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Traffic Noise and Property Values

MATS WILHELMSSON

Stockholm 2000

MEMORANDUM 5:50
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Abstract

This thesis consists of five papers about traffic noise and property values. Their aim was to analyze the impact of traffic noise on property values and to translate this effect into a monetary value. The method used was the hedonic technique in which the price of the property is assumed to be a function of its attributes (e.g. living area and indoor quality). It is possible to estimate implicit prices of all the attributes by regressing the property prices on housing and location attributes. These implicit prices could then be used to estimate the price and income sensitivity of the different attributes.

Essay 1, written together with my colleagues Kicki Björklund and Bo Söderberg, investigates the purposes, data sources, presentations and methodologies of published empirical works. Overall, these works exemplify good scientific practice. *Essay 2* is an analysis that estimates the marginal willingness-to-pay for a reduction in traffic noise. Noise is negatively capitalized into house values and the analysis shows that a house relatively far away from a nearby road would sell for 15-20 percent more than a house near the road. *Essay 3* presents a methodology for estimating the price and income elasticity of different housing attributes. This entails estimating a system of expenditure functions based on an additive preference function. The analysis indicates that housing attributes are relatively insensitive to price and income changes. *Essay 4* discusses whether an investment in noise abatements was justified economically. By analyzing house sales that has occurred more than once, where some of the houses were sold before and after the investment, it is possible to estimate the effect of the traffic noise barrier. The conclusion, in this particular case, is that investment in noise barriers is highly justified. *Essay 5* is my licentiate thesis that has already been presented.

Trafikbullers kapitalisering i fastighetsvärden

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Institutionen för fastigheter och byggande
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Referat

Denna doktorsavhandling är en sammanläggningsavhandling bestående av fem artiklar. Samtliga behandlar området trafikbullers kapitalisering i fastighetsvärden. Avsikten med avhandlingen är dels att analysera kapitaliseringseffekten, dels ”översätta” den till en samhällsekonomisk värdering. Metodiken som har används är den s k hedoniska tekniken i vilken man skattar den hedoniska prisekvationen. Det innebär att priset på fastigheten sätts i relation till ett antal egenskaper hos fastigheten där förekomsten av trafikbuller är ett av dessa egenskaper. De relativa betydelserna mellan olika egenskaper kan sedan tolkas som de marginella betalningsviljorna för respektive egenskap. I ett nästa steget utnyttjas betalningsviljorna för att skatta pris- och inkomstkänsligheten hos de olika egenskaperna, vilket tillsammans med den marginella betalningsviljan för t ex egenskapen förekomst av trafikbuller möjliggör skattningar av det samhällsekonomiska värdet som bl a används i trafikverkens samhällsekonomiska bedömningar.

Uppsats 1 är en rapport skriven tillsammans med mina kollegor Kicki Björklund och Bo Söderberg. Uppsatsen är en undersökning av tidigare gjorda empiriska analyser. *Uppsats 2* är en empirisk analys där den hedoniska prisekvationen skattas. Genom statistisk analys är det möjligt att skatta marginella betalningsviljor för respektive egenskap. I analysen testas modellens implicita antagandena om jämviktspriser på bostadsmarknaden samt symmetrisk information mellan säljare och köpare. I *uppsats 3* estimeras de enskilda egenskapernas pris- och inkomstkänslighet m h a ett system av utgiftsfunktioner. Slutsatsen är att samtliga undersökta egenskaper är relativt pris- och inkomstokänsliga. Känsligheten ökar dock vid ökad inkomst och familjestorlek. *Uppsats 4* är en undersökning som analyserar hur byggnationen av en bullerbarriär påverkar fastighetspriserna. Skillnaden i priserna före och efter byggandet av bullerbarriären utgör den samhällsekonomiska nyttan av investeringen som sedan jämförs med kostnaden. Slutsatsen är i detta fall att investeringen i bullerbarriär är samhällsekonomiskt motiverad. *Uppsats 5* är min tidigare framlagda licentiat avhandling.

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Stockholm, April 2000.

Mats Wilhelmsson

Traffic Noise and Property Values

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Traffic Noise and Property Values[1]

1. Introduction

This thesis is made up of five different papers, which concern the following problems: Is traffic noise capitalized into the value of houses and how much reduction in price can you in that case expect? Is it possible to "translate" this capitalization effect into a willingness-to-pay measure for a reduction in traffic noise? Does the household size, income or level of mortgages affect the willingness-to-pay? Does the construction of a noise barrier have a positive effect on value and is it justified economically to build noise barriers? These, and many more, are questions I try to answer in this thesis. In this introductory chapter of my thesis, I will put all the papers in perspective of economic theory and summarize their content.

