The Impact of Highway Noise Barriers on the Housing Prices of Neighborhoods.

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Selected paper prepared for presentation at the Southern Agricultural Economics Association (SAEA) Annual Meeting, Mobile, Alabama Texas, 4-7th, 2017.

Abstract

Recent empirical studies have investigated the impact of noise barriers on housing prices of adjacent homes. Their results have conflicting evidence. One important observation is that the existing literature examines the impact of berm barriers. Missing in this literature is the impact of barriers made out of other materials. This paper investigates the impact of Noise Barrier Walls (made out of other materials) on the market value of adjacent residential homes. We use a data set containing 141 noise barriers built in 12 counties of Washington State, U.S.A. The data on the location of noise barrier walls is obtained from Washington State Department of Transportation (WSDOT), Environmental Service Office (ESO) -Environmental Information Program. Two models are employed, the hedonic price model and a mofied hedonic model in a quasi-random experiment. The modified Hedonic price method results are very impressive: On average, Noise Barrier walls increase prices of residential homes within 300m by 15.24% . This impact decreases as the distance from the noise barriers increases. We estimate an increase in housing prices of 6.96 % more for houses between 300m and 600m away from the noise barrier.

Key words: Highway traffic noise, noise barrier walls, hedonic pricing method

I. Introduction

Recent empirical literature has rigorously investigated the effect of highway traffic noise on housing prices of adjacent homes. On the average, the literature reports a negative effect of highway traffic noise.That is, each decibel increase in noise level causes a reduction in the price of the affected house (i.e.,Nelson 1978 & 1982; Navrud 2002; Tinch 1995; Baranzini, Ramirez, Schaerer, & Thalmann, 2008; Allen, 1981; Anderson & Wise, 1977; Seo, Golub, & Kuby 2014; Brandt & Maennig 2011). However, these and many more recent studies have not considered the likely reversal of these negative effects when noise abatement measures are taken.

Todate, only three studies have been conducted to estimate the potential benefits from traffic noise reduction (i.e., Kamerud and von Buseck 1985; Hall and Welland 1987; and Julien & Lanoie 2007). Kamerud and Von Buseck (1985) opened this discussion with results claiming that noise barriers have no impact on neighboring housing prices. Hall and Welland (1987) attempted to overturn these results but their results were not consistent across the three data sites they studied for them to make any solid claims. Out of the three sites studied with existing noise barriers (Victoria Park, Etobicoke, and Leslie Street), results of two sites (Victoria Park and Etobicoke) had smaller noise discounts. These results are problematic because it is not clear why the third site with noise abatement measure produced a larger noise penalty than areas without abatement measures in place. Recently, Julien and Lanoie's (2007) published an article in the *Journal of International Real Estate Review* that gives results that are even more discouraging. By studying a sample of 134 respondents residing in an area in which a single noise barrier was constructed, the authors' report that noise barriers are associated with a 6 % decrease in the price of adjacent houses in the short run and 11% decrease in the long run.

Indeed, the results in the existing literature are ambiguous and counter conventional wisdom. This is because, the literature that measures the impact of highway traffic noise has an established finding that proximity to the highway is associated with lower housing prices. This is because houses closest to the highway are exposed to higher levels of noise levels. The noise level and thus its impact on housing prices reduces as the distance from the highway increases. On the other hand, the U.S department of transportation reports that noise barriers reduce sound levels and the reduction deduces as the distance from the wall increases. It is therefore expected that houses closest to the noise barrier will experience a larger positive impact from the construction of the noise barrier.

We however notice some fundamental problems in the current literature. In the first of these studies, Kamerud and Von Buseck (1985), considers two sites (i.e., Troy Meadows and Lakewood) both located near the same highway in Michigan, USA. An important observation with this study is that their results are not surprising because their study accesses the impact of an earth berm noise barrier which is estimated to reduce noise by only 6 to 7 decibels for the homes adjacent to the highway. In addition, the study is only based on one noise barrier the definition of noise abatement measures falls far short by many more efficient noise abatement methods such as the concrete noise barrier walls. Further, their analysis had only 24 observation for the after-barrier construction analysis, this is much less than statistically acceptable number of observation to produce reliable statistical estimates. Other critics have also commented on the limited number of control variables used in this study. By controlling for only year and size, many other factors that affect the price of a house are left out. In fact, the specifications used in this study are not consistent with hedonic price theory. such as other housing characteristics (lot size, garage size, number of Bedrooms, number of Bathrooms), demographics of the residents, other environmental characteristics or amenities (such as distance to the shopping malls, schools, medical services, recreational parks, among others) which means that the estimates are more likely to be suffering from omitted variable bias (Julien and Lanoie, 2007). Finally, there could be issues related to the hedonic model specification issues that were highlighted by Rosen (1974).

The study conducted by Hall and Welland (1987) uses un representative data and the estimations too do not include all the variables as according to the hgepodic price theory. On the other hand, Julien and Lanoie (2007) studies only one noise barrier, although they have a reasonable number of observations, results from studying one market with one barrier cannot be generalized. Also, according to Parmeter and Pope (2009), the use of Repeat Sales Data has a number of benefits but it can also give unreliable result. For example, repeat sale method only provides insights into price changes and the sample sizes are significantly reduced since homes that only sell once over the study period are dropped from the dataset. This means that the houses that sell repeatedly are not representative of the actual market trends.

In this paper, we reconcile the apparent belief that noise barrier walls have a negative or no significant impact on the housing prices in the neighborhoods. The paper provides estimates of the extent to which noise barriers reverse the negative impact that highway noise has on housing prices of adjacent homes. First, we assemble a dataset containing housing data with 141 noise barriers of different types, built from 1963 to 2009 in 12 counties of Washington State, United States. We use a Hedonic price model and a modified hedonic model to facilitate comparison with previous literature. Although our results do not incorporate many of the recent advances in hedonic model estimation, they reveal very interesting results. To preview the results, we find that, Hall and Welland (1987), Kamerud and Von Buseck (1985), Benoit and Lanoie's (2007) conclusions which are based on one barrier (Berm barrier) are quite misleading. Our results are based on barriers made out of other materials (concrete, precast, wood and block).

We find that, the impact noise barrier walls vary by distance of the house from the Barrier. On average, Noise Barrier walls increase prices of residential homes within 300m by 15.24% . This impact decreases as the distance from the noise barriers increases. We estimates an increase in housing prices of 6.96 % more for houses between 300m and 600m away from the noise barrier.

II. Background Information: Noise Barriers in the United States.

In the United States, noise barrier walls are the most commonly used high way noise abatement method[1].Other abatement measures include: use of buffer zones, modifying speed limits, restricting truck traffic, providing noise insulation among others (District Department of Transportation Noise Policy, 2011**)**. The United States Department of Transportation reports that by 2010, 47 State Departments of Transportation (SDOTs) and the Commonwealth of Puerto Rico had constructed over 2,748 linear miles of barriers at a cost of over $4.05 billion ($ 5.44 billion in 2010 dollars). Out of these, ten SDOTs account for approximately sixty-two percent (62%) of total barrier length and sixty-nine percent (69%) of total barrier cost. The US Department of transportation also reports that 20% of the total expenditure has occurred in the last five years; 42% in the last 10 years and 58% in the last 15 years in 2010 US dollars.

For the inventory period (2008-2010), the overall average cost, combining all materials, is $30.78 per square foot. The average unit cost, combining all materials, for the 10 years prior to 2010 is $30,56 per square foot. Approximately 264 miles of barriers have been built with high way program money other than Federal aid. For barrier constructed with federal aid, approximately 78% are Type I (a barrier built on a highway project for the construction of a highway on new location or the physical alteration of an existing highway which significantly changes either the horizontal or vertical alignment or increases the number of through traffic

[1] **T**he high way noise barriers are solid obstructions built between the highway and the homes along the highway.

lanes). Forty-six states and the commonwealth of Puerto Rico have constructed more than 1, 938 linear miles of Type I barriers, at a total cost of approximately $3.5 billion. Further, twenty-six states have constructed at least one type II noise barrier (a barrier built along an existing highway), at a total cost of more than $1.19 billion. Only three states and the District of Columbia have not constructed any noise barriers to date. These states are: Alabama, Rhode Island, and South Dakota.

Noise barrier walls are constructed using materials such as: concrete, block, wood, metal, earth berms, brick, and a combination of all these materials. Noise barriers are normally 12 to 15 feet tall. The U.S Department of Transportation also notes that noise barriers do not block all the noise but they reduce noise levels. It is estimated that an effective noise barrier can reduce noise levels by 10 to 15 decibels, cutting the loudness of traffic noise in half (U.S Noise Policy, 2011; U.S Department of Transportation, 2017). In addition, Benoit and Lanoie (2007) note that, the noise impact of highway traffic is felt within an area not farther than 300meters (around, 1,000 feet) from the highway. Bolt, Beranek, and Newman (1973, p.9) estimates that noise from a highway decreases by three to six decibels for each doubling of distance. This means that, the presence of noise barriers can improve housing prices that would otherwise be depressed by the noise externality. Implicitly reducing the noise discounts normally given to home buyers in the absence of noise abatement measures.

