, 1986), the trigger for compensation is average noise dB(A) above the "Immissionsgrenzwert" IGW. These IGW differ by planning zones, noise source and between day and night.

In Switzerland, several studies estimating the influence of noise nuisance on market rents for apartments exist (for an overview see Table 1 and Fahrländer Partner, 2013). One single study measures the influence of aircraft noise on values of investment properties (see Bundesgericht, 2011). The observed reductions of the market values of around 1.5% per dB(A) are significantly higher than the measured reductions on apartment rents of approximatly 0.3% per dB(A). This supports the hypothesis formulated above that noise not only causes losses at the income side, but also leads to higher costs and higher risks for the owner.

Table 1: Hedonic pricing studies in Switzerland

Authors	Study area	Dependent variable	N	Price reduction per dB(A) (approximately, in %)		Threshold in dB(A)	
				Day	Night	Day	Night
Baranzini & Ramirez (2005)	Canton of Geneva	Market rents	13'064	0.28*		50	
Baranzini et al. (2006)	Canton of Geneva	Market rents	2'794	0.18-0.22*		50/55	
Baranzini & Schaerer (2007)	Canton of Geneva	Market rents	10'396	0.20-0.23*		50	
Schaerer et al. (2007)	City of Geneva	Market rents	3'327	0.17-0.20*		50	
	City of Zurich	Market rents	3'194	0.37-0.38*		55	
Banfi et al. (2007)	City of Zurich	Market rents	6'204	0.20*	0.31*	55	50
	City of Lugano	Market rents	547	0.50*	0.60*	55	50
ZKB (2010)	Switzerland	Market rents	635'504	0.19*	0.19*	50[1]	40
				0.26**	0.26**	50[1]	40
				0.11***	0.11***	50[1]	40
Bundesgericht (2011)	Switzerland	Values of investment properties	2'000	1.20***		45	
				1.80***		50	

[1] if night noise < 40dB(A); * Road traffic noise, **Rail noise, ***Aircraft noise.

This article is structured as follows: Section 2 introduces the underlying data. Section 3 presents the results of the empirical models used to examine the effect of noise on contract rents, owner-side costs and market values of investment properties. Discussion of the results is found in section 4. Section 5 concludes.

2 DATA AND SAMPLES

2.1 DATA OF INVESTMENT PROPERTIES

The analysis is based on countrywide data of investment properties provided by institutional investors. Market values as of 31 December 2012 and cashflows (rental incoms, vacancies and owner-side costs) for the year 2012 are available.[2] The data pool includes 3'027 properties with 8'824 addresses and 240'000 rental units. The total market value of the represented properties is around 51.7 Billion Swiss Francs. The data include residential and commercial properties as well as mixed-use properties. Information is available on three levels: Properties, addresses and single rental units.[3] Market values, owner-side costs and structural variables are available on the property level. Locational data such as distances to points of interest and noise pollution is compiled for every single address. Rental incomes and detailed information about the rental units such as floor space and number of rooms are available on the rental unit level (for variable descriptions see Appendix A).

From the available data, samples with rental units as well as samples with properties are formed. With 2'362 observations the market value sample includes most of the pooled properties (Table 2). On the cost side, however, many records exist which can not be harmonised, or for which no owner-side costs are reported. The sample is thus reduced to 1'141 properties.

Table 2: Samples for econometric analysis

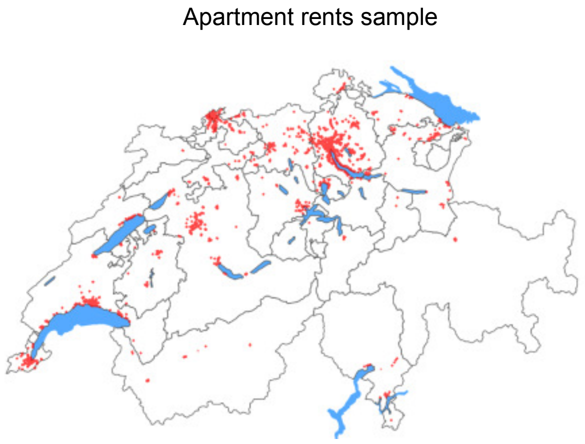
Sample	Number of properties	Number of addresses	Number of rental objects
Apartments	2'066	5'507	65'301
Offices	752	878	4'413
Retail	587	723	2'126
Restaurants	166	166	220
Owner costs	1'141		
Market values	2'362		

In general, it can be stated that the samples are well distributed over the country (see Figure 1). An obvious concentration of observations exists in the urban areas with a significant rental market.

2 Cashflows of Migros Pensionskasse represent the period between July 2012 and June 2013.

3 A single property can consist of several buildings or of several entrances into a building.

Figure 1: Spatial distribution of the samples



2.2 LOCATION VARIABLES

Hedonic models often use two location levels: the macro-location i.e. the village or city district and the micro-location, usually information of proximity to services, image of the neighbourhood, noise nuisance and others. While information of the general price level (macro-location) is used from the hedonic models of FPRE, the general assessment of the micro-location is derived from several parameters and proxies (see Appendix A).[4]

Noise exposure data is provided by the Federal Office for the Environment (FOEN). The noise database sonBASE was created in 2008 by the FOEN and contains noise data from different noise models. For this study, two different datasets are available. The first one, the grid data (10x10 meters) provides noise values at four meters above the ground. The second dataset includes the maximum noise value per building of the swissBUILDINGS3D building data set (provided by the Federal Office of Topography). The FOEN performs its own calculations for road traffic noise and railway noise. Data on aircraft noise is provided by the Federal Office of Civil Aviation (FOCA). For this study, the grid data from the calculation model 2009 and the building data set from the calculation model 2010 are available. This data allows assigning the noise exposure for each address. All the data is measured four metres above the ground (open windows) and is assigned to all floor levels. In addition, the data

[4] Fahrländer Partner (FPRE) provides hedonic models for market rents for daily use by owners, brokers and consultants. For the methodology see Fahrländer (2006).

represents average noise levels dB(A) for the period 0600 to 2200 hours (day) and 2200 to 0600 hours (night).

