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THE IMPACT OF AIRPORT NOISE ON WILLINGNESS TO PAY FOR RESIDENCES

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Abstract—The effects of aircraft noise following airport expansion on the willingness to pay (WTP) for residences is examined, using a contingent valuation approach. WTP estimates are elicited for a standard residence whose noise settings are systematically changed. The results show that most current compensation programs are inadequate, as they do not fully compensate home owners or renters for the loss associated with higher noise exposure. This analysis also shows that such valuations should analyze noise as a multi-attribute externality, rather than by a single composite measure. Finally, the results indicate that household WTP structures are kinked, whereby, beyond a certain disturbance threshold, households are unwilling to pay anything for the residence; yet, different households have different thresholds. This kinked WTP structure helps explain the higher noise premiums obtained in CVM studies relative to hedonic price estimates. Copyright © 1996 Elsevier Science Ltd

1. INTRODUCTION

Airport noise is often at the center of the acrimonious protracted conflicts surrounding airport expansion schemes. Two market-based approaches have been advanced to address such issues. The first is the establishment of noise-based landing fees (Cell, 1982). The second approach suggests that property rights over noise be designated (Feitelson, 1989a,b). To implement either of these suggestions, there is a need to estimate the utility loss due to increased exposure to aircraft noise.*

The most common approach used to value the cost of airport noise is the hedonic price method (HPM). Indeed, many such studies have shown airport noise to have an effect on property values around airports (Nelson, 1980, 1981; Uyeno *et al.*, 1993). Even so, the noise depreciation of property does not fully reflect the utility loss due to noise increase (Walters, 1975), and most empirical studies did not go on to uncover the underlying willingness-to-pay (WTP) structures (which are the base for true estimates of utility loss).

This study seeks to identify the effects of airport noise on WTP for residences, using the contingent valuation method (CVM). In doing so, the study has two goals: one, to facilitate the implementation of property rights approaches to airport noise; and two, to

*This statement is quite obvious when fees are considered. However, such estimation is also necessary for determining the cost of noise-rights, due to the high transaction cost of negotiations between a single large polluter and many potential victims, in the presence of multiple third-party effects. In the case of airports, a property rights solution thus deviates from the open-negotiation Coasian approach (where prices are determined through the market).

uncover the WTP structures underlying hedonic price functions. As the CVM is used to study the same market for which the HPM has been often used, this study provides clearer insights than can be gained by second-stage analyses suggested in much of the HPM literature (i.e. Freeman, 1979; Bateman, 1993).

In the next two sections, the background for the two goals is briefly sketched. Then, the potential of the CVM method in addressing these goals, and the issues it has to contend with are discussed. In Section 5, the study design is described. The effects of different airport noise attributes on WTP are presented in Section 6. Then, in Section 7, the WTP structures are further scrutinized. This scrutiny reveals a somewhat surprising kink in these structures. The implications of these findings are discussed in the final section.

2. THE AIRPORT NOISE PROBLEM

Airport capacity is increasingly a major bottleneck for aviation development. Such development is fostered by the transition from industrial to service based economies (Bell & Feitelson, 1991), and is thus of increasing macro-economic importance (Aschauer, 1989). However, the necessary expansion of capacity is hampered by community opposition, focussing on aircraft noise (Gesualdi, 1987). Actually, some of the most acrimonious and protracted land-use conflicts regard airport expansion schemes.

Two possible market-based approaches to address this problem are the establishment of noise-based landing fees (Cell, 1982), and the specification of airport noise rights (Feitelson 1989a,b). In essence, this latter approach argues that, on one hand, airports should be protected from damage claims stemming from residential encroachment into their noise zones, by specification of their historic noise rights in regulatory land use schemes. On the other hand, airports should be liable for any new noise they generate or limitations they place on land usage.* This requires, however, that the damages of an increase in noise exposure due to airport expansion be estimated in monetary terms.

