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The Effect of Noise Barriers on the Market Value of Adjacent Residential Properties*

Benoit Julien[†] *and Paul Lanoie*[‡]

Résumé / ***Abstract***

Ce texte présente la première étude sur l'impact des murs antibruit sur le prix des maisons adjacentes basée sur une analyse des ventes répétées, qui constitue la meilleure méthodologie pour étudier cette question. Essentiellement, une analyse des ventes répétées nous permet d'examiner la différence de prix de vente pour une maison donnée avant et après un événement qui aurait pu en affecter le prix. S'il y a une différence de prix « significative » entre les deux transactions, on peut alors attribuer cette différence à l'événement. Bien sûr, pour que cela soit vrai, il faut s'assurer de tenir compte des autres éléments qui auraient pu affecter le prix de la maison entre les deux ventes, comme l'évolution générale du marché immobilier ou les rénovations majeures qui auraient pu être faites. Notre étude se base sur un quartier de la ville de Laval, une banlieue de Montréal, où un grand mur antibruit a été construit en 1990 le long d'une autoroute. Nous avons pu obtenir des informations sur 134 maisons qui ont été vendues au moins deux fois pendant la période 1980 – 2000. En plus, nous avons pu avoir des informations sur l'ensemble du marché immobilier, comme dans toutes les autres analyses de ventes répétées, mais aussi sur les caractéristiques sociodémographiques du secteur et sur les rénovations majeures qui ont touché ces maisons durant la période. À notre connaissance, c'est la première fois que des informations sur les rénovations sont disponibles dans une analyse des ventes répétées. Nous concluons que le mur antibruit a entraîné une augmentation de 10 %, en moyenne, du prix des maisons dans notre échantillon.

This paper provides the first study on the impact of noise barriers on the price of adjacent houses based on a repeat sale analysis (RSA), arguably the best methodology to address this question. Essentially, a repeat sale analysis examines the differential between the prices of houses sold before and after an event that may have affected their value. If there is a significant change of price between the two transactions, it may be attributed to the event. Of course, for that to be true, the researcher must have controlled for other changes that may have had an effect on the house price between two sales, like the evolution of the real estate market and major renovations done to the house. We collected our data in a neighbourhood of Laval, a suburb of

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† Agriculture Canada.

‡ HEC Montréal, CIRANO, CIRPÉE and CIRAIG. All correspondence should be addressed to Paul Lanoie, Institut d'économie appliquée, École des Hautes Études Commerciales (HEC), 3000 Côte Ste-Catherine, Montréal, H3T 2A7. Email: paul.lanoie@hec.ca.

Montreal, where an important noise barrier has been built in 1990 along a highway. We were able to obtain information on 134 houses that have been sold at least twice during the period 1980 – 2000. In addition, we were able to get data on the real estate market in the area during the whole period, as in most RSA, but also on the demographic composition of the area and on major renovations that were done in these houses throughout the time span. To our knowledge, this is the first time that information on major renovations was available for a RSA. We conclude that the noise barrier has induced an increase of 10 %, on average, of the price of adjacent houses in our sample.

Mots clés : Contributions volontaires, pertes publiques, risque, ambiguïté, données expérimentales

Keywords: noise barriers, housing market, repeat sale analysis.

Codes JEL : H49, D81, C23, C92

1. Introduction

Quality of life is a growing preoccupation in our society. In particular, people are more and more concerned about the level of noise in their environment. Thus, it is not surprising that growing investments have been made in noise barriers during recent years[1].In order to determine if these investments contribute to increase a society's welfare, one has to be aware of all their effects. In general, noise barriers are efficient in reducing the level of noise (Ouimet, 1994), but they have other consequences, like affecting the price of adjacent houses. It is well established that an increase in the noise level leads to a decrease in the price of houses (for a recent survey, see Boardman et al., 2001), so that a reduction in noise should have the converse effect. However, some people argue that the aesthetic impact of the walls could lead to a price reduction, especially for houses located very close (Kamerud and von Buseck., 1985), so that, altogether, the net effect of a noise barrier on the price of adjacent houses is ambiguous theoretically, and has to be resolved empirically.

To our knowledge, two existing papers have tackled this question but, as we will see below, none of them has done it in a proper fashion. This paper provides the first study on the impact of noise barriers on the price of adjacent houses based on a repeat sale analysis (RSA), arguably the best methodology to address this question. Essentially, a repeat sale analysis examines the differential between the prices of houses sold before and after an event that may have affected their value. If there is a significant change of prices between the two transactions, it may be attributed to the event. Of course, for that to be true, the researcher must have controlled for other changes that may have had an effect on the house price between two sales, like the evolution of the real estate market and major renovations done to the house. In the past, RSA has been used to determine the impact of the construction of a train station (Gatzlaff and Smith, 1993), of a highway (Palmquist, 1982), or the discovery of a toxic landfill (Kohlhase, 1988) on the value of adjacent houses, but it has never been used to evaluate the impact of a noise barrier.