III. The Model

i. The Hedonic Price Method

The hedonic price method has been widely used to value environmental amenities in the housing market (Nelson, 1982; Hall and Welland 1987; Kamerud and Von Buseck 1985; Julien & Lanoie 2007 ; Blanco and Flindell 2011). The theory of the hedonic model has been popularized by Rosen (1974) who assumed that demand analyses of bundled goods such as housing units can be derived as a function of the good's characteristics. In studying transport noise, the model has had a wide application in studying air craft and highway noise (i.e., Paik 1972; Dygert 1973; Crowley 1973; Seo, Golub, & Kuby 2014; Brandt & Maennig 2011). Basically, the model assumes that there are private markets that are complementary to avoiding noise, including the market for residential housing. That is, it assumed that houses located in quiet environments fetch a higher price compared to houses in noisy locations. This differential in market value of identical homes in two different environments gives the implicit value for quiet or the discount value for noise. In its basic form, the hedonic price model is specified as:

$$Ph_i = \alpha_0 + \sum_{i=1}^{n} \alpha_i hAttributes_i + \theta_i Env + \varepsilon_i \qquad (1)$$

Where Ph_i is the sale price of the house, α_0 is the constant term, α_i is the *i*th coefficient for the *i*th house attribute, $hAttribute_i$ is the *i*th house attribute/characteristic. Examples of house characteristics include lotsize, number of bedrooms, number of bathrooms, house size in square feet, among others. *Env*, is a measure of the environmental attribute under investigation. Various studies analyzing the impact of highway traffic noise (i.e., Nelson, 1982; Blanco and Flindell 2011) and those considering noise abatement measures (Hall and Welland 1987; Kamerud and Von Buseck 1985; Julien & Lanoie 2007) have used differently constructed variables to account for noise. In our study, we use use dummy variables based on distance and barrier construction material to account for noise level.

The advantage of the hedonic price method is that it is based on a household's real willingness to pay for the dwelling's characteristics as revealed on the market (Baranzini, Ramirez,Schaerer, & Thalmann, 2008). The model assumes that prices for the houses are determined under perfect competition and are independent of individual buyers and sellers. Therefore, individuals' charateristics do not affect the price of houses. As studies have indicated (i.e., Nelson 1982; Taylor, Breston, and Hall 1982), highway traffic noise reduces the sale values of neighbouring homes. We therefore assume that highway traffic noise is compensated for by lower housing prices and that compensation is perfect, in that all houses exposed to the same level of noise are assigned a similar noise discout. This allows us to groups houses within the same distance as experiencing the same noise level. In doing so we hope that constructing noise barrier walls improve values of neighboring homes.

However, the hedonic price model as outlined in equation (1) is limited by a number of issues. First, in its basic form, the hedonic price model as outlined by Rosen (1974) assumes a one-neighbourhood one-type model of household sorting. This makes the model highly unrealistic since according to Thünen's theory, space is limited to allow for a uniform distribution of a one type of household in a given neighborhood. Various approaches have been used in literature to account for this heterogeneity in neighborhoods. These approaches can be categoried as price oriented (Costello 2001; Rothernberg 1991), benchmark oriented (Fik et. al., 2009; Abraham et al., 1994; Kauko and Goetgoluk 2005), and multilevel approach oriented (Tu & Goldfinch 1996; Goodman and Thibodeau 2007). The problem with these approaches is that they do not account for household preference heterogeneity. Recent literature has recommendend the use of discrete choice models instead.

Second, the issues of identification and functional form specificication. This is because: i) the demand and supply for houses are changing at the same time; ii) every individual buyer is different; iii) every single house is a sale of its own; iv) each transaction is its own equilibrium; v) every buyer has his/her own slope; and vi) for each demand only one point is observed and thus the demand functions for each of the attributes are unidentified (Freeman et.al.,2014. Page. 329). However, Palmquist (1992) has shown that when the externality is local as in the case of highway traffic noise, the hedonic price function could be assumed constant and thus the marginal willingness to pay for an environmental change can be determined from the implicit price directly; and thus knowledge of the marginal bid function is not required (Freeman et al., 2014. Page. 336).

Because the hedonic framework assumes each economic agent is familiar with the information necessary to evaluate all feasible exchanges as part of his or her housing choise, this assumption may not hold for a highly diverse market (Michaels & Smith 1990; Freeman et. al., 2014; Dale-Johnson 1982; Bourassa, Hoesli & Peng 2003; Baranzini, Ramirez,Schaerer, & Thalmann 2008). In this paper we assume that all economic agents are well informed about the housing market and thus we donot account for market segmentation. We however control for different geographical locations (of the houses and use the flexible functional form to estimate aggregate response.

Several functional forms for the hedonic price model have been used in the literature. The most common ones are: the linear, the quadratic, the log-log, the semi-log, the inverse semi-log, the exponential, and the boxcox transformations. The rationale for selecting the best functional form used by early researchers has been based on the goodness of fit criteria (Freeman. et. al, 2014). According the simulation study conducted by Cropper, Deck, and McConnell (1988) on functional form, including all housing characteristics in a hedonic price function yielded the linear and quadratic versions of the BoxCox transformation to be the most accurate in estimating the marginal implicit prices. In a more recent study conducted by Kuminorff, Parmeter, and Pope (2010), the most flexible specifications of the hedonic price function such as the quadratic box-cox model were found to perform better than the linear, log-liner, and log-log specifications (Kuminoff, Parmeter, and Pope 2010, Pg. 159). However, several studies have found that if the hedonic model is specified with omitted variables or incorrectly measured variables, the quadratic Box-Cox performs poorly (Palmquist 2005; Cropper, Deck, and McConnell 1988). Unfortunately, the basic hedonic model has also been highlighted to suffer from omitted variable bias. econometric issues. Ultimately, the hedonic price method has no defined functional form and theory provides very little guidance. For example, the estimation is plagued with multocollinearity as many characteristics of the houses go together; non-standard residuals, data segmentation as multiple housing markets may coexist with imperfect information and arbitrage.

Some studies have considered market segmentation as a way to account for heterogeneity in housing markets. However, studies that have used advanced methods of housing market segmentation study a single neighborhood and have used high resolution housedold data (Belasco, Farmer, Limpscomb 2012; Limpscomb and Farmer, 2005). We recognize that the kind of data such as the one used for this study there are possibly several levels at which segmentation needs to be done. Definitely, there are many reasons to believe that the 13 countries considered in this analysis embody different housing markets. However, limited by the census tract demographic nature of our data, we are only able to account for heterogeneity at the county level.

We therefore set out to estimate a flexible hedonic price model by checking for the most appropriate functional form that best fits our data. We augment the basic model with noise barrier characteristics and locational fixed effects to control for cross sectional spatial effects. Because we use a measure of distance from the barrier wall to account for the impact of the wall on the adjacent housing prices, we also recognize that distances to amenities are not consistent estimators of the true price impact of that amenity on the housing prices. Following Ross, Farmer, & Lipscomb (2011) we use quadratic control of longitude and latitude to control for location effects of price to assure unbiased estimates of non distance variables. The basic hedonic price model similar to the one used in Hall and Welland (1987) is specificied as follows.

$$\begin{aligned} Ph_i = \alpha_0 + \sum_h \alpha_h hAttributes + \sum_k \beta_k Demog \\ + \sum_m \lambda_m Barrir\_Xterics + \varepsilon_i \end{aligned} \qquad (2)$$

The descriptions of these varibles are listed in table 1 below. The barrier characteristics are construsted in several ways. For example we create dummy variables to indicate if the house was sold with or without a barrier. We then separate the barrier dummy according to the material used to construct the barrier. We categorize barrier construction material into two groups: Berm and Other. This separation is based of the ability of the material to reduce noise as already mentioned. We then group houses into distance bands from each of the barriers in our dataset. Effectively, our noise variable has temporal, spatial, and structural dimensions.

