Estimating non-marginal willingness to pay for railway noise abatements: Application of the two-step hedonic regression technique*

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Abstract

In this study we estimate the willingness to pay for railway noise abatements based on the effect of railway noise on property prices. We estimate both steps of the hedonic regression technique on a large data set of different Swedish regions which contains detailed information about railway noise along with socioeconomic characteristics for each property/household. The estimated demand relationship suggest welfare gains for a 1 dB reduction of railway noise as; 1240 SEK per individual and year at the baseline noise level of 71 dB, and 661 SEK at the baseline noise level of 61 dB. Below a noise level of 49.09 dB, individuals have no willingness to pay for railway noise abatements. In policy, these results can be used for cost benefit analysis and to derive marginal costs for infrastructure charges.

Keywords: Railway noise; Hedonic regression; Willingness to pay; Instrument variables

JEL Codes: C13; C21; Q51; Q53

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1 Introduction

Transport related noise is a major environmental and health problem in many developed countries. In Sweden, for example, recent calculations estimate that about 1 730 000 individuals and 225 000 individuals are exposed to transport noise above the equivalent level of 55 dB caused by road traffic and railway traffic, respectively (Simonsson, 2009). Furthermore, since one of the policy objectives for the transport sector is accessibility, transport activity naturally occurs most frequently in areas where people live and work. Thus, further urbanization in the future will *ceteris paribus* lead to even more problems caused by transport noise.

Considering these problems caused by noise, there is a demand for operations and investments that mitigate noise problems. However, these operations and investments are not costless which indicates that there is a trade-off between accepting the noise exposure and using valuable resources to reduce it.

The benefit of noise abatement efforts cannot be directly monetized since there is no market for noise abatement. Instead the willingness to pay (WTP) determined by individual preferences has to be derived either indirectly from another market where individuals implicitly trade noise exposure against other attributes, or by stated preference techniques.

The WTP for noise abatements is transport-policy relevant mainly for two reasons: (1), it should be included in cost benefit analysis (CBA) of operations and investments in transport infrastructure or other areas that impact the noise level; and (2), it can be used to derive marginal costs of transport noise useful for infrastructure charging which internalizes the external cost of noise as well as implies incentives for the noise polluters to invest in noise-reducing technologies or take other actions that reduces the noise level.

Earlier research that estimate the WTP for noise abatements mostly rely on regression on property prices based on Rosen's (1974) hedonic regression technique where the implicit price of noise is the parameter of the noise variable in a property price regression.[1] An important strength of using this method is that the data is based on revealed preferences, i.e. actual market data.

However, most previous research has focused on noise caused by road traffic, and sometimes aircraft, but not often on railway noise, where the latter also is a major problem in many countries. For example, the review of the hedonic methodology for transportation noise studies by Nelson (2008) refers merely on road and aircraft traffic. In addition, previous research, with a few exceptions, only focuses on the first step of the hedonic regression technique. Using the first step implies that the estimates are market-specific and is only valid for marginal changes of noise exposure.

Among other first-step hedonic studies, Andersson et al. (2009) estimated the *Noise Sensitivity Depreciation Index* (NSDI), which states the percentage reduction in property value due to a 1 dB increase in noise exposure, to be ranging from 0.08 to 4.09 including a strongly positive correlation between NSDI and the level of noise exposure for railway traffic. Furthermore, in a literature review by Bateman et al. (2001), 28 previous studies of road noise have resulted in an NSDI interval from 0.08 up to 2.22 with a mean NSDI of about 0.55. Additionally, in a Dutch study, Theebe (2004) estimates the NSDI for traffic noise reductions to be between 0.3 and 0.5. These mixed results point out that the WTP for noise abatements is to a high degree context dependent and highlights the need for a method that goes beyond the limits of the first-step analysis.

Therefore, Day et al. (2007) extended the analysis to incorporate the second step of the hedonic regression technique wherein demand functions for the good "peace and quiet", i.e. the opposite of noise, are estimated. These second-step estimates recovers the preference structure as they are not equilibrium dependent and are thus theoretically valid to use

[1] Some studies are also based on stated preference methods, for example Sælensminde (1999); Parumog et al. (2006).

for non-marginal changes of peace and quiet, which often is the case when noise-reducing operations are realized.

In this study, we estimate the demand for peace and quiet based on the two-step hedonic regression technique. We improve the method of Day et al. (2007) in three different aspects. First, we use data from several geographically separate submarkets to estimate the effect from railway noise on the property value. In particular we use data of seven different municipalities in Sweden where most of them differ significantly with respect to location and averages of socioeconomic characteristics. Day et al. (2007, p. 230) noted that a combination of first-stage analysis applied in more than one urban area together would provide a far stronger basis for identification of the demand relationship. Second, we perform the second stage of the hedonic regression technique to estimate the demand for peace and quiet by including socioeconomic characteristics of the individual level. Finally, we have access to a lot more properties that are exposed to railway noise.

The demand for peace and quiet is used to calculate welfare estimates of noise abatements, which also are applicable to other locations with another supply of quiet housing. Also, from the estimated demand for peace and quiet we can derive marginal costs that can be used for railway infrastructure charges, which however is not the scope of this paper and therefore not provided here.

The rest of the paper is outlined as follows. In the next section we describe the hedonic regression technique. In Section 3, we present our data including housing market segmentation, the estimation sample and descriptive statistics. Thereafter follows the modeling framework in Section 4. Section 5 provides results of the hedonic regression steps and the estimated welfare effects. The paper is concluded in Section 6.

2 Hedonic regression technique

The hedonic regression technique is the basis for the estimation in this paper. Rosen (1974) showed that in an economy with utility and profit maximizing individuals and firms, the marginal WTP for attributes of composite goods will equal their implicit prices in a differentiated market. Here below, we describe how the technique is used in our study.[2]

The property price model is formulated as

$$P_i = P(Q_i, \mathbf{A}_i, \mathbf{G}_i), \ \forall \ i \in j, \tag{1}$$

where i denotes the individual property, j denotes the housing market, Q is the level of peace and quiet, $\mathbf{A}$ is a vector of property characteristics, and $\mathbf{G}$ is a vector of geographical variables.

Rosen (1974) showed that the consumer's WTP for the good will equal its market price. We assume the market to be in optimum where the consumer's marginal WTP equals her marginal rate of substitution between the price of the good and any of the attributes, that is the slope of the price function determines the marginal WTP of the consumer. From Eq. (1) we can calculate the implicit price of peace and quiet, π_{ij}, as

$$\pi_{ij} = \frac{\partial P}{\partial Q_{ij}}, \tag{2}$$

where $\pi_{ij} > 0$ is expected.

Eq. (1) is known as the *first step* of the hedonic regression technique and reveals the marginal WTP in optimum, which also depends on the supply side of the market, i.e. it does not reveal the underlying preference structure. Therefore, in the *second step*, the

[2] See e.g. Bateman et al. (2001); Freeman (2003); Haab and McConnell (2003); Ekeland et al. (2004); Palmquist (2005); Andersson (2008) for a more comprehensive description of the technique, or the original source, Rosen (1974).

preference parameters are estimated using the results from the first step, together with information on the household of the property-owner, $\mathbf{S}$, which results in the estimated demand (Marshallian) for peace and quiet. From this demand we can calculate theoretically consistent WTP for non-marginal changes of peace and quiet. Note that by applying this method we assume a homogeneous demand function for all housing markets.[3]

In accordance with Day et al. (2007), we specify the equation in the second step as demand for peace and quiet and not the WTP-function as suggested by Rosen (1974). The main reason is the accessibility to instruments since endogeneity problems will arise in both specifications, but the instrumented variable will differ. To find instruments for peace and quiet, which is not correlated with the implicit price of peace and quiet through the property price, would be very difficult. In other words, we find it easier to instrument the implicit price of peace and quiet compared to the quantity of peace and quiet. Then, in our application, the second step model is specified as

$$Q_{ij} = Q(\pi_{ij}, \mathbf{S}_{ij}, \mathbf{A}_{ij}, \mathbf{G}_{ij}), \ \forall \ j. \tag{3}$$

3 Data

Data from seven Swedish municipalities with different characteristics are used in this study. The choice of the municipalities are mainly driven by a sufficient number of properties exposed to different levels of railway noise and no large roads close to the railway. We also want the municipalities to be geographically located in different parts of Sweden. The municipalities we use are Töreboda, Sollentuna, Falköping, Hässleholm, Kungsbacka, Alingsås and Gävle. The locations of these municipalities are shown in the

[3]Another possible estimation approach is to assume a specific utility function and derive non-marginal WTP from estimations of the expenditure rates (see e.g. Wilhelmsson, 2002).

map of Figure 1 and in Table 1, characteristics of the municipalities is presented.