3 MODELS AND RESULTS

To select the model variables, this study relies on Sirmans et al. (2005), Malpezzi (2002) and Wilhelmsson (2000) who evaluated the control variables which are most commonly used in hedonic studies. In a first step (section 3.1), impacts of different noise sources on different property types are expolored using nonparametric cubic splines (as shown in Fahrländer, 2006) in generalized additive models (Hastie & Tibshirani, 1990). Minimum thresholds of noise effects were detected in all cases, maximum limits only in some.

In a second step, log-linear hedonic models are developed to measure noise impacts on rents (section 3.2), owner costs (3.3) and market values (3.4) using OLS regressions. All models include fixed effects (macro-location price indicators) derived from the hedonic models of Fahrländer Partner (Fahrländer, 2006). In a third step, the empirically measured reductions on market values are compared to indirect reductions resulting from additional costs and reduced rents (3.5).

3.1 EXPLORATORY ANALYSIS OF NOISE IMPACT

To explore noise impacts, all the parameters describing the micro-location must be used to isolate the influence of noise nuisance. This can only be done with highly dissaggregated data representing the small-scale conditions at a certain address. For the explorative analysis of the impact of noise a generalized additive model with cubic regression splines is used to analyse the pattern of the impact of the different noise sources and levels on rents, costs and values. Since noise from different sources cannot be combined, every single noise source is tested seperatly.

The objective of these estimations is to find adequate thresholds for all models. The determination of the thresholds was performed manually for each combination of noise source and property type using spline plots as shown in Figure 2. The example shows the influence of rail noise at night on rents of apartments. The thresholds are later used to estimate partwise linear terms, with zero below the lower threshold, a linear slope between the lower and the upper threshold and a maximum for properties above the upper threshold.

Figure 2: Influence of rail noise at night on contract rents of apartments

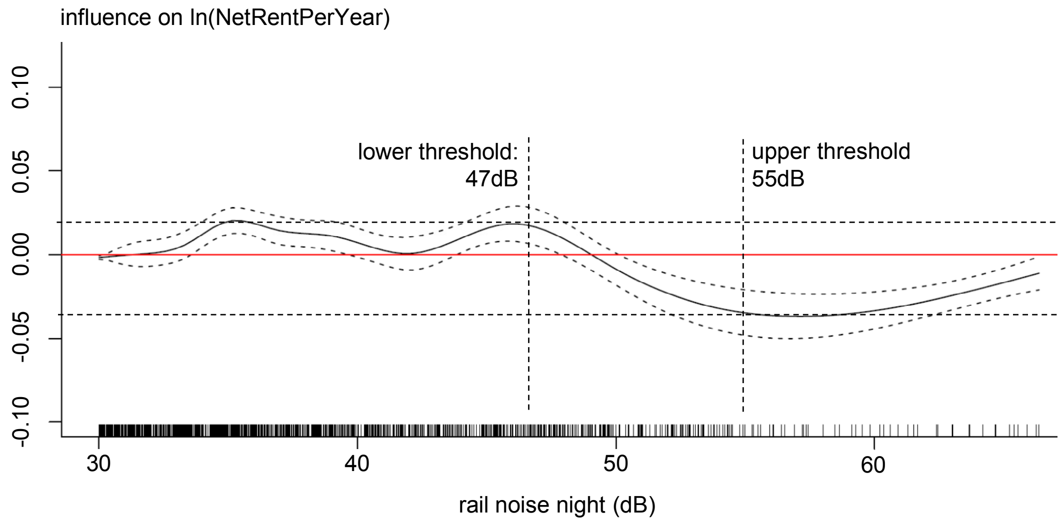


Table 3 shows the findings of the exploratory analysis. In the apartment rents model we found a maximum thresholds of noise impact at 57dB (aircraft noise) and 55dB (road and rail noise), the minimum and maximum thresholds are shown in the row "range". Apartment rents and market values of residential properties are sensitive to noise during the nights while office and retail rents are affected by daytime noise.

Table 3: Noise thresholds and affected observations

Model	Dependent variable	Period	N=	Aircraft noise		Road traffic noise		Rail noise	
				Range	Affected	Range	Affected	Range	Affected
Apartments	ln(rent) [CHF/a]	Night	65'301	50-57dB	1'301 (2.0%)	45-55dB	22'603 (34.6%)	47-55dB	2'658 (4.1%)
Offices	ln(rent) [CHF/a]	Day	4'413	>55dB	105 (2.3%)	>55dB	2'805 (63.6%)	>55dB	108 (2.4%)
Retail	ln(rent) [CHF/a]	Day	2'126	>50dB	26 (1.2%)	>55dB	1'425 (67.0%)	>40dB	335 (15.8%)
Restaurants	ln(rent) [CHF/a]	Night	220	no observations		>50dB	93 (42.3%)	>50dB	14 (6.4%)
Owner costs	ln(costs) [CHF/m2a]	Night	1'141	>50dB	30 (2.6%)	>45dB	451 (39.5%)	>47dB	20 (1.8%)
Market values									
Resid. properties	ln(value) [CHF/m2]	Night	1'945	>50dB	39 (2.0%)	>45dB	1'154 (59.3%)	>47dB	95 (4.9%)
Other properties	ln(value) [CHF/m2]	Day	417	>50dB	4 (1.0%)	>50dB	392 (94.0%)	>50dB	28 (6.7%)