1. For instance, Statistic Canada (1998) reports an increase in the Canadian annual investment in noise barriers of 10 % between 1995 and 1998.

We collected our data in a neighbourhood of Laval, a suburb of Montreal, where an important noise barrier has been constructed in 1990 along a highway. We were able to obtain information on 134 houses that have been sold at least twice during the period 1980 – 2000. In addition, we were able to get data on the real estate market in the area during the whole period, as in most RSA, but also on the demographic composition of the area and on major renovations that were done in these houses throughout the time span. To our knowledge, this is the first time that information on major renovations is available for a RSA, which allows us actually to conduct an "augmented" RSA. We conclude that the noise barrier has induced an increase of 10 %, on average, of the house prices in our sample.

The rest of the text is organized as follows. Section 2 presents a survey of the existing studies on the impact of noise barriers. Section 3 discusses our empirical strategy and data, while Section 4 presents our empirical results. Finally, we provide concluding remarks.

2. A survey of the existing literature

As mentioned earlier, there is a general consensus in the literature on the negative relationship between the noise level and the price of adjacent houses. Most of the studies which have tackled this question have used the hedonic pricing method. This method implies that regressions are run where houses' price is related to a vector of characteristics (physical characteristics of the house, market conditions, neighbourhood), including a variable capturing a certain environmental attribute like the noise level. Recent surveys (e.g., Boardman et al., 2001) have reported a "noise depreciation sensitivity index" around 0.65, which means that if the noise level increases by one NEF (Noise Exposure Forecast), then the price of an affected house decreases in value by 0.65 percent on average.

Some authors (Palmquist, 1982, Kohlhase, 1988, Mendelsohn et al., 1992) have criticized this method arguing that, with samples of houses from different neighbourhoods, it is difficult to distinguish between the effect of any environmental attribute on the price of adjacent houses and the effect of unobserved characteristics (e.g., criminality in the neighbourhood). These authors have suggested a variant of the standard hedonic pricing method, the repeat sale analysis (RSA) that we described above.

Using methodologies along these lines, two papers have looked specifically at the impact of noise barriers on the price of adjacent houses. We will describe and comment them in more details.

Kamerud and von Buseck (1985) study two sites—Troy Meadows, and Lakewood—located near the same highway (Interstate 75) in Michigan. Both locations comprise some 70 homes, most of them single-family dwellings. Troy Meadows is more “well-to-do”, and the houses there have some 30% more surface area than those at Lakewood. At both sites, noise levels near the highway are very high (more than 60 decibels).

In 1974, a natural sound barrier (earth berm) was built at Troy Meadows at a cost of $41,700. The entire bill was passed on to the residents, and payments could be spread over 11 years. The further the distance from the noise barrier, the lower was the amount charged. So residents in the first row nearest the screen had to pay more, since they benefited the most from it. The screen led to real noise reduction estimated at 6 or 7 decibels for residents in the first row.

The authors propose three exercises: 1) they examine the impact of noise on house values in Lakewood, noise being approximated by the distance between a house and the Interstate; 2) same exercise for Troy Meadows before 1974, noise being approximated by the row in which a house is located; and 3) same exercise for Troy Meadows after 1974 (i.e., after the wall was installed). In view of the nature of our approach, we will pay the most attention to the latter two exercises. In fact, the authors’ hypothesis is as follows: prior to 1974, other things being equal, houses in the first row at Troy Meadows had to sell for less than houses in the other rows owing to the noise level; after 1974, this price differential among rows should have narrowed, since because of the noise barrier the houses in the first row are no longer as unpleasant.

The general model used by the authors is expressed by this equation:

$$\text{Log (PRICE)} = \alpha + \beta \bullet \text{SIZE} + \gamma \bullet \text{YEAR} + \delta \bullet \text{LOCATION} + e$$

where PRICE indicates the amount of the sale; YEAR refers to the year of the sale, this variable being introduced to capture general market trends; SIZE is defined as the surface area of the house in square feet; and LOCATION is an approximation of the distance between the house and the Interstate which captures the noise level. The terms α, β, γ, and δ represent estimated coefficients, while e is the error term. For Troy Meadows, 47 transactions were used in the first estimate before the wall was built, and only 24 after the construction (between 1975 and 1980).