Road traffic is one of the most common sources of noise in Sweden and almost 1.6 million people were affected by it in their homes 1990. Nearly 20 percent of these people live in residential areas where the level of noise is above 65 dBA, that is, highly noise-polluted areas. It is, however, not easy to define noise. One definition is that noise is "unwanted sound", which means that the same level of sound is sometimes regarded as noise and sometimes not. High levels of noise can have serious health effects, but usually the sole existence of noise leads to only minor health problems. This can result in, e.g., sleeping problems and high blood pressure, but the main effect of traffic noise is mainly a nuisance. The non-existence of silence is, however, one of the highest ranked environmental problems in society and a number of surveys in different countries support this (SOU 1993:65). Therefore, the Swedish society has allocated many resources to reduce traffic noise in residential areas. However, in many cases no estimation of the benefits of such reduction has been carried out.

Furthermore, cost-benefit analysis concerning investments in roads use a monetary value of traffic noise and the analyses presented here form part of a total revision of all the monetary values in them. By analyzing the price difference of houses in quiet and noisy locations, such monetary values can been revealed. Moreover, it is possible to interpret the difference as the marginal willingness-to-pay for a reduction of traffic noise. However, it is a risk that its use can overstate the benefits of an improvement if the changes are non-marginal. A more general valuation needs information about the price- and income sensitivity. An alternative estimation of the benefit can be achieved by analyzing the price of the *same* house before and after the improvement, where the difference in price is interpreted as the benefit of the improvement.

The thesis consists of five different papers. I have written four of them on my own and the first of the five papers presented here, I have written together with Kicki Björklund and Bo Söderberg. It is not the first paper written but I have chosen to put it first because it is the starting point of the second phase of my research work for a doctoral degree. It is a review paper of econometric analyses made by other researchers, which were presented and published, in international journals. The second paper in my thesis is, in a sense, a summary paper of my licentiate thesis, even if I have improved the empirical part where marginal willingness-to-pay is estimated. The third paper I wrote during my one-year stay in Berkeley. In this paper, I estimate the income and own-price sensitivities for different housing attributes. In the fourth paper, I use the repeated-sales method to estimate benefits of the construction of noise barriers, which is compared with the costs. The fifth paper is my licentiate thesis.

[1] Comments from Roland Andersson, Samual Azasu and Svante Mandell are gratefully acknowledged.

2. The Hedonic Price Equation

A number of questions arise during the process of a household's choice of a dwelling place. First, the household must determine which type of housing it prefers. Does the household want to buy or rent, live in an apartment or in a single-family house? Secondly, if the household has decided to buy a single-family house, where should the property be located? Besides a large number of location attributes, there are a number of housing attributes that matters for the household. All the housing and location attributes, together with financial restrictions, determine how much the household wants to bid for a certain property available on the market. If this bid results in a transfer of the house, from the seller to the buyer, the price can be seen to be a function of a number of housing and location attributes. This relationship between price and attributes is often called *the hedonic price equation* and, by estimating this equation, something can be revealed about the relative dependency between the attributes. The implicit prices of the different attributes can then be calculated.

Court (1939) presented one of the first analyses that used the hedonic price method and he also defined the concept of *hedonic price comparisons* as "those which recognize the potential contribution of any commodity, a motor car in this instance, to the welfare and happiness of its purchasers and the community." The present thesis follows a long tradition of dissertations and papers that use the hedonic technique. Rosen's (1974) theoretical article formalized the technique and his article was very much the starting point of a revolution in this field. Since the middle of the 1970s, a large number of articles have been published.

To put it simply, Rosen theoretically shows that one can interpret the relative dependency between the attributes as the marginal willingness-to-pay. He also presented a procedure of how to use the estimated parameters in the estimation of the demand equation, that is, the demands for different attributes of the house in this case. By estimating the demand equation, it is possible to analyze how sensitive the household is to changes in the implicit prices (price elasticity) or household income (income elasticity). It is also possible to investigate how other socioeconomic characteristics of the household (e.g. family size) affect the price and income elasticities.