Table 1: Variable Description

Variable name	Description	Expected sign
hAttributes	**Housing attributes**	
Ph	Sale price of the house	
Sqft	Square feet-indicator of house size	+
Lotsize (Acres)	Size of the lot in acres	+
Bath	Number of bathrooms in the house	+
Bedrooms	Number of bedrooms in the house	+
House Age	The Age of the house	-
Demong	**Demographic characteristics**	
Norm_popdens	Population density of the the census tract	+
Per_nwhite	Percentage of people who are nonwhite in the census tract.	
Per_und18	Percentage of people below eighteen within a census tract	-
Per_ownocc	Percentage of houses that are owner occupied within a census tract.	+/-
	Barrier characteristics	
County	The county in which the wall was constructed.	+/-
Material	The material used to construct the wall.	+/-
Distance	The nearest distance between the noise barrier wall and the neighboring house. It constitutes two categories, dist300m, and dist600m.	+/-

ii. Modified Hedonic price method

To facilitate comparison we also estimate amodfied hedonic model similar to that estimated in Julien & Lanoie (2007). This method uses a price differential for the dependent variable. We estimate the following model:

$$\ln Ph_s - \ln Ph_f = (\sum_i^m \lambda_{ms} Barrier\_Xterics_{ms}) - (\sum_i^m \lambda_{mf} Barrier\_Xterics_{mf}) + \sum_i \alpha_i Dist + \varepsilon_i \quad (3)$$

Where the index, *s*, refers to the second sale and index, *f,* refers to the first sale of a given house m. *Ph* is the sale value of the house. *Barrier_Xterics* is a vector of barrier characteristics capturing the extistence of the wall, the year it was build, and the material uses to construct the wall. The characteric is also used to capture the distance of the house from the wall, or the distance from the highway for houses without a barrier. *Dist* is a vector of distance variables containing: longitude, latitude, and quadratic control of longitude and latitude. E is the error term.

IV. Data and Data sources

The study is conducted on the housing market in Washington State U.S.A. This State is made up of 39 counties and by 2010, the State had 244 noise barriers built in 114 locations which are distributed in 13 out of 39 counties. The counties include: Clark, Cowlitz Franklin, Island, King, Kitsap, Pierce, Skagit, Snohomish. Spokane, Thurston, Whatcom, Yakima. Out of these, King, Snohomish, and Clark have the largest number number of noise barrier walls i.e., 137, 54, and 39 respectively which accounts for 44.05%, 17.36% and 11.58% of the walls walls respectively[2]. The data on noise barriers is obtained from Washington State Department of Transportation (WSDOT), Environmental Services office (ESO) **-**Environmental Information Program.The barriers in this dataset were constructed from 1963 to 2009. The data includes wall characterostics such as, the type of wall, the length of the wall, the height of the wall, the material from wight the wall was construted (berm, concrete, precast, wood and other materials), the year the wall was built among others.

[2] Other counties: Cowlitz (5), Franklin (5), Island (4), Kitsap (12), Pierce (19), Skagit (6), Spokane (13), Thurston (11), Whatcom (5), and Yakima (2).

The housing data was purchased from DataQuick and it includes the transaction price of each house, the sale date , and a set of structural characteristics including square feet of the living area, the number of bathrooms, the number of bedrooms, the year the house was built, the lot size and physical address for each house. The physical address is used to get the latitude and longitude using GIS street maps and a geocoding routine. The map is then used to locate the counties with noise barrier walls and the respective houses neighboring the noise barrier walls. The population census data was obtained from the 2000 U.S population census. Figure 1 shows the study area while figure 2 shows the distribution of the noise barriers within the study area.

The final data set used in the analysis is a product of several levels of cleaning for outlying observation. For example, i) we drop observations containing walls for which the year they were constructed is not known, this because we cannot know the age of the house. Observations with houses that were constructed prior to 1900 are also dropped. ii) Observations with houses having less than one acre and more than 6 acres of lot zise are not not considered, this is because considering them gives unrealist results. iii) Obsevarions for houses that are farther that 600m are also dropped because according to Benoit and Lanoie (2007), the impact of noise is felt withing a distance of 300m from the highway. iv) Observations with missing transaction value, zero transaction value are dropped because these considered not to be in the market and thus their value is not known. v) Some houses appear to have been sold prior to their construction, these are dropped because it appears that the transaction value only reflects inprovemnets made on the houses. Another potential dimesion of housing improvement noted is when the sale difference is more than 100 percent. Values beyond 100 precent are also dropped.

Effectively, we are left with a dataset containing 9,073 observations, 141 noise barriers, in twelve (12) counties[3]. The houses were built between 1900 and 2007 and the housing sales took place between 1998 and 2008 for both the first and second sales. Table 2 provides the summary statistics for the housing characteristics in the 12 counties considerd for our analysis. The third row which is the difference between housing value at first sale and housing value at second sale shows that on average, housing prices increased in all the 12 counties. On average, the difference between housing sales is largest in King Country ($ 96, 334.69) and smallest in Cowlitz county ($5, 894.00). In addition, these results show an average house sale involved houses with similar characteristics. For example, in Clark county, an average transaction involved a house with 2,438.69 square feet, 3 bathrooms, 3 berooms and 3 acres of lotzise and these characteristics are similar to houses sold in other counties on average.

Out of the 141 noise bbariers in our data set, 77% were constructed from other materials (Concrete, precast, wood and Block) and 23 % are Berm Barriers. All the Berm barriers were constructed during the first sale between 1963 and 1997. The Berm barriers are of two types Type I (Capacity project) and Type O (Other). The barriers constructed from other materials were construted from between 1976 and 2009. They are of nine funding types, Type I (capacity project), Type I/S /state funded, Type II, TypeII/state funds only, Legislatively mandated , Other, privately funded, State funded, and Unknown.

V. Preliminary Results

The results are presented in two subsections. In sub section I, we present results using the basic hedonic price model estimated using Ordinary Least Squares. The results are presented in two tables. In the first table (table 3), we present results using data for the first and second sale

[3] Clarck, Cowlitz, Franklin, Island, King, Kitsap, Pierce, Skagit, Snohomish, Spokane, Thurston, Whatcom.

separately. In the second table (table 4) we present results that study how the difference in value between the two sales vary by the presence or absence of noise barriers. This model is used for exploratory purposes inorder get a feel of how the housing market in Washington State respondes to the presence or absence of barriers. In subsection II, we present results using double log model with the difference in sales as the dependent variable as shown in equation (3). The results of this model are preferred for two reasons, first, they fail to reject the RESET Test Null Hypothesis, which gives us confidence that our results are free of omitted variables. Second, because the dependent variable is a difference of housing value between the first and second sale, this set up gives a set up of a natural experiment that enables us to compare the change in housing values before and after the barriers were constructed. In addition, Other specifications such the Box Cox with different transformation and the double log applied to equation 2 yield results that have omitted variable bias, as tested using the RESET specification test. It is important to note that we have not used BoxCox transformation on equation (3) because some values in this variable are netagive. The results for this subsection are presented in tables 5 & 6. Further, the results in this section are estimated at a country level. This enables us to control for heterogeneity at the aggregate level.

Subsection I

Results using the first housing sale data (in columns 1 & 2) show that, on average, houses that have a berm barrier sell for 40,44.86 dollars less than houses sold without barriers. Specifying the noise variable to account for differences in construction material/ or nature of barrier reveals that, on average, houses sold with barriers constructed from other materials sell for 524.84 dollars less than houses sold without barriers. These results seem to follow the trend of results reported by Julien & Lanoie (2007). However, it should be noted that these impacts are highly agregated. More disagregated results which cluster houses into distance bands are presented in column 2. These results show that home owners in Washington State seem to have multidimensional preferences. Much as high noise seems to be a problem, proximity to the highway seems to be equally valuable. Evident here is that Berm barriers have a negative impact no matter the distance. This result fits into the explanation given in Kamerud and von Buseck, (1985) and Julien & Lanoie (2007) that some people are concerned about the aesthetic impacts of the barriers. This trend of results is similar to the results obtained for the second sale. It is important to note that as is predominatly known, the linear hedonis results have a specification problem since they fail the RESET specification test.

In table four, are the results using the difference in sale value as the dependent variable. These result show that the difference in sale value of a house increase by 11074.24 dollars if the house is within 300m and the second sale occurs after a barrier made out of Other materials is constructed compared to a house within 300m sold without a barrier. For houses 600m away from the barrier, the difference in their sale value goes down by 16707.30 dollars compared to house within 300m sold without a barrier. These results too do not pass the RESET specification test.

Subsection II

In this sub section we present results estimated using equation (3). The results are presented in tables 5, 6, and 7. The set up in this section allows for a quasi random experiment form of ananlysis. In table 5, this experimental set up is accounted for by the variable *New_Barrier*, adummy variable which equals unity if a barrier was constructed between sales. In column two, this variable is intracted with a distance dummy variable which equals unity if the housing unit is within 300m from the wall or highway. the results in this trable are very informative. The noise barriers have a positive and significant impact on adjacent housing prices. Because there were no New Berm barriers constructed between sales, the coefficient estimate for New_Berm represents the impact of noise barrier walls constructed using other materials. Our results suggest that the construction of noise barrier walls increase the housing prices by 13.64% ((exp(0.278)-1)*100) more than houses without new barriers.

