The Cost of Road Noise

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Abstract:

The cost of traffic noise has been the subject of several hedonic analyses, yet most of these are limited to the first stage estimation of the hedonic price function. The goal of the present research is to carry out a complete hedonic analysis to estimate and analyze household preference parameters. The analysis quantifies the willingness to pay to avoid road noise using a dataset of households and housing transactions in the Greater Copenhagen Area. The empirical strategy in the first stage analysis is aimed at simultaneously reducing the risk of omitted variable bias and the risk of measurement error in the noise measure. The latter arises because only a single cross-section of noise measures was available and was used for transactions over several years. The preference parameters are identified through the assumption of a simple functional form for utility. Willingness to pay for noise reductions is found to be increasing for higher levels of noise. A reduction of 2 dB is worth about twice as much when it occurs at 72 dB compared to the value of the reduction at 62 dB. Observable demographic characteristics explain some 32 percent of the variation in willingness to pay for a noise reduction. Some of the more important factors are income and household type, in particular, the presence of children is a significant factor in increasing willingness to pay. However, a large part of WTP heterogeneity is left unexplained, which may be a concern when considering benefit transfer. While it is possible to adjust for observable differences between areas in terms of e.g. household composition, selection into different areas based on unobserved taste cannot be controlled for in such a setting.

Keywords: Traffic noise, Valuation, Hedonic method

JEL: Q51, Q53, R41

Indholdsfortegnelse

1 Introduction

Noise pollution is defined as unwanted noise caused by human activity. The primary source of noise pollution is transportation and most importantly road traffic, which is found throughout the urban environment. Noise pollution interferes with recreation, conversation, interrupts sleep and can potentially be detrimental to productivity and health. The European Environment Agency estimates that more than 100 million Europeans are exposed to noticeable levels of traffic noise. The World Health Organization's European division estimates that traffic noise is harmful to the health of every third European citizen and that every fifth European is exposed to traffic noise levels at night which seriously impact their health. These health effects include hypertension and cardiovascular disease after long term exposure to traffic noise (WHO (2011)).

In the last decade noise pollution has received increased political attention in the European Union where the EU noise directive was put into place in 2002 (Commission (2011)). In Denmark construction of new residential areas is recommended to avoid locations with daytime noise in excess of 55 dB. However, approximately 1/3 of all existing Danish homes are exposed to traffic noise above this noise limit. Furthermore, traffic volumes are generally increasing all over Europe, and have increased by 10 percent in Denmark over the last 10 years. For these reasons, noise pollution is a salient issue in many urban municipalities and for infrastructure authorities. Several measures are undertaken to reduce noise at the emitter or the receiver through e.g. noise-reducing asphalt, sound barriers and noise insulation of homes. Additionally, municipalities in Denmark actively use urban planning in terms of zoning and traffic management to reduce noise exposure of residential areas, see Jensen and Rambøll (2010). Such measures are costly and beg the question what noise reductions are worth to households. Fortunately, it is possible to address this question by looking at the housing market, where noise exposure is frequently traded as part of the composite housing good.

The use of revealed preference methods for noise valuation is extensive. The hedonic method as proposed by Rosen (1974) lends itself naturally to recovering the welfare loss resulting from noise pollution. The literature on valuation of noise annoyance has been surveyed by Navrud (2002) and Nelson (2008). Almost all contributions focus on calculating the Noise Depreciation Index (NDI). This index describes the depreciation in housing prices associated with a 1 dB increase in noise levels. The NDI can be calculated from the results of a first stage hedonic analysis and is used to calculate "implicit prices" of noise pollution. The implicit prices from the first stage of Rosen's two stage method can only be used to valuate marginal changes in noise exposure and are specific to the area under study. For welfare effects of non-marginal changes it is necessary to recover the preference parameters of the household in the second stage of the hedonic analysis. The revealed preference literature on the estimation of household preference parameters for quiet is scarce (Wilhelmsson (2002), Day et al. (2007)). As a result, little is known about what characterizes the households that are sensitive to noise pollution as well as how much of the variation in taste for quiet is due to observables.

The aim of the present analysis is to recover and characterize the preference parameters and willingness to pay for quiet for the population in the Greater Copenhagen area. The dataset collected for this analysis is relatively large comprising almost 100,000 transactions over a period of 9 years. It is more detailed than most data used in hedonic analyses as it contains data on both housing and household characteristics at the individual level. Additionally, the measure of traffic noise used in the analysis has a very fine spatial resolution allowing the robust recovery of the effect of traffic noise on housing prices.

The analysis consists of two steps. In the first step the hedonic price function is estimated with a research design that limits the risk of omitted variables bias and measurement error invalidating the parameter estimates. The parameters from the first stage analysis are used to calculate "implicit prices" for each product attribute, which enter the second step of the analysis. Day et al. (2007) is the most recent of the few attempts to recover preference parameters for quiet.[1] They estimate pseudo-demand functions using spatially lagged implicit prices to instrument for endogeneous prices in the second stage of the hedonic. Their instrumental variable strategy relies on the assumption that the source of endogeneity in the second stage is not correlated across space. This is a strong assumption considering the spatial nature of the housing market. The second stage estimation in the current analysis is not based on instruments for estimating psuedo-demand functions, but rather achieves identification through the assumption of a simple functional form for utility. This approach is used in Bajari and Kahn (2005) to study preferences for racial segregation in the housing market. The approach is transparent, and does not require the use of instrumental variables. Due to sorting in the housing market valid instrumental variables are extremely hard to come by in the absence of multiple markets in time or space.[2] Another advantage of the Bajari-Kahn approach is that it does not require assuming a distribution for the unobserved preference parameters. The household preference parameters are recovered based on the implicit prices and analyzed to gain a deeper understanding of welfare effects of noise pollution and the substantial preference heterogeneity in the population. The details of the theoretical framework, the data and the econometric strategy are given below.

2 Theoretical framework

The household maximizes (current) utility subject to its budget constraint, which contains an annualized house price:

$$\underset{x,c}{max}\, U\left(h(x,z),c\right)\; s.t.\, y = \pi_t P\left(x,z\right) + c$$

where $h(x,z)$ is the housing good, c is a Hicksian composite consumption good, π_t is the user cost of housing and $P(x,z)$ is the house price. The price of a house given its attribuets is the outcome of the sorting of households on available homes. The first stage of a hedonic analysis estimates this hedonic price function to characterize the price of a home, P as a function of its attributes:

$$P_{ij} = f\left(X_i, z_i, \xi_j, e_{ij}; \Omega\right)$$

Here, X_i is a vector of observable housing and neighbourhood characteristics, z_i is road noise exposure, ξ_j is a vector of unobserved neighborhood characteristics, and e_{ij} is an unobserved idiosyncratic component. Ω is a vector of parameters in the hedonic price function.

[1]Swärdh et al. (2012) considers railway noise and follows an approach similar to the one in Day et al. (2007).

[2]Even with multiple markets the identifying assumption is that preferences across markets are identical, i.e. no sorting across markets due to unobservable preference heterogeneity.

The first order condition from the household's maximization problem provides the theoretical basis for the interpretation of the derivative of the hedonic price function as a welfare measure. Simultaneously, this is the foundation for the second stage estimation as it relates the household's marginal rate of susbtitution (MRS) to the price paid for an attribute. The second step of the analysis originally refers to the estimation of the household bid functions to recover the preference parameters. However, it is in this step of the analysis, that endogeneity of quantities and prices due to unobservable taste makes recovery of preference parameters difficult due to the lack of good instrumental variables, see e.g. McConnell and Phipps (1987),Epple (1987).

Following Bajari and Kahn (2005) the assumption of a simple utility structure can deliver estimates of the preference parameters without the need for instruments. Specifically, they assume separability of the housing attributes and logarithmic utility that is quasilinear in income. The utility structure for household i is:[3]

$$u_i(h(x_i), c_i) = \sum_k \beta_{ki} log(x_{ki}) + \beta_{zi} log(N - z_i) + c_i \tag{1}$$

Here, N is 1 unit larger than the maximum noise observed in the data to ensure that quiet contributes positively to utility. The preference parameters vary by household:

$$\beta_{li} = \theta_{li} + \alpha_{l0} + \sum_d \alpha_{ld} S_{di},\, l = k, z \tag{2}$$

With this specification, the household has an idiosyncratic taste component for each attribute, θ, and preferences depend on the household's observable characteristics in S_d. The vector S_d is a vector of sociodemographic variables like age, presence and age of children, education level of household, and indicators for whether the household contains retirees, students etc.

The parameters of preferences can be estimated non-parametrically as in Bajari and Kahn (2005). Solving for the first order condition of the household's utility maximization:

$$\beta_{zi} \frac{1}{(N - z)} = \pi_t \frac{\partial P}{\partial z} \Rightarrow \beta_{zi} = \pi_t \frac{\partial P}{\partial z} (N - z) \tag{3}$$

The random parameter β can then be decomposed to recover the determinants of taste for quiet including the unobservable taste parameter θ_i as the residual from the regression in equation 2. Based on this simple utility model it is possible to ask how much of the estimated willingness to pay for quiet is due to variations in observable characteristics such as age and education levels, and how much is due to unobserved taste. It is also possible to look at correlations between preferences for different attributes and to examine how these differ between demographic groups in the population.

3 The data

The dataset collected for this analysis consists of the population of residential properties sold in single household transactions in the period from 2000 to 2008 in the Greater Copenhagen area.[4] In

[3]The subscript i is used for both homes and households. There is a 1:1 correspondence between homes and households in the data and so the same index is used to keep notation simple.

[4]The data set consisted of the population of transactions taking place in the period of single family houses, terraced houses and apartments. The data was cleaned by eliminating transactions where the buyer was not a household (e.g. companies, organizations etc.). Furthermore, foreclosures and transactions between relatives were

total, there are 99,768 arms length transactions over the 9 year period. The Greater Copenhagen area covers a total of 16 municipalities. Of these the largest is the municipality of Copenhagen, which contains approximately half of the transactions in the full data set. The study area was chosen due to the availability of noise measures at residential properties for this area.

Housing market transactions and housing characteristics

Data describing the structural characteristics of the housing unit is available from the Danish Building Registry. This data covers e.g. the size of the living area, year of construction, roof material, number of bathrooms etc. The Danish Building Registry is updated regularly and the information contained in it therefore reflects the characteristics of the individual dwellings at the time at which data was extracted (June 2010). The registry also contains information on the date of the latest larger renovation. Here "large" means a renovation which required a permit from the municipality. This would be the case for e.g. house enlargement, construction of garages, or significant changes in outward appearance. This information is used to control for large renovations taking place after the transaction occurred. The registry also contains spatial coordinates describing the exact location of each housing unit. Based on these coordinates, different measures have been calculated using Geographical Information Systems describing accessibility and other locational attributes of the dwelling, e.g. distance to the center of Copenhagen, to the coastline, nearest train station etc. Data on the transaction describes the actual selling price and date of sale. A complete list of the variables included in the analysis can be found in the appendix.

Household data

The data on the households inhabiting the transacted properties is provided by Statistics Denmark. This data set describes the composition of households in terms of the number and age of children in the household, the age and number of adults, the education level of each of the adults, their place of birth, and whether they work full-time, part time or have retired from the labour market. Information on the household income after taxes and transfers is also available. The dataset on the households is merged with the data on transacted properties using the address. This process is carried out first for the year following the sale. If no inhabitants are found, inhabitants in the year of the sale are used, and finally, if no-one is registered at the address in that year either, the year before the sale is used. A match to household was achieved for approximately 97 percent of the transacted properties. For those properties that are matched, 93 percent are matched to households registered to the address in the year following a sale. Finally, households with extreme incomes after taxes and transfers were discarded from the sample used for analysis of preference heterogeneity. However, they were included in the estimation of the hedonic price function.[5]

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discarded. Transactions in which whole apartment buildings were sold to private households were also eliminated. Finally, homes smaller than 35 sqm were eliminated as were outliers in terms of the price per square meter. The aim of the study is to quantify tradeoffs for private households in their housing consumption decision. Therefore the sample used for the analysis should reflect the open market faced by private households. The data cleaning of the household data is described in footnote 4 and affects only the data used in the analysis of preference parameters.

[5] Extremely low income was defined as less income than their annual cost of housing determined by the user cost of owning a home, plus a minimum amount per person set at 40,000 DKK (2000-levels) for the first person and 20,000 DKK for each additional adult. This reduces the data set by 5,583 observations, the majority of which are students. In some of these cases, the parents are the likely owners of the property. Additionally, 27 observations with extremely high incomes (higher than 1,500,000 DKK after housing costs) were removed. Unfortunately, data

Measures of traffic noise exposure

Noise is measured in decibels (dB) on a logarithmic scale. An increase of 1 dB is just perceivable and a 10 dB increase corresponds to a doubling of the perceived noise level. To give an idea of the noise levels common in everyday life, 40 dB corresponds to the sound of a whisper at 30 cm distance and 100 dB is the sound of a propeller airplane at 30 meters distance. In an urban environment it will rarely be completely silent due to the ambient noise created by the presence of many people in a single place.

Due to the EU Directive on Noise the mapping of noise in larger urban conglomerations across the EU member states was required for the first time in 2007. In Denmark, only the Greater Copenhagen Area qualified for this mapping. Three different measures of the traffic noise exposure of each housing unit were utilized. The measures of noise are of varying quality both depending on the type of noise (rail, airport or road) and between municipalities. All three noise measures are model-based calculations of L_{den} (Day-Evening-Night). L_{den} is a measure of average noise in a 24 hour period over the course of a year, where different weights are assigned to noise exposure depending on the time of day.[6] The measures of road and rail noise used in this paper are calculated using the Nord2000 noise model, whereas the measure of airport noise has been calculated using DANSIM. In both cases, input for the calculations consists of various data on the type, frequency and speed of traffic as well as data on weather conditions. In the Nord2000 model information on the density of buildings and type of asphalt are also included, see Kragh et al. (2006).

Road noise

For 14 of the municipalities included in the analysis, the road noise exposure was calculated in two heights at the face of the buildings: 1,5 m and 4 m from the ground. For the municipality of Copenhagen, which contains almost 2/3 of the transactions for apartments, noise has been calculated at a finer level so that individual noise measures exist for each individual floor of a building.[7] All the calculations were carried out using data on traffic in 2005/6. Noise measures are reported to be reliable from around 45 dB upwards according to the engineers responsible for the mappings.

The calculation of the traffic noise measures are designed to describe the amount of noise deriving specifically from nearby roads at the individual housing unit. They do not take account of the general level of background noise present in the neighborhood, e.g. noise from industry, or from neighbors etc. The actual level of background noise present depends on the level of urban activity in the neighborhood and is an empirical question.

Baranzini et al. (2010) discuss the relationship between perceived traffic noise and scientific

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on wealth was not available for this analysis. The data cleaning of the household data only affects the data used for the analysis of the preference parameters as no transactions were barred from fitting the hedonic surface based on the demographic data.

[6]The formula used to calculate L_{den} is: $L_{den} = 10 \cdot log\frac{1}{24} \cdot \left(12 \cdot 10^{\frac{L_{day}}{10}} + 4 \cdot 10^{\frac{L_{eve}+5}{10}} + 8 \cdot 10^{\frac{L_{nig}+10}{10}}\right)$, so a penalty of 5 and 10 are added to noise levels in the evening and night where households are presumably more sensitive to noise. L_{day}, L_{eve} and L_{nig} are the A-weighted equivalent sound pressure levels for the corresponding 12, 4 and 8 hour periods: 7 AM to 7 PM, 7 PM to 11 PM and 11 PM to 7 AM.

[7]One municipality (Dragør) was not a part of the noise mapping and road noise measures do not exist for the transactions in this municipality. The municipality does not have any large roads and complaints of road noise are uncommon there. As a precaution however, all dwellings within 200 meters of a large road (6 meters wide) have been dropped from the analysis.

measures of traffic noise in their study of the Geneva housing market. They find that the perceived noise curve is flatter than the actual noise curve implying that people are less annoyed at a marginal increase in noise than indicated by scientific measures. For road noise above 55 dB they find that adding perceived noise levels to a hedonic regression already containing scientific noise measures does not improve the fit of their model.

Railway and airport noise

Railway and airport noise are included as controls in the study. In most of the study area, calculated rail noise measures exist from 2011 for the railways. However, one stretch between North-Western Copenhagen and Copenhagen Airport was not included in this mapping. Data from 2007 was available in 5 dB intervals and has been used to proxy for the noise from this stretch of railways in the relevant areas.[8] The level of detail in the mapping differs from the detail in the road noise mapping. As a result, railway noise is mainly included as a control variable and the estimates should be interpreted with caution.

Airport noise differs considerable from the other two sources of traffic noise. Airport noise is calculated for grids of 50 square meters using the DANSIM model which satisfies the requirements for the EU noise mapping (Plovsing (2009)). Since the source of noise is placed above the dwellings, the presence of other buildings does not dampen that noise as it is the case with the rail and road noise. In consequence, the spatial variation in airport noise is much smaller. Lower variation makes the effect of this type of noise hard to distinguish from other neighborhood effects.

4 Econometric strategy

There are a number of major concerns in estimating the first stage of the hedonic model. The hedonic relationship describes an equilibrium outcome in a market. In the 2000s, the Danish housing market evolved as most housing markets in Europe and the US: with dramatic housing price increases following liberalizations in the financing of real estate purchases. In Denmark, the most important changes was the introduction of payment free loans with varying interest rates in 2003 and a change in taxation of real estate which fixed taxes in nominal terms at the 2001 tax payment. These changes contributed to the dramatic increase in housing prices, which peaked in 2006. These changing market conditions make it likely that the hedonic equilibrium changed during the period suggesting that the data should not be pooled across all years. Three periods were identified in the data during which the regulatory environment remained stable. The first period (2000-2002) is before the liberalizations in the financial sector took place, the second period (2004-2005) is the beginning of the housing bubble and the final period (2007-2008) is after the burst of the housing bubble. The years 2003 and 2006 are left out of the estimations to concentrate

[8]The noise calculation model used for railway noise is constructed for calculation of road noise and has been adapted to calculate noise from railways. The accuracy with which this noise measure captures the perceived railway noise exposure is not known as railway noise is quite different in terms of duration and frequency. A measure of maximum railway noise exposure was also provided and comparison between this measure and the average 24 hour measure L_{den} revealed that only homes that experienced large maximum noise levels have positive 24 hour average railway noise in the mappings. Further, the mapping of railway noise was only required to cover homes exposed to railway noise above 55 dB and this limit was imposed by selecting buffers around the railways for which noise measures were calculated. In contrast to road noise therefore, rail noise has only been calculated for those housing units within a certain distance to the railroad.

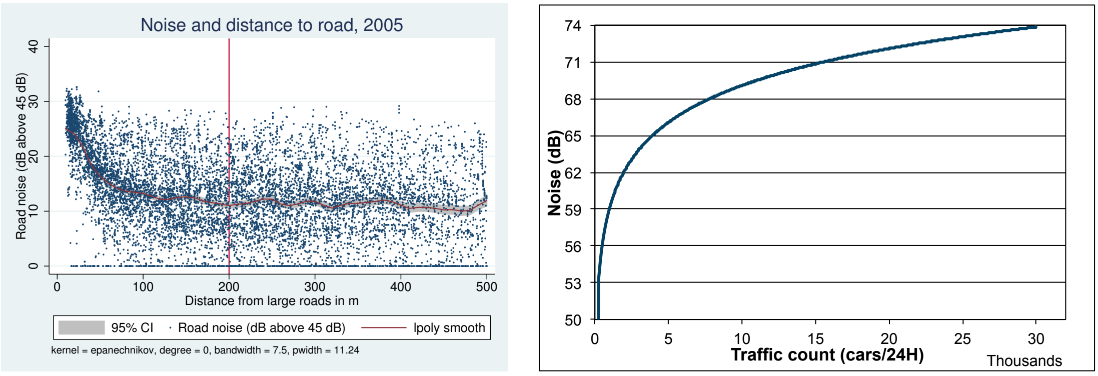


Figure 1: Noise variation and distance to a large road

on periods with stable market conditions.

The remaining challenges for estimating the hedonic price funciton concern mismeasurement of attributes or transaction prices, omitted variables, and choice of functional form. The research design employed here addresses each of these concerns in turn and will be described further detail below.

Measurement error

Most variables in the data set derive from Danish administrative data and are accurately measured characteristics of actual transactions. The main concern regarding measurement error is the variable of primary interest: road noise. Unfortunately, the measure of road noise used in the analysis is based on traffic counts for the short period covering the years 2005/2006. These measures have been used for housing transactions in the whole sample period (2000-2008). To reduce the risk that actual noise levels have changed substantially from the observed measures over the time period, a reduced sample based on homes within 200 meters of a *large road* is constructed. A large road is defined as a road wider than 6 meters and covers e.g. arterial roads and motorways. For many of the homes near large roads, these roads are the major source of noise pollution. This can be seen in figure 1, where there is a clear pattern in noise and distance to the large road for homes within a 200 m distance.

The large roads have relatively high traffic flows. The relationship between noise and amount of traffic is such, that doubling the traffic flow increases noise levels by 3 dB.[9] On large, busy roads therefore, changes in traffic volume over the course of 3-5 years on either side of 2005 would have to be large to affect noise levels noticeably.[10] Limiting the analysis to homes within 200 m of a large road reduces the data set by 60 percent. This reduction of the sample size enhances internal

[9]The relationship between noise and amount of traffic in fig. 1 is an example. The exact level of the noise generated depends on the speed and the asphalt on the road as well as the composition of vehicles (e.g. share of heavy vehicles).

[10]Traffic counts from roads entering the municipality of Copenhagen and key intersections in the center of Copenhagen in the period show that changes in traffic flows lie between -33 pct. and + 33 pct. of the 2005 count used to compute the noise measure. 7 out of 45 counting stations experienced more than 20 pct. variation in traffic flows corresponding to 1-2 dB changes in noise levels in the years 2000 or 2008 relative to 2005. Of these only 3 are in the data set. 2 of them are relatively new freeways (1997/8), which experienced (expected) rapid growth in traffic flows in the early 2000s. The remaining road was subject to a temporary closure in 2008 explaining the reduction in traffic in that year relative to 2005. The measurement error induced by the use of a single cross section thus seems to be of minor concern on these large roads.