The results indicate that prior to 1974, houses in the first row sold on average for 4% less than those in rows 2 to 4, and 9% less than those in row 5. After 1974, the price differentials among the rows remained the same. The authors conclude that the wall had no impact on house prices.

At least three reasons may lie behind this somewhat surprising result. First, according to a survey of residents, the wall had a downside. Some people complained about the unattractive layout, the lack of maintenance (weeds) and the presence of bikers drawn by the mound. Finally, some residents said they missed seeing the highway. So it is possible that these negative effects may have partially offset the benefits of the wall. Second, the additional payments by residents in row 1 to pay for construction of the wall could be taken into account by new buyers, and this may have made them less willing to pay for those houses. The authors acknowledge this possibility, but believe the additional cost of the wall for residents in row 1 is so low ($300 spread over 11 years) that it cannot have had a significant impact. Third, if the wall brings benefits to all Troy Meadows residents, the situation may be such that the houses in the first row are still the least attractive and a price differential among the rows remains. Unfortunately, the article provides no information on this point.

At least three major criticisms may be raised concerning this study. First, the statistical result which leads to the conclusion that price differentials among the rows did not change after the wall was built is not “significant” within the meaning that most statisticians give to the word. In fact, the estimated coefficient which indicates the price difference between houses in the first row and those in rows 2 to 4 after the wall was built is only 85% reliable. If, like most statisticians, we considered this coefficient to be not different from zero, the conclusion of the study would be quite different: the price differential between houses in row 1 and those in rows 2 to 4 would have vanished, and that would imply that the noise screen actually led to an increase in the relative value of the houses in row 1. Second, the number of control variables (YEAR, SIZE) is very limited compared with what is found in the rest of the literature, where many other aspects are documented (presence of a garage, finished basement, fireplace, pool, etc.). So it is possible that the estimated coefficients were biased as a result of this missing information. Third, the number of observations (24) for the regression conducted with transactions after the wall was built was very low.

Hall and Welland's study indirectly concerns the topic which interests us. It essentially asks the following question: is the relationship between house prices and the number of decibels affected by the presence of a noise barrier? In other words, does an additional decibel have a smaller or greater impact on a house buyer in a barrier setting than in a setting without a barrier? Other things being equal, if a noise barrier means an additional decibel has a negative impact on house prices that is lower than if there is no barrier, it may be indirectly concluded that the barrier makes noise less "detrimental" to property prices. Hence, this study tests whether the relationship between house prices and the number of decibels is linear or non-linear.

For their exercise, the authors proceed as follows. First, they estimate the relationship between noise levels and house prices in three Toronto-area districts where there are noise barriers (Victoria Park, Etobicoke and Leslie Street). These are residential neighbourhoods consisting primarily of single-family dwellings. They then compare the results obtained with those of Nelson (1982), who lists studies conducted in settings without noise barriers (average of -0.4% per decibel), and with those of another study conducted by Taylor et al (1982) in Ontario in a region with no barriers ($0.505/decibel).

As to the methodology, it is the same as that used by Kamerud et al (1985). But the authors of this study have access to more information on the houses bought and sold. In fact, they use two databanks: 1) data from the Property Office of the Ontario Ministry of Transportation and Communications; and 2) data from the Toronto Real Estate Board. The latter are more comprehensive than the former, since they allow many more control variables to be covered. Also, three different methods of measuring noise were used but, like the authors, we will emphasize the results using the conventional measurement, the Leq (24 hours). Indeed, that is what allows comparison with the results of the other studies.

Data covering about 100 transactions per site (completed between 1977 and 1985) are used to make an estimate for each of the sites, and these are then placed together for a final estimate covering all three sites. The results obtained for the first two sites (Victoria Park and Etobicoke) are slightly lower than those obtained in the rest of the literature (-0.34% in Victoria Park and -0.39% in Etobicoke), prompting the authors to conclude: “this may be partial evidence that the noise penalty is lower at barrier sites than at sites without barriers; that is barriers matter…this may be partial evidence in favour of a non-linear function between noise levels and house prices” (p. 11). Nonetheless, the results obtained at the third site (Leslie Street) are very high compared with all the studies that have been conducted on the question (2.1%) and, consequently, the results of the estimate made for all the observations (0.76%) are close to those of the rest of the literature.

The conclusion of the study as to the essential question it asks therefore depends on the weight one gives to the estimate made with the data from the third site. The authors tend to believe that a statistical anomaly is involved, and that only the results from the first two sites should be used. If this is so, the relationship between noise and house prices would then be lower at barrier sites than at sites without barriers, and this indirectly suggests that screens enhance property values. Nonetheless, the authors end on this note (p. 11): “That must remain speculation; the data are certainly inadequate to provide a clear test of that suggestion.”