Table 5: Estimation Results full dataset, 12 counties

	Model1	**Standard Errors**	**Model2**	**Standard Erros**
New_Barrier	0.128***	-0.012		
New_Barrier_d300m			0.142***	-0.013
New_Barrier_d600m			0.067*	-0.033
No_newBarrier_d600m			0.01	-0.011
d300m	-0.001	-0.01		
Clark	0.051	-0.097	0.055	-0.097
cowlitz	-0.078	-0.104	-0.064	-0.107
Franklin	-0.108	-0.109	-0.119	-0.109
Island	-0.002	-0.034	-0.005	-0.034
King	0.012	-0.018	0.011	-0.018
Kitsap	0.019	-0.025	0.02	-0.025
Pierce	0.016	-0.03	0.017	-0.03
Skagit	-0.021	-0.04	-0.015	-0.04
Spokane	-0.298	-0.196	-0.306	-0.195
Thurston	0.065	-0.043	0.066	-0.043
Whatcom	0.027	-0.053	0.039	-0.053
longitude	0.019	-0.029	0.024	-0.03
latitude	0.045	-0.03	0.043	-0.03
Longitude_diffsq	0.006	-0.008	0.005	-0.008
Latitude_diffsq	-0.007	-0.026	-0.01	-0.026
_constant	0.385	-3.587	1.085	-3.587
N	*9073*		*9073*	
Rsquared	*0.016*		*0.017*	
longlikelihood	*-3376.295*		*-3372.653*	
bic	*6916.626*		*6918.453*	

Note Variables not reported here are: longitude, latitude, Longitude_diffsq, latitude_diffsq, dummy =1 if first sale happened after 2003, and a Dummy=1 if Second sale happened after 2003. The values in parenthes are robust standard errors. ***, **, and * represent level of significance at the 1%, 5% and 10% respectively. RESET Test if Ramsey reset test. The Results of the test fail to reject the null hypothesis that model has omitted variables. Hypotheis Test 1 is a test of the Null: Dummy =1 if Other barrier on Both sales=Dummy =1 if Distance is within d300m

In column 2, this impact is separated to account for distance from the wall. The results indicate that distance from the wall has a significant impact on the housing prices. Our estimates suggest that houses within 300m from the wall experience an large impact from the wall than house farther from the wall. More specifically, houses within 300m from the wall realized a 15.24% ((exp(0.142)-1)*100) increase in their sale value while houses 600 m from the wall received only 6.96% ((exp(0.067)-1)*100) increase in their sale value. These results are comform to the expectations from theory. However, they are at odds with the results found in literature. Forexample Julien & Lanoie's (2007) report a negative impact. Although these results are highy significant, they do not pass the omitted variables test.

In tables 6 and 7, we modify equation 3 to include more variables and we estimate the model on each county separately. The vector *hAttributes* and *Demog* has the same variables and descriptions as in equation (2). *Dummy$_s$_timestr* is a dummy variable which equals unity if the second house sale happened after 2003. *Dummy$_f$_timestr* is a dummy variable which equals unity if the first house sale happened after 2003. In this experimental set up is captured in three variables: *Barrier_one_Other*, a dummy variable which equals unity if a house house was sold without a barrir for the first sale and sold with a barrier made out of Other material on the second sale. *Barrier_Both_Berm*, a dummy variable which equals one if the house was sold with a berm barrier in both transactions. *Barrier_Both_Other*, a dummy variable which equals one if the house was sold with a barrier made out of Other materials for the two transactions. We have n variable for no barrier at first sale and Berm barrier as second sales because our dataset does not have such house sales. In table 7 the experimental variables are constructed to account for distance of the house from the barrier.

In tables 6 and 7, we only present results for four counties: King, Snohomish, Clark, and Spokane. The results presented in these these tables are not affected by omitted variable bias and the standard errors are robust to heteroskedastcity. The results in table 6 do not account for the distance of the house from the wall and thus estimate an average value for all houses neighboring a highway with or without a barrier. In column 1, 2. 3 and 4 are the estimates from a models using data on King , Snohomish, Clark, and Spokane respectively. The results in this table show that on average, in King county, the construction of other walls at the second sale sell for 17% ((exp(0.42)-1)*100) less than houses sold without barriers. This value is statistically significant from zero at the 10% level of significamce. In Snohomish and Spokane county, barriers have no significant impact on housing sale values. On the other hand, Clark county increased the house value by 52.5 % ((exp(0.42)-1)*100) more than houses sold without a barrier following the construction of barriers made out of other materials. However, the value of houses sold with a berm barrier or Other barrier on both transactions had no significant change on their sale value. These results are not very informative, more detailed cagetorisation of the housing markets are presented in table 7.

The results in table 7 are bothersome as they do not behave according to expectation. The coefficient estimates for variables accounting for noise are not statistically significant in King and Snohomish counties. Which implies that, regardless of the material used to construct the noise barrier and the distance of the house, the housing market in these two counties does not place any value on noise barriers walls. However, a quick data check reveals that these two counties have share eight noise barrier walls. All these walls were constructed using concrete/precast and are of Type I (Capacity project). These are walls construsted in areas where new highways are constructed or in areas with an existing highways that has undergone major changes that could potentially increase the level of traffic. One important observation however, is that the number of observations, an equivalent to the number of houses neighbouring the barrier are less than five houses.

Table 6. Resulst for King, Snohomish, Clark, and Spokane Counties

	King	**Snohomish**	**Clark**	**Spokane**
ln(lotsize) Acres	0.067	0.06	0.288***	0.127
	(0.036)	(0.051)	(0.063)	(0.084)
ln(square feet)	0.314**	0.331***	0.459***	0.229
	(0.15)	(0.106)	(0.13)	(0.15)
No. of Bathrooms	0.073	0.011	0.025	0.166***
	(0.055)	(0.046)	(0.049)	(0.056)
Difference in years between sales	0.170***	0.165***	0.121***	0.161***
	(0.012)	(0.016)	(0.018)	(0.025)
Percentage of nonwhite	0.327	0.237	0.382	4.971
	(0.525)	(0.53)	(1.668)	(3.215)
Percentage under 18	-0.154	0.298	-1.878*	-1.738
	(0.697)	(1.056)	(1.003)	(2.026)
Percentage of owner occupied	0.035	0.121	-0.378	1.204***
	(0.242)	(0.378)	(0.505)	(0.454)
Population Density	3.439	0.854	4.547	-11.693
	(3.516)	(5.837)	(7.408)	(8.313)
Barrier-One-Other	-0.189*	-0.06	0.422***	0.195
	(0.099)	(0.163)	(0.086)	(0.128)
Barrier-Both-Berm	-0.042	-0.073	-0.524	.
	(0.072)	(0.124)	(0.592)	
Barrier-Both-Other	0.058	0.05	0.184*	0.228
	(0.061)	(0.137)	(0.086)	(0.233)
Dummy =1 if Distance is within d300m	0.166	-0.174	-0.132	-0.335**
	(0.055)	(0.077)	(0.087)	(0.126)
_cons	-51.158	260.023	226.63	1581.511
	(60.188)	(190.211)	(710.497)	(2111.13)
Number of Observations	*1610*	*1214*	*859*	*481*
R Squared	*0.338*	*0.281*	*0.397*	*0.355*
Loglikelihood	*-1905.43*	*-1633.723*	*-1126.76*	*-616.933*
bic	*3951.158*	*3402.378*	*2375.115*	*1338.856*
Hypthesis Test 1	*F(1, 1591) =2.29*	*F(1, 1195) = 0.88*	*F(1, 840) = 1.46*	*F(1, 463) = 0.96*
Prob > F	*0.1305*	*0.3474*	*0.2269*	*0.3278*
RESET TEST	***F(3, 1588) =1.68***	***F(3, 1192) = 0.83***	***F(3, 837) = 1.99***	***F(3, 460) = 1.34***
Prob > F	***0.1691***	***0.4752***	***0.1144***	***0.2603***

Note Variables not reported here are: longitude, latitude, Longitude_diffsq, latitude_diffsq, dummy =1 if first sale happened after 2003, and a Dummy=1 if Second sale happened after 2003. The values in parenthes are robust standard errors. ***, **, and * represent level of significance at the 1%, 5% and 10% respectively. RESET Test if Ramsey reset test. The Results of the test fail to reject the null hypothesis that model has omitted variables.