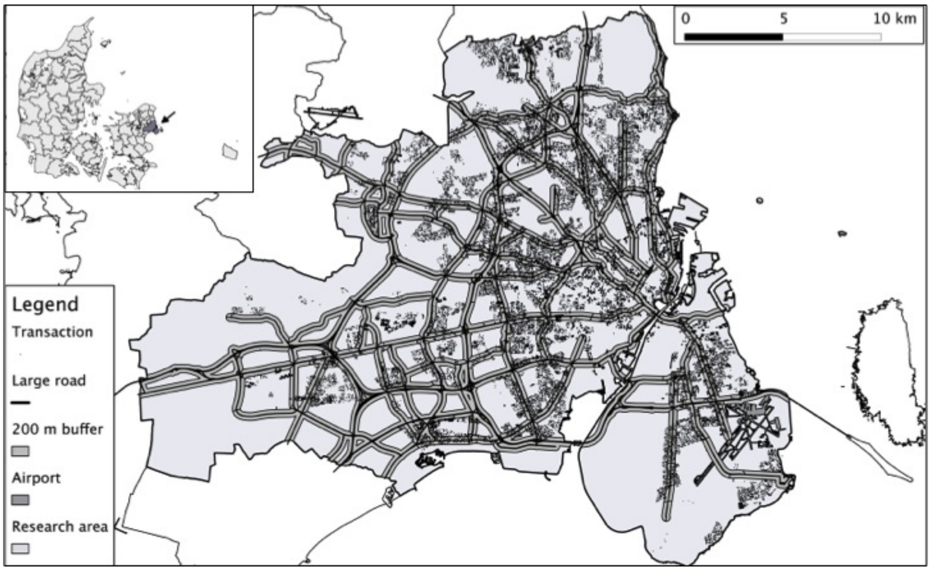


Figure 2: Large roads and borders with transactions

Table 1: Selected descriptive statistics of the housing transactions

	Within 200 m			Full sample		
Variable	min	max	mean	min	max	mean
Road noise $>$ 45 dB	0.0	36.6	15.7	0.0	41.0	12.7
Train noise $>$ 55 dB	0.0	17.1	0.2	0.0	20.1	0.1
Airport noise $>$ 45 dB	0.0	18.3	0.1	0.0	25.6	0.2
Area (m^2)	35.0	287.0	87	35.0	287.0	93.0
Rooms	1.0	11.0	3.0	1.0	14.0	3.3
Price (2000-DKK)	190,173.4	8,441,260	1,052,586.0	198,653.2	8,661,346.0	1,165,983.0
Green space (250 m)	0.0	0.7	0.0	0.0	1.0	0.0
Construction year	1620.0	2008.0	1939.7	1577.0	2008.0	1941.2

validity at the expense of external validity, but the remaining sample still includes a variety of homes with different characteristics.

A map of the area under study with the large roads and their 200 m borders is shown in figure 2. The dots in the figure are transactions in the full data set. It is clear, that some residential areas fall completely outside the sample with this approach. In particular, there are fewer single family houses in the reduced data set (26-27 %) than in the full data set (35 %). Table 1 displays a comparison of the most important characteristics of the homes in the reduced and full samples. The homes near large roads are a little smaller, a little cheaper and exposed to a little more noise on average than homes in the full sample. The density of road noise for the transactions in the full and reduced data set can be seen in figure 3. As might be expected, the whole distribution shifts slightly to the right when the sample is limited to homes near a large road. There is a smaller share of observations with road noise at 45 dB or less (only 3.6 percent of the reduced data set as compared to 9 percent of the full data set) and a higher proportion with high noise levels.

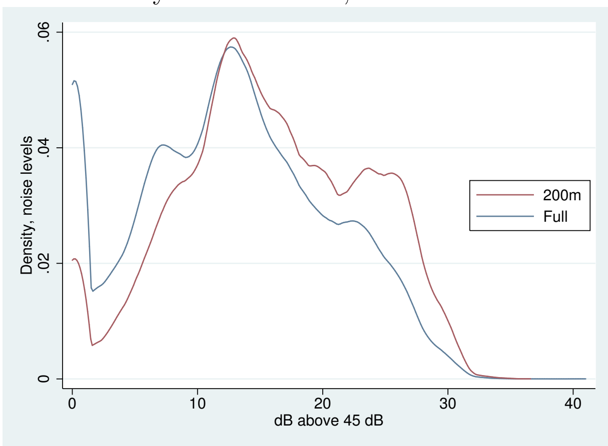
Five types of households were defined for the data depending on the age, composition of the household and the primary occupation of the adult household members. These 5 groups are retirees,

Table 2: Demographic groups

	200 m sample		Full sample	
Retirees	2,659	8.9	6,962	9.7
Families w/ children	7,545	25.2	20,615	28.6
Families, no children	5,819	19.5	14,198	19.7
Singles	8,054	26.9	17,932	24.9
Students	5,845	19.5	12,429	17.2
	29,922	100	72,136	100

Note: Extreme income households excluded, all 3 periods.

Figure 3: Density for road noise, full and reduced samples



families with children, couples without children, singles and students.[11] The large proportion of students in newly transacted properties is in part explained by the parents purchasing housing for their student children. This practice has become quite popular in Denmark due to difficulties in finding rental housing in the university cities and the low interest rates, which characterize the period under study. Most of these students are not the actual owners of the property in which they live which is evidenced by them not paying real estate taxes. Reducing the sample to the transactions within 200 m of a large road slightly changes the composition of the household types. There are fewer retirees and families with children and slightly more singles and students.

Omitted variables

Spatial fixed effects have become standard in the hedonic literature to control for omitted spatially varying covariates, ξ_j, cf. Kuminoff et al. (2010). In this research, spatial fixed effects are employed to account for spatially varying unobservable characteristics at a fine spatial scale. These fixed effects build on the road border research design and capture an area on one side of a stretch of road. An example is shown in figure 4, where the highlighted area is a single road border zone.

Descriptive statistics for the road border zones are given in table 3 including percentiles of the size of each road border zone and the number of observations. The average size of these road border

[11] Retirees are defined as: Average age of adults $>$ 55 years and no children. Families w/ children: Households containing children under the age of 18 years. Students: If at least one adult member of the household is a student and the average age is less than 35 years and no children. Singles consist of one adult household member, who is not a student, not retired and has no children. Families without children are the remaining households.

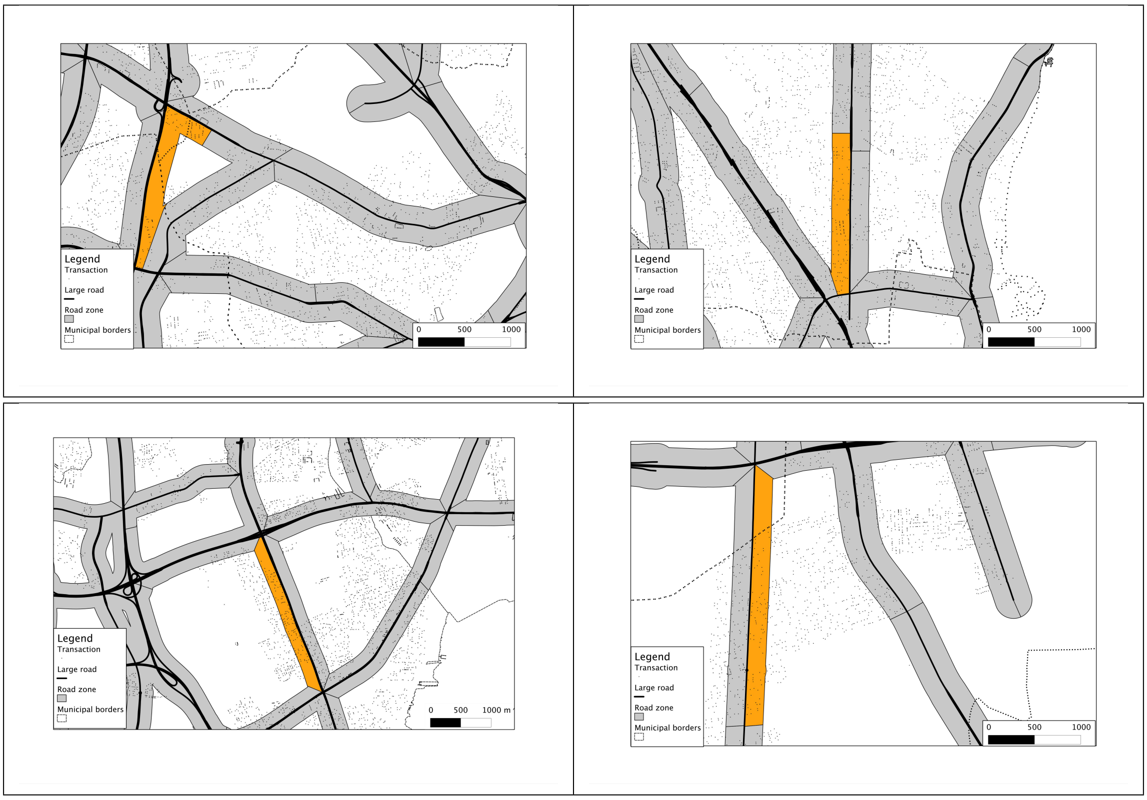


Figure 4: Examples, 200 m road border zone used for fixed effects

zones is 0.54 square kilometers, with the largest zone covering an area of 0.95 square kilometers. They are constructed such that a border zone is limited to one side of the road as large roads can act as barriers in the urban landscape and the character of a neighborhood may vary substantially from one side of the road to the other. There are a total of 215 road border zones in the data, however several of these contain very few observations. Border zones, which contained less than 20 transactions in a period (2-3 years), were discarded. The remaining data set within 200 m of a large road covers a total of 30,309 transactions divided between 160, 127 and 96 road border zones in the three periods.

Despite the small spatial scale of the fixed effect, substantial variation in road noise remains within road zones in a given year as illustrated in the images in figure 5. Road noise varies at a fine spatial scale due to e.g. buildings acting as sound barriers. It is therefore possible to identify effects on house prices of road noise exposure in these small areas despite the use of fixed effects.

Table 3: Descriptive statistics, road zones

Period	2000-2002			2004-2005			2007-2008	
Transactions	15,073			9,889			5,347	
Road border zones	160			127			96	
Border zone stats	p5	p25	p50	p75	p95	mean	min	max
Area (km^2) - 200 m	0.30	0.42	0.52	0.67	0.88	0.54	0.17	0.95
Obs./period - 200 m	27	55	115	228	482	163	20	552

Note: The Xth percentile of the distribution is given as pX.

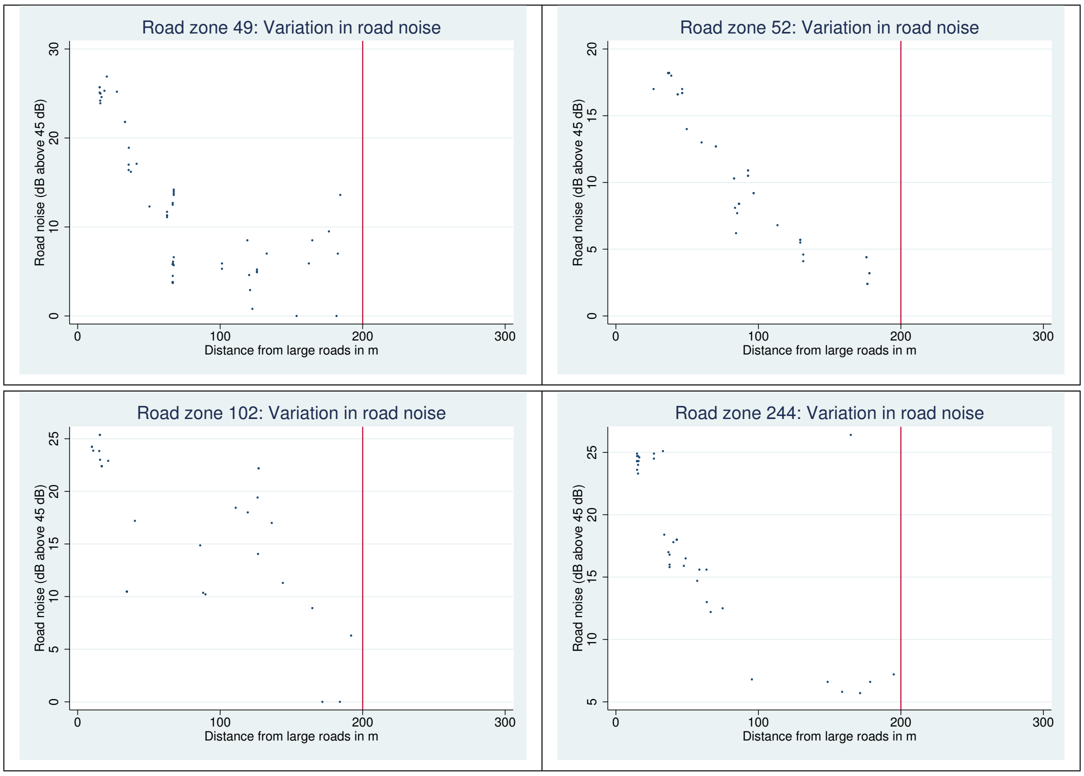


Figure 5: Examples, within road zone road noise variation

Functional form and estimation method

The shape of the hedonic price function is the outcome of sorting on both sides of the market. This makes it difficult to make clear predictions about the appropriate functional form for the different variables, although it is established, that the function is likely to be non-linear (Ekeland et al. (2004). It seems prudent therefore to allow substantial flexibility in the functional form so that the data can aid in determining the appropriate transformations. Bajari and Kahn (2005) estimate a hedonic model using local linear regression, however the estimation of such models is costly in terms of computing time and requires them to sample from their data set rather than use the full set of transactions. Given the size of the current data set and the number of covariates, the generalized additive model seems a suitable alternative.[12]

Flexibility in the functional form used for estimation of the hedonic price function is obtained through the use of thin plate splines for fitting the model to the data for the most important continuous covariates:

$$g(E(P_i)) = X_i\Omega + \sum_{m=1}^{M} f_m(h_{mi})$$

The generalized additive model is a generalization of the generalized linear model and requires the choice of a distribution within the exponential family and link function, $g(\bullet)$. As housing prices cannot be negative and based on the fit of the model to the data, a Gamma distribution was chosen with a logarithmic link function. The terms $f_m(\bullet)$ are smooth functions fit through the use of thin

[12]The `mgcv`-package in R developed by Simon Wood was used for this purpose. For more information about this software and the theory behind GAMs, see Wood (2006).

plate splines to M covariates that do not enter parametrically in X_i. To avoid overfitting, REstricted Maximum Likelihood (REML) is used to select the penalty on the wiggliness of the smooth terms. REML is a modification of traditional ML estimation in which the likelihood criterion is adapted so that the average weighted likelihood is maximized, where the average is taken over the distribution of the parameters of the model. The penalty on wiggliness of the smooth terms enters the likelihood function so "wiggliness" as captured by the higher order derivatives of the fitted function decreases the likelihood, for more details see Wood (2011). In determining the penalty on wiggliness, REML is less likely to result in overfitting than e.g. generalized cross validation. The dimensionality of the basis functions for the smooth components of the model must be set in advance. Here, for living space, the dimensionality is set to 9 basis functions, for the remaining covariates, the basis dimension is set to 5.[13]

The continuous variables fitted with splines include size of the living area (by type of dwelling: single family house or apartment), lot size, share of green space in neighbouring land use, distance to the central business district, and exposure to road noise by type of dwelling. A large number of covariates are included as factor variables: Number of toilets and bathrooms, number of stories in the building, the story for apartments, construction period, type of roof and building materials etc. Finally, distance to the nearest train/metro station, to the nearest industrial site and to the coast line as well as the additional noise measures for railway and airplane noise are included as linear parametric terms in the model. There are fewer homes exposed to railway and airplane noise and the measures are generally of poorer quality than the road noise measure, which makes it difficult to draw strong independent conclusions about their impact on house prices.[14] Municipality fixed effects and road border zone fixed effects are included to account for variations in municipal taxes and public goods as well as to control for potential omitted neighborhood variables. For comparison, models with the full data set using school attendance zone fixed effects are also estimated for each period.

5 First stage results

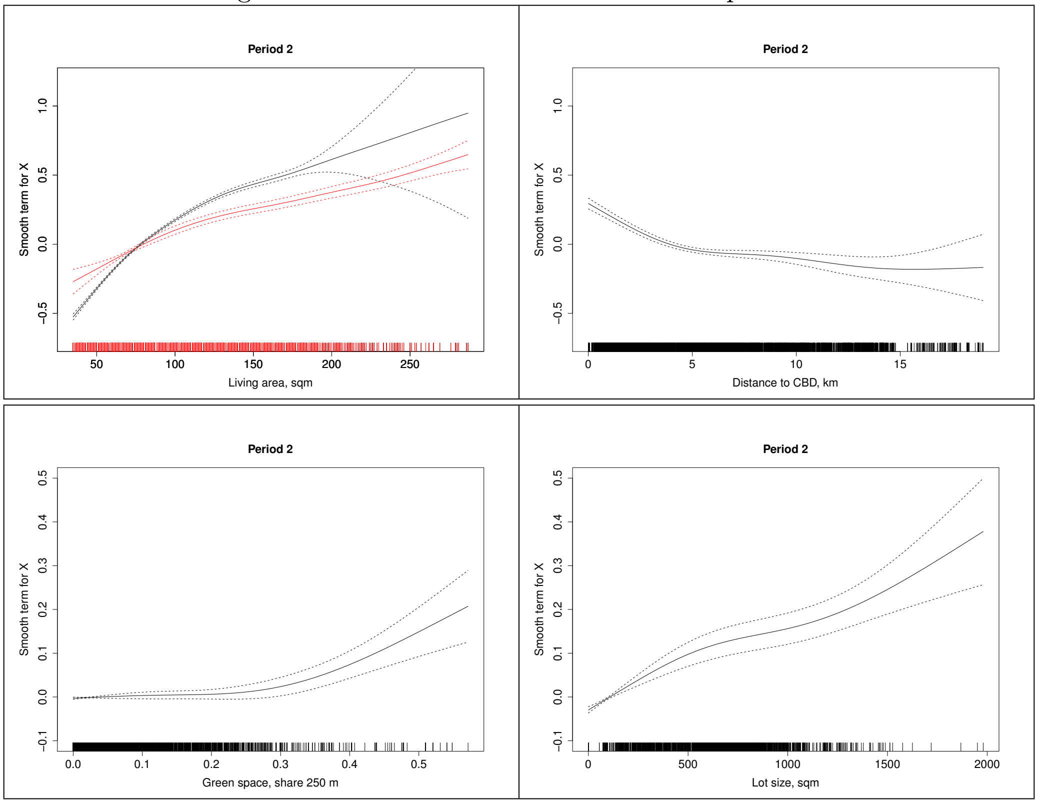
The hedonic price function is estimated separately for each period using the transaction price in 2000-levels.

An initial concern is determination of the level of background noise in the study area. While the measures of road noise are reported from 45 dB upwards, the level of background noise in an urban environment has often been measured at around 55 dB. This is often the threshold used in hedonic analyses (see e.g. Day et al. (2007)), however in many cases 55 dB is also the minimum level for regulatory purposes and therefore the minimum level available in the data for researchers. Here, the background noise level is assumed to be 45 dB. The models are reformulated so the negative of noise enters, i.e. "quiet", a larger number corresponds to less noise and large negative numbers

[13]The residuals of the models were regressed on the covariates with a much higher basis dimensionality to see if there was any remaining pattern to suggest that the basis dimension was too low. This was not the case.

[14]Aggregating the noise measures into a single measure of total traffic related noise was considered following guidelines from the Danish Environmental Protection Agency. These are based on an energy equivalence principle and require that assumptions be made about the dosis response relationship between dB measured and annoyance from each source to transform the dB to a comparable scale. If one source of noise dominates, the addition of further noise sources will not change the total noise level by much. As the relative annoyance from different measures of noise is an empirical question, no attempt was made to calculate an aggregate.

Figure 6: Estimated smooth functions for period 2



Note: The smooth functions are centered and shown on the scale of the linear predictor.

correspond to high levels of noise, e.g. exposure of -25 dB beyond the 45 dB minimum measured corresponds to actual exposure of 70 dB of noise at the outside of the dwelling.

The full estimation contains a total of 24 housing attributes in addition to the fixed effects and commenting on each parameter estimate would take up too much space here. The full estimates can be found in the appendix. In general, the estimates conform to expectations, e.g. additional rooms, living space and lot size are all associated with higher housing prices while proximity to industrial areas is associated with lower housing prices. Some examples of the smooth functions for living space, distance to the center of Copenhagen, green space and lot size estimated for period 2 are shown in figure 6. For living space, the smooth function is differentiated by type of home. The red line captures the function for houses and the black line for apartments. The confidence intervals are the dotted lines and the distribution of the data is indicated at the floor of the graph. The largest apartment has a living area of 195 sqm and as a consequence, the confidence interval gets very wide beyond this level. The same pattern emerges for the other covariates: when the density of observations is low, there is more uncertainty as indicated by the confidence intervals. There is some variation across periods in the estimated coefficients and the shape of the smooth spline-based functions, although the general tendencies remain the same.

The estimates for the road noise measures are displayed in figure 7 for the road border zones and in figure 8 for the full sample. These graphs plot the smooth function on the scale of the linear predictor of the model, where all other covariates are held constant. The slope of the smooth function is the slope of the (log)price function with respect to noise exposure. As is clear from the graphs in figures 7 and 8, the slope varies across the distribution of noise exposure suggesting that the standard semi-log specification of hedonic models with traffic noise implying a constant marginal effect is not appropriate. The only exception is for apartments in period 3, where the smooth function is very close to being linear. For both apartments (black curve) and houses (red curve) in the other periods, the outcome is a smooth function with prices increasing as the neighborhood becomes more quiet and stabilizing some 10 to 15 dB above 45 dB background noise. The distribution of the data is shown at the bottom of the graph. It is clear from the plots that the curve is steeper for houses than for apartments supporting the decision to distinguish between the two types of dwellings in the model.

For high levels of quiet, the slope of the smooth function for apartments and for houses in period 3 becomes negative implying that an increase in noise levels would be associated with an increase in prices. This result is obviously counterintuitive. There is larger uncertainty about the estimate as indicated by the confidence intervals. However, it may be, that at such low levels changes in noise cannot be detected in the denser urban environment where apartments are generally more likely to be found than houses. That is, the changes in noise levels are not perceived by the households.[15] In either case, the data is less informative on the preferences of these households who consumed very large amounts of quiet. Based on revealed preferences however, and the fact that noise exposure is associated with lower prices in general, these 10 percent of households who have located in very quiet locations have revealed that their total willingness to pay for quiet exceeds that of the majority of the households in the market. It would therefore be misleading to interpret the negative sign of the implicit price at such low levels as a distaste for quiet.