[Figure 1 about here.]

[Table 1 about here.]

We can see that the municipalities show a mixture of population size and location with respect to urban areas. Töreboda is a very small municipality located in the rural area. Sollentuna, Kungsbacka and Alingsås can be categorized as suburb municipalities located close to Stockholm or Göteborg. Gävle is the largest municipality and also the center of its region, whereas Falköping and Hässleholm is mid-sized municipalities located too far away from an urban area to be considered as suburb municipalities.

3.1 Data sources

The data set used originates from three sources. The data on prices and attributes of the properties are from the *National Land Survey of Sweden*. The property attributes also contain the geographical coordinates, which are used here to derive geographical variables. The data set covers all sales of single family houses from the autumn of 1996 to September 2009. We deflate the property prices to the value of 2009 by regional property price indices for the county of which the municipality belongs to.[4]

Railway noise levels are equivalent sound pressure levels (dB) for a full 24-hour period and calculated at two meters height above ground at the center of the property, following the standardized "Nordic methods" (Jonasson and Nielsen, 1996; Ringheim, 1996).

Individual socioeconomic characteristics are provided as register data by *Statistics Sweden*.[5] This means that we have data of all individuals that are registered to live in a

[4] These indices are used instead of consumer price index because the price increase of properties in Sweden between 1996 and 2009 was much larger than the increase of consumer prices. In fact, for properties this increase was 171 percent whereas the increase was only 17 percent for consumer prices.

[5] For integrity reasons, Statistics Sweden merge the socioeconomic data with our property data only under the condition

given housing property at the end of the purchase year of the property. The variables we utilize are income (available up to year 2008), age, household size and education level.

The following four sub subsections describe the groups of variables used as explanatory variables in the property price equations and in the demand equation respectively.

3.1.1 Structural variables

Structural variables define property characteristics. We use property type, living space, subsidiary space, property area, quality index, age of the dwelling, and an indicator variable for properties bordering on the sea/lake. Property types are distinguished between detached, linked by a garage and terraced. The quality index is based on a self-reported form that the house owners fill in for the tax assessment concerning the indoor-quality of the property, for instance the standard of the kitchen, number of bathrooms, the existence of an open fire place or a sauna, etc. When the age of the dwelling is missing we use 39 years, which is the average observable age of the dwelling in our estimation sample.

3.1.2 Geographical variables

The geographical variables are derived from the coordinates of each property and are supposed to capture accessibility differences and environmental disutility sources other than noise exposure within each municipality. As geographical variables, when applicable, we use distance to nearest train station, indicator for countryside[6], distance to nearest large main road, and distance to nearest motorway entrance road. Distance is throughout our study defined as the crow flies.

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that we cannot trace individual properties. This means that Statistics Sweden had deleted all geographical coordinates when we received the merged data set, which potentially can be a limit to our analysis since we cannot use coordinates in the second step of the hedonic model.

[6]In Sollentuna there is no clear countryside. Instead we divide Sollentuna into five different geographical areas.

3.1.3 Noise indicator

The most commonly used noise indicator is the A-weighted equivalent sound pressure level, which is an energy average over a certain time period, normally 24 hours, denoted as $L_{\mathrm{AEq,24h}}$. The A-weighting approximates the varying sensitivity of the human ear to different frequencies. The equivalent level is a good indicator of overall annoyance, but for sleep disturbance a better choice is the maximum level, which is normally defined as the maximum noise level occurring during a certain time period.

The dB-scale used in this study does not have a natural zero point; instead, the zero of the scale is determined by convention (see Sandberg and Ejsmont, 2002). The sound pressure level 0 dB corresponds to a sound pressure of 20 μPa, which is roughly the lowest audible level for a tonal sound at a frequency of 1000 Hz. The total absence of sound is represented by a sound pressure of 0 Pa, corresponding to negative infinity on the dB scale ($-\infty$ dB). For other environmental effects it makes sense to use valuations that vanish when the effect variable becomes zero (for instance, number of particles per m^3 describing air pollution), but the same is not true for noise measured in dBs. The effect should be zero when no negative effect is observed from noise, and in our study we have chosen to use a lower limit of 45 dB for $L_{\mathrm{AEq,24h}}$. This limit is somewhat arbitrarily determined, but the percentage of persons reporting that they are annoyed by traffic noise is very low below this level (Miedema and Oudshoorn, 2001).

The railway noise is calculated using the "Nordic method" for railway traffic noise (Ringheim, 1996). The noise exposure is calculated at the height of two meters above the center of the property area. The effect of screening by the terrain or noise barriers is taken into account but not the effect of buildings. The height profile is determined in a grid with a resolution of 25 meters.

As a control variable, road noise is also used in areas where there are major roads.

For the road traffic noise the L_{DEN} indicator is used, which is approximately 3 dB higher than the equivalent level $L_{\mathrm{AEq,24h}}$. The calculated values were taken from the official Swedish calculations according to the Environmental Noise Directive (END). The values are in 10 dB intervals starting from L_{DEN} 55 dB, so they are just a rough indication of the presence of road traffic noise.

In Alingsås and Kungsbacka there are areas which due to the properties of the ground are known to be sensitive to building vibrations mainly from freight traffic. Such vibrations increase the annoyance from noise reported in social surveys as reported in Öhrström et al. (2010), and may influence the WTP in these areas. There is no standardized calculation method for such vibrations, and apart from the properties of the ground and the track and embankment the details of the buildings are also very important. Therefore no effort has been taken to include vibrations as a variable in this study.

Finally, in accordance with Day et al. (2007), we transform the "bad" noise exposure to the "good" peace and quiet. Here we first set the noise exposure to be the calculated noise level minus 45. Then we multiply this variable with -1 and add slightly more than the maximum noise level of the full sample so that the lowest level of peace and quiet exceeds 1. Specifically, this means that peace and quiet is equal to 0 when the equivalent railway noise level is 75 dB. The reason for the latter operation is to ensure positive values of peace and quiet that can be transformed to its natural logarithm in an adequate way without resulting in extreme values.

3.1.4 Socioeconomic variables

For all individuals that are registered to live in a given housing property we have data on registered income, gender, age and education level. We translate these data to household variables as described below.

Our household income variable includes labor income, capital income and transfer payments for all household members. In accordance with the property prices, we deflate the income to the year of 2009. Labor income and capital income cannot be separated in our data and since we expect labor income to be larger than capital income for most of the households, we use the labor income index to deflate the sum of labor income and capital income. The Swedish transfer payment system uses a price-adjusted base amount to adjust transfer payments over time and therefore we also use this base amount to deflate the transfer payments to the value of year 2009.