Maclennan (1977) discusses a number of theoretical and empirical problems related to the estimation of the hedonic price equation. In particular, the implicit assumptions that usually underlie hedonic price equation are questioned. Generally, the market is assumed to be in equilibrium, though this is not always a realistic assumption. However, it seems to be relatively reasonable to assume equilibrium in the housing market when the sample is restricted in both time and space. Furthermore, he concludes that the possible existence of sub-markets is often ignored, as is the role of transaction and search costs. Maclennan also stresses the risk that omission of important variables causes estimation bias. Normally, it is assumed that the omitted attributes in the hedonic price equation are not correlated with the included one, which is not always the case.

The functional form of the hedonic price equation has been subject to some debate over the years and the commonly used linear hedonic price equation relies on implicit assumptions that are not likely to be realistic. For example, the linear form implies that the marginal valuation of an attribute is invariant with the quantity level. There is, however, nothing in economic

theory that postulates any particular functional form and Halvorsen and Pollakowski (1980), for example, use a Box-Cox transformation that empirically finds the best functional form.

Miller (1982) reviewed a number of empirical works. The purpose of his review was to focus on attributes that affect house values and on limitations of the hedonic method. His conclusion is that the understanding of how housing and location attributes influence house values is well established and that our attention must now focus on financial factors and transaction costs. Regarding the limitations, he especially emphasises that the problem with multicollinearity must be fully recognised.

The first two essays presented in this thesis very much follow the path of Rosen and address the problems raised by Maclennan and Miller. The first essay is a review article that investigates how published empirical work is presented, how the work is connected to previous theoretical discussion and how the result is presented and interpreted. The second essay is an analysis that employs the hedonic technique, but it tries to take some of the objections raised by Maclennan and Miller into consideration. Especially, the implicit assumption about equilibrium and symmetric information is thoroughly analysed and so is the question of multicollinearity.

Essay 1: An Investigation of Property Price Studies

The first essay presented in this thesis is a review written together with my colleagues Kicki Björklund and Bo Söderberg. The aim of the paper was to analyze published property price studies with respect to purpose, data sources, presentation and methodology.

A review article by McCloskey and Ziliak (1996) inspired the essay. Their study focused on the distinction between economic and statistical significance and their point was that an independent variable could be statistically significant without being significant or of importance in economic terms. Their findings indicate that the authors of the reviewed paper largely misunderstand the concept of statistical significance. Our paper followed McCloskey and Ziliak, but we considered a broader number of issues that fall in the category of good scientific practice. We discussed a number of basic guidelines concerning the reporting of research in general and in econometrics in particular and for each of these guidelines, a question was formulated. All the questions were constructed so that a “yes” indicated that the empirical analysis is in accordance to good scientific practice.

Two of the questions were related to the presentation of the work and how it was connected to previous research and theoretical discussion. Six questions were associated with how the considerations underlying the modeling procedure were presented and four questions with how the data was presented. Six questions were related to how the results were presented and interpreted. These 18 questions were then explored using a sample of published empirical studies.

Our selection of journals included the leading ones in real estate, housing and urban economics. The sampled articles consisted of property price or rent studies applying regression techniques. The total number of articles, published between 1990 and 1995, was 1,882 and the sample consisted of 145 articles (8 percent). Almost 85 percent of these were published in six of the twelve journals under consideration. As many as 100 of the 145 articles

were primarily focused on individual attributes and 45 on the model as a whole. Though this research area is well established and has been investigated for decades, a number of real estate sub-markets appear to have been sparsely investigated. This is particularly true regarding applications on income properties. Only 20 percent of the sample used return as the dependent variable and less than 30 percent presented empirical analysis employed on income properties. The increasing importance of the real estate market in connection to financial analysis supports our view that income properties should be studied by increasing the use of the hedonic technique.

The results from the different questions varied considerably. Under the assumption that all researchers follow the recommendations found in econometric textbooks and critical reviews, we expected the frequency of ”yes” answers to come rather close to 100 percent for most of the 18 questions. This was, however, not the case. The result was in some cases much lower. The frequency of “yes” answers ranged from 20 percent on each question up to over 90 percent, with an average of 58 percent. The total number of “yes” answers per article ranged from 5 to 15, with an average of 10. However, as a whole, the selected articles give recognition to the issues raised in our questionnaire and when we matched the results with those of McCloskey and Ziliak, we got the impression that the results were of a comparable nature.