From a technical standpoint, we feel this study is superior to the first one despite the statistical anomaly it appears to contain. The databanks used are more complete, and the number of observations is still sufficient to obtain reliable estimates. However, the conclusion as to the impact of noise barriers remains a risky one. Comparing with other studies conducted in a completely different context is a hazardous exercise. It would be more convincing if the relationship had been compared between noise and housing values obtained at the same site before and after construction of a noise barrier. The authors are themselves conscious of the tenuousness of their conclusion.

3. Empirical strategy and data

Examination of the two existing studies on the effect of the noise barriers on the market value of adjacent residential properties leads us to adopt the "repeat sale analysis" methodology. Following the literature on RSA, we estimate the following model where the dependent variable is a price differential:

$$\ln P_s - \ln P_f = \left(\sum_{i=1}^{k} \beta_{is} Z_{is} + \sum_{i=1}^{\ell} \alpha_{is} Y_{is} + \sum_{i=1}^{m} \delta_{is} X_{is} \right) - \left(\sum_{i=1}^{k} \beta_{if} Z_{if} + \sum_{i=1}^{\ell} \alpha_{if} Y_{if} + \sum_{i=1}^{m} \delta_{if} X_{if} \right) + \omega_i \cdot DISTANCE_i + \varepsilon_i$$

where the index *s* refers to the second sale of a given house in a pair of transactions and the index *f* refers to the first sale. P represents the sale price of the house. Z is a vector of variables capturing the existence of the wall, and the period during which it was built. The vector Y refers to economic and socio demographic factors, like the general real estate market price index, that may have affected the price of the house between two sales. The vector X represents the different characteristics of the house that may have changed (through renovations) between two sales. The variable DISTANCE captures the distance of the house from the wall, and, ε_i is an error term. As one can see, the independent variables are all expressed in differentials, except for the distance from the wall (DISTANCE), which is constant through time. Note also that a typical RSA would only include the vector Z and a variable, usually a price index, capturing the evolution of the housing market. We are actually performing an "augmented repeated sale analysis", as recommended by Dombrow et al. (1997). Descriptive statistics for all variables are provided in Table 1. It is noticeable that there is an average price increase of more than 22 000 $ (CAN) between two sales.

Table 1 : Descriptive statistics

Variables*	Average	Minimum	Maximum	Standard Deviation
PRICE DIFFERENTIAL	22640,35	-105000,00	126440,00	37443,09
BARRIER	0,54	0,00	1,00	0,50
CONSTRUCTION	0,03	-1,00	1,00	0,36
DISTANCE (IN METERS)	130,97	8,00	315,00	98,79
PRICE INDEX	23,43	-1,91	60,73	17,14
TIME (IN MONTHS)	89,91	1,00	235,00	54,51
MORTGAGE	-2,90	-16,05	5,25	3,34
TENANT COST	20,61	-0,50	58,10	13,19
OWNER COST	21,68	-1,00	60,30	13,95
AGE RATIO	-0,11	-0,42	0,30	0,18
INCOME	18421,15	0,00	42210,00	13892,23
PARTICIPATION	8,11	-5,70	21,90	7,31
FEMALE	1,69	-0,21	3,49	1,29
AGE	6,60	0,00	19,00	4,48
MUNICIPAL EVALUATION	19550,89	-106100,00	143300,00	27840,02
LAND EVALUATION	13165,17	-14600,00	76800,00	13348,24
RENOVATIONS	1428,36	0,00	75000,00	6510,97
TYPICAL EXTERNAL	5,63E-02	0,00	2,00	0,29
MAJOR EXTERNAL	0,10	0,00	2,00	0,36
MAJOR INSIDE	2,949E-02	0,00	2,00	0,24
INGROUND POOL	5,362E-03	0,00	1,00	7,313E-02
TYPICAL EXTERNAL (V)	270,39	0,00	25000,00	1702,86
MAJOR EXTERNAL (V)	1000,00	0,00	57000,00	5227,91
MAJOR INSIDE (V)	163,74	0,00	25000,00	1418,58
INGROUND POOL (V)	58,98	0,00	17000,00	804,39
INFRACTION	0,02	0,00	3,00	0,22