The choice to buy a property may be heavily dependent on expectations of future income and not only on income of the purchasing year of the property. To account for this effect we use the income of the purchasing year as well as the income the year after as covariates. Note also that for a purchase in the end of a year it may be more relevant to expect a stronger effect from the income in the year after compared to the income in the year of the purchase.

Education level is categorized in four different levels. We use indicator variables for the two oldest household members, which are assumed to be the adults. When there is no second oldest household member, i.e. for single households, and for households where the second oldest household member is more than 18 years younger than the oldest household member we use a combination indicator variable. The latter is supposed to capture the effect where the second oldest household member is the child of the oldest household member, which is not observable in data.

We also include the number of children in a household defined in different age groups. The groups are 0-3 years of age, 4-6 years of age, 7-11 years of age, and 12-17 years of age.

Finally, we also include an indicator variable for single households.

3.2 Market segmentations

To identify the different structures of the implicit prices of peace and quiet, we want to segment the market into different submarkets. Here it is important that the property demanders exogenously belong to a given market and which market they belong to should not be a decision simultaneously with their choice of peace and quiet and other housing attributes. In our data, we have distinguished geographical regions which are a natural basis for the housing market segmentation.

However, some of the municipalities belong to the same local labor market region and thus it can be questioned if they are distinguished housing markets.[7] This holds for Kungsbacka and Alingsås, and Töreboda and Falköping, respectively.[8] Our decision for these markets is based on a pooled first-stage hedonic OLS regression for the municipalities belonging to the same local labor market. Here we include an indicator for one of the municipalities and an interaction variable between the municipality indicator and peace and quiet. For Töreboda and Falköping, these variables are jointly significant with a p-value less than 0.001 so we conclude that these two municipalities are separate housing markets. For Kungsbacka and Alingsås, on the other hand, the corresponding p-value 0.314 and thus we merge Kungsbacka and Alingsås to one single housing market.

Furthermore, we do not want to use socioeconomic characteristics as the basis for housing market segmentation (as in Day et al., 2007) since these characteristics are used in the second step to identify shifts in the demand curve for peace and quiet. Thus we avoid the circularity in the estimation strategy caveated by Day et al. (2007, p. 230).

[7] Local labor market regions are defined by Statistics Sweden based on commuting flows between municipalities.

[8] Alingsås and Kungsbacka belong to the local labor market region of Göteborg whereas Töreboda and Falköping belong to the local labor market region of Skövde.

Then remains property characteristics as a potential source for further housing market segmentation. Living space, for example, would serve as a good basis for housing market segmentation since most property demanders have predetermined their demand for a house of a specific size, at least within a relatively narrow interval. In other words, property demanders mostly have decided if they want to purchase a small house or a large house. As will be described in subsection 4.2, we are using living space as an instrument variable and thus to use housing attributes also to segment the housing market is not adequate.

To sum up, our different housing markets will be based on the six different geographical regions in our data.

3.3 Estimation sample

To mitigate the effect of influential outliers and to create sufficiently homogeneous estimation samples we have restricted the samples in several ways.

Firstly, to be included in the sample, the equivalent railway noise level have to be above 45 dB, which is assumed to be the minimum noise level that can be experienced as disturbing and therefore influence the property price.[9] For Gävle, only properties with equivalent railway noise level above 50 dB is included. The complex structure of different motorways and railway lines in Gävle implies that including equivalent railway noise below 50 dB may distort the estimated model.

We also restrict the sample with respect to living space and property area. For living space we exclude observations of 30 square meters or lower and 506 square meters or higher. Regarding property area, we exclude areas above 10 000 square meters which we believe might be properties used for business activities and not for private housing. In

[9] A very low percentage of individuals report that they are annoyed by traffic noise below the level of 45 dB (Miedema and Oudshoorn, 2001).

addition, the railway noise is measured at the center of the property and if the property area is large, this measure point may be misleading since we do not observe where the dwelling-place is located. Only a few observations are excluded by these property size restrictions, however.

Since no registered income data for 2009 is available yet and since we use a lead variable of income, only data up to year 2007 is used in the estimation of the second step. In the first step estimation we still use data up to year 2009 to increase the number of observation and thus utilize the maximum available information. Also, for some households there is no available income, which means that the sample size of the second step will be further smaller than the sample size of the first step. However, these drop-outs are not in any way systematic with respect to the different housing markets.

3.4 Descriptive statistics

Descriptive statistics is presented in Table 2. When interpreting these data, recall that the included observations are only households that purchase a property exposed to railway noise. Keep also in mind the other types of sample restrictions that are described in subsection 3.3. We will point out what we consider as specifically interesting differences across the housing markets.

[Table 2 about here.]

First, we can notice the huge difference of property prices. The Stockholm suburb, Sollentuna, has the highest average property prices followed by the Göteborg suburbs Kungsbacka and Alingsås. The property prices are lowest in the rural housing market Töreboda. Also, the household income follows the same pattern, although the relative difference between the housing markets is much lower here. The structural variables are fairly similar across the housing markets with the exceptions that linked and terraced properties are more common in the suburb housing markets and in the regional center Gävle and that the property area generally is smaller in the suburb housing markets.

The average equivalent railway noise exposure is highest in Gävle which mostly depends on the exclusion of properties exposed to less than 50 dB in Gävle in contrast to 45 dB in the other housing markets. However, the average noise exposure is only slightly lower in Töreboda than in Gävle. Kungsbacka and Alingsås has the lowest average of noise exposure.

The number of children in different ages differs substantially across the housing markets. Generally, Sollentuna seems to have the highest average which probably depends on the high average property price leading to a selection effect. In urban areas, the high property price implies that only households with a very strong preference for an own property actually buy a property. One indicator for such a strong preference is likely to be a household with many children. Also, single households are most frequent in Töreboda followed by Hässleholm, which are the housing markets with the lowest average property price. With a relatively low property price, single households have a better opportunity to afford buying a property.

4 Modeling framework

4.1 Hedonic price regression - first step

When the relationship between noise and property prices is estimated, the choice of functional form is not self-evident and no guidance is provided by Rosen (1974). In general, implicit prices of attributes are not linear in property prices and, also, a linear specification would result in a constant implicit price of peace and quiet within a property market, which leaves us with a small number of observations for the second step, that is one observation per housing market. The most common way in the literature to estimate the first step in a hedonic model is the semi-logarithmic approach where the property price is transformed to its natural logarithm. However, based on explanatory power, we instead propose a log-log specification where both the property price and peace and quiet is included in its natural logarithmic form. This formulation is outperforming the semi-log specification in terms of adjusted R^2 for all of our housing markets.[10] The log-log model is formulated as

$$\ln P_i = \beta_0 + \beta_1 \ln Q_i + \sum_{n=1}^{N} \gamma_n f(a_{ni}) + \sum_{h=1}^{H} \lambda_h f(g_{hi}) + \varepsilon_i, \tag{4}$$

where the variables a and g that are not indicator variables are transformed to its natural logarithm. The calculated implicit price of peace and quiet based on Eq. (4) is given by

$$\pi_i = \frac{\partial P}{\partial Q_i} = \frac{\beta_1 P_i}{Q_i}. \tag{5}$$

In hedonic regressions on property prices spatial dependence is often handled through either a spatial error model or a spatial lag model (Anselin, 1999, 2003). With the spatial error model the OLS estimator is unbiased but not efficient (Anselin, 1999), whereas the marginal implicit price of a spatial lag model depends on both the direct effect and a spatial indirect effect (Kim et al., 2003).

Nonetheless, whether the indirect effect should be included when calculating the social benefit of a change in an attribute level is not clear. The inclusion of the indirect effect depends on the mechanism behind the influence of neighboring properties (Small and Steimetz, 2006). The externality of property values that influence the values of neighboring houses is either technological or pecuniary (Small and Steimetz, 2006). With a technological externality individuals obtain utility from living close to higher-

[10]These comparisons are based on OLS.

priced houses and the indirect effect should then be included. A pecuniary effect arises, for instance, when buyers use the prices of surroundings properties as a guide to the value of their property of interest. Here the indirect effect is a welfare neutral transfer and should therefore not be included.