Almost every empirical work in the articles rested on a theoretical discussion and comparisons to other studies were also common. However, only a small share of the papers, 27 percent, motivated the choice of functional form. The corresponding percentage for articles using a linear function was even lower, 18 percent. In almost 50 percent of the articles the choice of independent variables were motivated and a slightly larger group presented assumptions for the variables chosen. However, they did not discuss the risks connected with excluding possible relevant variables to the same extent. The presentations of the data were generally rather substantial, e.g. almost every article presented the number of observations and the data sources. The number of articles that presented descriptive statistics was lower and only 20 percent of the papers discussed the validity of the data, possibly indicating the assumed absence of measurement error in the data. Almost all articles, presented the explanatory power, but as few as 30 percent interpreted it. A large number of articles commented on significant figures and discussed the economic interpretation of estimated coefficients, but only 30 percent of them explicitly gave recognition to the multicollinearity problem, and only 25 percent presented a residual analysis.

Essay 2: The Impact of Traffic Noise on the Values of Single-Family Houses

The second essay in the thesis is an analysis that uses the first step in the estimation procedure proposed by Rosen’s (1974).

In this study, the impact of traffic noise on the prices of single-family houses was analyzed. The major difference between this study and earlier studies was the inclusion of the noise variable in the hedonic price equation. Normally, the existence of roads generates both positive and negative effects (e.g. access to the city, air pollution and aesthetic effects). By including only one variable that indicates the level of noise at each house, the estimated parameter will measure the net effect. Thus, both the positive effects and other negative externalities apart from traffic noise will influence the parameter. In the estimation of the

marginal willingness-to-pay, I tried to distinguish the effects of the noise and all other effects that the road generates by decomposing the noise variable into two separate variables. The first variable measured the level of noise at each house and the second variable the level of excess noise at each house that has a view of the major road. Hence, the first noise variable measures only the noise effects while the second variable measures all the negative effects. Furthermore, by restricting the sample relatively narrow in space I was able implicitly to assume that the positive effect is constant.

In the empirical part of the analysis, I estimated the hedonic price equation, that is, the transaction price as a function of housing and location attributes. Living area, lot size and indoor quality were used as housing attributes and the level of noise from the major road was used as a location attribute. Distances to minor roads, corner lot and closeness to park were other attributes I tested but these did not statistically improve the model. I used a variant of the Box-Cox transformation to find the statistically best fitting specification. It was, however, not possible to reject the log-linear specification. This specification results in implicit prices that are a function not only of the consumed quantity of the attribute in question, but also of the consumed quantity and paid implicit prices of all other housing and location attributes.

The implicit prices for all the attributes were estimated and the constancy over time was tested by a Chow-test. The formal statistical test indicated that the parameters were not constant over time. My conclusion, in this case, was that the main reason for non-constant parameters was non-equilibrium prices on the housing market during the first period (1986-1989) in the sample due to rapid changes in housing demand. As it is not possible to interpret the implicit price as marginal willingness-to-pay during periods when prices are not equilibrium prices, I did not use the first period further in the analysis.

In the empirical part, I also tested the assumption about symmetric information between buyers and sellers. It was carried out by analyzing the turnover rates between houses that are located close to the major road compared to houses far away. My hypothesis was that if asymmetric information exists the turnover rate should be higher for the properties close to the road. This hypothesis was rejected and, thus, symmetric information was a reasonable assumption to make.

As the implicit price of noise should be used in cost-benefit analyses of road investments, the property tax should be taken into consideration. The difference in the price of the houses, due to traffic noise, is only one part of the total cost for the society. The other part is the reduction in total sum of property tax collected by the government. If this part is not included, the cost (increasing noise level) or the benefit (reduction in noise level) will be underestimated. One condition is that the property tax is non-local as it is in Sweden. That is, there is no connection between property tax and the supply of locally available public goods. In the empirical analysis, I also tested if the property tax was fully capitalized into property values. The result indicated that the extent of underestimation is as high as 30 percent if property tax is not included in the valuation of traffic noise.

The estimated effect of noise on property prices was considerable. The empirical analysis suggested an average noise discount of 0.6 percent per decibel. This implies that a house located in a quiet area would sell for SEK 975,000, and SEK 650,000 if located near a road where noise is considerable. This is equivalent to a total discount of 30 percent. The estimated

willingness-to-pay for a reduction or willingness-to-accept an increase in the level of traffic noise should, however, only be used for non-marginal changes as the implicit price equation is not equal to the demand function.