* : All the variables, except DISTANCE, are expressed in differentials
V : Value

In the vector **Z**, we first find BARRIER, a dummy variable reflecting the existence or not of the noise barrier at the time of the transaction. As discussed earlier, the expected sign of this variable is ambiguous. Through the noise reduction, the barrier should lead to increases in the price of adjacent houses which could be counter-balanced by characteristics such as the aesthetic impact, so that the net effect has to be resolved empirically. In line with this argument, Ouimet (1994) indicates that the noise level has been reduced by 18 % following the introduction of the barrier, while 70 % of the respondents of a survey conducted in the area noted that there was a deterioration of their visual environment. Another dummy variable, CONSTRUCTION, captures the period during which the wall was built which lasted from May 1990 to August 1991. Again, the expected sign is not clear. The disturbances due to the construction of the wall could have influenced the price negatively, while the expected noise reduction due to the wall may have had the converse effect. In the same vein, the expected sign of the coefficient of the DISTANCE variable is ambiguous since the closer you are from the wall, the more likely you will benefit from the noise reduction, but the more likely you will suffer from the visual impact.

The vector **Y**, capturing economic and socio-demographic factors, contains nine variables. We first have five economic factors. The PRICE INDEX is capturing the evolution of the housing market in the area (the Laval-des-Rapides neighbourhood). Of course, the expected sign is positive. We also have the variable TIME, which represents the time period between two sales. On one side, in general, the longer is this period, the more likely the house will experience a price increase. However, the longer is this period, the older is the house and, as we will see below, the effect of the age on the price is ambiguous. MORTGAGE is representing the average mortgage rate of Canadian banks for one year. Everything else being equal, the higher is the mortgage rate, the lower is the demand for houses and the lower should be the price.

TENANT COST is a price index computed by Statistic Canada for the Province of Quebec reflecting the overall cost of being a tenant. Everything else being equal, the more costly it is to be a tenant, the higher should be the demand for houses, and the higher should be the price. OWNER COST is a similar variable capturing the cost of being an owner, and the converse effect is expected.

Among the socio-demographic variables, we first have the AGE RATIO, which is the ratio of population of age 20 – 34 to the population of age 35 – 54 in the area. It is well known that people are more likely to buy a house when they are younger, so that the higher is this ratio, the higher should be the demand for houses and the higher should be the price. The variables INCOME, capturing the average level of income in the area, and the variable PARTICIPATION, reflecting the area participation rate in the labour force, are expected to have a similar impact, and their coefficients should be positive. Finally, the proportion of FEMALE in the area is introduced to test if we can reproduce the result first obtained by Mayo (1981) that females pay a higher price for houses.

It should be noted that these four last variables are not necessarily exogenous. For instance, an increase in the price of houses could draw people with higher incomes, people who are more likely to participate in the labour force, or older people. In order to clarify this issue, we performed a Hausman test reported in the Appendix, which did not reject the hypothesis of exogeneity for any of these four variables.

The vector **X** includes certain characteristics of the house that may have changed through time. First, AGE represents the age of the house. On one hand, the older is the house, the less interesting it could be, especially if it was not renovated. On the other hand, some people may put more value on older houses because of their style, because they are often surrounded by mature trees, or other characteristics like that. The expected sign is thus ambiguous.

The variable MUNICIPAL EVALUATION represents the assessment which is made every three years by a professional for municipal tax purposes. It reflects the general state of the house and its coefficient is expected to be positive. The same applies for LAND EVALUATION, which captures the municipal evaluation of the land[2].

Finally, we were able to obtain many information on renovations that have affected houses. The variable RENOVATIONS represents the cumulative sum of money spent for renovations between two sales. These renovations are those for which the owner has to ask a permit at the

2. These two last variables could also have been included in the vector Y reflecting the economic conditions.

town hall. TYPICAL EXTERNAL refers to the number of usual external renovations that took place between two sales. By typical external renovation, we mean things like changing the roof, or the doors. MAJOR EXTERNAL captures the number of major external renovations like adding a room or a garage, or changing the coating (like going from aluminium to brick). MAJOR INSIDE represents the number of important inside renovations like the bathroom or the kitchen, while INGROUND POOL refers to the installation of this item. Note that, for the four last variables, we have the information both in terms of the number of permits that were requested, and in terms of the value of these renovations. Finally, the variable INFRACTIONS represents the number of infractions to the municipal code of construction detected by inspectors. These infractions have to be corrected in order to respect the code of construction, hence improving the quality of a house; so that the expected sign of the coefficient of this variable is positive.

We were able to obtain data on 134 houses that were sold at least twice during the period 1980 – 2000. Actually, each house was sold 2,8 times on average. We thus have 374 transactions and 187 observations (pairs of transactions). The neighbourhood is located in Laval, Québec, on both sides of a highway along which a noise barrier was built in 1990. The area has been chosen so that the houses are not further than 300 meters from the wall. The main information on the house price, the date of the transaction, municipal evaluation, were obtained from Laval town hall and the court house. Data on the local housing market was obtained from the Canadian Mortgage and Housing Corporation and from a real estate company, and data on socio-demographic factors was found in files from Statistics Canada.