We test for spatial dependence based on criteria taken from Anselin (2005, p. 196-200). For two of our markets, the spatial error model is preferred whereas the spatial lag model is preferred for the other four markets. However, referring to the unclearness whether the indirect effect should be included and our preference for applying the same spatial model for all markets, we use the spatial error model for all markets. We also use an inverse distance-based weight matrix and have tested different distance bands ranging from two kilometers up to the maximum distance. For each market, we choose the weight matrix that implies the highest log-likelihood.

The implicit price of peace and quiet calculated from Eq. (5) is given as the discounted sum of all yearly prices of peace and quiet for the expected lifetime of the property. To arrive at a yearly implicit price of peace and quiet we conveniently assume that the expected lifetime of the properties is infinite. Thus the yearly implicit price, π'_{ij}, is calculated as

$$\pi'_{ij} = \phi \pi_{ij}, \tag{6}$$

where ϕ is the discount rate. We use the expected real interest rate plus the yearly property taxation rate as the discount rate. Since we already have used property price indices to deflate the prices to 2009, we use the available interest rate with the longest fixed-term on the housing market in 2009 minus the expected inflation rate. The weighting average ten-year nominal interest rate in 2009 was 5.11 percent.[11] Since the Central Bank

[11] Holds for Swedbank, which is one of the largest providers for housing loans in Sweden and also provides data of historic interest rates on their web page, see http://hypotek.swedbank.se/rantor/historiska-rantor/historik-bostadsrantor-2008-2009.

of Sweden has an inflation objective of two percent we use a real interest rate of 3.11 percent.

The yearly property taxation for the years 1996 up to 2007 was 1 percent of the taxation value of the property.[12] Therefore, we calculate this part of the discount rate as 1 percent multiplied by the property taxation value divided by the property price.[13] This means that the discount rate, ϕ, is property-specific and Eq. (6) can be rewritten as

$$\pi'_{ij} = \phi_i \pi_{ij}. \tag{7}$$

4.2 Hedonic price regression - second step

In the second step we use the implicit price of peace and quiet along with the socioeconomic variables as regressors for the chosen level of peace and quiet in a linear specification.[14] Also, the variables from the first step is included to account for characteristics that are either substitutes or complements to peace and quiet. A positive parameter means a complement to peace and quiet whereas a negative parameter means a substitute to peace and quiet. However, we do not include distance to road since it is not defined for Töreboda. The model is formulated as follows

$$Q_{ij} = \alpha_0 + \alpha_1 \pi_{ij} + \sum_{m=1}^{M} \delta_m s_{mij} + \sum_{n=1}^{N} \kappa_n a_{nij} + \sum_{h=1}^{H} \theta_h g_{hij} + \epsilon_{ij}. \tag{8}$$

Note here that no variables are given in the natural logarithmic form. This difference between the second step equation and the first step equation is assumed to further improve

[12]The center-right government that was elected in Sweden 2006 had one of their electoral promises to decrease the property taxation for most properties by imposing a ceiling for the taxation, which was subsequently implemented from 2008. This proposal might have been affected the property prices before 2008 through individuals' expectations. However we only consider the property taxation according to the former legislation.

[13]For Gävle we do not have access to the property taxation value and therefore we use 0.75 percent as the taxation part of the discount rate, which originates from the objective of the legislation stating that the property taxation value should correspond to 75 percent of the property value.

[14]This demand relation may not be linear as described in Day et al. (2007), which is further discussed in Section 6.

the identification of the demand relationship.

The second step of the hedonic regression analysis based on Eq. (8) suffers from endogeneity problems as the implicit price is dependent on peace and quiet. Therefore we use the instrumental variable (IV) method and estimate Eq. (8) by two stage least squares (2SLS), which accounts for endogeneity problems.

To produce unbiased parameter estimates, the instruments must be strong and valid (see e.g. Cameron and Trivedi, 2005, p. 100). In our specific application, strong means that the instruments should explain a sufficient amount of the implicit price for peace and quiet whereas valid means that the instruments have to be uncorrelated with the error term in Eq. (8).

As the implicit price of peace and quiet depends on property price, property characteristics that are strongly correlated with the property price will be strongly correlated also with the implicit price of peace and quiet and therefore serve as strong instruments. We propose living space as such property characteristics. In additions, we use year indicator variables that significantly influence the implicit price of peace and quiet as instruments. These years are 2005, 2006 and 2007.

To be valid instruments, the instruments need to be uncorrelated with the decision process behind the choice of peace and quiet. Day et al. (2007) state that this decision process reflects specific characteristics of the household and its attitude to noise. We will argue that there is no specific relation between our instruments and the preferences against noise exposure. If a particular household has strong preferences against noise, it can either buy a small house or a large house far from the railway depending on its preferences for living space. On the other hand, if a particular household has weak preferences against noise it can still either buy a small house or a large house close to the railway depending on its specific preferences for living space. In other words, we assume that living space is neither a complement nor a substitute to peace and quiet. By controlling for socioeconomic characteristics in the second step the partial dependence of year indicators on demand for peace and quiet is presumed to be small. In other words, we assume that the preferences for peace and quiet are stable over time. By using these instruments for the implicit price of peace and quiet we can therefore identify the demand for peace and quiet.

To formally test if the instruments are strong and valid we provide some diagnostic tests. We rely on the minimum eigenvalue statistic of the instruments in the first-stage regression[15] to test for weak instruments and Sargan's test for overidentifying restrictions to test for validity.

5 Results

5.1 Hedonic price regression - first step

In Table 3, the results of the first step hedonic price regressions for the different housing markets are presented. That is the property price equation based on Eq. (4) with taking the spatial error structure into account. Also, summary statistics of the estimated implicit price of peace and quiet is presented in this Table.

[Table 3 about here.]

First we can see that the spatial parameter lambda is strongly significant in all markets, which clearly shows the importance of taking the spatial structure into account.

Peace and quiet is strongly significant in all housing markets except Gävle where it still is significant at the five-percent level.

[15]That is the first-stage regression of the *two-stage* regression in the 2SLS approach, which should not be confused with the *two steps* of the hedonic model.

In general, the results show strongly significant structural variables in all housing markets. Living space and quality index is positive and strongly significant for all markets. Age of the dwelling is significant for all markets except Gävle. Property area, subsidiary space, linked properties and terraced properties are all significant in about half of our markets and those are not the same for all of these attributes. Properties bordering on the sea/lake have often no effect on the selling price but this variable is significant for Sollentuna.

Among the geographical variables, distance to railway station is significant for all markets whereas distance to road is positively significant for Sollentuna and for Kungsbacka and Alingsås. Distance to road is capturing both positive accessibility effects and negative pollution, noise and barrier effects so its expected sign is ambiguous. In Sollentuna however, we control for the accessibility through the distance to motorway entrance road so here the positive effect of living further away from a major road is expected. Countryside is mostly negative but does not affect the property price in Hässleholm.

It should be emphasized that none of our parameter estimates is significant with an unexpected sign. Failure to detect significant effects, especially for the geographical variables, may therefore depend on problems with multicollinearity.

The estimated implicit price variable has the highest average for Sollentuna, whereas the average is lowest for Hässleholm. The distributions seems to be fairly similar since about the same ranking among the housing markets holds for the 10th percentile, 25th percentile, 75th percentile and 90th percentile. These differences across the housing markets highlight the risk of applying the first step hedonic results on other housing markets. The average estimated implicit price is 3.12 times higher in Sollentuna compared to Hässleholm. A generalized value for railway noise abatements will therefore differ substantially depending on which housing market it is based on. Also, if we take different levels of noise exposure and property values into account, the difference between the housing markets is substantial. This can be seen from the parameter estimates of peace and quiet, which range from 0.101 to 0.477. Hence, the underlying preference structure, which will be recovered in the second step, is very important.