The total value of damages accrued by an increase in noise exposure involves several components: one, the depreciation in property value (sustained by property owners); two, the loss of utility by residents who remain *in situ*; three, relocation costs and loss of place-specific surplus by households that move following the increase in noise exposure (Walters, 1975). While the first and third components can be estimated from market data, the second component can only be estimated by questionnaire-based approaches.

Today, many airports offer various compensation schemes (even if not termed so for legal reasons), to help overcome community opposition. The most widely used scheme is noise insulation.† A few airports, mostly in the U.S., also offer compensation for reduction in property values, or pay for home owners' relocation costs. However, even from the brief discussion above, it is clear that most such programs do not fully compensate for various forms of increase in exposure to airport noise, and particularly for residents who remain *in situ*.‡ To assess what schemes airports should provide to compensate for utility loss due to airport expansion, the relationship between changes in property values due to aircraft noise, consumer willingness to pay for quiet and household relocation due to noise need to be identified, as well as the effects of noise insulation on these relationships.

3. THE USE OF THE HEDONIC APPROACH TO AIRPORT NOISE

Since the introduction of civilian jet aircraft, airport noise has been an issue of significant controversy. From an economic perspective, the issue raised most often was the evaluation of the benefits of aircraft noise abatement. To this end, hedonic price

*On the types of rules that can be used to delineate such property rights, see Bromley (1991).

†In a survey of environmental measures taken by 104 European airports, conducted by the European region of the Airport Association Council International in late 1991, 50 airports (49% of the total number) reported that they offer noise insulation programs. Of these, 15 airports initiated this program voluntarily.

‡It should be borne in mind that such residents need not be property owners, and thus may not even benefit from compensation paid for any loss of property value, or enjoy the positive effect of noise insulation on property value.

studies have been conducted since the late 1960s. The first generation of such studies was reviewed by Nelson (1980).

Most of the hedonic price studies conducted in the 1970s employed cross-sectional housing data to estimate the implicit price per decibel of noise. This was expressed by the noise depreciation sensitivity index (NDSI), the percentage rate of depreciation in the price of a basic house for each unit increase in noise exposure (Walters, 1975; Nelson, 1980). Noise exposure was measured in all these studies by one of the scales combining loudness and number of events in a cumulative index, such as Noise Exposure Forecast (NEF) or Noise and Number Index (NNI). Most of the studies estimated log–log functions (usually using natural logarithms). The range of results reported by Nelson (1980, 1981) was between 0.4 and 1.1%. The average NDSI was 0.58%, and the most frequent measures were in the 0.5–0.6% range.

Since Nelson's work, several studies were carried out, improving on various facets of the previous analyses. While most of the studies analyzed the effects on detached single-family homes, Uyeno *et al.* (1993) analyzed also condominiums and vacant land. Levesque (1994) analyzed the price effects of various components of the noise index. With the exception of Pennington *et al.* (1990), all found statistically significant noise discounts.

The hedonic price approach has, however, several limitations which are important for the purpose of this study. As the limitations of the hedonic price method have been analyzed in detail in various studies, only those of interest for the purpose of this study are listed here.*

The hedonic price function, such as those estimated in the studies described above, identifies the implicit marginal purchase price for aircraft noise. However, unless strong assumptions are made, the implicit marginal price function will not correspond to the marginal willingness to pay function (Freeman, 1979). In most circumstances, we expect the marginal willingness-to-pay (MWTP) function to be steeper than the implicit price function.† In this case, each observation is a point in which the consumer's MWTP equals the implicit price function, as depicted in Fig. 1. Thus, if only small shifts occur in the noise climate, the discrepancy between the area under the implicit price function and