One concern with RSA is that one requires a sample of houses which are sold more often than average, which could introduce a bias in the selection of the sample (see, for instance, Gatzlaff and Haurin, 1997)[3]. Regarding that, we can present certain evidences showing that our sample does not suffer from this problem. First, our 134 houses account for 25 % of the 549 houses in the area delimited for our purposes. Second, Table 2 presents seven major characteristics of the houses in our sample and in the area of study: 1) types of house; 2) number of floors; 3) age; 4)

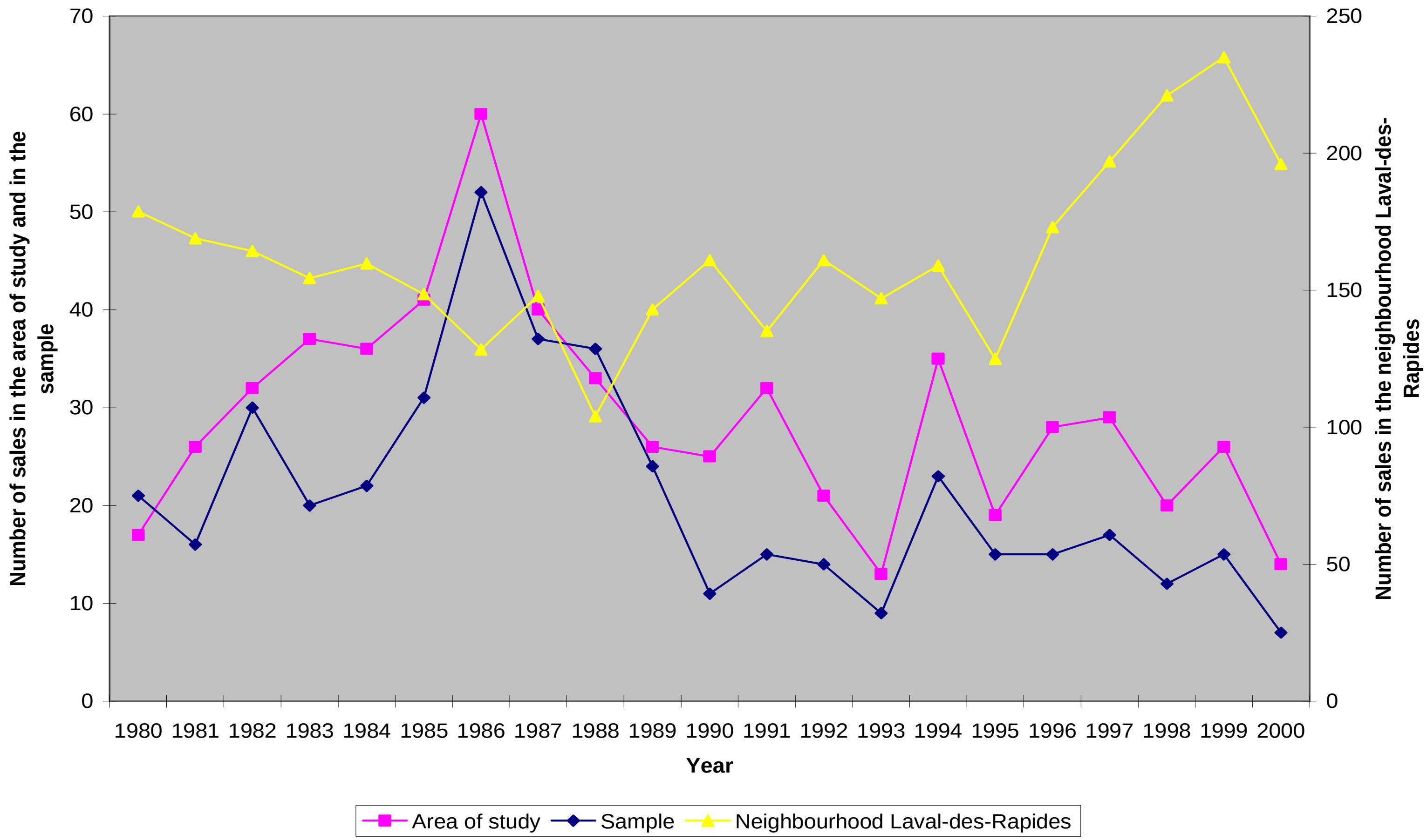
3. Actually, it would be possible to test formally if our sample is biased, but this would require data on houses that have not been sold. It was not possible for us to obtain such information. To our knowledge, only Gatzlaff and Haurin (1997) have done such a test, reporting weak evidence of the existence of a bias.

number of lodging units; 5) municipal evaluation; 6) number of transactions and 7) distance from the barrier. Again, apart from the number of transactions, which is obviously larger in our sample, we see important similarities between our sample and the other houses in our area of study. Third, Chart 1 shows the evolution of the number of transactions through time in our sample and in the area of study, and the trends are remarkably similar. Altogether, we consider that our sample is fairly representative of the area of study.