3.2 NOISE IMPACT ON CONTRACT RENTS

Two different models have been estimated explaining the contractual rents of apartments. Both models are based on equation (1) where β_i represent the coefficients of contiuous and dummy variables and $\hat{\beta}_i$ vectors of coefficients of factor variables and interaction terms. The noise interaction terms include a $RangeDummy$ to separate the effects within the lower and upper thresholds.

$$
\begin{aligned}
&ln(NetRentPerYear) = \\
&\qquad \propto + \beta_1 \cdot \ln(Macro) + \hat{\beta}_2(YearQuarter \times IsCentre) + \hat{\beta}_3(Exposition) \\
&\qquad + \beta_4 \cdot IsCloseToLake + \hat{\beta}_5(ZoneType \times IsCentre) + \hat{\beta}_6(DomSegmentDemand) \\
&\qquad + \hat{\beta}_7(SpatialType \times DistToLocalServices) + \hat{\beta}_8(NumServices600m \times IsCentre) \\
&\qquad + \hat{\beta}_9(SpatialType \times LandscapeQuality) + \hat{\beta}_{10}(PublicTranspGroup \times IsCentre) \\
&\qquad + \hat{\beta}_{11}(RangeDummy \times SpatialType \times AircraftNoiseNight) \\
&\qquad + \hat{\beta}_{12}(RangeDummy \times SpatialType \times RoadNoiseNight) \\
&\qquad + \hat{\beta}_{13}(RangeDummy \times SpatialType \times RailNoiseNight) \\
&\qquad + \beta_{14} \cdot YearOfConstruction + \beta_{15} \cdot YearOfConstruction^2 \\
&\qquad + \hat{\beta}_{16}(BuildingType) + \hat{\beta}_{17}(Condition) + \beta_{18} \cdot \ln(FloorArea) \\
&\qquad + \hat{\beta}_{19}(FloorLevel \times IsCentre) + \hat{\beta}_{20}(NumRooms) + \varepsilon
\end{aligned}
\tag{1}
$$

The first model does not include the spatial-type-interactions for the noise variables but country-wide coefficents for noise. All noise coefficients in this model turn out with a highly significant and negative impact. The second model includes interaction terms for different spatial types for road traffic noise and rail noise, as shown in Table 4.[5] The strongest price impact is found in rich communes (type 4), where each decibel road traffic noise above the threshold causes a rent decrease of approximately 0.33%. In suburban residental communes (types 5 and 6) the decrease is less (0.15% and 0.25% per decibel) but also highly significant. Apartment rents in big cities (type 1) and regional centres (type 2) are not significantly sensitive to road traffic noise. The rail noise coefficents are more difficult to estimate due to fewer observations with excessive rail noise. Significant coefficients can be estimated for large cities and residential communes of regional centres, where rail noise clearly causes lower apartment rents.

5 Selected estimation results are shown in Appendix B.

Table 4: Coefficients for noise nuisance on contractual apartment rents

	Spatial type							
	Switzerland	Type 1	Type 2	Type 3	Type 4	Type 5	Type 6	Type 7
Max. Aircraft noise night (>50dB)	**-0.0017**							
Road traffic noise night (>45dB)	**-0.0009**	0.0005	-0.0005	**-0.0014**	**-0.0033**	**-0.0015**	**-0.0025**	-0.0009
Rail noise night (>47dB)	**-0.0009**	**-0.0019**	0.0000	0.0000	0.0012	**-0.0007**	**-0.0016**	0.0004

Bold: $p < 0.01$.

Type 1: Large urban centres; Type 2: Middle-size urban centres; Type 3: Other centres; Type 4: Rich communes; Type 5: Residential communes of large urban centres; Type 6: Residential communes of middle-size uban centres and other centres; Type 7: Other communes.

Similar models are estimated for office and retail rental units as well as for restaurants. In the models for offices, significant negative coefficents can be estimated only in rich communes (type 4, see Table 5). Estimations for retail contract rents and restaurants do not generate significant coefficients. These models are therefore not subject to further analysis in this article.

Table 5: Coefficients for noise nuisance on contractual office rents

	Spatial type							
	Switzerland	Type 1	Type 2	Type 3	Type 4	Type 5	Type 6	Type 7
Aircraft noise day (>55dB)	-0.0088							
Road traffic noise day (>55dB)	0.0025	0.0038	0.0040	0.0114	**-0.0279**	-0.0060	0.0067	0.0061
Rail noise day (>55dB)	0.0025	0.0006	0.0043	-0.0021	0.0187	0.0042		-0.0082

Bold: $p < 0.01$.

Type 1: Large urban centres; Type 2: Middle-size urban centres; Type 3: Other centres; Type 4: Rich communes; Type 5: Residential communes of large urban centres; Type 6: Residential communes of middle-size uban centres and other centres; Type 7: Other communes.