Hypotheis Test 1 is a test of the Null: Dummy =1 if Other barrier on Both sales=Dummy =1 if Distance is within d300m

On the otherhand, the results for Clark county reveal that houses sold twice without a barrier in both transactions but 600m away from the highway had 31.9% ((exp(0.278)-1)*100) more value than houses without barrier within 300m meters from the highway. For houses without a barrier during the frist sales and a barrier made of Other barrier on the second sale, these resulst show that the housing value increased by 56.14% more for houses within 300m and by 72.7 % for houses 600m away from the wall.

These results are not statistically different according to the t-test results in table 8. Berm barriers are found to have no significant impact on Clark housing prices. Again, there no houses 600m away from Berm barriers in this dataset. For houses that sold with barrier made out of Other materials in both transaction, these results show that the presence of these barriers had a posive impact on the housing prices. Due to the large difference between these results and those presented for King and shohomish counties, and we do a quick check for details of barriers in the Clark county to ensure reliability of our results.

We find that, in the our data set, Clark county has 14 barriers and only two of these are shared with Cowltiz county. Out of these, only two barriers are Berm barriers the rest fall into our category of Other Barriers. The two Berm barriers have less than five observations which explains the insiginificant coeffient for Berm barriers. On the other hand, six of the 12 Other barriers have more than 50 observations each. Six out of the 12 other barriers are type I, two are type II, two type S, one type L/S, and one with unknown type. Another important dimension here is that five of the fourteen barriers were constructed after 2003. Although we do not have enough oberservations for the Berm barriers in this county, these results seem more reliable than the results obtained for King and Snohomish county.

Finally are the results for Spokane county and these are presented in the last column of table 7 with their corresponding hypothesis tests in table 8. These results show that housing prices for houses sold without barriers increased by 64.98% more for houses 600m away from the highway compared to houses within 300m and without noise barriers. The before and after effect of Other barriers is estimated to have increased the value of the housing unit within 300m by 29.59 % while houses 600m aways were not impacted.

According to hypotheis test 2, there is no significant difference in the change in housing value for houses 600m from the highway sold without a barrier and houses 300m meters away from the Other barriers. There are no barm barriers in spoken county. For houses sold with barriers built using other materials in both transactions show no significan impact for houses within 300m but houses beyond 300m meters sold for 91 % more than houses within 300m from the highway. These results are reliable because Spoken county has 11 noise barriers and none of them goes beyond Spokane county. All the 11 barriers are made from Other materials as per our categorization. Seven out of 11 barriers are Type I barriers, the rest are Type I/S (Type1/State funds only). The most important aspect of this county is that 5 out of 11 barrier have more than 50 oberservations. This makes the results reliable for evaluating the impact of barriers made out Other Barriers in Spoken county.

Table 7. Results for King, Snohomish, Clark, Spokane

	King	Snohomish	Clark	Spokane
ln (lotsize)Acres	0.075**	0.061	0.293***	0.137
	(0.036)	(0.051)	(0.064)	(0.085)
ln(square feet)	0.309**	0.331***	0.459***	0.219
	(0.15)	(0.106)	(0.131)	(0.152)
No. of Bathrooms	0.073	0.011	0.025	0.171***
	(0.055)	(0.046)	(0.05)	(0.056)
No. of years between sales	0.169***	0.164***	0.121***	0.163***
	(0.012)	(0.016)	(0.018)	(0.025)
No_Barrier_d600m	-0.457**	0.031	0.278*	0.501*
	(0.228)	(0.284)	(0.158)	(0.28)
Barrier_One_Other_d300m	-0.182*	-0.099	0.446***	0.259*
	(0.104)	(0.167)	(0.094)	(0.133)
Barrier_Oner_Other_d600m	-0.372	.	0.547***	0.229
	(0.26)	.	(0.161)	(0.272)
Barrier_Both_Berm_d300m	-0.054	-0.125	-0.492	.
	(0.074)	(0.136)	(0.591)	.
Barrier_Both_Berm_d600m	-0.366*	0.041	.	.
	(0.193)	(0.173)	.	.
Barrier_Both_Other_d300m	0.048	0.01	0.218**	0.216
	(0.061)	(0.141)	(0.095)	(0.25)
Barrier_Both_Other_d600m	0.13	.	0.287*	0.647**
	(0.138)	.	(0.16)	(0.281)
Constant	-66.991	250.348	294.321	2277.875
	(60.427)	(192.352)	(706.322)	(2345.68)
No. of Observation	*1610*	*1214*	*859*	*481*
R Squared	*0.34*	*0.281*	*0.397*	*0.359*
Loglikelihood	*-1902.857*	*-1633.569*	*-1126.24*	*-615.417*
bic	*3968.161*	*3409.171*	*2394.349*	*1348.175*
RESET TEST	***F(3, 1585)=***	***F(3, 1191) =***	***F(3, 835) =***	***F(3, 458)***
	1.54	***0.97***	***1.98***	***1.81***
Prob > F =	***0.203***	***0.4060***	***0.1156***	***0.1418***

Note: some variables are not reported in this table for ease of presentation and these include: longitude, latitude, Longitude_diffsq, latitude_diffsq, dummy =1 if first sale happened after 2003, and a Dummy=1 if Second sale happened after 2003, percentage of nonwhite people, percentage of people under 18years, percentage of owner occupied houses, and population density. The values in parenthes are robust standard errors. ***, **, and * represent level of significance at the 1%, 5% and 10% respectively. RESET Test if Ramsey reset test. All these results fail to reject null hypothesis that the model has omitted variables

Table 8: Hypothesis Testing

	Hypothesis Tests			
	King	**Snohomish**	**Clark**	**Spokane**
Test2	*F(1, 1588) = 1.27*	*F(1,1194) = 0.19*	*F(1, 838) = 1.18*	*F(1,461) =0.78*
Prob > F	*0.2606*	*0.6611*	*0.2771*	*0.3771*
Test 3	*F(1, 1588) = 0.50*	-	*F(1, 838) = 0.47*	*F(1, 461) = 0.01*
Prob > F	*0.4784*		*0.4951*	*0.9049*
Test4	*F(1, 1588) = 2.52*	*F(1,1194) = 1.89*	*F(1, 838) = 0.69*	-
Prob > F	*0.1128*	*0.1690*	*0.4059*	
Test5	*F(1, 1588) = 1.55*	-	*F(1, 838) = 2.53*	-
Prob > F	*0.2137*		*0.1117*	
	F(1, 1588) = 0.42	-	*F(1, 838) = 0.21*	*F(1, 461)=5.81*
	0.5179		*0.6440*	*0.0164*

Note:

Test 2: Ho: *No_Barrier_d600m - Barrier_One_Other_d300m = 0*

Test3: Ho: *Barrier_One_Other_d300m =Barrier_One_Other_d600m = 0*

Test4: *Barrier_Both_berm_d300m - Barrier_Both_berm_d600m = 0*

Test5: *Barrier_One_Other_d300m - Barrier_Both_berm_d300m = 0*

Test6: *Barrier_Both_Other_d300m - o.Barrier_Both_Other_d600m = 0*

VI. Conclusion

This study has questioned recent empriciacl studies claiming that noise barrier walls either have no impact or reduce the value of adjacent houses (Hall and Welland 1987; Kamerud and Von Buseck 1985; Julien & Lanoie 2007). Using the Framework similar to that used by Hall and Welland (1987) , we find that the results are overly misleading due to issues of omitted variable bias. These results do not get any better with various forms of specification. Although our reported results are based on a dataset pooled across counties, estimations by counties did not solve the omitted variable bias problem.

Going beyond the Hedonic price method, we employed the framework used in Julien & Lanoie (2007). Estimations using the pooled data produced results with omitted variable but the results are very intuitive. On average construction noise barriers walls has a posivite on adjacent homes. We estimate a 13.64% ((exp(0.278)-1)*100) more sale valve for houses with a barrier wall made out of other materials. More specifically, noise barrier walls increase prices of residential homes within 300m by 15.24% . This impact decreases as the distance from the noise barriers increases. We estimates an increase in housing prices of 6.96 % more for houses between 300m and 600m away from the noise barrier.

We therefor chose to run the estimation by county. Although this approach produced a model free of omitted variable bias, our results are only reliable for the impact of barriers made from other materials (concrete, precast, block, Comb, and wood. Our results have shown that Barriers made out of Other materials have a positive and significant impact on housing prices. This impact has been shown to vary by county and by the distance of the house from the noise barrier. For example in Clark County, the construction of a barrier increased housing prices within 300m from the wall by 56.14% while Spokane county realized an increase of 29.59% for similar housines. Constrained by the few observations for housing data with Berm barriers in our sample, we cannot make reliable claims for this kind of barrier.

Further research could consider dropping walls by county for which only a afew houses/observations are available for analysis. Also a better comparison with previous research on this topic would consider studing barriers shared by more than one county, that way we can see how the housing market in the different counties values the same walls. Another important source of variation for these walls is the type of funding, this is because according to the Noise discipline report (2009), federally funded highway noise barriers are built along highways for which the noise exceed 75dBA. Although we do not have much information about other sources barrier funding, this could signal differences in noise intensity and could be another area that could be explored.