There is little change in the distribution of noise levels across the three periods, see figure 9. Similarly, the shapes of the hedonic with respect to noise are quite similar for the first two periods, but seem a little steeper for low noise levels for the third period after the housing market decline. The first derivatives of the hedonic price function with respect to "quiet" were calculated by finite derivatives to recover the linear predictor, which was then multiplied with the inflation adjusted transactions price to recover implicit prices. With a logarithmic link function the linear predictor is the equivalent of the "noise depreciation index" and captures the percentage change in price for a 1 dB change in noise levels. The range is between -0.3 to +1.5 percent of the transactions price for a 1 dB decline in noise with a mean of 0.3 percent. This is within the range reported by Nelson (2008) and similar to findings in Day et al. (2007). The implicit prices are summarized in table 4 for the road border zone data and table 5 for the full data set. The median implicit price is higher in the third period, than in the first two periods, but the third quartile of implicit prices is higher in the second period.

The impact of fixed effects and road border research design

The sample is reduced to mitigate the risk of measurement error affecting the estimates and similarly, the fixed effects are implemented to account for unobservable neighborhood characteristics. The first three rows of table 4 and table 5 show results with fixed effects and the last three rows

[15] In an urban environment, background noise levels vary by neighborhood depending on the density of development and the activities in the neighborhood. While background noise levels are often set at the same level for a whole city, this is not likely to be an accurate decsription of how households perceive their noise exposure, as selection into quieter neighborhoods is likely correlated with overall preferences for quiet. A possible technical solution to this problem would be to impose monotonicity constraints on the smooth function fitted by the splines. Unfortunately, this is not easily done in the mgcv-package due to the large number of covariates (particularly the fixed effects) in the model. Future work will explore this issue further.

Figure 7: Road noise and residuals, 200 m sample

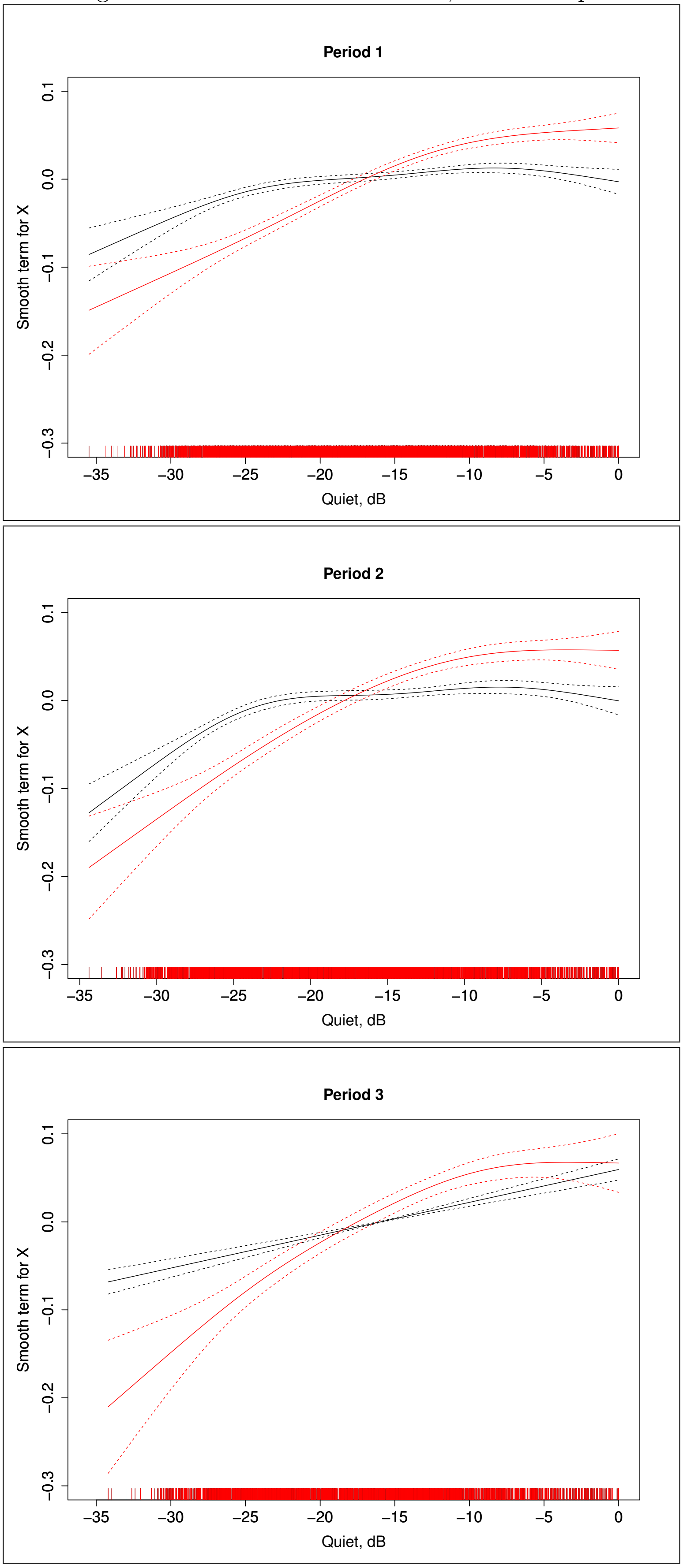


Figure 8: Road noise, full sample

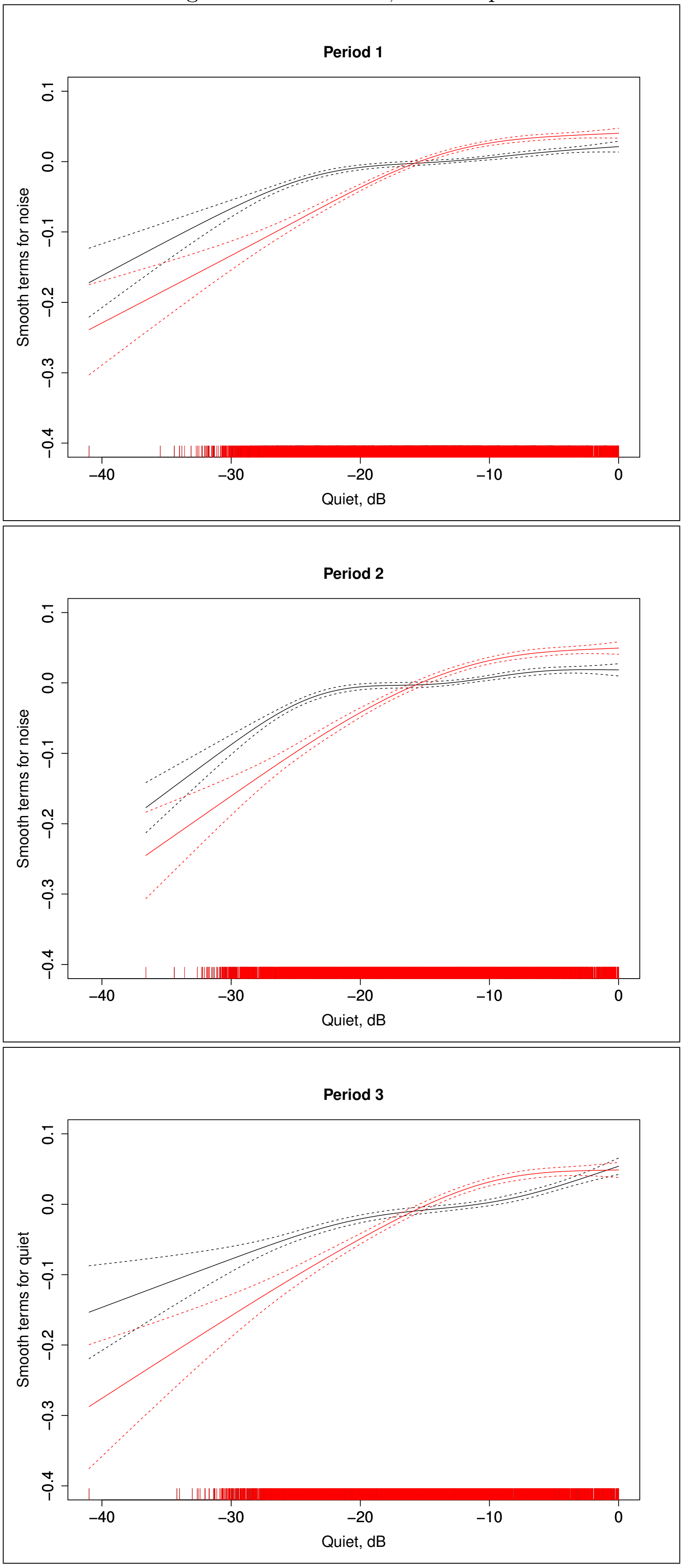


Table 4: Implicit prices in DKK (2000-levels), 200 m road border zones

With F.E.	Min	1st Q	Median	Mean	3rd Q	Max
Period 1	-8,648	849	1,560	3,287	4,520	44,950
Period 2	-9,224	459	1,286	3,795	6,352	54,690
Period 3	-2,076	2,276	2,976	4,702	5,083	52,868
No F.E.	Min	1st Q	Median	Mean	3rd Q	Max
Period 1	-7,804	1,059	2,273	4,429	6,704	52,747
Period 2	-4,837	537	1,909	4,601	7,624	56,098
Period 3	365	2,160	3,874	5,593	7,287	55,969

Abbreviations: F.E. is fixed effect and Q denotes quartile.

Table 5: Implicit prices in DKK (2000-levels), Full sample model

With F.E.	Min	1st Q	Median	Mean	3rd Q	Max
Period 1	270	1,048	1,890	3,869	5,045	48,899
Period 2	-511	950	2,133	4,603	7,044	57,758
Period 3	-947	1,717	3,257	4,886	5,948	55,101
No F.E.	Min	1st Q	Median	Mean	3rd Q	Max
Period 1	369	1,397	2,723	4,510	5,574	57,288
Period 2	172	1,501	2,763	5,180	7,356	59,825
Period 3	467	2,248	4,204	5,768	7,239	59,497

Abbreviations: F.E. is fixed effect and Q denotes quartile.

Note: The implicit prices are calculated for the 200m-sample.

show results without fixed effects for the same model. To facilitate comparison of the models with the full and reduced sample, implicit prices shown in both tables are for the homes in the 200 m sample only. The estimated implicit prices are rather similar across models although they tend to be a little smaller for the 200 m sample. In both cases, the use of fixed effects seems to reduce the implicit prices for changes in noise exposure, although the impact of the fixed effect varies across the distribution of implicit prices. The estimates with fixed effects are hard to compare across models as the full sample uses school attendance zones which are generally larger than the road border zones used for fixed effects in the reduced sample. The road border zones are generally smaller than the school attendance zones and would be expected to capture the same omitted neighborhood characteristics as the school attendance zones and more. Thus there is less likelihood that omitted

Figure 9: Distribution of road noise by period

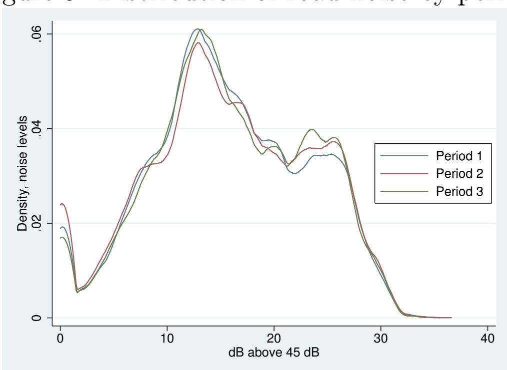


Table 6: Implicit price estimates and preference parameters

Annual price	Min	1st Q	Median	Mean	3rd Q	Max
Quiet per dB	-456	31	77	137	187	1,928
Living area per sqm	38	206	273	288	357	1,352
CBD per km	-293	426	1,079	1,471	2,057	13,586

Note: All prices in DKK (2000-levels).

β_{ki}	Min	1st Q	Median	Mean	3rd Q	Max
Quiet	-15,215	650	1,363	2,339	2,961	35,694
Living space	3,158	14,501	20,821	24,065	29,192	384,563
Proximity to CBD	-950	5,083	16,120	26,020	37,137	284,998

variable bias affects estimated parameters in the reduced sample.

The effectiveness of the sample reduction in dealing with measurement error is hard to assess. The potential measurement error is likely to be larger for homes with low noise levels in 2005/2006 as these homes are generally near less busy streets and therefore at a lower level on the curve depicted on the right in figure 1. However, it is hard to say whether the error will yield an over- or an underestimation of the noise level at the time of sale. While traffic has in general increased by an estimated 10 percent nationally over the whole sample period, the distribution of this additional volume of traffic on smaller roads in the Copenhagen area is not available for this analysis. Moreover the reduction in the sample to focus on homes near large roads is likely to have an additional effect in terms of reducing the overall heterogeneity in the types of homes available in the market. Similarly, the spatial scale of the fixed effects is smaller in the reduced sample, which helps to ensure that the variation in prices with traffic noise exposure is accurately captured. Differences in the estimated implicit prices between the full sample and the reduced sample reflect all of these aspects.

6 Recovering preference parameters

The implicit prices are converted to annual costs using the user cost of housing calculated by the Danish central bank with an average user cost of 3.7 percent over the period (see appendix for more detail). With these annualized measures in hand, the preference parameters can be estimated nonparametrically based on equation 1, repeated here for convenience.

$$\beta_{zi}\frac{1}{(N-z)} = \pi_t\frac{\partial P}{\partial z} \Rightarrow \beta_{zi} = \pi_t\frac{\partial P}{\partial z}\,(N-z)$$

The maximum level of quiet is set to be one unit larger than the maximum observed noise above the threshold of 45 dB in the sample: $N = max(z) + 1 = 36.5\,dB$. As the hedonic model estimated has a very large number of covariates and the main focus of this paper is traffic noise, the following section concentrates on the recovered preference parameters for quiet, living space, distance to the central business district. Table 6 shows the annual implicit prices and preference parameters for quiet, living space and proximity to the center of Copenhagen. There is substantial variation in preference parameters and in all cases, the distribution is highly skewed with a long right tail.

Table 7: Preference parameter correlations

	Quiet	Prox. to CBD	Living area
Quiet	1.00		
Prox. CBD	0.07	1.00	
Living area	0.49	0.49	1.00

Note: All correlations are significantly different from zero.

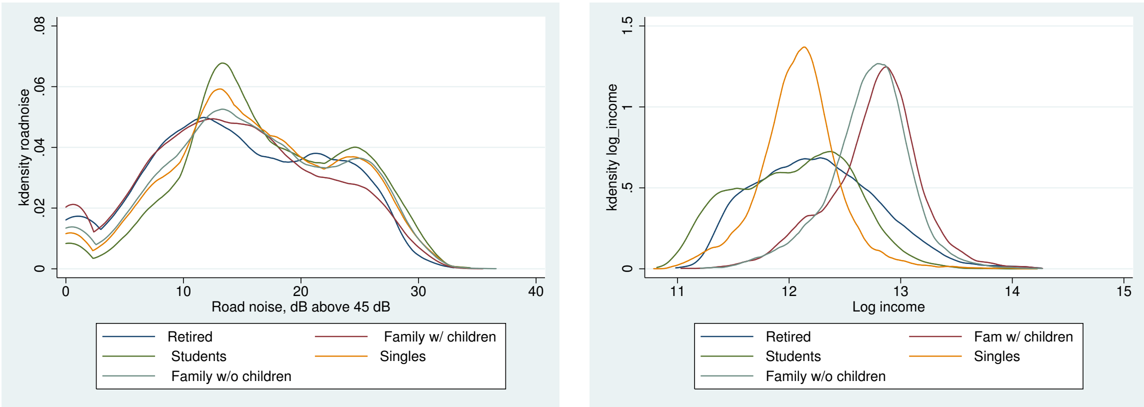


Figure 10: Demographic groups: noise levels and log income, 200 m sample

Correlations

The preference parameters for different housing attributes are correlated as shown in table 7. Preferences for a large living area and for proximity to the central business district are quite highly correlated. Preferences for quiet and size of living area are equally highly correlated, whereas preferences for quiet and for a central housing location are only weakly correlated.

Preference parameters would be expected to vary across demographic groups as these have different needs over the life cycle and because of life style sorting. Overall, couples with children seem to live in quieter areas, along with some retirees, see figure 10. The density of retirees seems bimodal however with substantial probability mass at higher noise levels. Students, singles and couples without children are more likely to live in noisier locations than families with children. There is also substantial variation in income across demographic groups with double-income households earning significantly more than the other types of households. The variation in preferences gives rise to variations in willingness to pay for noise reductions.

Welfare estimates

Based on the preference parameters, willingness to pay for changes in noise exposure from z^0 to z^1 can be calculated as $\beta_{zi}(log(N - z^0) - log(N - z^1))$. The following excludes the observations with negative preference parameters, as these preference parameters are not assumed to be accurate. These households have in a sense located at a corner solution (maximum quiet) and the first order condition used to recover their preference parameters is not necessarily satisfied with equality. To analyze the preferences of these quiet-loving households an assumption would need to be made about the distribution of the unobserved taste parameters. Since one aim of the analysis is to learn more about the unobserved taste parameter, imposing a distributional assumption would defeat

Table 8: Welfare estimates for changes in noise exposure

WTP	Min	1st Q	Median	Mean	3rd Q	Max
62 to 60 dB	0	81	149	265	322	3,488
72 to 70 dB	0	158	291	519	630	6,830
70 to 60 dB	1	518	954	1,699	2,062	22,357
61 to 60 dB	0	39	73	129	157	1,701
$-dP/dz$	0	41	87	154	204	1,928

Note: All values in DKK (2000-levels).

Table 9: Heterogeneity across demographic groups, WTP for 2 dB decrease at 72 dB

WTP	Min	1st Q	Median	Mean	3rd Q	Max
Retired	2	190	370	600	838	5,972
Fam w/ children	0	306	717	912	1,306	6,403
Fam w/o children	2	194	373	599	789	6,830
Students	2	129	221	287	349	5,475
Singles	2	123	204	282	321	4,072

Note: All values in DKK (2000-levels).

the purpose. Instead, focus is on those households, that have not located at the lowest noise levels.

Table 8 shows the distribution of annual willingness to pay for changes in noise exposure at different initial levels of noise together with the implicit price. A change from 61 to 60 dB is a marginal change at the sample mean (60.6 dB) and the WTP is clearly very close to the estimated implicit price. A change of 2 dB (from 62 to 60 dB) is worth a little bit more than twice the value of a 1 dB change. It is also worthwhile to note, that the 2 dB change is valued more when it occurs from a higher initial noise level as in the case of a 72 to 70 dB change. Reducing the noise level by approximately half as in the case of a 10 dB reduction is worth a considerable amount of money. In 2013 American dollars, the median WTP is 220 \$/year. This is comparable to the median WTP of 500 \$/year (2013-prices) found by Bajari & Kahn (2005) for an increase from 4 to 6 rooms (their figure 1, p.28). While these numbers do not seem unreasonabe, it should be kept in mind that the WTP for such large changes also relies on the functional form assumed for household utility.

The heterogeneity in WTP is associated with demographic characteristics as seen in table 9. The median WTP for a 2 dB reduction at 72 dB of road noise is highest for families with children under the age of 18. Families without children and retiree households have very similar WTP somewhat lower than families with children. Students and singles have the lowest WTP. This distribution of welfare estimates is consistent with the noise exposures of the different types of households depicted in figure 10. Those groups with lower WTP have more probability mass at higher noise levels consistent with a sorting equilibrium in which those willing to pay the least for quiet are settled in the least quiet locations.

Preference heterogeneity

To get a deeper understanding of the heterogeneity in preferences, regression analysis has been carried out to decompose the parameter β_{zi} into the demography-dependant components and the unexplained taste for quiet. Table 10 shows the results where the dependant variable is the will-

Table 10: WTP for quiet explained by demographics

WTP (72 to 70 dB)	Estimate	Std. Error	Pr(>|t|)
(Intercept)	-344.12	29.79	0.0000
Age	14.63	1.35	0.0000
Age (sq.)	-0.07	0.01	0.0000
Male	-11.33	8.77	0.1963
Couple	32.49	10.66	0.0023
Work part time	32.29	9.36	0.0006
Foreign born	-49.65	9.11	0.0000
Tenant	44.73	9.57	0.0000
Retired	-69.94	23.49	0.0029
Singles	-29.50	12.45	0.0178
Students	-16.49	12.09	0.1727
Youngest child: - under 2 yrs	224.45	11.57	0.0000
- 3-5 yrs	316.69	15.51	0.0000
- 6-9 yrs	306.42	22.61	0.0000
- 10-14 yrs	217.83	20.92	0.0000
- 15-17 yrs	172.81	29.35	0.0000
Income net of housing exp. (1,000 DKK)	1.63	0.03	0.0000
Education: -Primary school	-43.34	14.07	0.0021
- Vocational training	-35.15	11.13	0.0016
- Bachelors degree	-53.71	16.58	0.0012
- $<$ 5 years higher educ. (H.E.)	-35.08	11.89	0.0032
- $\geq$ 5 years H.E.	-52.19	12.50	0.0000
- PhD	-80.64	16.21	0.0000
Other controls: Household size (pos.sign.)			
N			25,804
R^2			0.32

Omitted: Education: Highschool graduate, Family w/o children.

Note: Observations with a negative WTP are excluded.

ingness to pay for a 2 dB reduction in noise levels. Willingness to pay can be seen to increase with age at a declining rate. Couples have a higher willingness to pay than singles, working part time and being a tenant is also associated with higher willingness to pay. As for the demographic groups, families with children have a higher willingness to pay, whereas singles and retirees have a significantly lower willingness to pay than a double-income household without children. The highest level of education achieved within the household also affects willingness to pay for quiet. Highschool graduates have a higher WTP than all other groups, with PhDs having the lowest WTP all else equal. Household income net of housing expenditure is also associated with a higher WTP for quiet. In total however, the observable characteristics of the household explain no more than 32 percent of the variation in WTP for a noise reduction.