3.3 NOISE IMPACT ON OWNER-SIDE COSTS

This model includes data of the owner-side running costs. Since the various cost categories cannot be consistenty harmonised for the different data providers, this model is only estimated for the total annual running costs per square meter floor area, as shown in equation (2). The noise interaction terms include a *RangeDummy* to separate the effects within the lower and upper thresholds.

$$
\begin{aligned}
&ln(RunningCostsPerSQM) = \\
&\qquad \propto\ + \hat{\beta}_1(ZoneType) + \hat{\beta}_2(PublicTranspGroup) \\
&\qquad + \hat{\beta}_3\ (RangeDummy \times AircraftNoiseNight) \\
&\qquad + \hat{\beta}_4\ (RangeDummy \times RoadNoiseNight) \\
&\qquad + \hat{\beta}_5\ (RangeDummy \times RailNoiseNight) \\
&\qquad + \beta_6 \cdot YearOfConstruction + \beta_7 \cdot YearOfConstruction^2 \\
&\qquad + \hat{\beta}_8(PropertyType) + \hat{\beta}_9(Condition) \\
&\qquad + \beta_{10} \cdot \ln\,(TotalFloorArea) + \beta_{11} \cdot AverageFloorAreaLiving + \varepsilon
\end{aligned}
\tag{2}
$$

The results of the estimation suggest that a positive interrelation between noise and owner-side costs exists (see Table 6). However, only the coefficient of the aircraft noise is statistically significant. The result can be interpreted as follows: each dB aircraft noise above 50dB causes 0.88% additional owner-side running costs.

Table 6: Coefficients for noise nuisance on owner-side costs

	Switzerland
Max. aircraft noise night (>50dB)	**0.0088**
Road traffic noise night (>45dB)	0.0044
Rail noise night (>47dB)	0.0011

Bold: $p < 0.01$.

3.4 NOISE IMPACT ON MARKET VALUES

Two models were estimated to assess noise impacts on market values. Both models are based on equation (3). The noise interaction terms include a $RangeDummy$ to separate the effects within the lower and upper thresholds.

$$
\begin{aligned}
&ln(MarketValuePerSQM) = \\
&\quad \propto + \beta_1 \cdot \ln(Macro) + \beta_2 \cdot (AverageContrDuration) + \hat{\beta}_3(Exposition) \\
&\quad + \beta_4 \cdot IsCloseToLake + \hat{\beta}_5(ZoneType) + \hat{\beta}_6(DomSegmentDemand) \\
&\quad + \hat{\beta}_7(DistToLocalServices \times IsCentre) + \hat{\beta}_8(NumServices600m \times IsCentre) \\
&\quad + \hat{\beta}_9(LandscapeQuality \times IsCentre) + \hat{\beta}_{10}(PublicTranspGroup \times IsCentre) \\
&\quad + \hat{\beta}_{11}(RangeDummy \times PropertyType \times AircraftNoiseNight) \\
&\quad + \hat{\beta}_{12}(RangeDummy \times PropertyType \times RoadNoiseNight) \\
&\quad + \hat{\beta}_{13}(RangeDummy \times PropertyType \times RailNoiseNight) \\
&\quad + \beta_{14} \cdot YearOfConstruction + \beta_{15} \cdot YearOfConstruction^2 \\
&\quad + \hat{\beta}_{16}(PropertyType) + \hat{\beta}_{17}(Condition) \\
&\quad + \beta_{18} \cdot \ln(TotalFloorArea) + \beta_{19} \cdot AverageFloorAreaAp + \varepsilon
\end{aligned}
\tag{3}
$$

The first model shows the influence of the explanatory variables on all properties where no spatial or typological distinction of the properties is made. This model confirms the expected relation beween noise and market values (see Table 7). The general negative noise effect on market values of investment properties can therefore be confirmed from an empirical perspective. In the second model, the noise effect is differentiated according to property types. The estimation shows that market values of pure residential properties ("Residential") and residential properties with additional utilizations ("Residential +") are signifcantly affected by all three types of noise. For office and retail properties, a similar effect can not be shown. However, a negative noise effect is indicated by the negative coefficients.

Table 7: Coefficients for noise nuisance on property market values

	Property type						
	All types	Residential	Residential+	Office	Office+	Retail	Mixed
Aircraft noise	**-0.0038**	**-0.0040**		-0.0368			
Road traffic noise	**-0.0023**	**-0.0044**	**-0.0090**	-0.0039	-0.0060	-0.0006	-0.0034
Rail noise	**-0.0023**	**-0.0028**	-0.0011	-0.0005	-0.0067	-0.0025	-0.0006

Bold: $p < 0.01$.

3.5 Direct and indirect noise impact on market values

As shown above, we have developed statistical models to quantify the noise impact on revenues and costs of investment properties. In addition, a model is available to estimate the influence of noise on market values. These models now allow to compute the value reduction of properties at a given noise exposure in two ways:

- Apply noise coefficients from the market value model to calculate the value reduction.
- Apply noise coefficients of the income and cost models to calculate the reduced net income. Then capitalize the reduced net income to calculate the value reduction.

We apply these two calculation methods to a typical residential property from the sample of this study. The property contains 40 apartments and generates CHF 600'000 net annual rental income. At 55dB aircraft noise, a value reduction of about 6.9% is expected due to the reduction of net rents, increased costs and higher risks (see Table 8). By contrast, the estimated reduction is only 2.0% when using the market value model.

Table 8: Example: direct and indirect noise impact on market values

	No aircraft noise	55dB aircraft noise	60dB aircraft noise
Net rental income [CHF/a]	600'000	594'922	592'902
Owner costs [CHF/a]	126'000	131'668	137'591
Net income [CHF/a]	474'000	463'254	455'312
Market value [CHF] as a function of costs and revenues[1]	11'850'000	11'029'853	10'840'757
Market value [CHF], using coefficients of the market value model	11'850'000	11'615'354	11'385'355
Reduction of market value, as a function of costs and revenues[1]		-6.9%	-8.5%
Reduction of market value, using coefficients of the market value model		-2.0%	-3.9%
Delta of reductions		4.9 PP	4.6 PP

[1]Net capitalization rate without noise: 4%, Net capitalization rate with noise: 4.2%.