The main limitations identified with this study is the use of Census Tract demographic characteristics. These characteristics are so myopic to provide any reliable estimates. This is because they have potential to bias the coeffient estimates and more importantly they have the potential to amplify standard errors. In addition, there is more cross sectional variation than we are actually controlled for in these preliminary results. For example, there more demographic characteristics that are are important in the housing market than we have controlled for such as the Age of home owner, the household size, the income of the home buyers, among others. Further, Our results could not provide a good comparison to previous research due to the limited number of observations for some barrier categories like the Berm Barriers.

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Figure 1: Map of Washington State showing the Study Area.

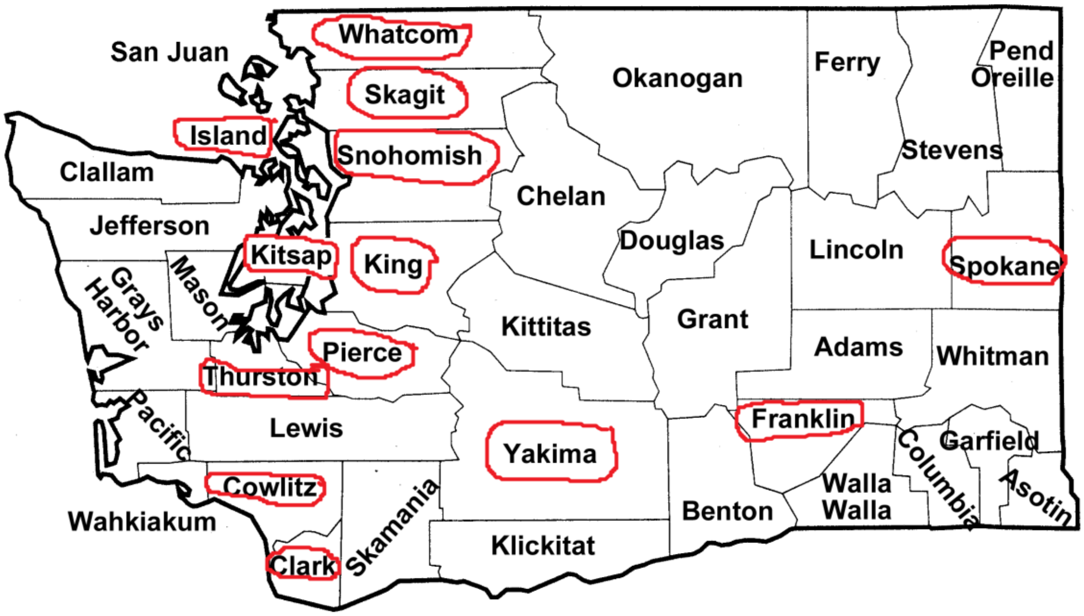

Figure 2: Map of Washington State showing the Location of Noise Barrier Walls in the Study Area

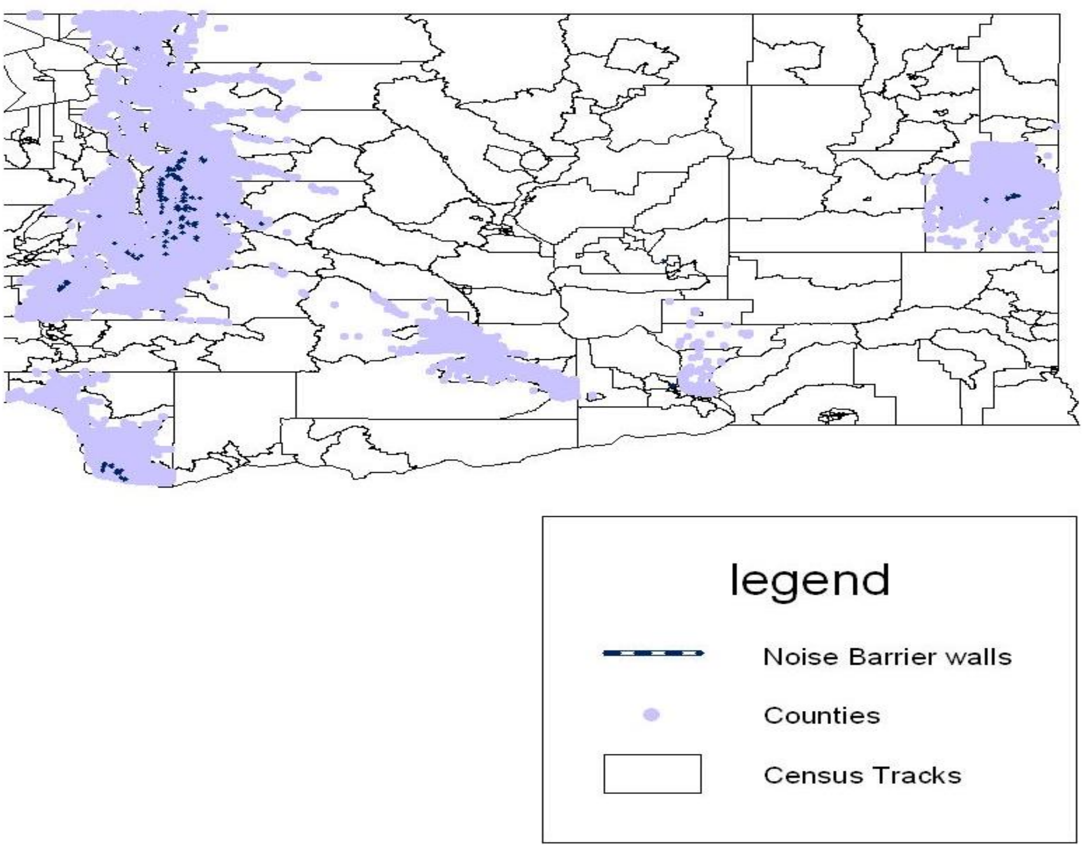

Table 2: Summary Statistics for Washington State Housing Characteristics.

	Variable	Mean	Std. Dev.	Min	Max	Obs
Clark	Value at First Sale	304,555.00	295,729.40	52,000.00	9,000,000.00	1172
	Value at 2nd Sale	352,819.50	175,778.20	8,249.00	2,000,000.00	1172
	Sale value Diff	48,264.48	279,882.80	-8,775,000.00	700,000.00	1172
	House Age at 1st Sale	21.93	21.95	0	105	1172
	House Age at 2nd Sale	24.42	21.93	0	107	1172
	Square Feet	2,438.69	967.94	696	7,944.00	1172
	No. of Bathrooms	2.64	0.91	1	7	1172
	No. of Bedrooms	3.39	0.85	1	11	1172
	lotsize (Acres)	3.01	1.62	1	5.93	1172
Cowlitz	Value at First Sale	268,319.30	105,657.00	135,000.00	448,000.00	16
	Value at 2nd Sale	274,213.30	95,354.49	125,000.00	430,000.00	16
	Sale value Diff	5,894.00	64,088.89	-106,000.00	107,250.00	16
	House Age at 1st Sale	30.31	25.35	0	88	16
	House Age at 2nd Sale	31.00	25.54	1	88	16
	Square Feet	1,887.38	696.24	576	3,094.00	16
	No. of Bathrooms	2.19	0.75	1	4	16
	No. of Bedrooms	3.13	0.62	2	4	16
	lotsize (Acres)	2.42	1.31	1	5.37	16
Franklin	Value at First Sale	156,862.10	99,054.36	20,000.00	505,000.00	25
	Value at Second Sale	186,526.50	128,494.30	30,000.00	614,000.00	25
	Sale value Diff	29,664.36	47,561.76	-49,499.00	135,000.00	25
	House Age at 1st Sale	32.48	18.88	0	68	25
	House Age at 2nd Sale	35.60	19.06	3	75	25
	Square Feet	1,714.40	620.74	794	3,384.00	25
	No. of Bathrooms	1.93	0.77	1	4	25
	No. of Bedrooms	3.40	1.00	2	7	25
	lotsize (Acres)	1.84	1.47	1	5.4	25
Island	Value at First Sale	339,953.80	189,113.70	116,500.00	1,100,000.00	73
	Value at 2nd Sale	411,676.30	218,782.50	60,000.00	1,500,000.00	73
	Sale value Diff	71,722.45	91,140.47	-220,575.00	400,000.00	73
	House Age at 1st Sale	25.49	26.72	0	105	73
	House Age at 2nd Sale	27.40	26.66	1	105	73
	Square Feet	2,180.14	1,190.28	650	8,572.00	73
	No. of Bathrooms	2.40	1.08	1	7.25	73
	No. of Bedrooms	3.07	1.22	1	8	73
	lotsize (Acres)	3.01	1.58	1	5.89	73
King	Value at First Sale	450,503.50	318,558.10	30,720.00	6,950,000.00	1983
	Value at 2nd Sale	546,838.20	314,108.50	10,000.00	3,550,000.00	1983
	Sale value Diff	96,334.69	209,194.30	-6,599,000.00	1,100,000.00	1983
	House Age at 1st Sale	23.55	20.83	0	107	1983
	House Age at 2nd Sale	26.81	20.62	0	108	1983