Based on these results, a large part of preference heterogeneity is due to unobservable taste. The distribution of the residuals from the decomposition of the preference parameter is shown in figure 11 together with a normal distribution. The distribution of unobserved taste seems to be less symmetric than a noise distribution and again has long tails. Often economists model unobserved heterogeneity using a normal distribution, e.g. in several random parameter models or in probit selection models. This assumption would not seem to be justified in the case of taste for quiet

Figure 11: Unobservable taste heterogeneity

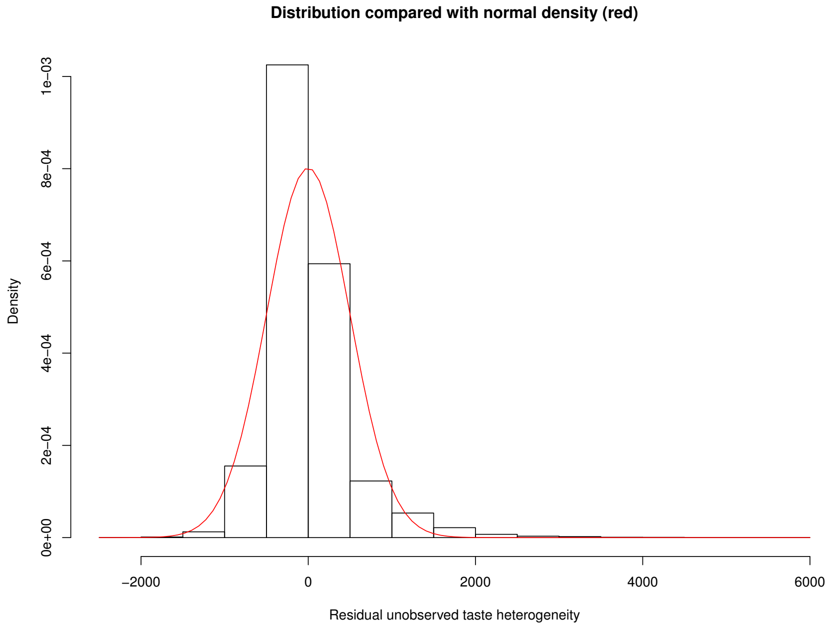


Table 11: Predicting WTP from demographic characteristics

	p5	p10	p25	p50	p75	p90	p95
Error in predicted WTP in % of WTP	-67.2	-56.3	-29.4	22.8	131.8	351.2	707.5

with the caveat that the estimates of unobserved taste heterogeneity are conditional on the simple utility structure in the model.

The fact that so little of the willingness to pay is explained by observable characteristics suggests, that one might worry about using the model to predict WTP for quiet outside the area under study. The relative error in WTP gives some idea of how wrong an estimate of WTP based solely on demographics and the estimated relationship here would be. The median relative deviation from actual WTP is an overestimation of WTP by 22.8 %. The model performs especially poorly in capturing the WTP of those households with relatively low WTP and would predict a WTP more than twice as large as the "actual" WTP in 30 % of the cases.

7 Concluding discussion

The analysis recovers robust estimates of the negative effect of traffic noise on housing prices. The detailed quality of the road noise measures and the road border research design reduce the potential impact of omitted variables bias and measurement error allowing the use of a single mapping of road noise to be used for 9 years of transactions. The road border research design slightly lowers willingness to pay estimates compared to the full sample with school district fixed effects. The identified effect of noise on property values is larger for single family and terraced houses than for apartments and there is some evidence to suggest, that urban background noise levels are higher in areas where apartments are the more prevalent housing type. The findings in terms of percentage change in house prices for a 1 dB increase in noise levels are comparable to findings in previous studies, though there is considerable variation across levels of noise due to the non-linear nature of the hedonic price function.

There is large variation across the population in the marginal willingness to pay recovered from the first stage of the hedonic model. With the assumption of a simple utility function, preference parameters are calculated from the estimates to shed light on the willingness to pay for non-marginal changes, and to explore the heterogeneity in preferences further. The preference parameters for living area, proximity to the center of Copenhagen and for quiet are all correlated with each other. The correlation of preference parameters for different housing attributes hints at the difficulty of finding valid instruments for use in a second stage estimation, since it is hard to think of any variable subject to household choice of housing, which would reasonably be uncorrelated with the household's unobserved taste for housing attributes.

Willingness to pay for noise reductions is found to be increasing for higher levels of noise, so the same reduction is worth about twice as much when it occurs from an initial noise level that is twice as high. For large changes such as reducing the level of noise by 10 dB, the median willingness to pay is found to be about half the size of the median willingness to pay estimates found in Bajari and Kahn (2005) for an increase in the number of rooms from 4 to 6. It should be emphasized that welfare estimates for large changes will rely substantially on the functional form assumption, whereas smaller changes near the households' observed equilibrium choices are less sensitive to these assumptions. Observable demographic characteristics explain some 32 percent of the variation in willingness to pay for a noise reduction. Some of the more important factors are income and household type, in particular, the presence of children is a significant factor in increasing willingness to pay. A large part of WTP heterogeneity is left unexplained, which may be a problem for use of these estimates in benefit transfer. While it is possible to adjust for observable differences between areas in terms of e.g. household composition, selection into different areas based on unobserved taste cannot be controlled for in such a setting.

The current paper adds to the existing literature by introducing a new way to use single year noise mappings in combination with multiple year transactions data. Additionally, by introducing the Bajari and Kahn (2005) -approach into the literature on the welfare effects of traffic noise, the analysis sheds new light on the relationship between household demographics and preferences for quiet. Much work remains to be done however. The preference parameters indicate that preferences for quiet are correlated with preferences for other housing attributes and a more specific modeling of the sorting behaviour of households in a discrete choice model or an equilibrium sorting model would be an interesting extension.

As in all revealed preference analyses, only the perceived benefits associated with the use of the home are captured in the willingness to pay measures here. As such these estimates are subject to asymmetric information (see Pope (2008) for an analysis of airport noise and information revelation), although road noise is likely to be more easily discovered by households than other more intermittent sources of noise. Additionally, costs associated with noise exposure at the work place or in schools and public parks is not captured here and would require a study of e.g. commercial properties and their traffic noise exposure. Finally, if households are unaware of the health risks associated with traffic noise, their actual willingness to pay may be higher than this study suggests.

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A Appendix

A.1 Changing housing market 2000-2008 and the user cost of housing

The Danish housing market was characterized by sharply rising prices peaking around 2006 at which point the market slowed down significantly (see fig. 12). These developments mirror events in other countries in the same period, and have similar causes. In the early 2000s a number of policy changes affected both the taxation of real estate and the financial instruments available for financing real estate purchases. For the last two hundred years, almost all property in Denmark has been financed through mortgage loans issued by mortgage credit institutions. Previously, mortgage lending was heavily regulated which made it difficult for credit institutions to create new financial products. However, following liberalizations in the late 1990s, mortgage credit institutions and banks were quick to launch new types of financing with variable interest rates and flexible payment schemes. Prior to 2000 almost all Danish mortgage loans were fixed-rate annuity loans. Since early 2000 the proportion of households using variable-rate financing has increased while interest rates were falling. In October 2003, the "payment free loan" was introduced as a 30 year loan with fixed or variable interest rate, but with a 10 year period of no payment on the principal. These loans quickly became very popular and constituted 19 percent (2004), 31 percent (2005) and 39 percent (2006) of the value of all loans. In addition to the introduction of these new instruments, the tax on real estate was fixed in nominal terms in 2001. Coupling these developments with high economic growth the outcome was a housing market bubble which burst in 2007 followed by declining prices and increasing times to sale, Dam et al. (2011). The number of sales in the period varies by year reflecting the drying up of the market in the later years (see fig. 13).

The changes in real estate financing and taxation directly impact the annual user cost of housing. The Danish Central Bank calculates the user cost of housing following the formula:

$$uc_t = (1 - d_\tau)r_t - E_t\left(\frac{dp}{dt}\right) + \tau_{h,t} + \delta$$

Here d_τ is a tax discount on interest payments, r_t is the weighted average interest rate: $r_t = (1 - v_t)r_{long,t} + \alpha_t r_{short,t}$, where v_t is the share of variable rate loans at time t and r_x is the long term and short term bond interest rate. The term $\frac{dp}{dt}^e$ captures the expected change in the house price, it is based on an Hodrick-Prescott-filtered time series of house prices. τ_h is the property tax and δ is depreciation (set to 0.01). The user cost generally fell from 2000 until 2006 before rising slightly as seen in figure 13. The main reason for the changes in the user cost of housing can be found in changing interest rates and the increasing proportion of households with variable rate loans. A series of estimations was carried out to test for changes in the hedonic price function over time. The hypothesis of identical coefficients across periods was rejected.

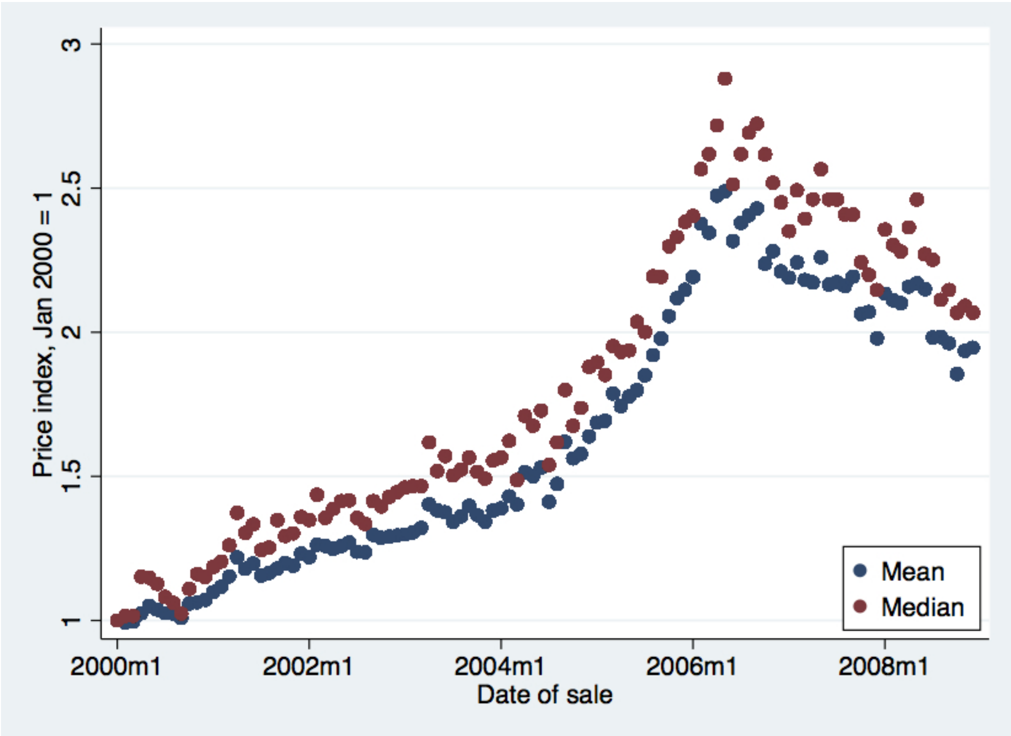

Figure 12: House price evolution, 2000-2008

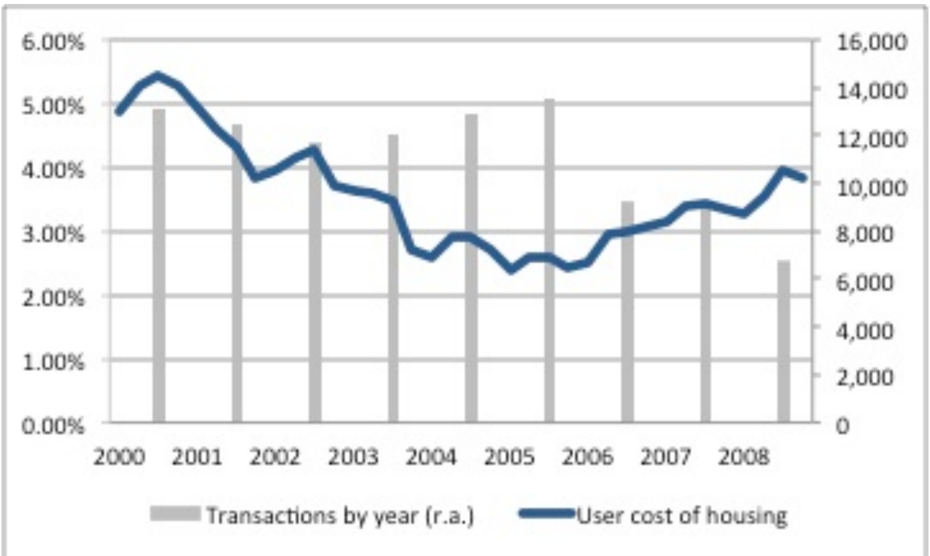

Figure 13: User cost of housing, Danish Central Bank

A.2 List of variables and descriptive statistics

Continuous variables:

- Table 12
- Table 13

Categorical variables:

- Table 14
- Table 15

Table 12: Continuous variables: 200 m sample descriptive statistics

200 m sample	Min	1st Q	Median	Mean	3rd Q	Max
Price_2000	190,173.40	716,579.95	1,033,629.00	1,163,916.58	1,432,496.00	8,441,260.00
Living space (sqm)	35.00	60.00	83.00	92.43	116.00	287.00
Road quiet (- 45 dB=0)	-41.00	-18.12	-12.70	-12.72	-7.06	0.00
Central Business District (Km)	0.00	2.63	4.99	6.12	8.72	20.92
Lot size (sqm)	0.00	0.00	0.00	207.13	399.00	1980.00
Green space within 250 m	0.00	0.00	0.00	0.05	0.06	0.88
Coast line (meters)	0.00	0.00	0.00	14.74	0.00	499.77
Station (meters)	0.00	0.00	0.00	105.92	229.65	499.96
Industry_500 (meters)	0.00	0.00	0.00	7.29	0.00	499.78
Train noise	0.00	0.00	0.00	0.14	0.00	20.14
Air noise	0.00	0.00	0.00	0.19	0.00	25.60

Table 13: Continuous variables: Full sample descriptive statistics

Full sample	Min	1st Q	Median	Mean	3rd Q	Max
Price_2000	190,173.40	716,579.95	1,033,629.00	1,163,916.58	1,432,496.00	8,441,260.00
Living space (sqm)	35.00	60.00	83.00	92.43	116.00	287.00
Road quiet (- 45 dB=0)	-41.00	-18.12	-12.70	-12.72	-7.06	0.00
Central Business District (Km)	0.00	2.63	4.99	6.12	8.72	20.92
Lot size (sqm)	0.00	0.00	0.00	207.13	399.00	1980.00
Green space within 250 m	0.00	0.00	0.00	0.05	0.06	0.88
Coast line (meters)	0.00	0.00	0.00	14.74	0.00	499.77
Station (meters)	0.00	0.00	0.00	105.92	229.65	499.96
Industry_500 (meters)	0.00	0.00	0.00	7.29	0.00	499.78
Train noise	0.00	0.00	0.00	0.14	0.00	20.14
Air noise	0.00	0.00	0.00	0.19	0.00	25.60

Table 14: Categorical variables - table I

Housing type	200 m sample	Full sample
Single family house	5182	19174
Terraced house	2215	8036
Apartment	22912	51561
Bathrooms	200 m sample	Full sample
0	505	1136
1	27846	70170
2	1886	7145
3 or more	72	320
Toilets	200 m sample	Full sample
0	54	84
1	25524	61514
2	4235	15501
3 or more	496	1672
Elevator	200 m sample	Full sample
0	26701	70468
1	3608	8303
Rooms	200 m sample	Full sample
1 room	2219	4785
2 rooms	11378	24554
3 rooms	6905	17837
4 rooms	5400	16512
5 rooms	2591	8635
6 or more rooms	1816	6448
Story	200 m sample	Full sample
-	7551	27524
Ground floor	4688	10882
1	5484	12318
2	5323	11805
3	3344	7802
4	2401	5645
5	958	1999
6	182	337
7 or more	378	459
Wall 3 (brick)	200 m sample	Full sample
0	4032	9835
1	26277	68936
Wall 2(concrete)		
0	26813	70857
1	3496	7914
Listed	200 m sample	Full sample
0	29738	76944
1	571	1827

Table 15: Categorical variables - table II

Stories_tot	200 m sample	Full sample
1	6455	23862
2	2498	7602
3	6669	12581
4	2558	6819
5	8219	20538
6	2669	5076
7	363	944
8	208	392
10	56	184
11	203	317
13	0	22
14	20	43
15	146	146
16	245	245
Roof	**200 m sample**	**Full sample**
Other	939	3110
Built up (flat roof)	2970	7567
Cement	1248	3589
Fibercement, asbestus	8758	22894
Tar paper	4720	10573
Glazed	11674	31038
Constr_year	**200 m sample**	**Full sample**
1900-1920	3946	10464
1920-1940	10066	22836
1940-1960	4569	13870
1960-1980	7383	19081
1980-2000	1008	2962
After 2000	405	2200
Before 1900	2932	7358
Renovations	**200 m sample**	**Full sample**
5-10 years before	491	1359
none	28922	74276
After sale	423	1646
Less than 5 years before	473	1490
Train noise F	**200 m sample**	**Full sample**
55-59 dB	741	2057
60-64 dB	183	476
65-69 dB	6	38
under 55 dB	29379	76200

A.3 Estimation results

200 meter sample with fixed effects

```
##########################################################################################

##Period 1

Family: Gamma
Link function: log

Formula:
Price_2000 ~ s(livingspace, by = factor(house)) + s(road_quiet, by = factor(house),
    k = 5) + s(CBD, k = 5) + s(lotsize, k = 4) + rooms.f + s(greensp250,
    k = 4) + +coastline + station + indu_500 + housingtype + +train_noise +
    air_noise + train_noise_F + +factor(toilets) + factor(bath) +
    wall_2 + wall_3 + roof + renov + constr_year + elevator +
    listed + factor(story) + stories_tot + +factor(roadid) + factor(municipality)

Parametric coefficients:
                              Estimate Std. Error t value Pr(>|t|)
(Intercept)                  1.349e+01  5.361e-02 251.681  < 2e-16 ***
rooms.f2 rooms               1.437e-01  6.436e-03  22.328  < 2e-16 ***
rooms.f3 rooms               1.992e-01  8.280e-03  24.062  < 2e-16 ***
rooms.f4 rooms               2.172e-01  9.453e-03  22.980  < 2e-16 ***
rooms.f5 rooms               2.237e-01  1.052e-02  21.254  < 2e-16 ***
rooms.f6 or more rooms       2.322e-01  1.178e-02  19.709  < 2e-16 ***
coastline                    3.027e-05  3.151e-05   0.961 0.336647
station                     -3.923e-05  9.605e-06  -4.084 4.44e-05 ***
indu_500                    -1.800e-05  3.747e-05  -0.480 0.630919
housingtype_terr            -1.267e-02  9.255e-03  -1.369 0.171046
housingtype_apt             -1.874e-01  2.370e-02  -7.908 2.81e-15 ***
train_noise                 -4.364e-03  1.359e-03  -3.211 0.001325 **
air_noise                   -4.284e-03  1.840e-03  -2.328 0.019913 *
train_noise_F60-64 dB       -5.719e-03  1.770e-02  -0.323 0.746644
train_noise_F65-69 dB       -8.979e-03  8.206e-02  -0.109 0.912865
train_noise_Funder 55 dB     2.398e-02  9.395e-03   2.552 0.010715 *
factor(toilets)1             1.651e-01  2.599e-02   6.352 2.18e-10 ***
factor(toilets)2             2.020e-01  2.650e-02   7.623 2.62e-14 ***
factor(toilets)3             2.381e-01  2.859e-02   8.328  < 2e-16 ***
factor(bath)1                4.326e-02  9.034e-03   4.789 1.70e-06 ***
factor(bath)2                3.679e-02  1.073e-02   3.428 0.000609 ***
factor(bath)3                3.846e-02  2.634e-02   1.460 0.144376
wall_2                       2.901e-02  1.044e-02   2.780 0.005449 **
wall_3                       8.079e-02  9.121e-03   8.858  < 2e-16 ***
roofBuilt up (flat roof)    -2.165e-02  9.333e-03  -2.319 0.020390 *
roofCement                  -5.961e-03  1.020e-02  -0.585 0.558840
roofFibercement asbestus    -1.562e-02  7.833e-03  -1.994 0.046218 *
roofTar paper               -9.010e-04  8.297e-03  -0.109 0.913530
```