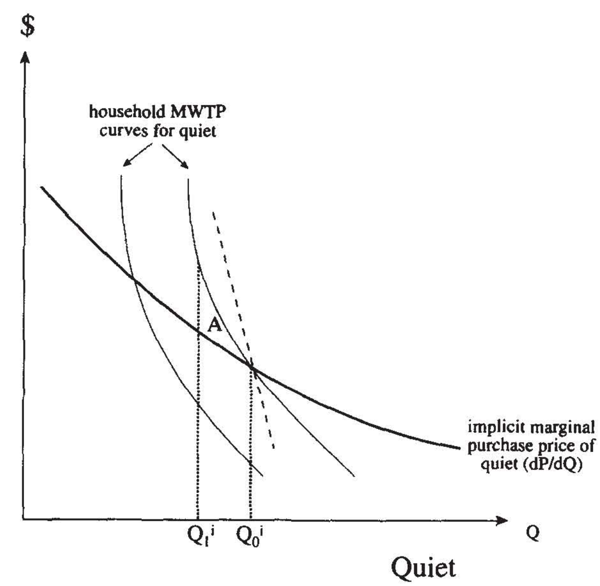

Fig. 1

*For comprehensive and detailed discussions of the hedonic rice method and its limitations, see Bateman (1993), Bartik (1988), Harris (1981), or Palmquist (1991).

†Otherwise, there would be no equilibrium solution, as any improvement above an initial position would lead to a widening excess of household MWTP over implicit marginal purchase price (Bateman, 1993, p. 243).

the area under the MWTP function is likely to be small. However, if a significant shift is expected in the noise picture, such as is often the case when a new runway or airport is opened, this discrepancy can be substantial (area A in Fig. 1).

To address this problem, many studies attempted to estimate the MWTP functions either by making certain assumptions regarding their shape, or by estimating them as a function of household attributes and the levels of environmental quality (air quality, quietness, etc.) chosen by the households (Freeman, 1979; Bateman, 1993). However, such second stage studies were not conducted for the airport noise issue. Moreover, the functions that can be estimated by this technique are continuous. However, recent advances in analyses of consumer valuation of changes in environmental quality suggest that such functions may actually not be continuous.

Kahneman and Tversky (1979, 1984) suggest that households have different values for losses and gains. Thus a household's MWTP function would be steeper, as depicted by a broken curve in Fig. 1. It is also quite likely that there be a kink at the equilibrium position (Bateman & Turner, 1993). Indeed, Loehman *et al.* (1994) recently identified and estimated different MWTP functions for gains versus losses of visibility and health from air pollution.

The hedonic approach assumes that households constantly re-evaluate their position, and adjust their consumption bundles (residential choices) to changing circumstances (Maler, 1977). This is only possible if transaction costs are low. Yet, residential markets involve significant transaction costs. Consequently, significant discrepancies have been found to exist between a household's willingness to pay for housing and neighborhood attributes and their market premiums (Dynarski, 1986). Therefore, the basic assumption underlying second stage analysis, that the level of an environmental characteristic consumed by a household and the implicit price of that attribute reflect a point in which the household's MWTP function intersects the marginal price function, should be questioned.

Hedonic price studies also require that the housing market not be segmented. However, in practice, there are several types of market segmentations (Feitelson, 1993), and at least some of them are likely to occur in most markets.

Finally, the data for hedonic price studies are often quite standardized, in the sense they are collected by an agency with goals different from the researcher's. It can be expected, therefore, that, in many cases, the introduction of preventive action by the seller (such as noise insulation) would not be recorded. In such cases, the regression of prices on noise exposure would not produce the accurate marginal valuation of noise.

Awareness of such lacuna has prompted several analysts to suggest that surveys be conducted as complements to hedonic price studies (Goodman, 1989; Smith, 1993); yet, only few such studies have been conducted, usually with the purpose of verifying the validity of CVM studies. To the best of these authors' knowledge, no such study was undertaken in the airport noise context.*

4. THE ISSUES AND POTENTIAL OF A CVM CONTRIBUTION IN THE AIRPORT EXPANSION CONTEXT

To overcome some of the problems noted above, this study uses the CVM approach to estimate directly the effect of changes in aircraft noise exposure on household WTP for residences; yet, in doing so, several issues have to be addressed.