	Square Feet	2,661.69	1,266.45	260	28,544.00	1983
	No. of Bathrooms	2.78	1.05	0.5	10	1983
	No. of Bedrooms	3.49	0.98	1	18	1983
	lotsize (Acres)	2.25	1.38	1	5.98	1983
Kitsap	Value at First Sale	284,819.80	203,814.20	22,000.00	2,037,162.00	1289
	Value at 2nd Sale	350,330.40	232,776.60	10,000.00	2,300,000.00	1289
	Sale value Diff	65,510.66	122,593.40	-1,730,000.00	916,292.00	1289
	House Age at 1st Sale	19.36	22.03	0	103	1289
	House Age at 2nd Sale	21.86	21.95	0	106	1289
	Square Feet	2,023.20	782.11	536	6,542.00	1289
	No. of Bathrooms	2.51	0.87	0.5	7	1289
	No. of Bedrooms	3.13	0.79	1	8	1289
	lotsize (Acres)	2.22	1.15	1	5.95	1289
Pierce	Value at First Sale	270,895.40	179,881.10	40,229.00	3,300,000.00	1346
	Value at 2nd Sale	334,447.90	198,088.40	10,000.00	2,465,000.00	1346
	Sale value Diff	63,552.47	122,327.30	-2,100,000.00	1,087,000.00	1346
	House Age at 1st Sale	23.62	23.57	0	107	1346
	House Age at 2nd Sale	26.30	23.34	0	108	1346
	Square Feet	2,554.16	1,193.20	484	11,284.00	1346
	No. of Bathrooms	2.18	0.77	0.75	10.75	1346
	No. of Bedrooms	3.19	0.85	1	10	1346
	lotsize (Acres)	2.02	1.32	1	5.84	1346
Skagit	Value at First Sale	311,558.60	438,981.40	47,699.00	6,000,000.00	203
	Value at 2nd Sale	349,929.60	215,704.80	30,500.00	1,800,000.00	203
	Sale value Diff	38,371.09	433,207.10	-5,916,667.00	510,000.00	203
	House Age at 1st Sale	40.36	34.44	0	106	203
	House Age at 2nd Sale	43.31	34.35	2	108	203
	Square Feet	2,011.68	871.32	570	8,473.00	203
	No. of Bathrooms	2.19	1.06	1	9	203
	No. of Bedrooms	3.06	0.86	1	7	203
	lotsize (Acres)	2.73	1.58	1	5.82	203
Snohomish	Value at First Sale	327,621.60	194,332.60	28,000.00	3,500,000.00	1429
	Value at 2nd Sale	402,685.00	211,523.60	15,000.00	3,800,000.00	1429
	Sale value Diff	75,063.45	163,799.80	-3,399,888.00	1,750,000.00	1429
	House Age at 1st Sale	19.58	22.00	0	107	1429
	House Age at 2nd Sale	22.62	21.93	0	107	1429
	Square Feet	2,297.71	923.90	509	9,163.00	1429
	No. of Bathrooms	2.56	0.87	0.5	8	1429
	No. of Bedrooms	3.24	0.81	1	11	1429
	lotsize (Acres)	2.80	1.60	1	5.97	1429
Spokane	Value at First Sale	227,097.50	141,527.10	17,264.00	1,350,000.00	630
	Value at 2nd Sale	267,839.70	149,152.90	11,910.00	882,700.00	630
	Sale value Diff	40,742.26	84,264.53	-970,000.00	342,528.00	630
	House Age at 1st Sale	25.03	23.65	0	107	630

	House Age at 2nd Sale	27.68	23.63	0	108	630
	Square Feet	1,612.31	558.36	568	5,727.00	630
	No. of Bathrooms	2.76	1.12	1	11	630
	No. of Bedrooms	3.77	1.19	1	17	630
	lotsize (Acres)	2.96	1.68	1	5.98	630
Thurston	Value at First Sale	237,869.20	134,835.40	16,340.00	2,200,000.00	772
	Value at 2nd Sale	290,148.60	131,882.20	15,000.00	1,043,000.00	772
	Sale value Diff	52,279.40	104,769.10	-1,984,000.00	418,000.00	772
	House Age at 1st Sale	18.99	21.67	0	105	772
	House Age at 2nd Sale	21.80	21.68	0	107	772
	Square Feet	2,075.63	752.98	724	5,691.00	772
	No. of Bathrooms	2.36	0.82	0.75	7	772
	No. of Bedrooms	3.07	0.60	1	6	772
	lotsize (Acres)	2.67	1.61	1	5.85	772
Whatcom	Value at First Sale	257,839.40	144,445.80	54,000.00	830,000.00	135
	Value at 2nd Sale	338,386.80	188,783.20	57,500.00	1,100,000.00	135
	Sale value Diff	80,547.41	91,895.29	-129,000.00	450,000.00	135
	House Age at 1st Sale	37.31	32.95	0	108	135
	House Age at 2nd Sale	39.70	32.62	0	108	135
	Square Feet	1,876.70	692.95	363	4,392.00	135
	No. of Bathrooms	2.16	1.00	1	8	135
	No. of Bedrooms	3.19	0.95	1	6	135
	lotsize (Acres)	3.35	1.58	1	5.83	135
Total						**9073**

Note: summary Statistics for housing characteristics for 12 counties in Washington State containing Noise Barrier Walls.

Table 3: Basic Hedonic Regressions Results

	First Sale OLS Estimation		Second Sale OLS Estimation	
Dependent Var ($Sale Price)	***1***	***2***	***3***	***4***
	With Barrier Dummy	**With Barrier and Distance**	**With Barrier Dummy**	**With Barrier and Distance**
Lotsize (Acres)	3101.68*	3152.04*	3414.13**	3480.24**
	(1798.40)	(1804.94)	(1444.13)	(1441.18)
Sqare feet	83.452***	83.48***	91.28***	91.26***
	(13.16)	(13.19)	(14.09)	(14.10)
No. of Bathrooms	37521.56***	37471.121***	45804.19***	45812.51***
	(10048.14)	(10074.23)	(10590.39)	(10598.44)
House Age (1st/2nd) sale	-2207.97***	-2207.63***	-1974.99***	-1966.60***
	(338.28)	(339.36)	(266.62)	(267.18)
House Age sq (1st/2nd) sale	22.69***	22.70***	16.77***	16.70***
	(5.03)	(5.04)	(2.74)	(2.74)
Percentage of nonwhite p'ple	-32100.00	-33141.43	-139340.2***	-139175.3***
	(68325.01)	(68185.00)	(46958.37)	(46950.69)
Percentage of under 18yrs	-117814.1**	-115494.10**	-139376.70***	-139456***
	(54648.09)	(54431.12)	(53473.24)	(53401.68)
Percentage of owner Occup.	18760.52	17636.09	45771.29*	46016.64*
	(27762.12)	(28058.42)	(23590.24)	(23638.54)
Population density	1821313***	1827510***	1803222***	1806248***
	(644000.00)	(644380.9)	(407000.00)	(406820.4)
Dummy=1 if with 300m	28627.44***		32162.27***	
	(3986.69)		(4683.65)	
Dummy =1 if Berm Barrier	-40440.86***		-50499.09***	
	(6523.63)		(6740.39)	
Dummy =1 if Other Barrier	-524.84*		-2958.63	
	(6480.58)		(5330.35)	
Dummy =1 if Berm and 300m		-37926.66***		-48130.41***
		(6898.93)		(7132.44)
Dummy =1 if Berm and 600m		-76099.07***		-92008.88***
		(8932.43)		(9478.46)
Dummy =1 if Other and 300m		2109.04		-1728.89
		(7332.33)		(5904.82)
Dummy =1 if Other and 600m		-31541.18***		-32614.41***
		(7303.16)		(7783.59)
=1 if No Barrier and 600m		-20046.96***		-26286.29***
		(6737.11)		(8078.70)
Dummy =1 if Clark	305655.5***	310155.70***	339752.60***	342588.50***
	(55172.01)	(55704.16)	(39805.92)	(40112.85)