The model fit is strong for most of the housing markets with the squared correlation, corresponding to the conventional R^2-measure, in the interval 0.332-0.661. The model fit is considerably lower for Sollentuna and Gävle compared to the other housing markets, which indicates that for these markets there are probably some variations in the property prices that are of local knowledge type, which we cannot control for in our models.

5.2 Hedonic price regression - second step

The second step estimates are presented in Table 4. We present the results of both the OLS estimation, which is assumed to be suffering from endogeneity problems, and the consistent 2SLS estimation with the endogenous implicit price of peace and quiet instrumented by living space and year indicators for 2005, 2006 and 2007.[16]

[Table 4 about here.]

First, we need to check the IV-approach with some diagnostic tests. The test of week instruments has a critical value of 16.85 for significance at the five-percent level. Our test statistic is about 47, wherefore we strongly reject the null hypothesis of weak instruments and conclude that our instruments are strong. The Sargan's test of valid instruments has a p-value of 0.266, which means that we cannot reject the null hypothesis of invalid instruments. Note that this result is not evidence for valid instruments but no evidence for invalid instruments. Since our instruments satisfy the diagnostic tests we conclude that they are adequate for our application.

[16] The result of the first-stage regression of the IV-estimation can be provided by the authors on request.

Furthermore, the results show that the relationship between the implicit price and peace and quiet is negative as expected and also strongly significant.[17] Among the socioeconomic variables, the income effect is positive as expected. To include future income is a way to control for the influence of expected income on the chosen level of peace and quiet when households decide to purchase a property. Expected income is found to be very important for the choice of peace and quiet while current income in fact is non-significant.

The number of children 0-3 years of age is positively influencing the demand for peace and quiet. However, there is no significant effect for the number of children in the other age groups and for single households.

The included first-step variables tell us if they are substitutes or complements to peace and quiet. For distance to railway station, the only geographical variable included, is the effect assumed to be driven by geographical constraints and should not be interpreted as a substitutes to peace and quiet. For the structural variables; property area, subsidiary space, quality index and bordering on the sea/lake are complements to peace and quiet whereas age of the dwelling is a substitute. Generally, we can say that if you choose more of an attractive attribute you also choose more of peace and quiet. Finally, linked properties are complements to peace and quiet whereas terraced properties are substitutes to peace and quiet, both in comparison to detached properties, which is the reference.

5.3 Welfare estimates

The result of the second step is the estimated demand for peace and quiet, i.e. based on preferences only and not affected by the supply side of the housing markets. This means that we can calculate welfare estimates for non-marginal changes of railway noise exposure. Also, by assuming the demand structure to be the same across Sweden we

[17] Note that, as in Day et al. (2007), we do not consider the uncertainty of the implicit price estimates when these are used in the second step.

generalize the welfare estimates to hold for the whole country of Sweden.

The estimated demand relationship expressed in the conventional price-quantity space where all other covariates are evaluated at their respective sample means is given as $P = 1501 - 57.94Q$, where P is price in 2009 prices and Q is peace and quiet. A change in peace and quiet will lead to a change in consumer surplus, which is the area below the demand curve bounded by the *ex ante* peace and quiet and the *ex post* peace and quiet. This change in consumer surplus is the welfare effect of a change in peace and quiet.

Household size is taken into account by dividing the welfare estimates by 3.02, the average number of household members in the estimation sample, which implies that the demand is defined per individual. We have also transformed the demand to account for income differences between Sweden in general and the seven municipalities of this study weighted with respect to the number of included observations per housing market. This transformation implies multiplying with a factor of 0.914, which means that the average income in Sweden is approximately nine percent lower than in our sample. Q is defined so that 0 corresponds to an equivalent railway noise level of 75 dB, whereas the maximum level of equivalent railway noise in our estimation sample is 71.08 dB. The estimated demand reveals that individuals have no willingness to pay for reducing railway noise below an equivalent railway noise level of 49.09 dB.

In Table 5, the welfare estimates for a 1 dB decrease in railway noise with different baseline noise exposure are presented. These estimates are based on the demand equation above. As we can see, for a reduction of the equivalent railway noise level from 71 dB to 70 dB the average Swedish citizen is willing to pay 1240 SEK[18] per year and for a reduction of the equivalent railway noise level from 61 dB to 60 dB the WTP is 661 SEK.

[Table 5 about here.]

[18] At 20th of December 2010, 1 EUR is 9 SEK.

95 percent confidence intervals based on standard errors calculated by the delta method are also presented in Table 5. The confidence intervals are relatively narrow, for example the WTP for a reduction of equivalent railway noise level from 71 dB to 70 dB is very likely to be in the range of 977 SEK to 1504 SEK.

In Table 5, we also present welfare estimates for elimination of the railway noise at different baseline levels of noise. Here we can see that the WTP for eliminating railway noise of 71 dB is approximately 13 901 SEK per individual and year.

6 Concluding discussion

In this study we estimate the demand for peace and quiet, and thus also the willingness to pay (WTP) for railway noise abatements, based on hedonic regressions on property prices. We estimate both steps of the hedonic model, which means that our estimated demand for peace and quiet is theoretically consistent for non-marginal changes in noise exposure. Since we use different municipalities around Sweden as different housing markets and generalize the results to account for average household size in our estimation sample and income in Sweden in general, we believe that our welfare estimates for noise exposure can be generally applicable in Sweden.

To compare with Day et al. (2007), the only application of the hedonic second step for railway noise valuation that the authors are aware of, we found a stronger dependence between the WTP and the noise level, i.e. we have found a more inelastic price elasticity of demand for peace and quiet. This means that our welfare estimates are higher for high baseline levels of railway noise and lower for low baseline levels of railway noise. To reduce the equivalent railway noise level from 71 dB to 70 dB, the average Swedish resident is willing to pay 1240 SEK. Day et al. (2007) estimate the same WTP to be equivalently 771 SEK.[19] For a baseline noise level of 56, on the other hand, we estimate the WTP to be 371 SEK whereas Day et al. (2007) estimate this WTP to equivalently 548 SEK. The welfare estimates of Day et al. (2007) is thus decreasing slowly when the baseline railway noise is decreasing, which means that the WTP does not reach zero for a noise level where individuals not are assumed to be disturbed by traffic, a result that can be seen as an inconsistency since they assume a background urban noise level of 55 dB. Here we believe that our estimated demand where the WTP is zero below a noise level of 49.09 dB and that WTP increase continuously above this noise level is more consistent.

If we compare with ASEK, the Swedish official values based on road noise (SIKA, 2008), our welfare estimates are much less progressive. In 2006 years prices, the ASEK-value is 2371 SEK for a reduction from 71 dB to 70 dB, which is much higher than our estimates. For a reduction from 56 dB to 55 dB, the ASEK-value of 280 SEK is lower than our estimate although fairly similar when we take the different base years into account.

We have estimated a linear demand, which is not for certain the adequate functional form. Note however that the linearity in the second step should not be confused with a linear estimate in the first step of the hedonic model. Since we estimate the second step of the hedonic model, this linear demand still means that the WTP for a 1 dB noise reduction is higher the higher the baseline noise level is.