Table 2 : Characteristics of the houses

	Area of study	Sample
Number of houses	549	134
Type of houses		
Single family	71,6%	62,0%
Duplex	14,4%	15,3%
Triplex	7,6%	10,9%
Quadruplex	3,7%	7,3%
Multiplex	2,8%	4,4%
Number of floors		
Average	1	1
Minimum	1	1
Maximum	3	3
Year of construction		
Average	1958	1958
Minimum	1847	1847
Maximum	1997	1988
Number of lodging units		
Average	2	2
Minimum	1	1
Maximum	8	8
Municipal Evaluation		
Average	108900$	114564$
Minimum	9400$	50400$
Maximum	398000$	274200$
Number of transactions	610	373
Average	1,1	2,8
0 sale	41,5%	N/A
1 sale	31,8%	N/A
2 sales	15,4%	55,5%
3 sales	7,6%	24,8%
4 sales	3,1%	10,9%
5 sales	1,6%	6,6%
Distance from the wall		
Average	140m	135m
Minimum	5m	8m
Maximum	315m	315m
Number of houses adjacent to the wall	67	21

CHART 1: Evolution of the transactions



4. Empirical results

Table 3 presents the empirical results for three specifications of equation (1). The first one contains only the variables encountered in a typical repeat sale analysis: the variables capturing the presence of the wall and the evolution of the real estate market. This specification allows us to evaluate how our “augmented” RSA performs compared to the typical RSA. Specification (2) uses the number of renovations to capture the extent of the renovations done between two sales, while specification (3) uses the value of these renovations. We performed tests to detect potential serial correlation, and we did not reject the hypothesis of absence of first-order serial correlation.[4] Furthermore, the estimations are done using the ordinary least-square method adjusted by White’s (1980) heteroskedastic-consistent covariance matrix to correct the estimates for unknown forms of heteroskedasticity.

First, specification (1) shows that, when we use a standard RSA approach, the impact of the wall is negative and significant, while it is the converse in the other specifications. The adjusted R2 of specification (1) being much lower than for the other specifications, we conclude that the “augmented” RSA version is preferable. Furthermore, the two other specifications, which differ in terms of the variables used to capture the extent of renovations done between two sales, perform equally well, and present very similar results. We will focus on these specifications in the rest of our discussion.

Concerning the variables related to the noise barrier (vector Z), we first see that the coefficient of BARRIER is positive and significant in specifications (2) and (3), showing that, on average, the construction has lead to an increase of 10 % in the price of the houses in our sample. The coefficient of the variable CONSTRUCTION, capturing the construction period, is negative and barely significant, suggesting that the disturbances due to the construction had a negative influence on buyers. The variable DISTANCE, capturing the distance from the wall, is positive and weakly significant in specification (2), and positive but not significant in specification (3). This is a weak evidence that houses in our sample further from the wall have more benefited

4. The Durbin-Watson statistic was at 2,037 and the Box-Pierce statistic was at 19,635. In both cases, this is not significant.

from a price increase. This could be due to the fact that, being further away, they suffer less from the visual impact.

Table 3 : Empirical results (t-statistics)