As the first goal of this study is to provide a basis for compensation for increased exposure to aircraft noise following airport expansion, it would seem logical to ask respondents how much compensation they would demand. In other words, willingness to accept (WTA) measures are intuitively appealing.

However, following the extensive analyses and discussions of the differences between WTP and WTA measures, a consensus has emerged that only WTP measures should be

*This is the case, despite early recognition of the potential contribution of surveys, and notable calls for undertaking such surveys (i.e. Walters, 1975; Nelson, 1981).

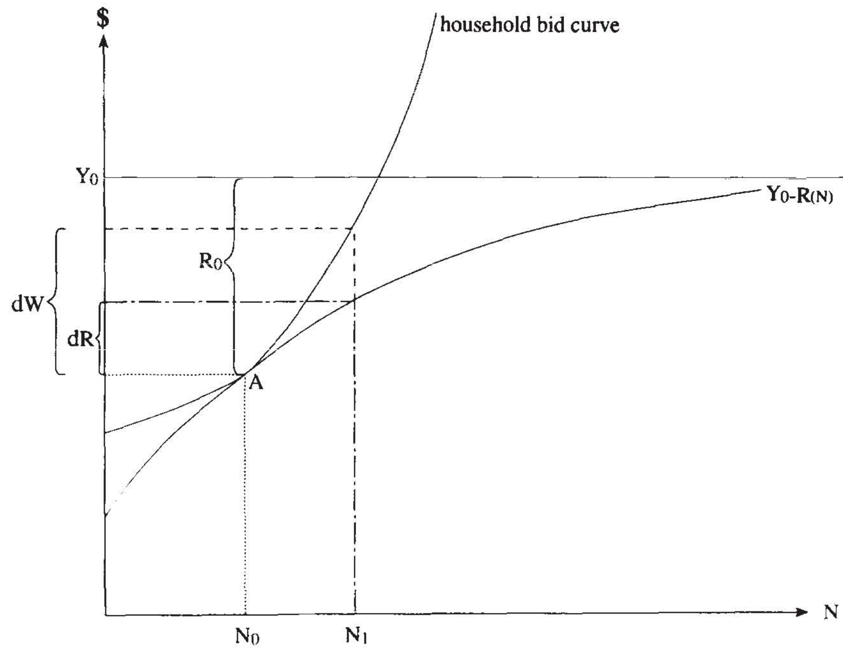

Fig. 2

used (Cummings *et al.*, 1986; Mitchell & Carson, 1989; Bateman & Turner, 1993). The reasons for this conclusion include the greater familiarity that households have with purchasing decisions, and, consequently, the more valid answers they provide to WTP questions (lower probability for a hypothetical bias), income effects and the larger number of outliers in WTA valuations leading many analysts to doubt their validity.* Still, as the difference also reflects the basic discrepancy between loss and gain situations, the implication of using WTP measures is that the estimates derived can be viewed as the lower bound to the compensation required in situations where noise exposure increases.

The second goal of this study requires that the CVM findings be related to prior HPM studies. So far, only few comparisons have been made between CVM and other methods for valuing environmental goods or services (Smith, 1993). One of the few studies that compared hedonic price and CVM results was conducted by Brookshire *et al.* (1982). An adaptation of the model they used for the noise issue at hand is presented in Fig. 2.

The vertical axis in Fig. 2 is a composite commodity with a price of unity, and thus also represents prices. The horizontal axis represents noise levels. Y_0 is a representative household's income level. Y_0–$R(N)$ is the disposable income for purchase of the composite good. $R(N)$ is the rental value of the residences, which is a declining function of noise. This is depicted by a decreasing difference between Y_0 and Y_0–$R(N)$ as noise increases. The bid curve represents a household's MWTP for the residence, as a function of noise and the composite commodity.