Table continues				
Dummy = 1 if cowlitz	219807.5***	221121.30***	269024.40***	269455***
	(42085.07)	(42325.58)	(37909.36)	(38146.13)
Dummy =1 if Franklin	170272.7***	176640***	178547***	182766.10***
	(52546.61)	(53146.40)	(46441.20)	(46759.98)
Dummy =1 if Island	-55673.97***	-59317.55***	-55592.78***	-60623.02***
	(18617.82)	(19308.80)	(20583.68)	(21170.90)
Dummy =1 if King	104879.3***	106295.80***	127871***	129033.70***
	(10847.98)	(10884.31)	(11662.91)	(11727.83)
Dummy =1 if Kitsap	1627.16	2944.53	18890.73	18965.73
	(14141.03)	(14012.89)	(13723.82)	(13884.86)
Dummy =1 if Pierce	-16200.00	-1.45E+04	4915.13	6504.13
	(17237.11)	-17206.132	(17915.81)	(17870.76)
Dummy =1 if Skagit	-29400.00	-3.44E+04	-69293.85***	-74974.93***
	(32491.14)	-33580.476	(17003.15)	(17226.42)
Dummy =1 if Spokane	28840.56	30010.672	-2832.10	-8070.14
	(68883.85)	-68276.228	(72897.88)	(72668.16)
Dummy =1 if Thurston	14176.80	17567.643	25418.42	26831.26
	(21826.52)	-21448.226	(21159.93)	(21217.16)
Dummy =1 if Whatcom	-80737.07***	-88588.45***	-84999***	-94461.77***
	(23422.26)	(25118.48)	(27831.05)	(29208.01)
Longitude	3639.34	2859.29	1941.03	84.94
	(16471.32)	(16494.47)	(15025.05)	(15331.62)
Latitide	132634.4***	136535.20***	160889.60***	164722.7***
	(15517.41)	(16027.52)	(13394.41)	(13782.84)
Longitude_diffsq	-4366.89	-4231.04	-3504.62	-2966.86
	(3283.67)	(3238.33)	(2803.87)	(2858.32)
Latitude_diffsq	-48503.86***	-46813.78***	-462000.72***	-44235.81***
	(13521.73)	(13653.42)	(10328.96)	(10480.66)
_cons	-5888240**	-6141179**	-7498104***	-7877634***
	(2330000.00)	(2369534)	(1880000.00)	(1945165)
N	***9073***	***9073***	***9,073***	***9073***
Adj. RSquared	***0.383***	***0.383***	***0.563***	***0.563***
ll	***-124000.00***	***-1.24E+05***	***(122,000.00)***	***-1.22E+05***
bic	***247000.00***	***2.47E+05***	***244,000.00***	***2.44E+05***
RESET: F(3, 9032) =	***236.18***	***235.28***	***412.73***	***412.11***
Prob > F =	***0.0000***	***0.0000***	***0.0000***	***0.0000***

Note: Values in parentheses are robust standard errors. . ***, **, and * represent level of significance at the 1%, 5% and 10% respectively. RESET Test if Ramsey reset test. All these results reject to null hypothesis that the model has no omitted variables

Table 4: Results Using Difference in Sales Value

	1	*2*	*3*	*4*
Lotsize (Acres)	57.04	17.11	29.63	64.04
	(1586.09)	(1577.70)	(1582.63)	(1591.72)
Square feet	6.29*	6.26*	6.24*	6.16*
	(3.70)	(3.72)	(3.71)	(3.71)
Bathroom	11674.92**	11182.59***	11181.02***	11246.36***
	(3631.33)	(3674.61)	(3677.69)	(3685.10)
Time btn Sales (years)	21737.62***	16738.10***	16743.31***	16757.67***
	(864.31)	(905.68)	(905.40)	(906.40)
Percentage of Nonwhite	-92783.04	-93651.70	-93293.49***	-90758.88
	(61241.36)	(61150.10)	(61768.23)	(61665.99)
Percentance under 18	-13825.87	-19778.12	-19385.49	-22360.28
	(45187.62)	(44994.01)	(45135.90)	(45010.26)
Percentange of owner Occupied	27493.16	33228.16	33108.50	35310.94
	(22146.92)	(22010.76)	(22303.60)	(22605.49)
Population density	-149156.60	-104063.60	-113019.40	-116883.40
	(637215.30)	(632771.50)	(623230)	(623712)
Dummy = 1 if Barrier on the 2nd sale	11704.31*	6695.02		
	(5120.79)	(5242.86)		
Dummy =1 if Barrier on Both sales	-7821.70	-13463.42***		
	(4891.67)	(4408.41)		
Dummy =1 if Barrier within 300m	1273.70	2072.70	2099.74	
	(2962.88)	(2929.73)	(2935.10)	
Dummy =1 if 2nd Other Barrier			6774.21	
			(5226.21)	
Dummy =1 if Both Berm			-14133.38***	
			(4806.11)	
Dummy =1 if Both Other			-12975.75**	
			(5881.73)	
Dummy =1 if no Barrier, house after 300m				-1965.22
				(5488.38)
Dummy=1 if 2nd Other d300m				11074.24*
				(6014.68)
Dummy =1 if 2nd Other d600				-16707.30**
				(8054.06)
Dummy=1 if both Berm , d300m				-13929.96***
				(5093.08)

Table 4 continued

Dummy =1 if Both Berm, d600m				-17296.41**
				(7047.97)
Dummy =1 if Both Other, d 300m				-14101.75**
				(6786.86)
Dummy =1 if Both Other, d600m				-7691.02
				(5533.65)
Dummy =1 if Clark	34828.61	26848.86	26932.50	26924.84
	(53238.98)	(51875.11)	(51921.13)	(52394.95)
Dummy=1 if cowlitz	40483.70	23666.51	23838.82	26862.20
	(39782.91)	(37533.87)	(37519.48)	(38119.00)
Dummy=1 if Franklin	22493.88	26419.60	24898.89	20811.46
	(45211.44)	(44818.16)	(45170.62)	(45817.01)
Dummy = 1 if Island	19701.94	11446.11	10949.09	8568.73
	(12377.62)	(12851.24)	(13592.76)	(14041.42)
Dummy =1 if King	25102.69***	23673.93***	23355.67*	23115.66**
	(8634.45)	(8517.69)	(9013.40)	(9024.91)
Dummy =1 if Kitsap	14831.17	14910.18	14928.72	14120.74
	(11995.65)	(11941.97)	(11898.32)	(11645.92)
Dummy= 1 if Pierce	19987.90	14755.52	14595.18	14863.94
	(14137.18)	(13869.70)	(14263.81)	(14249.87)
Dummy =1 if Skagit	-47046.03	-50070.37	-50586.91	-50176.48
	(33495.70)	(33200.20)	(33323.68)	(34465.98)
Dummy =1 if Spokane	-8257.91	21774.41	17285.06	8275.25
	(50667.56)	(50037.73)	(53994.87)	(53095.32)
Dummy =1 if Thurston	21300.80	19526.47	19130.89	17702.30
	(18154.37)	(18013.78)	(19173.95)	(18724.73)
Dummy =1 if Whatcom	-7173.59	-11522.02	-12140.07	-11613.75
	(20358.10)	(19961.41)	(19307.61)	(20866.60)
Longitude	1955.93	1853.51	2167.368	2044.82
	(15168.69)	(15072.36)	(14634.86)	(14503.77)
Latitude	27867.39	25420.49	25707.09*	25644.63
	(14456.97)	(13973.08)	(13947.36)	(14275.01)
Longitude_diffsq	-886.81	-2079.27	-1990.86	-1665.41
	(2861.64)	(2814.30)	(2960.27)	(2869.94)
Latitude_diffsq	2617.58	3250.90	3248.55	2844.57
	(12673.41)	(12659.05)	(12663.52)	(12788.36)
Dummy = if Year of 1st sale is > 2003		-21325.67***	-21367.87***	-21347.33***
		(5138.69)	(5166.36)	(5168.90)
Dummy = if Year of 2nd sale is > 2003		51256.66***	51229.02***	51093.91***
		(3742.27)	(3719.10)	(3727.25)

Table continued

Constant	-1141351	-1049917	-1024915	-1035652
	(2174631)	(2148884)	(2120775)	(2127086)
No. of Observation	9073	9073	9073	9073
Log Likelihood	-1.22E+05	-1.22E+05	-1.22E+05	-1.22E+05
bic	2.45E+05	2.45E+05	2.45E+05	2.45E+05
RESET: F(3, 9032) =	***236.18***	***235.28***	***412.73***	***412.11***
Prob > F =	***0.0000***	***0.0000***	***0.0000***	***0.0000***

Note: Values in Parentheses are robust standard errors. . ***, **, and * represent level of significance at the 1%, 5% and 10% respectively. RESET Test if Ramsey reset test. All these results reject null hypothesis that the model has no omitted variables