roofGlazed	1.805e-03	7.922e-03	0.228	0.819729	
renov_none	3.999e-02	1.192e-02	3.354	0.000799	***
renov_after sale	-3.982e-02	1.416e-02	-2.812	0.004937	**
renov_last 5 yr	4.165e-02	1.481e-02	2.813	0.004918	**
constr_year1920-1940	-7.195e-03	5.309e-03	-1.355	0.175376	
constr_year1940-1960	-6.204e-03	6.288e-03	-0.987	0.323809	
constr_year1960-1980	-8.345e-03	6.637e-03	-1.257	0.208658	
constr_year1980-2000	1.083e-01	9.258e-03	11.695	< 2e-16	***
constr_year_after 2000	2.139e-01	1.692e-02	12.643	< 2e-16	***
constr_year_bef 1900	-1.101e-02	6.072e-03	-1.813	0.069897	.
elevator	-9.617e-03	6.240e-03	-1.541	0.123301	
listed	5.570e-02	1.115e-02	4.994	5.99e-07	***
factor(story)1	-5.982e-02	1.760e-02	-3.398	0.000681	***
factor(story)2	-4.239e-02	1.761e-02	-2.407	0.016089	*
factor(story)3	-3.400e-02	1.765e-02	-1.926	0.054155	.
factor(story)4	-2.704e-02	1.790e-02	-1.511	0.130815	
factor(story)5	-2.159e-02	1.806e-02	-1.195	0.231956	
factor(story)6	-1.519e-02	1.894e-02	-0.802	0.422535	
factor(story)7	3.226e-02	2.388e-02	1.351	0.176695	
factor(story)8	1.868e-02	2.434e-02	0.768	0.442795	
stories_tot2	2.412e-02	7.693e-03	3.136	0.001716	**
stories_tot3	-1.357e-02	9.623e-03	-1.410	0.158445	
stories_tot4	-2.002e-02	1.091e-02	-1.835	0.066534	.
stories_tot5	-4.220e-02	1.103e-02	-3.826	0.000131	***
stories_tot6	-3.954e-02	1.195e-02	-3.308	0.000941	***
stories_tot7	-5.117e-02	1.910e-02	-2.679	0.007384	**
stories_tot8	3.293e-03	2.057e-02	0.160	0.872812	
stories_tot10	-1.245e-01	4.232e-02	-2.942	0.003267	**
stories_tot11	-7.265e-02	2.378e-02	-3.056	0.002249	**
stories_tot14	-6.188e-02	5.358e-02	-1.155	0.248118	
stories_tot15	-9.617e-02	2.913e-02	-3.301	0.000965	***
stories_tot16	4.220e-02	3.846e-02	1.097	0.272486	
factor(municipality)147	8.716e-02	8.590e-03	10.147	< 2e-16	***
factor(municipality)151	-1.619e-01	4.393e-02	-3.684	0.000230	***
factor(municipality)153	-1.547e-01	8.215e-02	-1.883	0.059737	.
factor(municipality)157	2.544e-02	2.014e-02	1.263	0.206611	
factor(municipality)159	1.657e-02	3.625e-02	0.457	0.647543	
factor(municipality)161	-3.706e-02	7.465e-02	-0.496	0.619579	
factor(municipality)163	-1.176e-01	2.897e-02	-4.059	4.96e-05	***
factor(municipality)165	-1.100e-01	8.614e-02	-1.278	0.201415	
factor(municipality)167	-8.640e-02	2.212e-02	-3.905	9.45e-05	***
factor(municipality)169	-2.739e-02	6.522e-02	-0.420	0.674450	
factor(municipality)173	9.480e-04	4.132e-02	0.023	0.981697	
factor(municipality)175	-5.657e-02	1.535e-02	-3.685	0.000229	***
factor(municipality)185	1.893e-02	1.725e-02	1.097	0.272599	
factor(municipality)187	-7.999e-02	8.395e-02	-0.953	0.340696	
Road border fixed effects		YES			

```
Signif. codes:  0 *** 0.001 ** 0.01 * 0.05 . 0.1   1

Approximate significance of smooth terms:
                                 edf Ref.df       F  p-value
s(livingspace):factor(house)0  5.078  5.604 1227.30  < 2e-16 ***
s(livingspace):factor(house)1  4.759  5.741  215.98  < 2e-16 ***
s(road_quiet):factor(house)0   3.525  3.873   20.25 3.36e-16 ***
s(road_quiet):factor(house)1   3.010  3.498   81.41  < 2e-16 ***
s(CBD)                         3.739  3.957   75.06  < 2e-16 ***
s(lotsize)                     1.530  1.880   38.64  < 2e-16 ***
s(greensp250)                  2.761  2.956    8.38 1.65e-05 ***
---
Signif. codes:  0 *** 0.001 ** 0.01 * 0.05 . 0.1   1

R-sq.(adj) =  0.897   Deviance explained = 91.7%
REML score = 1.9944e+05  Scale est. = 0.019301   n = 15073

##########################################################################################

##Period 2

Family: Gamma
Link function: log

Formula:
ksum_2000 ~ s(livingspace, by = factor(house)) + s(road_quiet, by = factor(house),
    k = 5) + s(CBD, k = 5) + s(lotsize, k = 4) + rooms.f + s(greensp250,
    k = 4) + +coastline + station + indu_500 + housingtype + +train_noise +
    air_noise + train_noise_F + +factor(toilets) + factor(bath) +
    wall_2 + wall_3 + roof + renov + constr_year + elevator +
    listed + factor(story) + stories_tot + +factor(roadid) + factor(municipality)

Parametric coefficients:
                                Estimate Std. Error t value Pr(>|t|)
(Intercept)                    1.360e+01  7.474e-02 181.995  < 2e-16 ***
rooms.f2 rooms                 1.121e-01  8.001e-03  14.007  < 2e-16 ***
rooms.f3 rooms                 1.610e-01  1.000e-02  16.096  < 2e-16 ***
rooms.f4 rooms                 1.734e-01  1.145e-02  15.153  < 2e-16 ***
rooms.f5 rooms                 1.869e-01  1.305e-02  14.322  < 2e-16 ***
rooms.f6 or more rooms         2.047e-01  1.491e-02  13.728  < 2e-16 ***
coastline                      6.737e-05  3.583e-05   1.880 0.060095 .
station                       -3.158e-05  1.207e-05  -2.615 0.008926 **
indu_500                      -9.869e-05  5.183e-05  -1.904 0.056947 .
housingtype_terr               2.882e-02  1.326e-02   2.174 0.029740 *
housingtype_apt               -1.331e-01  3.025e-02  -4.399 1.10e-05 ***
train_noise                   -5.640e-03  1.678e-03  -3.361 0.000779 ***
air_noise                     -4.967e-04  2.423e-03  -0.205 0.837592
train_noise_F60-64 dB         -2.048e-02  2.190e-02  -0.935 0.349631
train_noise_F65-69 dB         -2.732e-02  1.441e-01  -0.190 0.849592
```

train_noise_Funder 55 dB	3.258e−03	1.177e−02	0.277	0.782030	
factor(toilets)1	8.526e−02	3.907e−02	2.182	0.029124	*
factor(toilets)2	1.080e−01	3.965e−02	2.724	0.006454	**
factor(toilets)3	1.685e−01	4.183e−02	4.029	5.65e−05	***
factor(bath)1	4.018e−02	1.264e−02	3.180	0.001480	**
factor(bath)2	4.181e−02	1.489e−02	2.809	0.004978	**
factor(bath)3	5.827e−02	3.684e−02	1.582	0.113750	
wall_2	−1.948e−02	1.346e−02	−1.447	0.147820	
wall_3	1.480e−02	1.162e−02	1.274	0.202699	
roofBuilt up (flat roof)	6.494e−03	1.097e−02	0.592	0.553964	
roofCement	2.438e−02	1.240e−02	1.966	0.049379	*
roofFibercement, asbestus	−1.624e−03	9.007e−03	−0.180	0.856927	
roofTar paper	−1.484e−03	9.584e−03	−0.155	0.876930	
roofGlazed	1.675e−02	9.041e−03	1.853	0.063924	.
renov_none	6.795e−03	1.046e−02	0.649	0.516128	
renov_after sale	−1.046e−01	1.950e−02	−5.363	8.38e−08	***
renov_last 5 yr	4.338e−02	1.592e−02	2.725	0.006433	**
constr_year1920−1940	−1.455e−02	6.683e−03	−2.178	0.029455	*
constr_year1940−1960	−3.008e−02	7.963e−03	−3.777	0.000160	***
constr_year1960−1980	−4.484e−02	8.384e−03	−5.348	9.10e−08	***
constr_year1980−2000	2.610e−02	1.195e−02	2.183	0.029030	*
constr_year_after 2000	1.358e−01	1.607e−02	8.450	< 2e−16	***
constr_year_bef 1900	−6.455e−03	7.523e−03	−0.858	0.390884	
elevator	−2.902e−02	7.652e−03	−3.793	0.000150	***
listed	7.385e−02	1.277e−02	5.782	7.62e−09	***
factor(story)1	−7.120e−02	2.007e−02	−3.547	0.000392	***
factor(story)2	−4.849e−02	2.012e−02	−2.410	0.015960	*
factor(story)3	−4.056e−02	2.017e−02	−2.011	0.044386	*
factor(story)4	−3.518e−02	2.051e−02	−1.716	0.086261	.
factor(story)5	−2.445e−02	2.074e−02	−1.179	0.238310	
factor(story)6	−7.380e−03	2.171e−02	−0.340	0.733955	
factor(story)7	−1.365e−02	2.809e−02	−0.486	0.627114	
factor(story)8	1.745e−02	2.825e−02	0.618	0.536831	
stories_tot2	2.477e−02	1.033e−02	2.397	0.016531	*
stories_tot3	−1.378e−03	1.233e−02	−0.112	0.911056	
stories_tot4	−2.103e−03	1.383e−02	−0.152	0.879196	
stories_tot5	−2.919e−02	1.397e−02	−2.090	0.036636	*
stories_tot6	−3.915e−02	1.519e−02	−2.578	0.009944	**
stories_tot7	−3.513e−02	2.310e−02	−1.521	0.128379	
stories_tot8	−2.002e−02	2.376e−02	−0.842	0.399683	
stories_tot10	1.351e−02	4.866e−02	0.278	0.781268	
stories_tot11	−6.739e−02	2.656e−02	−2.537	0.011181	*
stories_tot14	−1.528e−01	5.514e−02	−2.771	0.005592	**
stories_tot15	−5.623e−02	3.924e−02	−1.433	0.151908	
stories_tot16	3.447e−02	4.634e−02	0.744	0.457034	
factor(municipality)147	6.767e−02	1.035e−02	6.538	6.54e−11	***
factor(municipality)151	−3.355e−02	7.443e−02	−0.451	0.652233	
factor(municipality)153	−1.272e−01	1.033e−01	−1.232	0.217944	
factor(municipality)157	7.663e−02	2.677e−02	2.863	0.004208	**

```
factor(municipality)159          1.298e-01  4.401e-02   2.950 0.003183 **
factor(municipality)161         -3.658e-02  8.963e-02  -0.408 0.683244
factor(municipality)163          9.941e-04  3.941e-02   0.025 0.979877
factor(municipality)165         -4.224e-02  1.162e-01  -0.363 0.716301
factor(municipality)167         -8.372e-02  2.929e-02  -2.859 0.004264 **
factor(municipality)173          1.222e-01  4.903e-02   2.492 0.012726 *
factor(municipality)175         -8.367e-02  1.751e-02  -4.778 1.80e-06 ***
factor(municipality)185         -5.186e-02  2.120e-02  -2.446 0.014453 *
factor(municipality)187         -7.605e-02  1.071e-01  -0.710 0.477517

Road border fixed effects                    YES
---
Signif. codes:  0 *** 0.001 ** 0.01 * 0.05 . 0.1   1

Approximate significance of smooth terms:
                                 edf  Ref.df  F    p-value
s(livingspace):factor(house)0    5.182  5.734 789.52  < 2e-16 ***
s(livingspace):factor(house)1    4.650  5.651  97.59  < 2e-16 ***
s(road_quiet):factor(house)0     3.712  3.951  27.61  < 2e-16 ***
s(road_quiet):factor(house)1     2.982  3.472  59.09  < 2e-16 ***
s(CBD)                           3.659  3.927  73.31  < 2e-16 ***
s(lotsize)                       2.730  2.951  30.41  < 2e-16 ***
s(greensp250)                    2.725  2.943  10.37 1.01e-06 ***
---
Signif. codes:  0 *** 0.001 ** 0.01 * 0.05 . 0.1   1

R-sq.(adj) =   0.89   Deviance explained = 90.7%
REML score = 1.3128e+05  Scale est. = 0.020278   n = 9889
##########################################################################################

##Period 3
Family: Gamma
Link function: log

Formula:
ksum_2000 ~ s(livingspace, by = factor(house)) + s(road_quiet, by = factor(house),
    k = 5) + s(CBD, k = 5) + s(lotsize, k = 4) + rooms.f + s(greensp250,
    k = 4) + +coastline + station + indu_500 + housingtype + +train_noise +
    air_noise + train_noise_F + +factor(toilets) + factor(bath) +
    wall_2 + wall_3 + roof + renov + constr_year + elevator +
    listed + factor(story) + stories_tot + +factor(roadid) + factor(municipality)

Parametric coefficients:
                                  Estimate Std. Error t value Pr(>|t|)
(Intercept)                      1.372e+01  7.081e-02 193.749  < 2e-16 ***
rooms.f2 rooms                   1.045e-01  1.169e-02   8.941  < 2e-16 ***
rooms.f3 rooms                   1.638e-01  1.444e-02  11.343  < 2e-16 ***
rooms.f4 rooms                   1.769e-01  1.650e-02  10.718  < 2e-16 ***
rooms.f5 rooms                   1.833e-01  1.888e-02   9.712  < 2e-16 ***
```

rooms.f6 or more rooms	2.168e-01	2.176e-02	9.966	< 2e-16	***
coastline	2.033e-05	5.137e-05	0.396	0.692286	
station	-5.328e-05	1.671e-05	-3.189	0.001439	**
indu_500	-7.113e-05	8.132e-05	-0.875	0.381797	
housingtype_terr	-3.994e-02	1.785e-02	-2.238	0.025280	*
housingtype_apt	-2.138e-01	4.169e-02	-5.127	3.05e-07	***
train_noise	-5.333e-03	2.422e-03	-2.201	0.027759	*
air_noise	-2.700e-03	4.282e-03	-0.631	0.528279	
train_noise_F60-64 dB	-1.748e-02	3.058e-02	-0.572	0.567621	
train_noise_F65-69 dB	6.524e-03	1.068e-01	0.061	0.951299	
train_noise_Funder 55 dB	7.624e-03	1.636e-02	0.466	0.641287	
factor(toilets)1	3.734e-02	4.970e-02	0.751	0.452529	
factor(toilets)2	7.666e-02	5.059e-02	1.515	0.129767	
factor(toilets)3	1.611e-01	5.455e-02	2.954	0.003152	**
factor(bath)1	3.867e-02	1.610e-02	2.402	0.016329	*
factor(bath)2	5.156e-02	1.993e-02	2.587	0.009719	**
factor(bath)3	-6.277e-02	4.837e-02	-1.298	0.194462	
wall_2	-3.299e-02	1.955e-02	-1.687	0.091578	.
wall_3	1.452e-02	1.665e-02	0.872	0.383046	
roofBuilt up (flat roof)	9.278e-03	1.579e-02	0.588	0.556859	
roofCement	-1.371e-02	1.826e-02	-0.751	0.452972	
roofFibercement, asbestus	-5.525e-03	1.375e-02	-0.402	0.687788	
roofTar paper	3.098e-02	1.453e-02	2.132	0.033026	*
roofGlazed	9.434e-03	1.372e-02	0.687	0.491807	
renov_none	-1.385e-02	1.596e-02	-0.868	0.385506	
renov_after sale	-1.545e-01	5.713e-02	-2.704	0.006881	**
renov_last 5 yr	-8.417e-03	2.775e-02	-0.303	0.761614	
constr_year1920-1940	-3.289e-02	9.195e-03	-3.577	0.000351	***
constr_year1940-1960	-4.972e-02	1.120e-02	-4.439	9.24e-06	***
constr_year1960-1980	-7.734e-02	1.206e-02	-6.411	1.57e-10	***
constr_year1980-2000	7.521e-03	1.664e-02	0.452	0.651346	
constr_year_after 2000	9.151e-02	1.936e-02	4.728	2.33e-06	***
constr_year_bef 1900	-2.036e-02	1.050e-02	-1.939	0.052552	.
elevator	1.290e-02	1.028e-02	1.255	0.209490	
listed	5.087e-02	1.977e-02	2.573	0.010107	*
factor(story)1	-5.677e-02	3.050e-02	-1.861	0.062771	.
factor(story)2	-3.381e-02	3.059e-02	-1.105	0.269000	
factor(story)3	-1.786e-02	3.065e-02	-0.583	0.560045	
factor(story)4	-1.359e-02	3.104e-02	-0.438	0.661454	
factor(story)5	-3.280e-03	3.118e-02	-0.105	0.916210	
factor(story)6	1.730e-02	3.235e-02	0.535	0.592908	
factor(story)7	1.756e-02	4.083e-02	0.430	0.667145	
factor(story)8	4.747e-02	4.191e-02	1.133	0.257385	
stories_tot2	-9.295e-03	1.372e-02	-0.677	0.498245	
stories_tot3	-6.118e-02	1.739e-02	-3.519	0.000437	***
stories_tot4	-7.161e-02	1.970e-02	-3.634	0.000282	***
stories_tot5	-1.236e-01	1.941e-02	-6.368	2.08e-10	***
stories_tot6	-1.375e-01	2.093e-02	-6.573	5.42e-11	***
stories_tot7	-1.128e-01	2.898e-02	-3.890	0.000101	***

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stories_tot8                    -1.585e-01  3.235e-02  -4.900  9.89e-07 ***
stories_tot10                   -1.749e-01  4.119e-02  -4.246  2.21e-05 ***
stories_tot11                   -3.176e-01  3.847e-02  -8.255  < 2e-16 ***
stories_tot14                   -1.270e-01  8.020e-02  -1.583  0.113500
stories_tot15                   -9.670e-02  5.286e-02  -1.829  0.067425 .
stories_tot16                   -1.532e-01  6.621e-02  -2.313  0.020753 *
factor(municipality)147          7.952e-02  1.418e-02   5.607  2.17e-08 ***
factor(municipality)151         -3.657e-02  1.055e-01  -0.347  0.728807
factor(municipality)153         -4.445e-01  1.109e-01  -4.006  6.25e-05 ***
factor(municipality)157          7.599e-02  3.312e-02   2.295  0.021798 *
factor(municipality)159          2.437e-01  6.836e-02   3.566  0.000366 ***
factor(municipality)161         -1.565e-01  9.616e-02  -1.627  0.103705
factor(municipality)163         -1.684e-01  7.438e-02  -2.263  0.023650 *
factor(municipality)165         -2.038e-01  1.312e-01  -1.553  0.120377
factor(municipality)167         -1.154e-02  3.641e-02  -0.317  0.751341
factor(municipality)169          3.820e-01  1.658e-01   2.304  0.021278 *
factor(municipality)173          1.780e-01  7.406e-02   2.403  0.016290 *
factor(municipality)175         -6.054e-02  2.431e-02  -2.490  0.012813 *
factor(municipality)185          2.984e-02  3.441e-02   0.867  0.385951
factor(municipality)187         -3.066e-01  1.182e-01  -2.594  0.009523 **

Road border fixed effects                 YES
---
Signif. codes:  0 *** 0.001 ** 0.01 * 0.05 . 0.1   1

Approximate significance of smooth terms:
                                 edf   Ref.df      F   p-value
s(livingspace):factor(house)0   4.835   5.498  560.689 < 2e-16 ***
s(livingspace):factor(house)1   5.083   6.102   74.033 < 2e-16 ***
s(road_quiet):factor(house)0    1.017   1.034   97.190 < 2e-16 ***
s(road_quiet):factor(house)1    2.798   3.311   34.611 < 2e-16 ***
s(CBD)                          3.532   3.870   45.226 < 2e-16 ***
s(lotsize)                       1.015   1.031    8.995 0.00247 **
s(greensp250)                   2.574   2.862    1.676 0.17228
---
Signif. codes:  0 *** 0.001 ** 0.01 * 0.05 . 0.1   1

R-sq.(adj) =  0.894   Deviance explained = 91.9%
REML score =  71235   Scale est. = 0.021552   n = 5347

##########################################################################################
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200 m sample without fixed effects

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##############################################################################################

##Period 1

Family: Gamma
Link function: log

Formula:
ksum_2000 ~ s(livingspace, by = factor(house)) + s(road_quiet, by = factor(house),
    k = 5) + s(CBD, k = 5) + s(lotsize, k = 4) + rooms.f + s(greensp250,
    k = 4) + +coastline + station + indu_500 + housing_type + +train_noise +
    air_noise + train_noise_F + +factor(toi3) + factor(bad3) +
    wall_2 + wall_3 + roof + renov + constr_year + elevator +
    listed + factor(story) + stories_tot + +factor(municipality)