Point A describes the household's original situation. The household at this point pays a rent of R_0 for a residence subject to an N_0 noise level. If noise exposure increases from N_0 to N_1, the household's compensating variation will be dW, the amount necessary to maintain its current welfare level. The market rent declines, however, only by dR (due to the existence of less noise sensitive consumers). As can be seen in Fig. 2, $dW > dR$. Brookshire *et al.* (1982) have shown this conclusion to hold also when household tastes or income vary.

The actual welfare loss suffered by the household would be dW as long as the household remains in place. If the household relocates, the actual welfare loss would be the

*For a further discussion, see Hanemann (1991) or Bateman and Turner (1993).

relocation and transaction costs (Palmquist, 1992), and the loss of place-specific utility (Walters, 1975). These would necessarily be smaller than dW. Thus, from this perspective, the estimates derived in a CVM study would be the upper bound for welfare loss, and thus for compensation.

In summary, dW would provide an upper bound in the case where a household would change its residential consumption due to an increase in aircraft noise, and a lower bound for compensation if a household chooses to stay when noise exposure worsens.

5. THE STUDY DESIGN

In the study design, several singular features were included. First of all, both renters and homeowners were surveyed. Home owners are interested in both the use value and the market value of their homes. Airport compensation schemes usually focus on this group. Also, HPM studies usually analyze noise effects on owner-occupied homes. However, in many communities, there is a significant number of people who rent a residence. This group is primarily interested in the use value of the residence, yet, the noise effects on the rental market have not received much attention to date. This is somewhat surprising as renters may seem to be the more pertinent group for such valuations, given their frequent need to evaluate their residential choice. Moreover, their transaction costs and relocation costs are usually lower than for homeowners, and thus this market may be more responsive to changes in noise exposure.

Secondly, the effects of several noise attributes were analyzed. Most noise evaluations use the well known NEF, NNI or Ldn measures of noise exposure. These measures are all based on the assumption that noise annoyance is a function of some average noise exposure, whereby low noise intervals 'compensate' for peak noise. However, as Schultz (1982) notes, this assumption is but one of three possible noise annoyance models. The others are the detectability model, whereby annoyance is dichotomous, and the mere existence of detectable noise is the main source of discomfort, regardless of volume (as in the case of odors), and the high threshold model, whereby annoyance is not affected by noise history, but rather exclusively by the peak events. Indeed several socio-acoustical studies have found that the level of peak events is the major source of annoyance, while the frequency of events is a secondary cause of annoyance (Rylander *et al.*, 1980; Arnon, 1986).*

Thirdly, the effects of noise insulation were specifically analyzed. As noted before, the disregard for such measures may bias hedonic estimates, and is important for policy purposes, as this is the most common compensation scheme offered by airports.

Fourthly, the effects of low overflights were included. Such overflights do not only affect noise, but also present a threat (however remote), as most accidents occur along takeoff and landing corridors. They present, thus, a safety threat, in addition to the noise problem.

To test these questions, 10 disturbance scenarios were tested, out of the 15 possible combinations described in Table 1. The five possible scenarios deleted (noted by minuses in Table 1) were illogical or low-probability combinations (such as low overflights but with no noise or only minor noise disturbance).

Table 1. The scenarios used

Noise level / Other attributes	No noise	Occasional noise		Frequent noise	
		Minor	Severe	Minor	Severe
None	+	+	+	+	+
Sound-proofing	–	–	+	+	+
Overflights	–	–	+	–	+

*In a recent HPM study Levesque (1994) found that frequency and loudness of events did have separate effects on prices.

Table 2. Variable definitions

WTP:	willingness to pay for purchase of stated residence.
RNT:	willingness to pay rent for stated residence.
HNOIS:	dummy variable, has value of '1' if hypothetical residence is subject to noise.
HFREQ:	dummy variable, has value of '1' if hypothetical residence is subject to frequent noise disturbances.
HSEVER:	dummy variable, has value of '1' if hypothetical residence is subject to severe noise.
HOVHD:	dummy variable, has value of '1' if hypothetical residence is subject to overhead flights.
HSNDPRF:	dummy variable, has value of '1' if hypothetical residence is sound-proofed.
INCOM:	income.
AGE:	age.
HHSIZE:	number of people in household.
NOISE:	noise classification of respondent.
NOISEFCT:	an interaction effect between HNOIS and NOISE.
USEFFCT:	an interaction effect between HNOIS, frequency of usage of the airport, and whether flights are for business.
HPNN:	price for house with no noise.
RPNN:	rent for apartment with no noise.