3. The Estimation of the Demand Equation

Follain and Jiminez' (1985) article is an extensive review of work aimed at estimating the demand for housing and location attributes. They especially discuss and analyze if it is possible to use Rosen's second step. The result indicates that it is possible, but a number of potential problems may arise. For example, it may be impossible to identify the parameters in the demand equation, as the variation in the implicit price is only a result of the assumption of the functional form of the hedonic price equation. Another problem that may arise is the fact that the household simultaneously chooses implicit price and quantity of the attribute, which induces an endogeneity problem in the estimation of the parameters in the demand equation. One solution to the latter problem is to use instrumental variables, such as income and other socioeconomic characteristics of the household. That is, to find variables that are correlated to the attribute in question but not to the stochastic term in the demand equation. Epple (1987) questions this procedure, or more correctly the use of socioeconomic characteristics as instrument variables. However, he also concludes that socioeconomic characteristics of the household can be suitable instruments if all housing attributes are measured and no measurement error in the variables exists.

Mayo's (1982) article is an overview of the estimation of demand equations. He especially discusses the log-linear specification of the demand equation and the difference between the use of aggregated and individual data. The review indicates that aggregation bias exists and, thus, that estimates of own-price and income elasticity are usually higher with the use of aggregated data. He also discusses the potential bias arising from the definition of the income variable in the demand equation. Current income is commonly used in the demand equation, but if the transitory income is high, it seems that the use of current income results in a downward bias of the income elasticity. In the second half of Mayo's article, he strongly recommends the use of linear expenditure functions instead of log-linear demand equations. The main reasons are as follows. In the first place, the linear expenditure system is more flexible, especially for the inclusion of demographic variables. Secondly, it does not concentrate on estimating *the* price and income elasticity and it is better grounded in economic theory. He emphasizes the possibility that price and income elasticity can differ among households, something the linear demand equation cannot easily handle.

My third essay presented in the present thesis and summarized below explores Rosen's second step by making an explicit assumption about the utility function. The price and income elasticities concerning three different housing attributes are estimated by a system of linear expenditure functions.

Essay 3: Household Expenditure Pattern of Housing Attributes

This paper presents estimates of income and own-price elasticities for a number of housing attributes. The method used relies on Rosen's (1974) proposed two-step estimation procedure. To be able to identify the structural parameters a restriction of the utility function has been imposed. By maximizing a utility function subject to a budget restriction, it is possible to derive a number of expenditure functions concerning all the housing attributes and all other

goods. Solving this system of expenditure functions makes it possible to estimate price and income elasticities. Surprisingly, the linear expenditure system has not been employed before in this type of study.

The system of household expenditure function of housing attributes is based on the additive Stone-Geary utility function, which is a reasonable assumption if households base their decision on budget shares. The expenditure function consists of two different parts, namely the base amount and the marginal budget share. The base amount is defined as the household's minimum need of different goods and the marginal budget share is defined as how much the household would increase the consumption of an attribute if income increases by one unit. By allowing the base amounts and the marginal budget shares to vary linearly with family size, I extend the traditionally linear expenditure system. To my knowledge, the latter has not been done before. Furthermore, savings are included in the household budget constraint. That is, the household equity position is included in the expenditure functions.

The system of expenditure has been estimated for four different housing attributes, namely living area, lot size, and indoor and outdoor quality. Outdoor quality is defined as the absence of traffic noise. Besides the consumption of housing attributes, the household consumes other goods, which is defined as the difference between permanent income and mortgages on the house. The difference between price and mortgage is naturally the households' equity, that is, their savings.

The implicit prices for all the housing attributes have been estimated by a Box-Cox transformed hedonic price equation. A log-linear specification cannot be rejected. The parameters have also been formally tested for constancy over time, which cannot be rejected. Furthermore, the robustness of the estimates in the linear expenditure system has been tested for different choices of specifications of the hedonic price equation and different specifications in different periods. The conclusion is that the estimated parameters are rather insensitive to the choice of functional form.

The results indicate that the minimum need of housing attributes as well as all the other goods and the marginal budget shares vary linearly with family size. If income increases marginally, the household would allocate more resources to living area and indoor quality than to lot size and outdoor quality. That is, the living-area and indoor-quality attributes are more sensitive to changes in income.