Parametric coefficients:
                                 Estimate Std. Error t value Pr(>|t|)
(Intercept)                     1.355e+01  2.919e-02 464.175  < 2e-16 ***
rooms.f2 rooms                  1.218e-01  4.762e-03  25.581  < 2e-16 ***
rooms.f3 rooms                  1.747e-01  6.009e-03  29.072  < 2e-16 ***
rooms.f4 rooms                  1.822e-01  6.712e-03  27.147  < 2e-16 ***
rooms.f5 rooms                  1.861e-01  7.344e-03  25.339  < 2e-16 ***
rooms.f6 or more rooms          1.931e-01  8.033e-03  24.035  < 2e-16 ***
coastline                       2.320e-04  1.259e-05  18.431  < 2e-16 ***
station                        -4.051e-05  5.394e-06  -7.510 6.04e-14 ***
indu_500                        1.384e-04  1.850e-05   7.485 7.30e-14 ***
housing_type_terr               4.102e-03  4.987e-03   0.823 0.410767
housing_type_apt               -1.225e-01  1.623e-02  -7.547 4.54e-14 ***
train_noise                    -4.428e-03  9.839e-04  -4.500 6.81e-06 ***
air_noise                      -5.574e-03  9.901e-04  -5.629 1.82e-08 ***
train_noise_F60-64 dB           2.991e-03  1.196e-02   0.250 0.802479
train_noise_F65-69 dB          -5.407e-02  4.131e-02  -1.309 0.190531
train_noise_Funder 55 dB        5.288e-04  5.496e-03   0.096 0.923357
factor(toi3)1                   1.724e-01  2.383e-02   7.233 4.81e-13 ***
factor(toi3)2                   2.247e-01  2.405e-02   9.343  < 2e-16 ***
factor(toi3)3                   2.780e-01  2.490e-02  11.166  < 2e-16 ***
factor(bad3)1                   6.525e-02  6.824e-03   9.561  < 2e-16 ***
factor(bad3)2                   6.849e-02  7.672e-03   8.927  < 2e-16 ***
factor(bad3)3                   2.935e-02  1.575e-02   1.863 0.062408 .
wall_2                          7.706e-03  6.352e-03   1.213 0.225074
wall_3                          6.042e-02  5.665e-03  10.665  < 2e-16 ***
roofBuilt up (flat roof)       -1.913e-02  5.653e-03  -3.384 0.000716 ***
roofCement                     -1.650e-02  6.211e-03  -2.657 0.007895 **
roofFibercement, asbestus      -1.833e-02  4.751e-03  -3.859 0.000114 ***
roofTar paper                  -8.339e-03  5.087e-03  -1.639 0.101133
roofGlazed                      7.654e-03  4.741e-03   1.614 0.106430
renov_none                      9.201e-03  8.701e-03   1.057 0.290291
```

renov_after sale	−7.334e−02	9.795e−03	−7.487	7.20e−14	***
renov_last 5 yr	2.695e−02	1.033e−02	2.610	0.009050	**
constr_year1920−1940	−3.764e−02	3.241e−03	−11.612	< 2e−16	***
constr_year1940−1960	−4.478e−02	3.756e−03	−11.922	< 2e−16	***
constr_year1960−1980	−4.874e−02	4.057e−03	−12.013	< 2e−16	***
constr_year1980−2000	8.850e−02	5.942e−03	14.896	< 2e−16	***
constr_year_aft 2000	1.814e−01	8.396e−03	21.604	< 2e−16	***
constr_year_bef 1900	2.309e−02	3.821e−03	6.043	1.53e−09	***
elevator	2.782e−02	4.207e−03	6.613	3.81e−11	***
listed	1.027e−01	6.073e−03	16.906	< 2e−16	***
factor(story)1	−1.006e−01	1.320e−02	−7.624	2.51e−14	***
factor(story)2	−8.020e−02	1.319e−02	−6.079	1.22e−09	***
factor(story)3	−6.777e−02	1.326e−02	−5.112	3.20e−07	***
factor(story)4	−6.406e−02	1.340e−02	−4.780	1.76e−06	***
factor(story)5	−5.747e−02	1.354e−02	−4.243	2.21e−05	***
factor(story)6	−4.892e−02	1.431e−02	−3.419	0.000630	***
factor(story)7	−3.419e−03	1.940e−02	−0.176	0.860133	
factor(story)8	1.750e−02	2.108e−02	0.830	0.406397	
stories_tot2	4.389e−02	4.549e−03	9.648	< 2e−16	***
stories_tot3	9.842e−03	5.844e−03	1.684	0.092206	.
stories_tot4	3.275e−03	6.528e−03	0.502	0.615875	
stories_tot5	−1.627e−02	6.340e−03	−2.567	0.010270	*
stories_tot6	−1.841e−02	7.205e−03	−2.555	0.010630	*
stories_tot7	1.026e−02	1.172e−02	0.876	0.381121	
stories_tot8	6.545e−02	1.589e−02	4.118	3.83e−05	***
stories_tot10	−3.973e−02	1.988e−02	−1.999	0.045662	*
stories_tot11	−5.550e−03	1.991e−02	−0.279	0.780379	
stories_tot13	4.909e−02	5.387e−02	0.911	0.362146	
stories_tot14	−1.956e−02	4.294e−02	−0.456	0.648682	
stories_tot15	−1.096e−01	2.285e−02	−4.795	1.63e−06	***
stories_tot16	−2.650e−02	2.608e−02	−1.016	0.309594	
factor(municipality)147	8.810e−02	3.379e−03	26.070	< 2e−16	***
factor(municipality)151	−1.392e−01	9.963e−03	−13.970	< 2e−16	***
factor(municipality)153	−1.908e−01	9.186e−03	−20.772	< 2e−16	***
factor(municipality)155	−1.341e−02	1.073e−02	−1.250	0.211181	
factor(municipality)157	2.681e−01	5.128e−03	52.284	< 2e−16	***
factor(municipality)159	3.584e−02	6.271e−03	5.715	1.10e−08	***
factor(municipality)161	−1.165e−01	9.295e−03	−12.533	< 2e−16	***
factor(municipality)163	−7.476e−02	9.384e−03	−7.967	1.67e−15	***
factor(municipality)165	−1.848e−01	1.093e−02	−16.903	< 2e−16	***
factor(municipality)167	−9.343e−02	5.660e−03	−16.506	< 2e−16	***
factor(municipality)169	−2.026e−01	1.569e−02	−12.914	< 2e−16	***
factor(municipality)173	1.519e−01	8.150e−03	18.638	< 2e−16	***
factor(municipality)175	−5.351e−02	5.890e−03	−9.085	< 2e−16	***
factor(municipality)185	−4.076e−02	6.401e−03	−6.368	1.94e−10	***
factor(municipality)187	−1.487e−01	1.006e−02	−14.776	< 2e−16	***

Road border fixed effects NO

```
Signif. codes:  0 *** 0.001 ** 0.01 * 0.05 . 0.1   1

Approximate significance of smooth terms:
                                  edf Ref.df       F p-value
s(livingspace):factor(house)0   5.577  5.957 2897.42  <2e-16 ***
s(livingspace):factor(house)1   5.864  6.820  576.61  <2e-16 ***
s(road_quiet):factor(house)0    3.600  3.906  114.79  <2e-16 ***
s(road_quiet):factor(house)1    3.554  3.873  152.71  <2e-16 ***
s(CBD)                          3.965  3.999  330.54  <2e-16 ***
s(lotsize)                      1.004  1.009  289.76  <2e-16 ***
s(greensp250)                   2.255  2.599   55.08  <2e-16 ***
---
Signif. codes:  0 *** 0.001 ** 0.01 * 0.05 . 0.1   1

R-sq.(adj) =   0.86   Deviance explained = 89.4%
REML score = 4.9766e+05  Scale est. = 0.02492   n = 37074

################################################################################################

##Period 2


Family: Gamma
Link function: log

Formula:
ksum_2000 ~ s(livingspace, by = factor(house)) + s(road_quiet, by = factor(house),
    k = 5) + s(CBD, k = 5) + s(lotsize, k = 4) + rooms.f + s(greensp250,
    k = 4) + +coastline + station + indu_500 + housing_type + +train_noise +
    air_noise + train_noise_F + +factor(toi3) + factor(bad3) +
    wall_2 + wall_3 + roof + renov + constr_year + elevator +
    listed + factor(story) + stories_tot + +factor(municipality)

Parametric coefficients:
                                Estimate Std. Error t value Pr(>|t|)
(Intercept)                    1.379e+01  3.918e-02 351.990  < 2e-16 ***
rooms.f2 rooms                 9.675e-02  5.617e-03  17.225  < 2e-16 ***
rooms.f3 rooms                 1.482e-01  6.886e-03  21.524  < 2e-16 ***
rooms.f4 rooms                 1.594e-01  7.660e-03  20.810  < 2e-16 ***
rooms.f5 rooms                 1.650e-01  8.493e-03  19.428  < 2e-16 ***
rooms.f6 or more rooms         1.818e-01  9.421e-03  19.299  < 2e-16 ***
coastline                      2.124e-04  1.455e-05  14.593  < 2e-16 ***
station                       -2.147e-05  6.444e-06  -3.332 0.000864 ***
indu_500                       1.200e-04  2.103e-05   5.705 1.18e-08 ***
housing_type_terr              2.268e-02  6.698e-03   3.386 0.000710 ***
housing_type_apt              -1.666e-01  1.892e-02  -8.807  < 2e-16 ***
train_noise                   -3.620e-03  1.174e-03  -3.082 0.002058 **
air_noise                     -8.274e-03  1.104e-03  -7.494 6.90e-14 ***
train_noise_F60-64 dB         -2.053e-02  1.405e-02  -1.461 0.144061
```

train_noise_F65−69 dB	−1.287e−01	4.471e−02	−2.880	0.003981	**
train_noise_Funder 55 dB	−8.370e−03	6.691e−03	−1.251	0.210944	
factor(toi3)1	4.827e−02	3.492e−02	1.382	0.166918	
factor(toi3)2	8.732e−02	3.515e−02	2.484	0.012984	*
factor(toi3)3	1.399e−01	3.606e−02	3.879	0.000105	***
factor(bad3)1	6.186e−02	8.856e−03	6.985	2.93e−12	***
factor(bad3)2	8.299e−02	9.874e−03	8.405	< 2e−16	***
factor(bad3)3	6.545e−02	1.882e−02	3.477	0.000507	***
wall_2	−9.521e−03	7.435e−03	−1.281	0.200332	
wall_3	2.468e−02	6.561e−03	3.762	0.000169	***
roofBuilt up (flat roof)	−1.274e−02	6.337e−03	−2.011	0.044370	*
roofCement	2.382e−03	7.274e−03	0.327	0.743338	
roofFibercement, asbestus	−7.740e−03	5.460e−03	−1.418	0.156304	
roofTar paper	4.222e−03	5.767e−03	0.732	0.464150	
roofGlazed	2.043e−02	5.401e−03	3.782	0.000156	***
renov_none	−1.783e−02	6.724e−03	−2.652	0.008011	**
renov_after sale	−1.053e−01	1.054e−02	−9.987	< 2e−16	***
renov_last 5 yr	−8.711e−03	9.759e−03	−0.893	0.372081	
constr_year1920−1940	−3.761e−02	3.935e−03	−9.559	< 2e−16	***
constr_year1940−1960	−6.807e−02	4.549e−03	−14.964	< 2e−16	***
constr_year1960−1980	−7.238e−02	4.874e−03	−14.852	< 2e−16	***
constr_year1980−2000	2.328e−02	6.807e−03	3.420	0.000627	***
constr_year_aft 2000	5.222e−02	7.160e−03	7.294	3.10e−13	***
constr_year_bef 1900	1.032e−02	4.659e−03	2.214	0.026838	*
elevator	1.737e−02	4.625e−03	3.757	0.000172	***
listed	7.624e−02	7.180e−03	10.619	< 2e−16	***
factor(story)1	−3.601e−02	1.517e−02	−2.373	0.017631	*
factor(story)2	−1.414e−02	1.517e−02	−0.932	0.351385	
factor(story)3	−2.702e−03	1.524e−02	−0.177	0.859290	
factor(story)4	4.512e−03	1.543e−02	0.292	0.769962	
factor(story)5	1.540e−02	1.559e−02	0.988	0.323209	
factor(story)6	3.450e−02	1.640e−02	2.104	0.035408	*
factor(story)7	7.221e−02	2.119e−02	3.408	0.000655	***
factor(story)8	9.316e−02	2.305e−02	4.042	5.31e−05	***
stories_tot2	3.040e−02	5.522e−03	5.506	3.71e−08	***
stories_tot3	9.095e−03	6.911e−03	1.316	0.188192	
stories_tot4	4.975e−03	7.698e−03	0.646	0.518050	
stories_tot5	−1.354e−02	7.471e−03	−1.813	0.069832	.
stories_tot6	−1.208e−02	8.485e−03	−1.424	0.154494	
stories_tot7	−8.526e−03	1.210e−02	−0.705	0.481040	
stories_tot8	−1.657e−02	1.619e−02	−1.023	0.306127	
stories_tot10	2.365e−02	2.337e−02	1.012	0.311555	
stories_tot11	−6.534e−02	1.635e−02	−3.996	6.45e−05	***
stories_tot13	3.979e−02	5.805e−02	0.686	0.492988	
stories_tot14	−2.068e−02	3.756e−02	−0.551	0.581880	
stories_tot15	−1.461e−01	2.938e−02	−4.971	6.70e−07	***
stories_tot16	−1.260e−01	2.961e−02	−4.255	2.10e−05	***
factor(municipality)147	6.123e−02	3.982e−03	15.379	< 2e−16	***
factor(municipality)151	−1.740e−01	1.232e−02	−14.120	< 2e−16	***

```
factor(municipality)153         -2.361e-01  1.154e-02 -20.456  < 2e-16 ***
factor(municipality)155         -6.289e-02  1.309e-02  -4.806 1.55e-06 ***
factor(municipality)157          2.625e-01  6.294e-03  41.705  < 2e-16 ***
factor(municipality)159         -1.664e-02  7.557e-03  -2.202 0.027647 *
factor(municipality)161         -1.696e-01  1.124e-02 -15.085  < 2e-16 ***
factor(municipality)163         -1.144e-01  1.163e-02  -9.838  < 2e-16 ***
factor(municipality)165         -2.503e-01  1.329e-02 -18.828  < 2e-16 ***
factor(municipality)167         -1.227e-01  7.072e-03 -17.346  < 2e-16 ***
factor(municipality)169         -2.899e-01  1.886e-02 -15.368  < 2e-16 ***
factor(municipality)173          1.180e-01  1.002e-02  11.781  < 2e-16 ***
factor(municipality)175         -9.994e-02  6.918e-03 -14.446  < 2e-16 ***
factor(municipality)185         -8.712e-02  7.630e-03 -11.418  < 2e-16 ***
factor(municipality)187         -2.179e-01  1.247e-02 -17.475  < 2e-16 ***

Road border fixed effects          NO
---
Signif. codes:  0 *** 0.001 ** 0.01 * 0.05 . 0.1   1

Approximate significance of smooth terms:
                                 edf Ref.df       F  p-value
s(livingspace):factor(house)0  5.423  5.857 2113.21  < 2e-16 ***
s(livingspace):factor(house)1  5.069  6.060  382.20  < 2e-16 ***
s(road_quiet):factor(house)0   3.832  3.983   95.38  < 2e-16 ***
s(road_quiet):factor(house)1   3.350  3.750  135.81  < 2e-16 ***
s(CBD)                         3.959  3.999  324.69  < 2e-16 ***
s(lotsize)                     1.748  2.153  115.47  < 2e-16 ***
s(greensp250)                  1.647  1.983   23.67 6.39e-11 ***
---
Signif. codes:  0 *** 0.001 ** 0.01 * 0.05 . 0.1   1

R-sq.(adj) =  0.856   Deviance explained = 88.5%
REML score = 3.4692e+05  Scale est. = 0.025119  n = 25805

##########################################################################################

##Period 3


Family: Gamma
Link function: log

Formula:
ksum_2000 ~ s(livingspace, by = factor(house)) + s(road_quiet, by = factor(house),
    k = 5) + s(CBD, k = 5) + s(lotsize, k = 4) + rooms.f + s(greensp250,
    k = 4) + +coastline + station + indu_500 + housing_type + +train_noise +
    air_noise + train_noise_F + +factor(toi3) + factor(bad3) +
    wall_2 + wall_3 + roof + renov + constr_year + elevator +
    listed + factor(story) + stories_tot + +factor(municipality)
```

```
Parametric coefficients:
                                Estimate Std. Error t value Pr(>|t|)
(Intercept)                    1.390e+01  4.589e-02 302.845  < 2e-16 ***
rooms.f2 rooms                 7.939e-02  8.249e-03   9.624  < 2e-16 ***
rooms.f3 rooms                 1.251e-01  9.880e-03  12.660  < 2e-16 ***
rooms.f4 rooms                 1.365e-01  1.077e-02  12.669  < 2e-16 ***
rooms.f5 rooms                 1.536e-01  1.174e-02  13.081  < 2e-16 ***
rooms.f6 or more rooms         1.737e-01  1.301e-02  13.352  < 2e-16 ***
coastline                      2.353e-04  1.887e-05  12.472  < 2e-16 ***
station                       -1.752e-05  8.640e-06  -2.027 0.042629 *
indu_500                       1.757e-04  2.865e-05   6.135 8.73e-10 ***
housing_type_terr             -1.212e-02  7.872e-03  -1.539 0.123790
housing_type_apt              -1.896e-01  2.228e-02  -8.508  < 2e-16 ***
train_noise                   -2.584e-03  1.663e-03  -1.554 0.120253
air_noise                     -9.034e-03  1.541e-03  -5.863 4.64e-09 ***
train_noise_F60-64 dB         -4.623e-02  1.923e-02  -2.404 0.016224 *
train_noise_F65-69 dB         -1.407e-01  5.383e-02  -2.613 0.008978 **
train_noise_Funder 55 dB      -2.451e-02  8.903e-03  -2.753 0.005918 **
factor(toi3)1                  6.579e-02  3.991e-02   1.649 0.099256 .
factor(toi3)2                  9.879e-02  4.019e-02   2.458 0.013985 *
factor(toi3)3                  1.953e-01  4.173e-02   4.679 2.90e-06 ***
factor(bad3)1                  3.724e-02  1.163e-02   3.203 0.001365 **
factor(bad3)2                  5.888e-02  1.296e-02   4.543 5.60e-06 ***
factor(bad3)3                  1.645e-02  2.687e-02   0.612 0.540492
wall_2                        -1.365e-02  9.609e-03  -1.421 0.155458
wall_3                         3.079e-02  8.520e-03   3.614 0.000303 ***
roofBuilt up (flat roof)      -2.185e-02  8.329e-03  -2.623 0.008719 **
roofCement                    -1.769e-02  9.492e-03  -1.863 0.062456 .
roofFibercement, asbestus     -1.880e-02  7.217e-03  -2.605 0.009201 **
roofTar paper                  1.093e-02  7.744e-03   1.412 0.157965
roofGlazed                     3.756e-03  7.176e-03   0.523 0.600749
renov_none                    -1.136e-02  8.408e-03  -1.351 0.176608
renov_after sale              -1.003e-01  2.316e-02  -4.329 1.50e-05 ***
renov_last 5 yr                1.401e-02  1.501e-02   0.933 0.350787
constr_year1920-1940          -5.889e-02  5.361e-03 -10.986  < 2e-16 ***
constr_year1940-1960          -7.986e-02  6.178e-03 -12.927  < 2e-16 ***
constr_year1960-1980          -1.008e-01  6.616e-03 -15.228  < 2e-16 ***
constr_year1980-2000           1.158e-02  9.320e-03   1.243 0.213982
constr_year_aft 2000           5.252e-02  9.280e-03   5.659 1.55e-08 ***
constr_year_bef 1900           2.469e-02  6.273e-03   3.935 8.35e-05 ***
elevator                       5.133e-02  6.442e-03   7.968 1.72e-15 ***
listed                         8.705e-02  9.973e-03   8.728  < 2e-16 ***
factor(story)1                -8.848e-02  1.918e-02  -4.612 4.01e-06 ***
factor(story)2                -6.684e-02  1.921e-02  -3.480 0.000502 ***
factor(story)3                -5.515e-02  1.931e-02  -2.856 0.004290 **
factor(story)4                -5.125e-02  1.958e-02  -2.617 0.008880 **
factor(story)5                -3.393e-02  1.979e-02  -1.714 0.086508 .
factor(story)6                -1.119e-02  2.088e-02  -0.536 0.592146
factor(story)7                -3.220e-03  2.871e-02  -0.112 0.910704
```

```
factor(story)8                   5.972e-02  3.226e-02    1.851 0.064134 .
stories_tot2                     3.492e-02  7.035e-03    4.965 6.95e-07 ***
stories_tot3                    -8.217e-03  9.495e-03   -0.865 0.386788
stories_tot4                    -1.631e-02  1.055e-02   -1.547 0.121991
stories_tot5                    -5.961e-02  1.020e-02   -5.846 5.12e-09 ***
stories_tot6                    -6.692e-02  1.162e-02   -5.759 8.62e-09 ***
stories_tot7                    -6.764e-02  1.608e-02   -4.207 2.61e-05 ***
stories_tot8                    -3.273e-02  1.947e-02   -1.681 0.092807 .
stories_tot10                   -4.742e-02  2.750e-02   -1.724 0.084638 .
stories_tot11                   -1.669e-01  2.477e-02   -6.738 1.66e-11 ***
stories_tot13                   -1.772e-02  7.685e-02   -0.231 0.817621
stories_tot14                   -5.562e-02  6.138e-02   -0.906 0.364879
stories_tot15                   -1.299e-01  3.865e-02   -3.361 0.000779 ***
stories_tot16                   -1.778e-01  4.645e-02   -3.828 0.000130 ***
factor(municipality)147          7.896e-02  5.336e-03   14.797  < 2e-16 ***
factor(municipality)151         -1.507e-01  1.594e-02   -9.451  < 2e-16 ***
factor(municipality)153         -2.351e-01  1.492e-02  -15.760  < 2e-16 ***
factor(municipality)155         -1.860e-02  1.759e-02   -1.057 0.290406
factor(municipality)157          2.712e-01  8.393e-03   32.313  < 2e-16 ***
factor(municipality)159         -1.114e-04  1.041e-02   -0.011 0.991461
factor(municipality)161         -1.368e-01  1.511e-02   -9.053  < 2e-16 ***
factor(municipality)163         -1.053e-01  1.449e-02   -7.270 3.77e-13 ***
factor(municipality)165         -2.064e-01  1.748e-02  -11.813  < 2e-16 ***
factor(municipality)167         -9.059e-02  9.639e-03   -9.398  < 2e-16 ***
factor(municipality)169         -2.525e-01  2.548e-02   -9.910  < 2e-16 ***
factor(municipality)173          1.319e-01  1.353e-02    9.750  < 2e-16 ***
factor(municipality)175         -6.704e-02  9.708e-03   -6.905 5.19e-12 ***
factor(municipality)185         -6.270e-02  1.013e-02   -6.189 6.21e-10 ***
factor(municipality)187         -1.564e-01  1.666e-02   -9.385  < 2e-16 ***

Road border fixed effects          NO
---
Signif. codes:  0 *** 0.001 ** 0.01 * 0.05 . 0.1   1

Approximate significance of smooth terms:
                                  edf Ref.df       F  p-value
s(livingspace):factor(house)0   5.214  5.705 1472.14  < 2e-16 ***
s(livingspace):factor(house)1   4.450  5.414  338.41  < 2e-16 ***
s(road_quiet):factor(house)0    3.461  3.835   97.48  < 2e-16 ***
s(road_quiet):factor(house)1    3.146  3.601   88.64  < 2e-16 ***
s(CBD)                          3.927  3.997  196.62  < 2e-16 ***
s(lotsize)                      1.019  1.037   94.39  < 2e-16 ***
s(greensp250)                   2.454  2.772   26.83 3.52e-16 ***
---
Signif. codes:  0 *** 0.001 ** 0.01 * 0.05 . 0.1   1

R-sq.(adj) =  0.846   Deviance explained = 89.2%
REML score = 2.15e+05  Scale est. = 0.027827   n = 15892
```

##

Full model with fixed effects

NB: School attendance zones are contained within municipalities, so these fixed effects also capture other differences in e.g. taxation between municipalities.