A telephone survey was conducted in three communities near a major hub airport where a significant expansion is planned. Homeowners in the three communities were asked to state their willingness to pay for a four-bedroom single family residence located in an area with no aircraft noise at all. Then, they were asked to state their willingness to pay for the same residence when it is located in sites subject to different levels of noise exposure, frequencies of noise disturbances and overhead flights. A similar sequence was conducted for renters, only they were asked how much monthly rent they would be willing to pay for a three-bedroom residence.*

The use of a single residence scenario for each sub-market, varying only noise descriptions, overcomes the need to control for variation in non-noise housing attributes. Thus, direct estimates of the tradeoff between noise and all other attributes, as depicted in Fig. 2, can be derived.

As respondents live in the proximity of a major airport, they are familiar with the noise issue, as well as with the payment vehicle, residence purchase or rent. Consequently, no hypothetical bias was expected.† While a strategic bias is possible in this case, the sophistication it requires of respondents in a short (and from their perspective, unexpected) phone conversation, as well as the ample evidence that respondents do not show such sophistication, even under less stringent conditions (Cummings *et al.*, 1986), reduces the likelihood of such a bias.

6. THE EFFECTS OF NOISE ATTRIBUTES ON WTP

The analysis was conducted in two stages. In the first stage, ordinary least-square regressions were run to determine the contribution of the various noise attributes to household WTP for the standard residences. To this end, the noise attributes included in the residence descriptions were defined as dummy variables. The definitions of all variables included in the various regressions appear in Table 2.

In the first set of regressions, home buyers' and renters' WTP were analyzed as a function of exposure to noise, severity of exposure, frequency of noise incidents, overflights and whether the residence has been insulated against noise. The regressions were run for all respondents that had a positive valuation of the residence when it was not subject to any noise. The respondents that expressed no willingness-to-pay for the standard residence, even when not subject to noise, were deleted from the rest of the analysis.

*The choice of residence sizes followed a brief survey of realtors in the region. The residence sizes were chosen to be slightly above the regional average for each sub-market (home ownership versus rental), so as to reduce the likelihood of respondents stating they are not willing to pay anything for such a residence due to it being too small. On the other hand, as the residence is to be seen as viable in the region, and within the grasp of most respondents, a description of a luxury residence was also avoided.

†To verify this point respondents' mean valuation of a residence in a quiet area was compared to that of a small sample of realtors. No significant difference was found.

The results of the first set of regressions show that, for both sub-markets, all noise attributes are significant at the 0.01 level, with the correct signs. All forms of noise reduced the basic residence value, while sound-proofing mitigated these effects. The two noise attributes shown to have the greatest effect are the exposure to noise and the severity of exposure. Noise insulation does not fully mitigate for the deleterious effects of noise.

However, the level of explanation in the first set of regressions is low, explaining only 18% of the variation of home owners WTP, and 13% of the renters' WTP variation. This low level of explanation can be the outcome of several factors. Firstly, individuals vary in their valuation of the standard residence. As we are not interested in the valuation of the standard residences as such, the value of the residence when not subject to noise can be introduced into the regression, thus controlling for the individual variance in standard residence valuation. This was done in the second set of regressions.

Secondly, there may be group differences due to differences in income, age or previous noise exposure. To address these possibilities, income, age and household size were also introduced in the second set of regressions, as was previous exposure to noise. This latter effect is included in two ways. Firstly, it is possible that current noise exposure affects the basic residence valuation, and thus it is included as a dummy variable. Secondly, it is possible that actual exposure to noise affects the valuation of hypothetical exposure. Thus, an interaction effect dummy variable is included between exposure to noise and valuation of such exposure in the residence description (between NOISE and HNOISE). Finally, an interaction effect between the use of the airport and the valuation of noise exposure (HNOISE) is included, to check whether extensive use of the airport increases the tolerance of noise.