This large difference is surprising because one would expect more or less the same market value reductions from the two calculation methods.[6] In the example, the net income is capitalized and therefore considered perpetual. In today's appraisals for investment properties the discounted cashflow method (DCF) is widely used. In DCF models, the assumptions about revenues and costs are not constant, but depending on market conditions and the property itself. A lower estimate for income potential of noise-affected properties is expected than for non-noise-exposured properties. In addition, higher costs and vacancies would probably be assumed. The direct reduction of market values would therefore be stronger than in this simple capitalization of the value components. The empirical results show the contrary (for discussion see section 4.2).

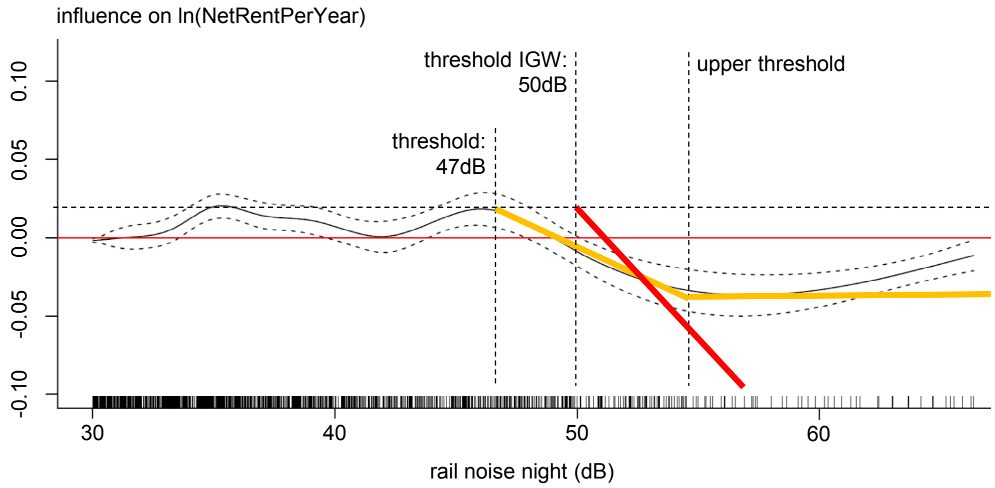
4 DISCUSSION

4.1 THRESHOLDS AND COEFFICIENTS

As shown in section one, most of the existing studies use the “IGW” as a threshold to quantify noise effects on rents and prices. In this study we show that the different noise types have different thresholds that also differ from the thresholds given by the LSV. Thresholds also vary across residential and non-residential properties. In our tests, this leads to different coefficients in comparison to IGW-based models even if we use identical data. Figure 3 shows schematically how the choice of the threshold affects the noise influence for residential rents using rail noise data. The higher the threshold is set, the greater the discount will be. This example illustrates that the IGW-based coefficients poorly estimate the actual noise impact whereas the coefficient estimated with the lower – empirical – threshold is accurate. In addition, the effect at a high noise level is overestimated in a model using only a lower threshold since data suggest the use of an additional upper threshold is necessary. It has to be assumed that existing Swiss studies using IGW-based thresholds are inaccurate.

6 Since appraisals usually also consider potential rents instead of contract rents i.e. the re-rental to a market rent in the future, the directly at the market value measured reduction should even be bigger than the one calulation with the net capitalization model.

Figure 3: Variation of the coefficient using different thresholds (schematic)



4.2 SWISS TENANCY LAW AND AVERAGE RENTAL PERIOD

The reasons for the different market value reductions (as shown in section 3.5) may be found in the Swiss tenancy law. Rents for dwellings within existing rental agreements can only be adjusted in accordance with the change of the "reference interest rate" (Referenzzinssatz) and the consumer price index CPI. In case of a change of tenant, the rent can be adjusted to the market level. Typically, in an investment property the rental income is a mixture between older, indexed rents, and newer rents which are closer to the current market level. The rents observed in this study are therefore a mixture and they have – in a market with rising market rents for around 15 years – increased stronger than the reference interest rate and the CPI. It must therefore be assumed that the net income and thus the market value of a property increases with a higher tenant turnover. A proxy for tenant turnover is the average rental period within a property. The analysis of the available data shows that the average contract duration is also dependent on the noise nuisance, at least for aircraft and rail noise (see Figure 4).[7] Therfore, it is reasonable to assume that a tenant moves after a shorter period of time when he lives in a noise affected apartment compared to a situation without noise nuisance. With every change of tenant, the owner has the possibility to adjust the rent to the market level. Therefore the Swiss tenancy law may have the side effect of reducing noise-induced losses on gross revenue within periods of increasing market rents.

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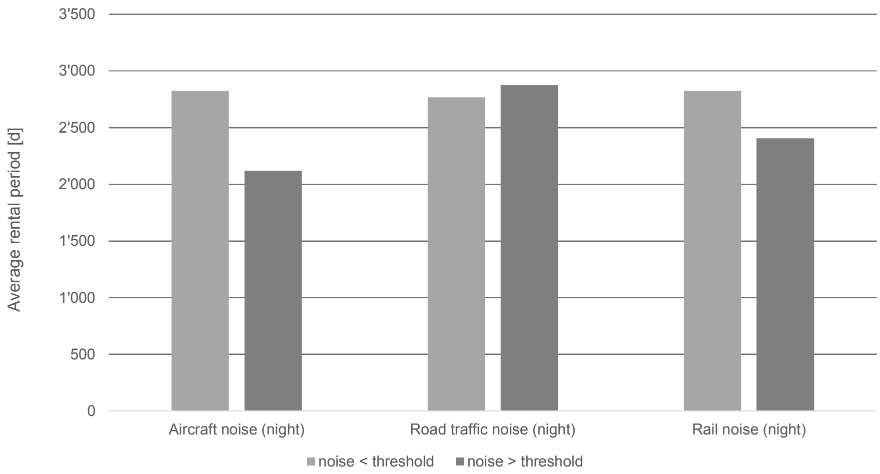
7 Apartments with a high nuisance of road traffic noise are typically in the big cities, where market situation is extremely tense, expecially in the lower price segments.