```
###############################################################################################
##Period 1


Family: Gamma
Link function: log

Formula:
ksum_2000 ~ s(livingspace, by = factor(house)) + s(road_quiet, by = factor(house),
    k = 5) + s(CBD, k = 5) + s(lotsize, k = 4) + rooms.f + s(greensp250,
    k = 4) + +coastline + station + indu_500 + housing_type + +train_noise +
    air_noise + train_noise_F + +factor(toi3) + factor(bad3) +
    wall_2 + wall_3 + roof + renov + constr_year + elevator +
    listed + factor(story) + stories_tot + +factor(skole_id)

Parametric coefficients:
                                  Estimate Std. Error t value Pr(>|t|)
(Intercept)                      1.400e+01  3.921e-02 357.063  < 2e-16 ***
rooms.f2 rooms                   1.313e-01  4.597e-03  28.559  < 2e-16 ***
rooms.f3 rooms                   1.878e-01  5.800e-03  32.369  < 2e-16 ***
rooms.f4 rooms                   1.971e-01  6.462e-03  30.503  < 2e-16 ***
rooms.f5 rooms                   1.987e-01  7.048e-03  28.184  < 2e-16 ***
rooms.f6 or more rooms           2.051e-01  7.687e-03  26.682  < 2e-16 ***
coastline                        1.122e-04  1.366e-05   8.216  < 2e-16 ***
station                         -2.571e-05  5.739e-06  -4.480 7.50e-06 ***
indu_500                         8.239e-05  1.944e-05   4.238 2.26e-05 ***
housing_type_terr                2.946e-03  5.515e-03   0.534 0.593189
housing_type_apt                -1.256e-01  1.637e-02  -7.672 1.73e-14 ***
train_noise                     -9.523e-03  9.569e-04  -9.953  < 2e-16 ***
air_noise                        7.903e-04  1.070e-03   0.739 0.460163
train_noise_F60-64 dB            3.911e-05  1.135e-02   0.003 0.997251
train_noise_F65-69 dB           -2.847e-02  3.914e-02  -0.727 0.466955
train_noise_Funder 55 dB         1.474e-02  5.677e-03   2.596 0.009433 **
factor(toi3)1                    1.577e-01  2.264e-02   6.966 3.31e-12 ***
factor(toi3)2                    2.066e-01  2.285e-02   9.040  < 2e-16 ***
factor(toi3)3                    2.424e-01  2.366e-02  10.248  < 2e-16 ***
factor(bad3)1                    5.589e-02  6.451e-03   8.664  < 2e-16 ***
factor(bad3)2                    5.740e-02  7.255e-03   7.911 2.62e-15 ***
factor(bad3)3                    3.676e-02  1.487e-02   2.472 0.013443 *
wall_2                           1.160e-02  6.122e-03   1.894 0.058170 .
wall_3                           5.818e-02  5.380e-03  10.813  < 2e-16 ***
roofBuilt up (flat roof)        -2.254e-02  5.534e-03  -4.073 4.65e-05 ***
roofCement                      -8.407e-03  5.995e-03  -1.402 0.160796
roofFibercement, asbestus       -1.743e-02  4.614e-03  -3.778 0.000158 ***
```

```
roofTar paper                 -1.438e-02  4.963e-03  -2.898 0.003761 **
roofGlazed                     6.148e-03  4.620e-03   1.331 0.183279
renov_none                    -1.282e-03  8.353e-03  -0.153 0.878058
renov_after sale              -7.231e-02  9.411e-03  -7.683 1.59e-14 ***
renov_last 5 yr                2.669e-02  9.922e-03   2.690 0.007140 **
constr_year1920-1940          -1.511e-02  3.336e-03  -4.528 5.98e-06 ***
constr_year1940-1960          -1.047e-02  3.817e-03  -2.743 0.006098 **
constr_year1960-1980          -7.841e-03  4.134e-03  -1.897 0.057843 .
constr_year1980-2000           1.195e-01  5.826e-03  20.510  < 2e-16 ***
constr_year_aft 2000           2.118e-01  8.440e-03  25.090  < 2e-16 ***
constr_year_bef 1900           2.620e-03  4.017e-03   0.652 0.514167
elevator                      -9.983e-03  4.229e-03  -2.361 0.018250 *
listed                         7.929e-02  6.149e-03  12.895  < 2e-16 ***
factor(story)1                -9.888e-02  1.277e-02  -7.744 9.86e-15 ***
factor(story)2                -7.766e-02  1.276e-02  -6.085 1.18e-09 ***
factor(story)3                -6.513e-02  1.281e-02  -5.084 3.72e-07 ***
factor(story)4                -6.172e-02  1.295e-02  -4.765 1.90e-06 ***
factor(story)5                -5.503e-02  1.308e-02  -4.206 2.60e-05 ***
factor(story)6                -5.134e-02  1.379e-02  -3.724 0.000196 ***
factor(story)7                -6.010e-03  1.849e-02  -0.325 0.745207
factor(story)8                 1.476e-02  2.005e-02   0.736 0.461516
stories_tot2                   3.022e-02  4.492e-03   6.726 1.77e-11 ***
stories_tot3                  -1.146e-03  5.764e-03  -0.199 0.842331
stories_tot4                  -2.328e-02  6.533e-03  -3.563 0.000368 ***
stories_tot5                  -2.200e-02  6.473e-03  -3.398 0.000679 ***
stories_tot6                  -2.502e-02  7.366e-03  -3.396 0.000684 ***
stories_tot7                  -3.654e-02  1.143e-02  -3.199 0.001382 **
stories_tot8                   5.811e-02  1.542e-02   3.770 0.000164 ***
stories_tot10                 -4.742e-02  1.981e-02  -2.394 0.016691 *
stories_tot11                 -5.547e-02  1.987e-02  -2.791 0.005250 **
stories_tot13                 -1.445e-02  5.116e-02  -0.282 0.777566
stories_tot14                 -7.167e-02  4.099e-02  -1.748 0.080413 .
stories_tot15                 -1.389e-01  2.308e-02  -6.018 1.78e-09 ***
stories_tot16                  6.453e-02  2.598e-02   2.484 0.012989 *

School attendance zone fixed effect         YES
---
Signif. codes:  0 *** 0.001 ** 0.01 * 0.05 . 0.1   1

Approximate significance of smooth terms:
                                 edf Ref.df       F p-value
s(livingspace):factor(house)0  5.542  5.935 2811.11  <2e-16 ***
s(livingspace):factor(house)1  5.541  6.520  558.02  <2e-16 ***
s(road_quiet):factor(house)0   3.627  3.917   59.52  <2e-16 ***
s(road_quiet):factor(house)1   3.404  3.785  134.16  <2e-16 ***
s(CBD)                         3.858  3.990   37.28  <2e-16 ***
s(lotsize)                     2.657  2.920  114.93  <2e-16 ***
s(greensp250)                  2.378  2.711   36.52  <2e-16 ***
---
```

```
Signif. codes:  0 *** 0.001 ** 0.01 * 0.05 . 0.1   1

R-sq.(adj) =  0.879   Deviance explained = 90.7%
REML score = 4.9581e+05  Scale est. = 0.022026   n = 37074

##########################################################################################

##Period 2


Family: Gamma
Link function: log

Formula:
ksum_2000 ~ s(livingspace, by = factor(house)) + s(road_quiet, by = factor(house),
    k = 5) + s(CBD, k = 5) + s(lotsize, k = 4) + rooms.f + s(greensp250,
    k = 4) + +coastline + station + indu_500 + housing_type + +train_noise +
    air_noise + train_noise_F + +factor(toi3) + factor(bad3) +
    wall_2 + wall_3 + roof + renov + constr_year + elevator +
    listed + factor(story) + stories_tot + +factor(skole_id)

Parametric coefficients:
                                  Estimate Std. Error t value Pr(>|t|)
(Intercept)                      1.431e+01  5.435e-02 263.344  < 2e-16 ***
rooms.f2 rooms                   1.056e-01  5.462e-03  19.344  < 2e-16 ***
rooms.f3 rooms                   1.570e-01  6.699e-03  23.437  < 2e-16 ***
rooms.f4 rooms                   1.673e-01  7.462e-03  22.423  < 2e-16 ***
rooms.f5 rooms                   1.714e-01  8.241e-03  20.800  < 2e-16 ***
rooms.f6 or more rooms           1.864e-01  9.130e-03  20.418  < 2e-16 ***
coastline                        6.561e-05  1.582e-05   4.148 3.36e-05 ***
station                         -1.389e-05  6.918e-06  -2.008 0.044625 *
indu_500                         7.906e-05  2.227e-05   3.550 0.000385 ***
housing_type_terr                1.854e-02  6.925e-03   2.678 0.007419 **
housing_type_apt                -1.717e-01  1.900e-02  -9.035  < 2e-16 ***
train_noise                     -8.556e-03  1.160e-03  -7.374 1.71e-13 ***
air_noise                       -2.813e-03  1.246e-03  -2.259 0.023916 *
train_noise_F60-64 dB           -2.326e-02  1.347e-02  -1.727 0.084111 .
train_noise_F65-69 dB           -9.077e-02  4.277e-02  -2.122 0.033832 *
train_noise_Funder 55 dB         1.036e-02  6.992e-03   1.482 0.138440
factor(toi3)1                    4.251e-02  3.326e-02   1.278 0.201206
factor(toi3)2                    7.306e-02  3.347e-02   2.183 0.029078 *
factor(toi3)3                    1.183e-01  3.435e-02   3.444 0.000575 ***
factor(bad3)1                    4.966e-02  8.462e-03   5.869 4.44e-09 ***
factor(bad3)2                    6.945e-02  9.444e-03   7.355 1.97e-13 ***
factor(bad3)3                    6.396e-02  1.797e-02   3.559 0.000372 ***
wall_2                          -1.146e-02  7.265e-03  -1.578 0.114564
wall_3                           1.611e-02  6.310e-03   2.553 0.010672 *
roofBuilt up (flat roof)        -2.369e-02  6.250e-03  -3.791 0.000151 ***
roofCement                       4.722e-03  7.089e-03   0.666 0.505347
```

```
roofFibercement, asbestus          -9.780e-03  5.347e-03  -1.829 0.067394 .
roofTar paper                      -6.602e-03  5.679e-03  -1.163 0.245025
roofGlazed                          1.706e-02  5.308e-03   3.213 0.001315 **
renov_none                         -7.642e-03  6.556e-03  -1.166 0.243773
renov_after sale                   -9.378e-02  1.026e-02  -9.138  < 2e-16 ***
renov_last 5 yr                     1.246e-02  9.481e-03   1.315 0.188667
constr_year1920-1940               -1.552e-02  4.075e-03  -3.808 0.000140 ***
constr_year1940-1960               -3.568e-02  4.655e-03  -7.664 1.86e-14 ***
constr_year1960-1980               -3.525e-02  5.001e-03  -7.050 1.84e-12 ***
constr_year1980-2000                4.539e-02  6.827e-03   6.649 3.02e-11 ***
constr_year_aft 2000                1.062e-01  7.798e-03  13.619  < 2e-16 ***
constr_year_bef 1900               -5.982e-03  4.872e-03  -1.228 0.219449
elevator                           -8.994e-03  4.655e-03  -1.932 0.053368 .
listed                              6.073e-02  7.176e-03   8.464  < 2e-16 ***
factor(story)1                     -4.227e-02  1.479e-02  -2.857 0.004275 **
factor(story)2                     -1.981e-02  1.480e-02  -1.338 0.180750
factor(story)3                     -9.443e-03  1.485e-02  -0.636 0.524949
factor(story)4                     -1.045e-03  1.504e-02  -0.070 0.944582
factor(story)5                      1.013e-02  1.518e-02   0.667 0.504714
factor(story)6                      2.973e-02  1.594e-02   1.865 0.062198 .
factor(story)7                      7.289e-02  2.040e-02   3.573 0.000353 ***
factor(story)8                      8.749e-02  2.217e-02   3.946 7.97e-05 ***
stories_tot2                        1.704e-02  5.487e-03   3.106 0.001899 **
stories_tot3                        3.299e-03  6.872e-03   0.480 0.631251
stories_tot4                       -2.065e-02  7.790e-03  -2.651 0.008033 **
stories_tot5                       -3.299e-02  7.717e-03  -4.275 1.92e-05 ***
stories_tot6                       -3.861e-02  8.754e-03  -4.410 1.04e-05 ***
stories_tot7                       -2.636e-02  1.225e-02  -2.152 0.031394 *
stories_tot8                       -2.597e-02  1.600e-02  -1.623 0.104598
stories_tot10                      -5.061e-04  2.336e-02  -0.022 0.982719
stories_tot11                      -6.953e-02  1.732e-02  -4.015 5.96e-05 ***
stories_tot13                      -2.898e-02  5.576e-02  -0.520 0.603331
stories_tot14                      -8.191e-02  3.663e-02  -2.236 0.025342 *
stories_tot15                      -1.787e-01  2.978e-02  -6.001 1.99e-09 ***
stories_tot16                      -4.507e-02  2.998e-02  -1.503 0.132788

School attendance zones fixed effects   YES
---
Signif. codes:  0 *** 0.001 ** 0.01 * 0.05 . 0.1   1

Approximate significance of smooth terms:
                                 edf Ref.df       F  p-value
s(livingspace):factor(house)0  5.370  5.821 2089.29  < 2e-16 ***
s(livingspace):factor(house)1  5.003  5.995  357.72  < 2e-16 ***
s(road_quiet):factor(house)0   3.841  3.984   61.86  < 2e-16 ***
s(road_quiet):factor(house)1   3.324  3.734  125.08  < 2e-16 ***
s(CBD)                         3.815  3.984   57.80  < 2e-16 ***
s(lotsize)                     2.662  2.923   88.17  < 2e-16 ***
s(greensp250)                  1.292  1.515   38.98 5.54e-14 ***
```

```
---
Signif. codes:  0 *** 0.001 ** 0.01 * 0.05 . 0.1   1

R-sq.(adj) =  0.876   Deviance explained = 89.7%
REML score = 3.4598e+05  Scale est. = 0.022633   n = 25805

##########################################################################################

##Period 3


Family: Gamma
Link function: log

Formula:
ksum_2000 ~ s(livingspace, by = factor(house)) + s(road_quiet, by = factor(house),
    k = 5) + s(CBD, k = 5) + s(lotsize, k = 4) + rooms.f + s(greensp250,
    k = 4) + +coastline + station + indu_500 + housing_type + +train_noise +
    air_noise + train_noise_F + +factor(toi3) + factor(bad3) +
    wall_2 + wall_3 + roof + renov + constr_year + elevator +
    listed + factor(story) + stories_tot + +factor(skole_id)

Parametric coefficients:
                                Estimate Std. Error t value Pr(>|t|)
(Intercept)                    1.427e+01  7.486e-02 190.631  < 2e-16 ***
rooms.f2 rooms                 9.195e-02  7.931e-03  11.593  < 2e-16 ***
rooms.f3 rooms                 1.442e-01  9.519e-03  15.145  < 2e-16 ***
rooms.f4 rooms                 1.529e-01  1.037e-02  14.738  < 2e-16 ***
rooms.f5 rooms                 1.663e-01  1.128e-02  14.738  < 2e-16 ***
rooms.f6 or more rooms         1.819e-01  1.249e-02  14.565  < 2e-16 ***
coastline                      8.780e-05  2.066e-05   4.250 2.15e-05 ***
station                       -6.923e-06  9.147e-06  -0.757 0.449175
indu_500                       1.301e-04  3.002e-05   4.335 1.47e-05 ***
housing_type_terr             -1.472e-02  8.500e-03  -1.732 0.083281 .
housing_type_apt              -1.973e-01  2.300e-02  -8.577  < 2e-16 ***
train_noise                   -9.881e-03  1.612e-03  -6.129 9.05e-10 ***
air_noise                     -4.479e-03  1.666e-03  -2.688 0.007202 **
train_noise_F60-64 dB         -3.440e-02  1.840e-02  -1.869 0.061596 .
train_noise_F65-69 dB         -9.735e-02  5.111e-02  -1.905 0.056849 .
train_noise_Funder 55 dB       3.440e-03  9.418e-03   0.365 0.714928
factor(toi3)1                  5.515e-02  3.768e-02   1.464 0.143311
factor(toi3)2                  8.349e-02  3.795e-02   2.200 0.027825 *
factor(toi3)3                  1.572e-01  3.940e-02   3.990 6.63e-05 ***
factor(bad3)1                  2.730e-02  1.102e-02   2.477 0.013244 *
factor(bad3)2                  5.289e-02  1.229e-02   4.304 1.69e-05 ***
factor(bad3)3                  3.477e-02  2.558e-02   1.359 0.174087
wall_2                        -5.632e-03  9.370e-03  -0.601 0.547766
wall_3                         2.787e-02  8.166e-03   3.413 0.000644 ***
roofBuilt up (flat roof)      -2.888e-02  8.090e-03  -3.570 0.000358 ***
```

```
roofCement                        -1.988e-02  9.139e-03  -2.175 0.029653 *
roofFibercement, asbestus         -2.312e-02  6.972e-03  -3.317 0.000914 ***
roofTar paper                     -2.408e-04  7.520e-03  -0.032 0.974458
roofGlazed                         1.825e-03  6.962e-03   0.262 0.793174
renov_none                        -1.093e-02  8.106e-03  -1.348 0.177579
renov_after sale                  -1.036e-01  2.194e-02  -4.722 2.35e-06 ***
renov_last 5 yr                    1.689e-02  1.442e-02   1.172 0.241407
constr_year1920-1940              -3.389e-02  5.506e-03  -6.155 7.71e-10 ***
constr_year1940-1960              -4.734e-02  6.297e-03  -7.518 5.86e-14 ***
constr_year1960-1980              -5.938e-02  6.710e-03  -8.850  < 2e-16 ***
constr_year1980-2000               3.901e-02  9.244e-03   4.220 2.46e-05 ***
constr_year_aft 2000               1.246e-01  9.840e-03  12.665  < 2e-16 ***
constr_year_bef 1900              -6.494e-03  6.544e-03  -0.992 0.321010
elevator                           1.746e-02  6.463e-03   2.702 0.006895 **
listed                             5.282e-02  1.004e-02   5.262 1.44e-07 ***
factor(story)1                    -8.190e-02  1.841e-02  -4.448 8.74e-06 ***
factor(story)2                    -5.933e-02  1.844e-02  -3.217 0.001297 **
factor(story)3                    -4.827e-02  1.853e-02  -2.605 0.009185 **
factor(story)4                    -4.146e-02  1.880e-02  -2.206 0.027426 *
factor(story)5                    -2.185e-02  1.898e-02  -1.151 0.249740
factor(story)6                    -1.139e-02  2.001e-02  -0.569 0.569213
factor(story)7                    -5.588e-03  2.723e-02  -0.205 0.837428
factor(story)8                     5.565e-02  3.063e-02   1.817 0.069260 .
stories_tot2                       2.568e-02  7.005e-03   3.666 0.000247 ***
stories_tot3                      -2.180e-02  9.390e-03  -2.321 0.020282 *
stories_tot4                      -4.860e-02  1.056e-02  -4.604 4.18e-06 ***
stories_tot5                      -7.839e-02  1.039e-02  -7.547 4.69e-14 ***
stories_tot6                      -8.920e-02  1.186e-02  -7.520 5.80e-14 ***
stories_tot7                      -8.608e-02  1.609e-02  -5.351 8.88e-08 ***
stories_tot8                      -5.120e-02  1.935e-02  -2.646 0.008147 **
stories_tot10                     -9.151e-02  2.698e-02  -3.392 0.000696 ***
stories_tot11                     -2.219e-01  2.494e-02  -8.897  < 2e-16 ***
stories_tot13                     -9.454e-02  7.305e-02  -1.294 0.195608
stories_tot14                     -1.252e-01  5.870e-02  -2.132 0.033011 *
stories_tot15                     -1.700e-01  3.948e-02  -4.306 1.67e-05 ***
stories_tot16                     -6.356e-02  4.572e-02  -1.390 0.164476

School attendance zone fixed effects    YES
---
Signif. codes:  0 *** 0.001 ** 0.01 * 0.05 . 0.1   1

Approximate significance of smooth terms:
                                  edf Ref.df       F p-value
s(livingspace):factor(house)0   5.154  5.661 1451.35 < 2e-16 ***
s(livingspace):factor(house)1   4.509  5.479  305.98 < 2e-16 ***
s(road_quiet):factor(house)0    3.239  3.686   59.83 < 2e-16 ***
s(road_quiet):factor(house)1    3.206  3.651   86.94 < 2e-16 ***
s(CBD)                          3.855  3.990   31.80 < 2e-16 ***
s(lotsize)                      2.752  2.957   41.45 < 2e-16 ***
```

```
s(greensp250)                    2.358  2.696   25.01  9.4e-15 ***
---
Signif. codes:  0 *** 0.001 ** 0.01 * 0.05 . 0.1   1

R-sq.(adj) =  0.869   Deviance explained = 90.6%
REML score = 2.1437e+05  Scale est. = 0.024545  n = 15892

###########################################################################################
```

Full model without fixed effects

```
################################################################################

##Period 1


Family: Gamma
Link function: log

Formula:
ksum_2000 ~ s(livingspace, by = factor(house)) + s(road_quiet, by = factor(house),
    k = 5) + s(CBD, k = 5) + s(lotsize, k = 4) + rooms.f + s(greensp250,
    k = 4) + +coastline + station + indu_500 + housing_type + +train_noise +
    air_noise + train_noise_F + +factor(toi3) + factor(bad3) +
    wall_2 + wall_3 + roof + renov + constr_year + elevator +
    listed + factor(story) + stories_tot + +factor(municipality)