All the estimates of the income elasticities are of a reasonable magnitude and the results indicate that living area and outdoor quality are more income elastic than the attributes lot size and indoor quality. The overall price elasticity of housing is estimated to be -0.4 and the income elasticity to be around 0.5. The income elasticity increases with available income, family size and loan-to-value ratio. Especially, households' with children and low down payments have higher income elasticity with respect to the housing attributes living area and outdoor quality and the income elasticity for this subgroup is estimated to be around 0.7 for the attribute living area and 0.6 for the attribute outdoor quality.

4. A Case Study of Traffic Noise Abatement

In Essay 4 the following question is investigated: Is an investment in traffic noise barrier economically justified or not? Of course, it would be possible to answer the question by using the estimate of the marginal willingness-to-pay for a reduction in noise level, estimated in Essay 2, together with information on price and income elasticity, estimated in Essay 3. However, it is sometimes difficult to estimate accurately the noise level before and after the investment. Thus, it is difficult to quantify the environmental improvement. One method that does not need information about the exact change in environmental quality is a method that analyzes house prices before and after the environmental improvement, the so-called repeated-sales method. One of the disadvantages with the method is that the method could only be used ex post, that is, when the investment has already been carried out.

Bailey, Muth and Nourse (1963) introduced the method of the repeated-sales. They addressed the problem concerning variations in quality among houses over time and its consequences in the construction of property price indices. The standard way to address this problem is by applying the hedonic technique. However, when the changes in quality have been large or are difficult to identify and quantify, the hedonic price index can be biased. If, however, changes in quality of the same property can be assumed to be zero and by only analyzing properties that have been sold more than once, an unbiased price index can be constructed. By analyzing the ratio in prices (final sale and initial sale price) between two sales of the same property, the price indices can be estimated using regression techniques.

Few studies have employed the repeated-sales method in the estimation of the benefit of environmental changes. Nourse (1963) used a price index approach in a study where he analyzed if public housing had a positive benefit on surrounding houses. He concludes that there was some positive difference in price trend, that is, in favor of public housing. Palmquist (1982) used the repeated-sales method to estimate the effect on house values of an environmental change (reduction in highway noise) while controlling for the overall changes in real estate price level. Mendelsohn (1987) also used the same method, but treated the overall price change differently compared to Palmquist. Instead of estimating the general price change, he used gross national product as a deflator. His conclusion was that environmental change had a significant effect on property values.

Essay 4: Valuation of Traffic-Noise Abatements

The fourth essay investigates whether or not an investment in a traffic noise barrier is economically justified. I have used the repeated-sales method to estimate the benefits of building a traffic noise barrier. The repeated-sales method use transaction data, but only those sales for which the same house has been sold at least twice. Thus, for every house I have data on an initial sale and a final sale. The price movement that has occurred between the first and second sale is compared with the price change in the total housing market. For a number of sales, I have properties where the initial sales took place before the noise barrier investment and the final sale after. By including a dummy variable in the regression model, it is possible to isolate the noise barrier effect. Two hypotheses were tested and verified. The first concerns if there is a capitalization effect and the second whether the capitalization effect depends on the distance from the house to the road.

The repeated-sales method is especially suitable when there is a large improvement in the environment. Compared to the hedonic method, the repeated-sales method is not affected by

the misspecification of the functional form and the omission of the relevant housing attributes as long as they do not change over time. The disadvantage with the repeated-sales method is that the estimation is based on a smaller sample, that is, there is a problem of sample selection bias. Another problem is the implicit assumption of the constancy of the parameters over time. Both these potential problems were investigated using formal statistical tests. I have also tested if multiple repeated-sales differ from single repeated-sales and included observed changes in housing attributes in the specification of the repeated-sale function.

By estimating the hedonic price equation, I tested if a sample selection bias exists and if the assumption of constancy in parameters over time holds. In addition to including the housing attributes in the hedonic price equation I also included a dummy variable where the value one (1) indicated if the sale belonged to a repeated-sale and zero (0) otherwise. I further included a number of interaction variables where all the housing attributes were multiplied with a set of time dummies. The conclusions, in this case, are that sample selection bias did not exist and the assumption about constancy in the parameters over time could not be rejected.