To relax the linearity assumption we might choose another functional form for the second step. Poudyal et al. (2009) used a log-log function in the second step when they estimated the demand for urban recreation parks. However, the log-log model states a non-linear demand relationship by definition, which also can be seen as an inflexibility of the model. Moreover, we have already used a log-log specification in the first step. Including a squared term of the implicit price is another possible approach. When test-

[19] It is not straight-forward to convert the estimates of Day et al. (2007), which are given per property and in the value of 1997. We have assumed 2.36 individuals per household (see Nellthorp et al., 2007), 46.6 percent increase in real income in the UK between 1997 and 2009 and an exchange rate of 10.59 between GBP and SEK.

ing this approach in the IV regression, that is instrumenting the implicit price and then calculate the square term of the instrumented implicit price, the linear term is still negative and strongly significant whereas the squared term is not significant at conventional significance levels with a p-value of 0.369. Thus we cannot reject the linear specification of the demand for peace and quiet.

As described earlier, neither the functional form of the first step model is self-evident. We proposed a log-log formulation whereas the semi-logarithmic function is most common in the hedonic literature. Therefore, we have also tested a semi-log specification estimated by OLS in the first step with the same variable specification followed by the IV-approach in the second step. The results are very similar with slightly lower welfare estimates for noise abatements but still within the 95 percent confidence interval of our log-log model. This result provides support for the consistency of our model.

The WTP for noise abatements as estimated in this paper only takes into account the effect that is capitalized into the property market and there may be other effects that is not included here. First, we can consider that individuals do not spend all their time in their own homes but also at work, in school and in different public areas. This indicates a social cost that is in fact larger than what is estimated through the property market (Nijland and van Wee, 2008). Furthermore, there is a possibility that all negative health effects caused by transport-related noise are not capitalized into the property market. In welfare economics we usually assume that individuals know their own best and that their preference-based choices are utility maximizing. On the other hand, if medical service and labor related insurances to a great extent is subsidized, as in Sweden, there is a further external cost of noise if individuals do not take the complete health effect of noise into account. The official Swedish ASEK-values, referred to earlier in this Section, is adding a 42 percent health factor to the hedonic implicit price (SIKA, 2008). Such a policy implementation is of course possible also for our estimates but the evidence for doing so is not examined in our study.

There are, however, other effects that probably offset the possible absence of health effects. For example, many individuals live in apartments, where the access to outdoor areas, which is more disturbed by noise than indoor areas for given dB, is lower than in owned properties. Then the effect for apartment-living individuals may be lower than for property-owners. Also, individuals that are living in rented apartments tend to have a lower income in general compared to property-owners. In Nellthorp et al. (2007), this latter effect for the UK is calculated to a 17.5 percent decrease of the welfare estimates.

Although some caveats are presented here above, our study is an important contribution to the literature as it is based on the two-step hedonic regression technique and uses combined data of geographically different housing markets and individual socioeconomic characteristics.

References

Andersson, H.: 2008, 'Willingness to pay for car safety: Evidence from Sweden'. *Environmental and Resource Economics* **41**(4), 579–594.

Andersson, H., L. Jonsson, and M. Ögren: 2009, 'Property Prices and Exposure to Multiple Noise Sources: Hedonic Regression with Road and Railway Noise'. *Environmental and Resource Economics* **45**, 73–89.

Anselin, L.: 1999, 'Spatial Econometrics'. Mimeo, University of Texas at Dallas, USA.

Anselin, L.: 2003, 'Spatial externalities, spatial multipliers, and spatial econometrics'. *International Regional Science Review* **26**(2), 153–166.

Anselin, L.: 2005, 'Exploring Spatial Data with GeoDaTM : A Workbook'. Spatial Analysis Laboratory, Department of Geography, University of Illinois, Urbana-Champaign.

Bateman, I., B. Day, I. Lake, and A. Lovett: 2001, 'The effect of road traffic on residential property values: A literature review and hedonic pricing study'.

Cameron, A. C. and P. K. Trivedi: 2005, *Microeconometrics: Methods and Applications*. New York: Cambridge University Press.

Day, B., I. Bateman, and I. Lake: 2007, 'Beyond implicit prices: Recovering theoretically consistent and transferable values for noise avoidance from a hedonic property price model'. *Environmental and Resource Economics* **37**(1), 211–232.

Ekeland, I., J. J. Heckman, and L. Nesheim: 2004, 'Identification and estimation of hedonic models'. *Journal of Political Economy* **112**(1), S60–S109.

Freeman, A. M.: 2003, *The Measurement of Environmental and Resource Values: Theory and Methods*. Washington DC: Resources for the Future, second edition edition.

Haab, T. C. and K. E. McConnell: 2003, *Valuing Environmental and Natural Resources: The Econometrics of Non-Market Valuation*. Cheltenham, UK: Edward Elgar.

Jonasson, H. and H. Nielsen: 1996, 'Road Traffic Noise – Nordic Prediction Method'. TemaNord 1996:525, Nordic Council of Ministers, Copenhagen, Denmark. ISBN 92-9120-836-1.

Kim, C. W., T. T. Phipps, and L. Anselin: 2003, 'Measuring the benefits of air quality improvement: A spatial hedonic approach'. *Journal of Environmental Economics and Management* **45**(1), 24–39.

Miedema, H. M. E. and C. G. M. Oudshoorn: 2001, 'Annoyance from transportation noise: Relationships with exposure metrics DNL and DENL and their confidence intervals'. *Environmental health perspectives* **109**(4), 409–416.

Nellthorp, J., A. L. Bristow, and B. Day: 2007, 'Introducing willingness-to-pay for noise changes into transport appraisal: An application of benefit transfer'. *Transport Reviews* **27**(3), 327–353.

Nelson, J. P.: 2008, *Hedonic Methods in Housing Markets: Pricing Environmental Amenities and Segregation*, Chapt. Hedonic Property Value Studies of Transportation Noise: Aircraft and Road Traffic, pp. 57–82. New York: Springer.

Nijland, H. and B. van Wee: 2008, 'Noise valuation in ex-ante evaluations of major road and railroad projects'. *European Journal of Transport and Infrastructure Research* **8**(3), 216–226.

Öhrström, E., A. Gidlöf-Gunnarsson, M. Ögren, and T. Jerson: 2010, 'Effekter av buller och vibrationer från tågtrafik'. Rapport 4:2010, Occupational and Environmental Medicine, University of Gothenburg.

Palmquist, R. B.: 2005. *Handbook of Environmental Economics: Valuing Environmental Changes, Vol.2 of Handbooks in Economics 20, Chapter Property Value Models* pp. 763–819.

Parumog, M., S. Mizokami, and R. Kakimoto: 2006, 'Value of traffic externalities from attribute-based stated choice: Route choice experiment'. *Transportation Research Record* **1954**, 52–60.

Poudyal, N. C., D. G. Hodges, and C. D. Merrett: 2009, 'A hedonic analysis of the demand for and benefits of urban recreation parks'. *Land Use Policy* **26**(4), 975–983.

Ringheim, M.: 1996, 'Railway Traffic Noise – Nordic Prediction Method'. TemaNord 1996:524, Nordic Council of Ministers, Copenhagen, Denmark. ISBN 92-9120-837-X.

Rosen, S.: 1974, 'Hedonic prices and implicit markets: Product differentiation in pure competition'. *Journal of Political Economy* **82**(1), 34–55.

Sandberg, U. and J. A. Ejsmont: 2002. *Tyre/Road Noise Reference Book*.

SIKA: 2008, 'Samhällsekonomiska principer och kalkylvärden för transportsektorn: ASEK 4'. Report 2008:3, Swedish Institute for Transport and Communications Analysis (SIKA), Östersund, Sweden.

Simonsson, B.: 2009, 'Uppskattning av antalet exponerade för väg, tåg- och flygtrafikbuller överstigande ekvivalent ljudnivå 55 dBA'. Report, WSP, Stockholm, Sweden.