Parametric coefficients:
                              Estimate Std. Error t value Pr(>|t|)
(Intercept)                  1.355e+01  2.919e-02 464.175  < 2e-16 ***
rooms.f2 rooms               1.218e-01  4.762e-03  25.581  < 2e-16 ***
rooms.f3 rooms               1.747e-01  6.009e-03  29.072  < 2e-16 ***
rooms.f4 rooms               1.822e-01  6.712e-03  27.147  < 2e-16 ***
rooms.f5 rooms               1.861e-01  7.344e-03  25.339  < 2e-16 ***
rooms.f6 or more rooms       1.931e-01  8.033e-03  24.035  < 2e-16 ***
coastline                    2.320e-04  1.259e-05  18.431  < 2e-16 ***
station                     -4.051e-05  5.394e-06  -7.510 6.04e-14 ***
indu_500                     1.384e-04  1.850e-05   7.485 7.30e-14 ***
housing_type_terr            4.102e-03  4.987e-03   0.823 0.410767
housing_type_apt            -1.225e-01  1.623e-02  -7.547 4.54e-14 ***
train_noise                 -4.428e-03  9.839e-04  -4.500 6.81e-06 ***
air_noise                   -5.574e-03  9.901e-04  -5.629 1.82e-08 ***
train_noise_F60-64 dB        2.991e-03  1.196e-02   0.250 0.802479
train_noise_F65-69 dB       -5.407e-02  4.131e-02  -1.309 0.190531
train_noise_Funder 55 dB     5.288e-04  5.496e-03   0.096 0.923357
factor(toi3)1                1.724e-01  2.383e-02   7.233 4.81e-13 ***
factor(toi3)2                2.247e-01  2.405e-02   9.343  < 2e-16 ***
factor(toi3)3                2.780e-01  2.490e-02  11.166  < 2e-16 ***
factor(bad3)1                6.525e-02  6.824e-03   9.561  < 2e-16 ***
factor(bad3)2                6.849e-02  7.672e-03   8.927  < 2e-16 ***
factor(bad3)3                2.935e-02  1.575e-02   1.863 0.062408 .
wall_2                       7.706e-03  6.352e-03   1.213 0.225074
wall_3                       6.042e-02  5.665e-03  10.665  < 2e-16 ***
roofBuilt up (flat roof)    -1.913e-02  5.653e-03  -3.384 0.000716 ***
roofCement                  -1.650e-02  6.211e-03  -2.657 0.007895 **
roofFibercement, asbestus   -1.833e-02  4.751e-03  -3.859 0.000114 ***
roofTar paper               -8.339e-03  5.087e-03  -1.639 0.101133
roofGlazed                   7.654e-03  4.741e-03   1.614 0.106430
```

renov_none	9.201e-03	8.701e-03	1.057	0.290291	
renov_after sale	-7.334e-02	9.795e-03	-7.487	7.20e-14	***
renov_last 5 yr	2.695e-02	1.033e-02	2.610	0.009050	**
constr_year1920-1940	-3.764e-02	3.241e-03	-11.612	< 2e-16	***
constr_year1940-1960	-4.478e-02	3.756e-03	-11.922	< 2e-16	***
constr_year1960-1980	-4.874e-02	4.057e-03	-12.013	< 2e-16	***
constr_year1980-2000	8.850e-02	5.942e-03	14.896	< 2e-16	***
constr_year_aft 2000	1.814e-01	8.396e-03	21.604	< 2e-16	***
constr_year_bef 1900	2.309e-02	3.821e-03	6.043	1.53e-09	***
elevator	2.782e-02	4.207e-03	6.613	3.81e-11	***
listed	1.027e-01	6.073e-03	16.906	< 2e-16	***
factor(story)1	-1.006e-01	1.320e-02	-7.624	2.51e-14	***
factor(story)2	-8.020e-02	1.319e-02	-6.079	1.22e-09	***
factor(story)3	-6.777e-02	1.326e-02	-5.112	3.20e-07	***
factor(story)4	-6.406e-02	1.340e-02	-4.780	1.76e-06	***
factor(story)5	-5.747e-02	1.354e-02	-4.243	2.21e-05	***
factor(story)6	-4.892e-02	1.431e-02	-3.419	0.000630	***
factor(story)7	-3.419e-03	1.940e-02	-0.176	0.860133	
factor(story)8	1.750e-02	2.108e-02	0.830	0.406397	
stories_tot2	4.389e-02	4.549e-03	9.648	< 2e-16	***
stories_tot3	9.842e-03	5.844e-03	1.684	0.092206	.
stories_tot4	3.275e-03	6.528e-03	0.502	0.615875	
stories_tot5	-1.627e-02	6.340e-03	-2.567	0.010270	*
stories_tot6	-1.841e-02	7.205e-03	-2.555	0.010630	*
stories_tot7	1.026e-02	1.172e-02	0.876	0.381121	
stories_tot8	6.545e-02	1.589e-02	4.118	3.83e-05	***
stories_tot10	-3.973e-02	1.988e-02	-1.999	0.045662	*
stories_tot11	-5.550e-03	1.991e-02	-0.279	0.780379	
stories_tot13	4.909e-02	5.387e-02	0.911	0.362146	
stories_tot14	-1.956e-02	4.294e-02	-0.456	0.648682	
stories_tot15	-1.096e-01	2.285e-02	-4.795	1.63e-06	***
stories_tot16	-2.650e-02	2.608e-02	-1.016	0.309594	
factor(municipality)147	8.810e-02	3.379e-03	26.070	< 2e-16	***
factor(municipality)151	-1.392e-01	9.963e-03	-13.970	< 2e-16	***
factor(municipality)153	-1.908e-01	9.186e-03	-20.772	< 2e-16	***
factor(municipality)155	-1.341e-02	1.073e-02	-1.250	0.211181	
factor(municipality)157	2.681e-01	5.128e-03	52.284	< 2e-16	***
factor(municipality)159	3.584e-02	6.271e-03	5.715	1.10e-08	***
factor(municipality)161	-1.165e-01	9.295e-03	-12.533	< 2e-16	***
factor(municipality)163	-7.476e-02	9.384e-03	-7.967	1.67e-15	***
factor(municipality)165	-1.848e-01	1.093e-02	-16.903	< 2e-16	***
factor(municipality)167	-9.343e-02	5.660e-03	-16.506	< 2e-16	***
factor(municipality)169	-2.026e-01	1.569e-02	-12.914	< 2e-16	***
factor(municipality)173	1.519e-01	8.150e-03	18.638	< 2e-16	***
factor(municipality)175	-5.351e-02	5.890e-03	-9.085	< 2e-16	***
factor(municipality)185	-4.076e-02	6.401e-03	-6.368	1.94e-10	***
factor(municipality)187	-1.487e-01	1.006e-02	-14.776	< 2e-16	***

School attendance zone fixed effects NO

```
---
Signif. codes:  0 *** 0.001 ** 0.01 * 0.05 . 0.1   1

Approximate significance of smooth terms:
                                   edf Ref.df       F p-value
s(livingspace):factor(house)0    5.577  5.957 2897.42  <2e-16 ***
s(livingspace):factor(house)1    5.864  6.820  576.61  <2e-16 ***
s(road_quiet):factor(house)0     3.600  3.906  114.79  <2e-16 ***
s(road_quiet):factor(house)1     3.554  3.873  152.71  <2e-16 ***
s(CBD)                           3.965  3.999  330.54  <2e-16 ***
s(lotsize)                       1.004  1.009  289.76  <2e-16 ***
s(greensp250)                    2.255  2.599   55.08  <2e-16 ***
---
Signif. codes:  0 *** 0.001 ** 0.01 * 0.05 . 0.1   1

R-sq.(adj) =   0.86   Deviance explained = 89.4%
REML score = 4.9766e+05  Scale est. = 0.02492   n = 37074

##########################################################################################

##Period 2


Family: Gamma
Link function: log

Formula:
ksum_2000 ~ s(livingspace, by = factor(house)) + s(road_quiet, by = factor(house),
    k = 5) + s(CBD, k = 5) + s(lotsize, k = 4) + rooms.f + s(greensp250,
    k = 4) + +coastline + station + indu_500 + housing_type + +train_noise +
    air_noise + train_noise_F + +factor(toi3) + factor(bad3) +
    wall_2 + wall_3 + roof + renov + constr_year + elevator +
    listed + factor(story) + stories_tot + +factor(municipality)

Parametric coefficients:
                                   Estimate Std. Error t value Pr(>|t|)
(Intercept)                       1.379e+01  3.918e-02 351.990  < 2e-16 ***
rooms.f2 rooms                    9.675e-02  5.617e-03  17.225  < 2e-16 ***
rooms.f3 rooms                    1.482e-01  6.886e-03  21.524  < 2e-16 ***
rooms.f4 rooms                    1.594e-01  7.660e-03  20.810  < 2e-16 ***
rooms.f5 rooms                    1.650e-01  8.493e-03  19.428  < 2e-16 ***
rooms.f6 or more rooms            1.818e-01  9.421e-03  19.299  < 2e-16 ***
coastline                         2.124e-04  1.455e-05  14.593  < 2e-16 ***
station                          -2.147e-05  6.444e-06  -3.332 0.000864 ***
indu_500                          1.200e-04  2.103e-05   5.705 1.18e-08 ***
housing_type_terr                 2.268e-02  6.698e-03   3.386 0.000710 ***
housing_type_apt                 -1.666e-01  1.892e-02  -8.807  < 2e-16 ***
train_noise                      -3.620e-03  1.174e-03  -3.082 0.002058 **
air_noise                        -8.274e-03  1.104e-03  -7.494 6.90e-14 ***
```

train_noise_F60-64 dB	-2.053e-02	1.405e-02	-1.461	0.144061	
train_noise_F65-69 dB	-1.287e-01	4.471e-02	-2.880	0.003981	**
train_noise_Funder 55 dB	-8.370e-03	6.691e-03	-1.251	0.210944	
factor(toi3)1	4.827e-02	3.492e-02	1.382	0.166918	
factor(toi3)2	8.732e-02	3.515e-02	2.484	0.012984	*
factor(toi3)3	1.399e-01	3.606e-02	3.879	0.000105	***
factor(bad3)1	6.186e-02	8.856e-03	6.985	2.93e-12	***
factor(bad3)2	8.299e-02	9.874e-03	8.405	< 2e-16	***
factor(bad3)3	6.545e-02	1.882e-02	3.477	0.000507	***
wall_2	-9.521e-03	7.435e-03	-1.281	0.200332	
wall_3	2.468e-02	6.561e-03	3.762	0.000169	***
roofBuilt up (flat roof)	-1.274e-02	6.337e-03	-2.011	0.044370	*
roofCement	2.382e-03	7.274e-03	0.327	0.743338	
roofFibercement, asbestus	-7.740e-03	5.460e-03	-1.418	0.156304	
roofTar paper	4.222e-03	5.767e-03	0.732	0.464150	
roofGlazed	2.043e-02	5.401e-03	3.782	0.000156	***
renov_none	-1.783e-02	6.724e-03	-2.652	0.008011	**
renov_after sale	-1.053e-01	1.054e-02	-9.987	< 2e-16	***
renov_last 5 yr	-8.711e-03	9.759e-03	-0.893	0.372081	
constr_year1920-1940	-3.761e-02	3.935e-03	-9.559	< 2e-16	***
constr_year1940-1960	-6.807e-02	4.549e-03	-14.964	< 2e-16	***
constr_year1960-1980	-7.238e-02	4.874e-03	-14.852	< 2e-16	***
constr_year1980-2000	2.328e-02	6.807e-03	3.420	0.000627	***
constr_year_aft 2000	5.222e-02	7.160e-03	7.294	3.10e-13	***
constr_year_bef 1900	1.032e-02	4.659e-03	2.214	0.026838	*
elevator	1.737e-02	4.625e-03	3.757	0.000172	***
listed	7.624e-02	7.180e-03	10.619	< 2e-16	***
factor(story)1	-3.601e-02	1.517e-02	-2.373	0.017631	*
factor(story)2	-1.414e-02	1.517e-02	-0.932	0.351385	
factor(story)3	-2.702e-03	1.524e-02	-0.177	0.859290	
factor(story)4	4.512e-03	1.543e-02	0.292	0.769962	
factor(story)5	1.540e-02	1.559e-02	0.988	0.323209	
factor(story)6	3.450e-02	1.640e-02	2.104	0.035408	*
factor(story)7	7.221e-02	2.119e-02	3.408	0.000655	***
factor(story)8	9.316e-02	2.305e-02	4.042	5.31e-05	***
stories_tot2	3.040e-02	5.522e-03	5.506	3.71e-08	***
stories_tot3	9.095e-03	6.911e-03	1.316	0.188192	
stories_tot4	4.975e-03	7.698e-03	0.646	0.518050	
stories_tot5	-1.354e-02	7.471e-03	-1.813	0.069832	.
stories_tot6	-1.208e-02	8.485e-03	-1.424	0.154494	
stories_tot7	-8.526e-03	1.210e-02	-0.705	0.481040	
stories_tot8	-1.657e-02	1.619e-02	-1.023	0.306127	
stories_tot10	2.365e-02	2.337e-02	1.012	0.311555	
stories_tot11	-6.534e-02	1.635e-02	-3.996	6.45e-05	***
stories_tot13	3.979e-02	5.805e-02	0.686	0.492988	
stories_tot14	-2.068e-02	3.756e-02	-0.551	0.581880	
stories_tot15	-1.461e-01	2.938e-02	-4.971	6.70e-07	***
stories_tot16	-1.260e-01	2.961e-02	-4.255	2.10e-05	***
factor(municipality)147	6.123e-02	3.982e-03	15.379	< 2e-16	***

```
factor(municipality)151          -1.740e-01  1.232e-02 -14.120  < 2e-16 ***
factor(municipality)153          -2.361e-01  1.154e-02 -20.456  < 2e-16 ***
factor(municipality)155          -6.289e-02  1.309e-02  -4.806 1.55e-06 ***
factor(municipality)157           2.625e-01  6.294e-03  41.705  < 2e-16 ***
factor(municipality)159          -1.664e-02  7.557e-03  -2.202 0.027647 *
factor(municipality)161          -1.696e-01  1.124e-02 -15.085  < 2e-16 ***
factor(municipality)163          -1.144e-01  1.163e-02  -9.838  < 2e-16 ***
factor(municipality)165          -2.503e-01  1.329e-02 -18.828  < 2e-16 ***
factor(municipality)167          -1.227e-01  7.072e-03 -17.346  < 2e-16 ***
factor(municipality)169          -2.899e-01  1.886e-02 -15.368  < 2e-16 ***
factor(municipality)173           1.180e-01  1.002e-02  11.781  < 2e-16 ***
factor(municipality)175          -9.994e-02  6.918e-03 -14.446  < 2e-16 ***
factor(municipality)185          -8.712e-02  7.630e-03 -11.418  < 2e-16 ***
factor(municipality)187          -2.179e-01  1.247e-02 -17.475  < 2e-16 ***

School attendance zone fixed effects   NO
---
Signif. codes:  0 *** 0.001 ** 0.01 * 0.05 . 0.1   1

Approximate significance of smooth terms:
                                 edf Ref.df       F  p-value
s(livingspace):factor(house)0  5.423  5.857 2113.21  < 2e-16 ***
s(livingspace):factor(house)1  5.069  6.060  382.20  < 2e-16 ***
s(road_quiet):factor(house)0   3.832  3.983   95.38  < 2e-16 ***
s(road_quiet):factor(house)1   3.350  3.750  135.81  < 2e-16 ***
s(CBD)                         3.959  3.999  324.69  < 2e-16 ***
s(lotsize)                     1.748  2.153  115.47  < 2e-16 ***
s(greensp250)                  1.647  1.983   23.67 6.39e-11 ***
---
Signif. codes:  0 *** 0.001 ** 0.01 * 0.05 . 0.1   1

R-sq.(adj) =  0.856   Deviance explained = 88.5%
REML score = 3.4692e+05  Scale est. = 0.025119   n = 25805

##########################################################################################

##Period 3


Family: Gamma
Link function: log

Formula:
ksum_2000 ~ s(livingspace, by = factor(house)) + s(road_quiet, by = factor(house),
    k = 5) + s(CBD, k = 5) + s(lotsize, k = 4) + rooms.f + s(greensp250,
    k = 4) + +coastline + station + indu_500 + housing_type + +train_noise +
    air_noise + train_noise_F + +factor(toi3) + factor(bad3) +
    wall_2 + wall_3 + roof + renov + constr_year + elevator +
    listed + factor(story) + stories_tot + +factor(municipality)
```

```
Parametric coefficients:
                                Estimate Std. Error t value Pr(>|t|)
(Intercept)                    1.390e+01  4.589e-02 302.845  < 2e-16 ***
rooms.f2 rooms                 7.939e-02  8.249e-03   9.624  < 2e-16 ***
rooms.f3 rooms                 1.251e-01  9.880e-03  12.660  < 2e-16 ***
rooms.f4 rooms                 1.365e-01  1.077e-02  12.669  < 2e-16 ***
rooms.f5 rooms                 1.536e-01  1.174e-02  13.081  < 2e-16 ***
rooms.f6 or more rooms         1.737e-01  1.301e-02  13.352  < 2e-16 ***
coastline                      2.353e-04  1.887e-05  12.472  < 2e-16 ***
station                       -1.752e-05  8.640e-06  -2.027 0.042629 *
indu_500                       1.757e-04  2.865e-05   6.135 8.73e-10 ***
housing_type_terr             -1.212e-02  7.872e-03  -1.539 0.123790
housing_type_apt              -1.896e-01  2.228e-02  -8.508  < 2e-16 ***
train_noise                   -2.584e-03  1.663e-03  -1.554 0.120253
air_noise                     -9.034e-03  1.541e-03  -5.863 4.64e-09 ***
train_noise_F60-64 dB         -4.623e-02  1.923e-02  -2.404 0.016224 *
train_noise_F65-69 dB         -1.407e-01  5.383e-02  -2.613 0.008978 **
train_noise_Funder 55 dB      -2.451e-02  8.903e-03  -2.753 0.005918 **
factor(toi3)1                  6.579e-02  3.991e-02   1.649 0.099256 .
factor(toi3)2                  9.879e-02  4.019e-02   2.458 0.013985 *
factor(toi3)3                  1.953e-01  4.173e-02   4.679 2.90e-06 ***
factor(bad3)1                  3.724e-02  1.163e-02   3.203 0.001365 **
factor(bad3)2                  5.888e-02  1.296e-02   4.543 5.60e-06 ***
factor(bad3)3                  1.645e-02  2.687e-02   0.612 0.540492
wall_2                        -1.365e-02  9.609e-03  -1.421 0.155458
wall_3                         3.079e-02  8.520e-03   3.614 0.000303 ***
roofBuilt up (flat roof)      -2.185e-02  8.329e-03  -2.623 0.008719 **
roofCement                    -1.769e-02  9.492e-03  -1.863 0.062456 .
roofFibercement, asbestus     -1.880e-02  7.217e-03  -2.605 0.009201 **
roofTar paper                  1.093e-02  7.744e-03   1.412 0.157965
roofGlazed                     3.756e-03  7.176e-03   0.523 0.600749
renov_none                    -1.136e-02  8.408e-03  -1.351 0.176608
renov_after sale              -1.003e-01  2.316e-02  -4.329 1.50e-05 ***
renov_last 5 yr                1.401e-02  1.501e-02   0.933 0.350787
constr_year1920-1940          -5.889e-02  5.361e-03 -10.986  < 2e-16 ***
constr_year1940-1960          -7.986e-02  6.178e-03 -12.927  < 2e-16 ***
constr_year1960-1980          -1.008e-01  6.616e-03 -15.228  < 2e-16 ***
constr_year1980-2000           1.158e-02  9.320e-03   1.243 0.213982
constr_year_aft 2000           5.252e-02  9.280e-03   5.659 1.55e-08 ***
constr_year_bef 1900           2.469e-02  6.273e-03   3.935 8.35e-05 ***
elevator                       5.133e-02  6.442e-03   7.968 1.72e-15 ***
listed                         8.705e-02  9.973e-03   8.728  < 2e-16 ***
factor(story)1                -8.848e-02  1.918e-02  -4.612 4.01e-06 ***
factor(story)2                -6.684e-02  1.921e-02  -3.480 0.000502 ***
factor(story)3                -5.515e-02  1.931e-02  -2.856 0.004290 **
factor(story)4                -5.125e-02  1.958e-02  -2.617 0.008880 **
factor(story)5                -3.393e-02  1.979e-02  -1.714 0.086508 .
factor(story)6                -1.119e-02  2.088e-02  -0.536 0.592146
```

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factor(story)7                    -3.220e-03  2.871e-02   -0.112 0.910704
factor(story)8                     5.972e-02  3.226e-02    1.851 0.064134 .
stories_tot2                       3.492e-02  7.035e-03    4.965 6.95e-07 ***
stories_tot3                      -8.217e-03  9.495e-03   -0.865 0.386788
stories_tot4                      -1.631e-02  1.055e-02   -1.547 0.121991
stories_tot5                      -5.961e-02  1.020e-02   -5.846 5.12e-09 ***
stories_tot6                      -6.692e-02  1.162e-02   -5.759 8.62e-09 ***
stories_tot7                      -6.764e-02  1.608e-02   -4.207 2.61e-05 ***
stories_tot8                      -3.273e-02  1.947e-02   -1.681 0.092807 .
stories_tot10                     -4.742e-02  2.750e-02   -1.724 0.084638 .
stories_tot11                     -1.669e-01  2.477e-02   -6.738 1.66e-11 ***
stories_tot13                     -1.772e-02  7.685e-02   -0.231 0.817621
stories_tot14                     -5.562e-02  6.138e-02   -0.906 0.364879
stories_tot15                     -1.299e-01  3.865e-02   -3.361 0.000779 ***
stories_tot16                     -1.778e-01  4.645e-02   -3.828 0.000130 ***
factor(municipality)147            7.896e-02  5.336e-03   14.797  < 2e-16 ***
factor(municipality)151           -1.507e-01  1.594e-02   -9.451  < 2e-16 ***
factor(municipality)153           -2.351e-01  1.492e-02  -15.760  < 2e-16 ***
factor(municipality)155           -1.860e-02  1.759e-02   -1.057 0.290406
factor(municipality)157            2.712e-01  8.393e-03   32.313  < 2e-16 ***
factor(municipality)159           -1.114e-04  1.041e-02   -0.011 0.991461
factor(municipality)161           -1.368e-01  1.511e-02   -9.053  < 2e-16 ***
factor(municipality)163           -1.053e-01  1.449e-02   -7.270 3.77e-13 ***
factor(municipality)165           -2.064e-01  1.748e-02  -11.813  < 2e-16 ***
factor(municipality)167           -9.059e-02  9.639e-03   -9.398  < 2e-16 ***
factor(municipality)169           -2.525e-01  2.548e-02   -9.910  < 2e-16 ***
factor(municipality)173            1.319e-01  1.353e-02    9.750  < 2e-16 ***
factor(municipality)175           -6.704e-02  9.708e-03   -6.905 5.19e-12 ***
factor(municipality)185           -6.270e-02  1.013e-02   -6.189 6.21e-10 ***
factor(municipality)187           -1.564e-01  1.666e-02   -9.385  < 2e-16 ***

School attendance zone fixed effects    NO
---
Signif. codes:  0 *** 0.001 ** 0.01 * 0.05 . 0.1   1

Approximate significance of smooth terms:
                                 edf Ref.df       F  p-value
s(livingspace):factor(house)0  5.214  5.705 1472.14  < 2e-16 ***
s(livingspace):factor(house)1  4.450  5.414  338.41  < 2e-16 ***
s(road_quiet):factor(house)0   3.461  3.835   97.48  < 2e-16 ***
s(road_quiet):factor(house)1   3.146  3.601   88.64  < 2e-16 ***
s(CBD)                         3.927  3.997  196.62  < 2e-16 ***
s(lotsize)                     1.019  1.037   94.39  < 2e-16 ***
s(greensp250)                  2.454  2.772   26.83 3.52e-16 ***
---
Signif. codes:  0 *** 0.001 ** 0.01 * 0.05 . 0.1   1

R-sq.(adj) =  0.846   Deviance explained = 89.2%
REML score = 2.15e+05  Scale est. = 0.027827   n = 15892
```