Figure 4: Average rental period and noise exposure



4.3 NOISE AND INVESTMENT DECISIONS

In this study, the influence of noise on values and value components of investment properties is analysed. Contracts of existing apartments, offices and retail spaces are used as empirical objects of investigation. What can not be examined, however, is the influence of noise on investment decisions. We assume – and this was also confirmed in interviews with several players in the market – that investors, developers and landowners optimise properties within the existing law considering noise influences. For example, in some cases apartments are not built on the lower floors near heavily traveled roads, although it would be permitted in the corresponding zone and it would – if there were no noise – yield higher rental incoms than other utilitsations. In extreme cases, entire buildings with offices, retail spaces or industrial uses are implemented as «noise catchers» in order to create profitable residential uses in other parts of the building lot. The noise exposure leads, in such cases, already at the point of investment decision to a reduced value of the property. We further asume that long term strategies on renovation or repositioning of existing properties are affected by the noise as well. An excellent example of this behaviour can be observed at the Weststrasse in Zurich: In 2010, a massive reduction in road noise was achieved by a major traffic planning project (Kanton Zürich, 2011). In the decades before, only little investment was made anlong this road and the buildings were mostly inhabited by housholds with low incomes. Since the end of the project, major investments by the owners of the buildings were done and the social structure of households has already changed significantly.

There is still a need for research in this area. Today, there is no transparency about noise-induced owner-side losses in cases where the investment decision is dependent on the noise situation. Scientific work on this issue would probably be based on the analysis of case studies, comparing investment projects in scenarios with and without noise, realising «best use» projects while opimising rental incomes.

5 CONCLUDING REMARKS

This study quantifies the impact of noise nuisance on rents, costs and values of investment properties. We assume that this is only possible in the range of medium noise. The coefficients are probably only reliable in relatively homogeneous noise situations, since the study is based on averaged day and night values. In extreme situations (i.e. strong aircraft noise in the early morning) the actual price impacts are likely to be higher. Strong noise nuisance most likely affects investment decisions and the effects can therefore not be observed empirically. To do so, it would be necessary to assess the highest and best use for each property with the assumption that there was no noise pollution.

The data used in this study represent the last few years, a period marked by rising rents and tight supply. The measured noise coefficients are valid for this period and can vary with changing market conditions. We suspect that apartment seekers cannot fully cover their preferences (i.e. noise sensitivity) in the current market environment. Furthermore, there is evidence that noise sensitivity of people varies greatly due to the genetic predisposition.

This study does not allow any conclusions about the effects of noise on privately owned residential properties. There, the impacts may be different than in the investment property sector.

APPENDIX

A: VARIABLES AND EXPECTED IMPACTS

Table 9: Model on apartment rents: descriptive statisics and expected impacts

	Variable	Description	Min	Max	Median	SD	Exp. impact
Dependent							
	NetRentPerYear	Net rent per year [CHF/a]	3'352	76'392	15'216	6'156	
Macro-location and contract							
	Macro	Price level FPRE [CHF/m^2a]	139	536	250	56	+
	IsCentre	Is in a urban centre [dummy]					
	SpatialType	Spatial type [factor]					
	YearQuarter	Quarter of the contract [factor]	1995	2013	2011	4	+
Micro-location							
	IsCloseToLake	Dist. to lake of max. 500m [dummy]					
	Exposition	Expostion [factor]					
	ZoneType	Building zone [factor]					
	DomSegementDemand	Dominant segment of demand [factor][8]					
	DistToLocalServices	Distance to a local supplier (shop, post…) [km]	0.0	2.2	0.3	0.2	-
	NumServices600m	Number of local suppliers within 600m [num]	0	4	3	1.4	+
	LandscapeQuality	Landscape quality index [index]	3.7	30.3	20.5	4.3	+
	PublicTranspGroup	Public transport group [factor]					
	AircraftNoiseNight	Max. aircraft noise night [dB]	30	62	30	3.7	-
	RoadNoiseNight	Road traffic noise night [dB]	30	68	42	7.8	-
	RailNoiseNight	Rail noise night [dB]	30	66	30	5.5	-
Object and property							
	YearOfConstruction	Year of construction [num]	1903	2013	1973	20.73	+
	BuildingType	Type of building [factor]					
	Condition	Condition of the building [factor]	1.0	5.0	3.0		+
	FloorArea	Floor area of the apartment [m^2]	20	199	80	25.5	+
	NumRooms	Number of rooms in apartment [num]	1.0	9.0	3.5	1.1	+
	FloorLevel	Floor level [num]	-2	18	2	2.2	+

[8] Segmentation of demand in the housing market as described in Fahrländer Partner & sotomo (2012).