Sælensminde, K.: 1999, 'Stated choice valuation of urban traffic air pollution and noise'. *Transportation Research Part D: Transport and Environment* **4**(1), 13–27.

Small, K. A. and S. Steimetz: 2006, 'Spatial Hedonics and the Willingness to Pay for Residential Amenities'. Working Papers 050631, Department of Economics, University of California-Irvine.

Theebe, M. A. J.: 2004, 'Planes, trains, and automobiles: The impact of traffic noise on house prices'. *Journal of Real Estate Finance and Economics* **28**(2-3), 209–234.

Wilhelmsson, M.: 2002, 'Household expenditure patterns for housing attributes: A linear expenditure system with hedonic prices'. *Journal of Housing Economics* **11**(1), 75–93.

Table 1: Description of the municipalities

Municipality	Population	Local labor market	Railway lines	Motorways	Closest urban area	Regional center (yes/no)
Töreboda	9238	Skövde	Västra Stambanan	-	Göteborg (170 km)	No
Sollentuna	63 174	Stockholm	Ostkustbanan	E4	Stockholm (13 km)	No
Falköping	31 419	Skövde	Västra Stambanan Jönköpingsbanan	-	Göteborg (108 km)	No
Hässleholm	50 036	Kristianstad	Södra Stambanan Skånebanan Markarydsbanan	-	Malmö (78 km)	No
Kungsbacka	73 763	Göteborg	Västkustbanan	E20/E6	Göteborg (24 km)	No
Alingsås	37 465	Göteborg	Västra Stambanan	E20	Göteborg (42 km)	No
Gävle	94 255	Gävle	Ostkustbanan Norra Stambanan Bergslagsbanan	E4 R80	Stockholm (158 km)	Yes

Notes: a; Local labor markets are defined by Statistics Sweden based on commuting flows between municipalities.
b; Population data is from November 1st of 2009.

Table 2: Descriptive statistics: Mean values and standard deviations (in parenthesis)

Variable	Housing market						Expected sign
	Töreboda	**Sollentuna**	**Falköping**	**Hässleholm**	**Kungsbacka and Alingsås**	**Gävle**	
First-step variables							
Property price	685 918	3 749 929	1 332 310	1 354 171	2 482 976	1 613 278	
	(383 601)	(1 337 199)	(550 053)	(578 497)	(833 141)	(765 374)	
Railway noise	55.18	52.99	54.08	53.39	52.65	55.23	+ (Peace and quiet)
	(5.50)	(4.84)	(4.89)	(5.59)	(5.63)	(3.93)	
Property area	1496.142	785.790	933.523	1087.971	861.137	1003.778	+
	(1376.625)	(524.085)	(802.403)	(640.221)	(751.435)	(649.384)	
Living space	118.114	127.059	130.908	123.385	132.638	121.886	+
	(45.573)	(34.579)	(43.801)	(40.107)	(44.280)	(39.777)	
Subsidiary space	47.743	42.261	60.884	60.310	46.085	n.a.	+
	(43.928)	(42.012)	(45.774)	(44.989)	(42.797)		
Age of dwelling	51.750	39.198	45.833	42.257	44.752	52.152	-
	(27.504)	(21.090)	(26.290)	(21.662)	(25.268)	(31.644)	
Quality index	27.486	28.777	28.992	28.738	28.331	28.953	+
	(5.351)	(5.050)	(5.331)	(5.258)	(5.189)	(5.678)	
Detached	0.947	0.620	0.900	0.936	0.704	0.818	Reference
Linked	0.035	0.169	0.060	0.032	0.169	0.125	-
Terraced	0.018	0.211	0.040	0.032	0.127	0.057	-
Bordering on the sea/lake	0.018	0.004	0	0.002	0.005	0.013	+
Road noise	n.a.	53.676	n.a.	n.a	n.a.	n.a.	-
		(7.084)					
Distance road	n.a.	746.403	1356.331	1722.247	1231.138	2010.857	Ambiguous
		(446.973)	(539.440)	(690.284)	(1080.810)	(1647.249)	
Distance railway station	5088.834	830.219	1698.122	2178.928	1114.530	4089.863	-
	(5568.373)	(284.858)	(1899.324)	(1774.186)	(844.891)	(2570.625)	
Distance motorway entrance road	n.a.	1172.854	n.a.	n.a.	n.a.	n.a	-
		(403.721)					
Countryside	n.a.	n.a.	0.167	0.339	0.143	0.592	-
No of observations	720	3594	947	1459	1454	1092	-
Second-step variables							
Household income	425 537	903 024	620 810	550 075	681 208	660 800	+
	(267 636)	(607 286)	(545 597)	(496 675)	(405 040)	(409 325)	
Single household	0.248	0.132	0.134	0.191	0.135	0.120	-
No of children 0-3 years of age	0.297	0.456	0.395	0.305	0.377	0.378	+
	(0.550)	(0.655)	(0.599)	(0.550)	(0.618)	(0.591)	
No of children 4-6 years of age	0.137	0.202	0.234	0.145	0.191	0.186	+
	(0.351)	(0.449)	(0.496)	(0.400)	(0.435)	(0.425)	
No of children 7-11 years of age	0.186	0.273	0.222	0.226	0.251	0.198	+
	(0.468)	(0.596)	(0.538)	(0.556)	(0.548)	(0.495)	
No of children 12-17 years of age	0.175	0.201	0.199	0.192	0.257	0.195	+
	(0.474)	(0.524)	(0.586)	(0.519)	(0.599)	(0.497)	
No of observations	451	2270	688	952	981	842	

Notes: a; Standard deviations of indicator variables are not shown since they are determined by the mean, μ, according to $\sqrt{\mu(1-\mu)}$.
b; In Sollentuna the expected sign for distance to road is negative since we control for accessibility through distance to motorway entrance road.
c; n.a stands for not available.

Table 3: Hedonic first step estimates

Variable	**Housing market**					
	Töreboda	**Sollentuna**	**Falköping**	**Hässleholm**	**Kungsbacka and Alingsås**	**Gävle**
ln Peace and quiet	0.477***	0.204***	0.282***	0.170***	0.101***	0.189**
	(0.112)	(0.038)	(0.051)	(0.031)	(0.033)	(0.084)
ln Property area	0.161***	0.168***	0.013	0.031	0.145***	0.050
	(0.039)	(0.018)	(0.029)	(0.028)	(0.044)	(0.038)
ln Living space	0.454***	0.358***	0.508***	0.624***	0.491***	0.550***
	(0.073)	(0.023)	(0.039)	(0.042)	(0.035)	(0.054)
ln Subsidiary space	0.020*	0.012***	0.014**	0.002	0.010*	n.a.
	(0.011)	(0.003)	(0.007)	(0.005)	(0.005)	
ln Age of dwelling	-0.272***	-0.068***	-0.123***	-0.189***	-0.118***	-0.019
	(0.039)	(0.009)	(0.019)	(0.016)	(0.018)	(0.033)
ln Quality index	1.042***	0.247***	0.805***	0.697***	0.346***	0.518***
	(0.155)	(0.033)	(0.066)	(0.062)	(0.051)	(0.085)
Linked	-0.038	-0.027	-0.136***	-0.104***	-0.009	-0.122*
	(0.059)	(0.030)	(0.044)	(0.033)	(0.033)	(0.063)
Terraced	-0.178**	0.025	-0.289***	-0.101**	0.067	-0.014
	(0.088)	(0.032)	(0.046)	(0.042)	(0.069)	(0.083)
Bordering on the sea/lake	0.134	0.209***	n.a.	0.255	0.057	0.091
	(0.092)	(0.059)		(0.169)	(0.160)	(0.078)
ln Road noise	n.a.	0.102	n.a.	n.a	n.a.	n.a.
		(0.070)				
ln Distance road	n.a.	0.146***	0.040	-0.003	0.056***	-0.004
		(0.024)	(0.028)	(0.022)	(0.011)	(0.019)
ln Distance railway station	-0.153***	-0.092***	-0.091***	-0.158***	-0.056***	-0.189***
	(0.022)	(0.023)	(0.028)	(0.034)	(0.020)	(0.059)
ln Distance motorway entrance	n.a	-0.014	n.a.	n.a.	n.a.	n.a.
		(0.028)				
Countryside	n.a	n.a.	-0.152**	-0.061	-0.117***	-0.425***
			(0.064)	(0.038)	(0.040)	(0.132)
Lambda	0.411***	0.993***	0.756***	0.592***	0.446***	0.427***
	(0.105)	(0.006)	(0.105)	(0.071)	(0.088)	(0.086)
Distance band (kilometers)	3	2	10	2	2	3
No of observations	720	3594	947	1459	1454	1092
Squared correlation	0.581	0.332	0.661	0.628	0.522	0.348
Implicit price - 10th percentile	287	765	357	210	234	293
Implicit price - 25th percentile	406	962	471	280	304	426
Implicit price - mean	643	1331	701	426	442	612
Implicit price - 75th percentile	808	1606	855	511	527	766
Implicit price - 90th percentile	1090	2016	1118	682	697	983