	Basic RSA	Renovations (quantity)	Renovations (value)
R^2 ajusted	*0.4693*	*0.5796*	*0.5809*
CONSTANT	0.899E-03 (0.083)	2.62E-04 (0.017)	4.69E-03 (0.309)
BARRIER	-0.113 (-8.884)***	0.10082 (2.222)**	0.10776 (2.413)**
CONSTUCTION		-5.83E-02 (-1.646)	-5.92E-02 (-1.650)*
DISTANCE (IN METER)		1.15E-04 (1.803)*	7.52E-05 (1.198)
PRICE INDEX	0.780E-02 (6.43)***	8.65E-03 (6.291)***	8.14E-03 (5.850)***
TIME (IN MONTHS)		-5.55E-04 (-0.585)	-2.56E-04 (-0.265)
MORTGAGE		2.72E-04 (0.087)	1.17E-03 (0.380)
TENANT COST		-1.69E-02 (-1.592)	-1.95E-02 (-1.870)*
OWNER COST		7.05E-03 (0.693)	9.23E-03 (0.917)
AGE RATIO		-0.20816 (-0.962)	-0.16373 (-0.751)
INCOME		4.06E-06 (0.696)	5.14E-06 (0.884)
PARTICIPATION		1.07E-02 (1.430)	1.05E-02 (1.385)
FEMALE		-5.51E-02 (-2.096)**	-5.80E-02 (-2.195)**
AGE		9.33E-03 (1.874)*	7.27E-03 (1.495)
MUNICIPAL EVALUATION		3.81E-07 (1.184)	2.58E-07 (0.861)
LAND EVALUATION		-3.38E-06 (-3.741)***	-2.97E-06 (-2.999)***
RENOVATIONS		2.00E-06 (0.929)	
TYPICAL EXTERNAL		6.18E-02 (2.249)**	
MAJOR EXTERNAL		-3.09E-03 (-0.107)	
MAJOR INSIDE		5.44E-02 (2.569)**	

INGROUND POOL		-1.99E-02 (-0.626)	
TYPICAL EXTERNAL			4.37E-06 (0.782)
MAJOR EXTERNAL			5.76E-07 (0.323)
MAJOR INSIDE (V)			1.47E-05 (2.728)***
INGROUND POOL (V)			1.63E-07 (0.080)
INFRACTION		4.64E-02 (2.166)**	9.28E-02 (7.415)***

*** Significant at 1%
** Significant at 5%
* Significant at 10%

With respect to the economic and socio-demographic factors (vector Y), we first find, not surprisingly, that the price difference between sales is strongly related to the evolution of the housing market in the neighbourhood (PRICE INDEX). However, none of the coefficients of the other economic factors (MORTGAGE, TENANT COST, OWNER COST) is consistently significant in both specifications (2) and (3). Among the socio-demographic factors, only the coefficient of FEMALE is consistently negative and significant in both specifications (2) and (3). This contradicts the only previous result of Mayo (1981) showing a positive relationship. Our result could be due to the fact that, it is generally recognized that women earn lower salaries than men (Baker and Fortin, 1999) and, given that the participation rate of women in the labour force is much higher today than in the seventies, this effect could play a role in our sample and not in that of Mayo (1981).

Concerning the vector of houses' characteristics (X), the coefficients of certain variables are consistently significant across specifications. First, we have the LAND EVALUATION whose coefficient is negative and significant, but the impact is very weak (elasticity of 0,2 E-06). This result is counter-intuitive. One potential explanation is that, since the municipal evaluation of the value of the land and of the house are done every three years, they may capture with a delay the actual price fluctuations on the market. So that, in a moving market, a decrease in the land evaluation registered three years ago could be associated with a price increase this year. Second, the coefficients of the variables capturing the TYPICAL EXTERNAL renovations (the number of permits), and the MAJOR INSIDE renovations (both the number of permits and the value of the renovations) are, as expected, positive and significant. Finally, the coefficient of the variable INFRACTIONS, capturing the number of infractions to the municipal code of construction detected at the time of a sale, is positive and significant in both specifications. This was expected since these infractions lead to further renovations before the house can be sold.

5. Conclusion

In a context where people are looking for a better quality of life (less noise, less pollution, more safety, etc), and where public authorities are sensitive to these requests and invest more resources to increase welfare, we study the impact of a particular measure aimed at improving public satisfaction: noise barriers. This paper provides the first study on the impact of noise barriers on the price of adjacent houses based on a repeat sale analysis (RSA), arguably the best methodology to address this question. We collected our data in a neighbourhood of Laval, a suburb of Montreal, where an important noise barrier has been constructed in 1990 along a highway. We were able to obtain information on 134 houses that have been sold at least twice during the period 1980 – 2000. In addition, we were able to get data on the real estate market in the area during the whole period, as in most RSA, but also on the demographic composition of the area, and on major renovations that were done in these houses throughout the time span. To our knowledge, this is the first time that information on major renovations was available for a RSA. We conclude that the noise barrier has induced an increase of 10 %, on average, of the price of adjacent houses in our sample. It would be useful to conduct similar studies in other areas to confirm the robustness of this result.

Appendix : Hausman test

Variables[1]	t	Hypothesis of exogeneity
INCOME	1,196	Not rejected
AGE RATIO	-1,106	Not rejected
PARTICIPATION	-0,832	Not rejected
FEMALE	0,031	Not rejected

[1] The instrument used for the test is the lagged variable.

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