The result is highly statistically significant and none of the two hypotheses can be rejected. That is, there seems to be a capitalization effect and it is distance dependent as expected. The benefit has been computed as the total price increases, due to the noise barrier alone, multiplied with the number of houses in the stock. The benefit is estimated to be around SEK 25,500 per meter noise barrier, which should be compared to a construction cost of only SEK 5,400 per meter. Therefore, the investment in a noise barrier is justified economically in this particular case.

Appendix

Essay 5: Traffic Noise and Property Value (Trafikbuller och fastighetsvärden)

The fifth essay is written in Swedish and has been presented and accepted as a Licentiate Degree in Engineering in 1997.

Chapter 1 discusses the background, the choice of method and the definition of noise. Why is it necessarily to have an estimation of the monetary value of traffic noise? Since the beginning of 1980s, the Swedish Road Association has performed a cost-benefit analysis before investments in roads. One component in these analyses is of course the negative externality of traffic noise. An early monetary valuation of traffic noise was based on a property value study carried out in 1974. The aim of essay 5 was to revise this valuation. The analysis presented is also based on property values and the reason for this choice of method is that the hedonic method analyzes observed individual choices. Alternative methods are usually based on hypothetical questions, which can create a bias in the estimated willingness-to-pay for a reduction in traffic noise. Another question discussed in chapter one is about the definition of noise. Sometimes noise is defined as “all unwanted sound”, which is not a very clear definition. The definition indicates that noise is very much a question of experience. Noise is usually measured in the logarithm unit decibel. Decibel A (dBA) is a filter that tries to imitate the human ear.

Chapter 2 discusses different welfare measures. Three different measures is described, namely the consumer surplus (CS), compensating variation (CV) and equivalent variation (EV). CS is calculated by integrating the demand equation over the relevant price change, that is, the

measure will include both price and income effect. CV and EV on the other hand only measure the price effect. CV is based on the initial utility level and EV on the final utility level. The conclusion is that compensating variation (CV) is the preferred welfare measure, but the use of consumer surplus can be used as an approximation if the income elasticity is low.

Chapter 3 presents a thorough analysis of the hedonic technique. The first two sections describe Rosen's (1974) proposed two-step approach. The following two sections discuss some of the objection that has been raised against the hedonic model. I especially elaborate on the objection that has been raised against the equilibrium condition, the interpretation of the non-linear budget restriction implied by the non-linear price equation, the assumption about continuous housing attributes, and the question of market segmentation. Further, I briefly present the critique against Rosen's second step, namely the identification and endogeneity problem. The main conclusion is that: first, it is important to investigate if the market is in equilibrium. If not, it is not possible to interpret the estimated implicit prices as marginal willingness-to-pay. Second, it is equally important to analyze whether or not the housing market consists of any sub-markets and third, whether it is reasonable to assume that the implicit assumption about continuity in housing attributes holds. It has, however, been shown that a continuous approach performs as well as a discrete approach.

In chapter 4, I discuss the hedonic price equation, that is, the choice of functional form and the choice of attributes. I first conclude that there is nothing in the theory that postulates any particular functional form of the hedonic price equation. The choice of functional form is very much an empirical question. Second, housing and location attributes such as living area, lot size, indoor quality are attributes that are typically used in this type of studies. Finally, the inclusion of the noise variable is not without problems. If the noise level at each house is directly included in the hedonic price equation there is a risk that the estimated parameter not only measures the effect of noise, but also other negative externalities as well as positive externalities that the road generates. I have solved this problem by restricting the sample area to be relative small and, thus, implicitly assumed that the positive effects are constant. Further, I have decomposed the noise variable into two separate variables. One that measures the level of noise at each house and one that measures the excess of noise for visually exposed houses.

Chapter 5 to 7 presents the empirical analysis. I have estimated the hedonic price equation, tested for asymmetric information between seller and buyer, tested the equilibrium condition, and analyzed the residuals. The main conclusion is that traffic noise is capitalized into property values and that the estimated parameters are statistically significant. That is, the data supports the hypothesis about capitalization. The results also seem to be rather robust.

In chapter 8, I transform the implicit price of traffic noise into a cost-benefit valuation. The analysis indicates a noise discount in the range of 0.5 to 5.0 percent per decibel. The valuation supports the valuation used today, but the estimates also suggest a slightly higher valuation for houses exposed to very high noise levels and a lower valuation for houses that are not so noise polluted. The recommended noise valuation is less linear compared to the valuation that has been previously used.

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