Notes: a; Dependent variable is the natural logarithm of the property price.
b; ***, ** and * denote difference from zero at the one, five and ten percent significance level respectively.
c; The models include yearly dummy variables but for simplicity these coefficients are not shown in the table.
d; Robust standard errors are given in parenthesis.
e; Implicit price is given in SEK per property and year in 2009 prices.
f; The models also include an intercept.
g; n.a stands for not available.
h; The model for Sollentuna includes four indicator variables of geographical areas instead of countryside.

Table 4: Hedonic second step estimates

Variable	OLS	2SLS
Implicit price	-0.004***	-0.005***
	(0.000)	(0.001)
ln Household income	-0.004	0.003
	(0.035)	(0.035)
ln Household income year t+1	1.552***	1.790***
	(0.155)	(0.264)
Single household	0.140	0.303
	(0.422)	(0.442)
No of children 0-3 years of age	0.253**	0.314**
	(0.115)	(0.124)
No of children 4-6 years of age	-0.101	-0.071
	(0.142)	(0.144)
No of children 7-11 years of age	0.150	0.202
	(0.117)	(0.125)
No of children 12-17 years of age	-0.084	-0.068
	(0.121)	(0.123)
Property area	0.029***	0.037***
	(0.011)	(0.012)
Subsidiary space	0.003*	0.003**
	(0.001)	(0.001)
Age of dwelling	-0.025***	-0.026***
	(0.003)	(0.003)
Quality index	0.069***	0.084***
	(0.012)	(0.016)
Linked	-0.775***	-0.653***
	(0.213)	(0.229)
Terraced	0.614***	0.555***
	(0.176)	(0.184)
Bordering on the sea/lake	2.372***	2.449***
	(0.677)	(0.720)
Distance railway station	-0.526***	-0.573***
	(0.027)	(0.044)
No of observations	6184	6184
R^2	0.237	0.229

Notes: a; Dependent variable is peace and quiet.
b; ***, ** and * denote difference from zero at the one, five and ten percent significance level respectively.
c; The models include education dummy variables, which for simplicity are not shown here.
d; Robust standard errors are given in parenthesis.
e; Distance railway station is defined in kilometers.
f; Property area is defined in hundreds square meters.
g; The models also include an intercept.

Table 5: Welfare estimates of changes in peace and quiet

Noise level change	**Welfare estimate**	**95 percent CI**
71 ⇔ 70	1240	[977 ; 1504]
66 ⇔ 65	951	[764 ; 1137]
61 ⇔ 60	661	[552 ; 770]
56 ⇔ 55	371	[339 ; 403]
51 ⇔ 50	81	[35 ; 128]
71 ⇔ 49.09	13 901	[10 929 ; 16 873]
66 ⇔ 49.09	8279	[6639 ; 9920]
61 ⇔ 49.09	4106	[3410 ; 4802]
56 ⇔ 49.09	1381	[1244 ; 1519]
51 ⇔ 49.09	105	[69 ; 142]

Notes: a; Noise is given in equivalent dB.
b; The welfare estimates are given in SEK per individual and year in 2009 prices.
c; The 95 percent confidence interval is based on standard errors calculated by the delta method.

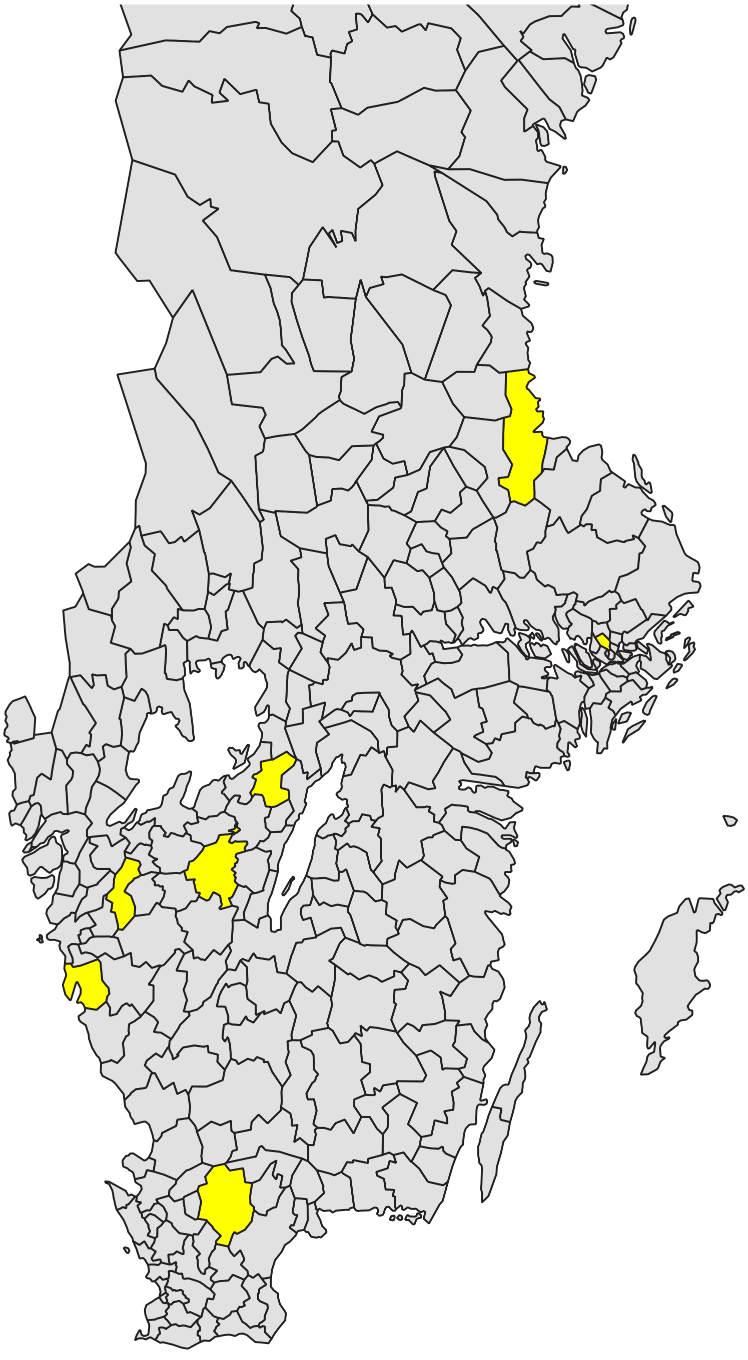

Figure 1: Map over the seven municipalities