Table 10: Models on costs and market values: descriptive statisics and expected impacts

Variable	Description	Min	Max	Median	SD	Exp. impact values	Exp. impact costs
Dependent							
RunningCostsPerSQM	Annual running costs [CHF/m^{2}a]	21	129	44	27.1		
MarketValuePerSQM	Market value per m2 [CHF/m^2]	885	49'123	3'402	3'125		
Macro-location and contract							
Macro	Price level FPRE [CHF/m^{2}a]	52	2'496	202	175	+	
AverageContrDuration	Average contract run-time [d]	96	41'705	2'999	3'093	+	-
IsCentre	Is in a urban centre [dummy]						
SpatialType	Spatial type [factor]						
Micro-location							
IsCloseToLake	Dist. to lake of max. 500m [dummy]						
Exposition	Expostion [factor]						
ZoneType	Building zone [factor]						
DomSegementDemand	Dominant segment of demand [factor]						
DistToLocalServices	Distance to a local supplier (shop, post…) [km]	0.00	2.13	0.21	0.23	-	
NumServices600m	Number of local suppliers within 600m [num]	0	4	3	1.4	+	
LandscapeQuality	Landscape quality index [index]	3.7	30.3	21.5	4.4	+	
PublicTranspGroup	Public transport group [factor]						
AircraftNoiseNight	Max. aircraft noise night [dB]	30	62	30	8.0	-	+
RoadNoiseNight	Road traffic noise night [dB]	30	70	48	7.2	-	+
RailNoiseNight	Rail noise night [dB]	30	66	30	6.2	-	+
Object and property							
YearOfConstruction	Year of construction [num]	1600	2013	1969	29.6	+	-
PropertyType	Type of property [factor]						
Condition	Condition of the building [factor]	1.0	5.0	2.0		+	-
TotalFloorArea	Total floor area property [m^2]	90	56'350	2'573	5'537	+/-	-
AverageFloorAreaAp	Average apartment size [m2]	16	223	77	19.7	-	-

B: ESTIMATION RESULTS

Vectors of coefficients $\hat{\beta}_i$ (factor variables and interaction terms) are not completely shown in the following table due to their length. Instead the table shows a selection of combined characteristics. Noise coefficients are not shown since these are presented in section 3.

Table 11: Model on apartment rents: selected coefficients

	Global		*IsCentre*=1 (yes)		*IsCentre*=0 (no)		*SpatialType=4*	
Dependent: *ln(NetRentPerYear)*	Coeff	t value	Coeff	t value	Coeff	t value	Coeff	t value
Macro-location and contract								
ln(Macro)	**0.4087**	78.5	**-**	-	**-**	-	**-**	-
YearQuarter: 2000:4	**-**	**-**	**-0.2115**	-11.4	**-0.1708**	-5.7	**-**	-
YearQuarter: 2012:3	**-**	**-**	**0.0444**	3.4	**0.1014**	3.7	**-**	-
Micro-location								
IsCloseToLake: Yes	0.0030	1.0	-	-	-	-	-	-
Exposition								
ZoneType : Residential	-	-	**0.0000**	0-level	**0.0000**	0-level	-	-
ZoneType : Central/old town	-	-	**-0.0178**	-4.7	**0.0109**	2.9	-	-
DomSegementDemand : 2	0.0107	1.3	-	-	-	-	-	-
DomSegementDemand : 4	**0.0244**	2.9	-	-	-	-	-	-
DomSegementDemand : 8	**0.1035**	11.7	-	-	-	-	-	-
DistToLocalServices	-	-	-	-	-	-	**0.0375**	2.7
NumServices600m: 0	-	-	**0.0000**	0-level	**0.0000**	0-level	-	-
NumServices600m: 4	-	-	-0.0190	-2.6	**0.0192**	3.8	-	-
LandscapeQuality	-	-	-	-	-	-	**0.0031**	4.2
PublicTranspGroup: A	-	-	**0.0905**	13.4	-	-	-	-
PublicTranspGroup: B	-	-	**0.0835**	13.0	0.0051	1.7	-	-
PublicTranspGroup: C	-	-	**0.0714**	11.2	**0.0133**	4.8	-	-
Object and property								
YearOfConstruction	**-0.1253**	-24.7	-	-	-	-	-	-
YearOfConstruction^2	**0.00003**	25.2	-	-	-	-	-	-
BuildingType: 6-10 Apartments	**-0.0235**	-2.6	-	-	-	-	-	-
BuildingType: 11-15 Apartments	**-0.0277**	-3.1	-	-	-	-	-	-
BuildingType: > 15 Apartments	**-0.0520**	-5.9	-	-	-	-	-	-
Condition: 5.0	**0.0000**	0-level	-	-	-	-	-	-
Condition: 4.0	**-0.0399**	-10.1	-	-	-	-	-	-
Condition: 3.0	**-0.0880**	-22.5	-	-	-	-	-	-
ln(FloorArea)	**0.7150**	232.4	-	-	-	-	-	-
NumRooms: 2.5	**-0.0348**	-10.1	-	-	-	-	-	-
NumRooms: 3.5	**-0.0296**	-10.9	-	-	-	-	-	-
NumRooms: 4.5	**0.0000**	0-level	-	-	-	-	-	-
NumRooms: 5.5	**0.0183**	4.3	-	-	-	-	-	-
FloorLevel: Ground floor	-	-	**0.0000**	0-level	**0.0000**	0-level	-	-
FloorLevel: 3th floor	-	-	**0.0304**	9.3	**0.0391**	8.1	-	-
FloorLevel: 5th floor	-	-	**0.0471**	6.9	**0.0287**	3.0	-	-
Degrees of freedom: 64'983, adjusted R^2: 0.78								

Bold: $p < 0.01$.

REFERENCES

Andersson, H., L. Jonsson and M. Ögren (2009), “Property prices and exposure to multiple noise sources: hedonic regression with road and railway noise”, in: *Environmental and Resource Economics*, vol. 45, no. 1, p. 73-89.

Banfi, S. et al. (2007), “Zahlungsbereitschaft für eine verbesserte Umweltqualität am Wohnort. Schätzungen für die Städte Zürich und Lugano für die Bereiche Luftverschmutzung, Lärmbelastung und Elektrosmog von Mobilfunkantennen”, in: *Umwelt-Wissen*, Nr. 0717, Bundesamt für Umwelt, Bern.

Baranzini, A. and J.V. Ramirez (2005), “Paying for quietness: the impact of noise on Geneva rents”, in: *Urban Studies*, vol. 45, no. 4, p. 633-646.

Baranzini, A. et al. (2006), “Feel or measure it. Percieved vs. Measured Noise in Hedonic Models”, in: *Transportation Research Part D: Transport and Environment*, vol. 5D, no. 8, p. 473-482.

Bundesgericht (2011), “BGE 138 II 77, 9. Auszug aus dem Urteil der I. öffentlich-rechtlichen Abteilung i.S. Flughafen Zürich AG und Kanton Zürich gegen X. und Eidgenössische Schätzungskommission Kreis 10 (Beschwerde in öffentlichrechtlichen Angelegenheiten) 1C_100/2011 / 1C_102/2011 vom 9. Dezember 2011”.

Bundeskanzlei (1986), „Lärmschutz-Verordnung (LSV)“ vom 15 Dezember 1986 (Stand am 1. August 2010), 814.41.

Day, B., I. Bateman and I. Lake (2007), “Beyond implicit prices: recovering theoretically consistent and transferable values for noise avoidance from a hedonic property price model”, in: *Environmental Resource Economics*, vol. 37, p. 211-232.

Dekkers, J.E.C. and J.W. van der Straaten (2009), “Monetary valuation of aircraft noise: A hedonic analysis around Amsterdam airport” *Ecological Economics*, vol. 68, no. 11, p. 2850-2858.

Fahrländer Partner (2013), ”Berechnungsmodell für die LAN“. Bericht zu Handen des Bundesamts für Umwelt. Zürich (mimeo).

Fahrländer Partner & sotomo (2012), “Nachfragersegmente im Wohnungsmarkt, Konzeption & Überblick”. http://fpre.ch/de/02_nase/NaSeWo_ueberblick.pdf.

Fahrländer, S. (2006), “Semiparametric Construction of Spatial Generalized Hedonic Models for Private Properties”, in: Swiss Journal of Economics and Statistics, vol. 2006, no. 4, p. 501-528.

Hastie, T. and R. Tibshirani (1990), *Generalized Additive Models*, London.

Kanton Zürich (2011), “Wirkungskontrolle Westumfahrung und A4 Knonaueramt. Kurzbericht”, Volkswirtschaftsdirektion, Kanton Zürich, Zürich.

Kim, K.S., S.J. Park and Y.-J. Kweon (2007), “Highway traffic noise effects on land price in an urban area”, in: *Transportation Research Part D: Transport and Environment*, vol. 12, no. 4, p. 275-280.

Malpezzi, S. (2002), “Hedonic pricing models: A selective and applied review”, in: T. O’Sullivan and K. Gibb (eds.), *Housing Economics and Public Policy*, Blackwell Science, Oxford.

Nelson, J.P. (2008), “Hedonic property studies of transportation noise: aircraft and road traffic”, in: A. Baranzini, J. Ramirez, C. Schaerer and P. Thalmann (eds.), *Hedonic Methods in Housing Markets. Pricing Environmental Amenities and Segregation*, Springer, New York.

Schaerer et al. (2007), “Using the Hedonic Approach to Value Natural Land Uses in an Urban Area: An Application to Geneva and Zurich”, in: *Economie Publique/Public Economics*, vol. 2007/1, no. 20, p. 147-167.

Sirmans, G.S., D.A. Macpherson and E.N. Zietz (2005), ”The composition of Hedonic Pricing Models”, in: *Journal of Real Estate Literature*, vol. 13, no. 1, p. 3-43.

Willhelmsson, M. (2000), “The impact of traffic noise on the values of single-family houses”, in: *Journal of Environmental Planning and Management*, vol. 43, no. 6, p. 799-815.

Zürcher Kantonalbank (2010), *Die Spezialgesetzliche Ausgleichsnorm SAN. Anwendbarkeit hedonischer Modelle zur Minderwertbestimmung*, Zürich.

ZUSAMMENFASSUNG

In dieser Studie ermitteln wir mittels hedonischer Modelle den Lärmeinfluss auf Mieten, Kosten und Werte von Renditeliegenschaften in der Schweiz. Landesweite Daten wurden durch institutionelle Immobilieninvestoren zur Verfügung gestellt. Die Effekte werden für Flug-, Strassen- und Bahnlärm gemessen. Wir zeigen, dass Lärmeffekte zwischen unteren und oberen Schwellenwerten auftreten und sich zwischen verschiedenen Lärmarten und Nutzungen unterscheiden. Die Lärmwirkung beginnt teilweise bereits unterhalb des Immissionsgrenzwertes (IGW) und verstetigt sich bei einem – je nach Lärmart und Nutzung unterschiedlichen – oberen Schwellenwert. Lärm beeinflusst aber auch Investitionsentscheide. So werden an lärmbelasteten Lagen beispielsweise Büros anstelle von Wohnungen gebaut etc. Diese wichtigen Effekte können mit den vorliegenden Daten nicht berücksichtigt werden. Wir zeigen, dass direkt gemessenen Abschläge auf den Marktwerten niedriger sind als aufgrund der empirischen Mindererträge und Mehrkosten erwartet würde. Der Grund dafür ist im Schweizerischen Mietrecht zu finden. Wohnungsmieten mit bestehenden Verträgen können nur in Übereinstimmung mit dem Referenzzinssatz und der allgemeinen Teuerung angepasst werden. Da die durchschnittliche Vertragslaufzeit mit zunehmender Lärmbelastung abnimmt, wird der negative Lärmeffekt in Zeiten steigender Marktmieten deutlich kompensiert.