In Table 3, the variables included in each set of regressions are detailed, as well as the regression statistics. In addition, the sign of the coefficient is shown, and whether the coefficient was significant at the 99% level (bold signs indicating the significant coefficients). As can be seen in Table 3, the level of explanation in the second set of regressions, while higher than previously, still explains only about a third of the variation.

A third factor that may affect the level of explanation is the estimated functional form of the rent gradient with respect to several of the explanatory variables. From a theoretical perspective, a non-linear form makes sense, as it is unlikely that the marginal effect of noise on WTP will be the same in low- and high-levels of noise exposure (Bateman, 1993).

Table 3. WTP and RNT regression specifications

	Homeowners				Renters			
Variables	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
HNOIS	–	–	–	–	–	–	–	–
HFREQ	–	–	–	–	–	–	–	–
HSEVER	–	–	–	–	–	–	–	–
HOVHD	–	–	–	–	–	–	–	–
HSNDPRF	+	+	+	+	+	+	+	+
INCOM		–	–			+	+	
ln(INC)				–				–
NOISE		–	+	+		+	+	+
HHSIZE		–	+			–	+	
ln(HHSIZE)				–				+
NOISEFCT		–	–	–		–	–	–
USEFCT		–	+	+		–	–	–
HPNN		+	+					
ln(HPNN)				+				
RPNN						+	+	
ln(RPNN)								+
R^2	0.177	0.356	0.686	0.526	0.131	0.376	0.633	0.802
Adj. R^2	0.176	0.353	0.684	0.523	0.129	0.372	0.630	0.801
F-value	153.9	118.0	306.3	155.7	80.2	86.7	204.6	481.0
N	3586	2577	1695	1815	2662	1737	1436	1639

+ and — indicate coefficient signs.
Bold text indicates a significant coefficient at the 0.01 level.

Table 4. Homeowners' and renters non-linear regression results (standard errors in parentheses)

Dependent variable	ln(WTP)	ln(RNT)
Intercept	0.741**	1.160**
	(0.098)	(0.074)
HNOIS	−0.072*	−0.089*
	(0.031)	(0.018)
HFREQ	0.105**	0.056**
	(0.017)	(0.018)
HSEVER	−0.157**	−0.092**
	(0.019)	(0.020)
HOVHD	−0.027	−0.088**
	(0.026)	(0.027)
HSNDPRF	0.094**	0.055**
	(0.019)	(0.021)
NOISEFCT	−0.083**	−0.000
	(0.011)	(0.009)
USEFCT	0.001**	−0.000
	(0.0002)	(0.000)
ln(WTP)	0.845**	
	(0.020)	
ln(RNT)		0.817**
		(0.011)
R^2	0.5553	0.7754
Adj. R^2	0.5533	0.7743
N	1815	1639

*Significant at the 0.1 level.
**Significant at the 0.01 level.

However, several non-linear specifications failed to improve the level of explanation, largely due to the significant number of zero valuations for the standard residence when subject to significant noise. When these zero valuations were deleted, in the third set of regressions, the level of explanation rose, to approximately two-thirds of the variation. However, it should be noted that these regressions only analyze those respondents willing to buy or rent residences with the specified noise levels. Consequently, the mean WTP for residences is an overestimate, thus necessarily underestimating the effect of noise on WTP.

An analysis of several alternative functional forms showed the log–log specification to provide a significant improvement of renters WTP once the zero valuations were removed. However, as seen in the fourth set of regressions in Table 3, most household attributes were not significant in these analyses. Consequently, they were deleted in the final set of regressions, whose results are displayed in Table 4.

As the regressions in Table 4 have a log–log form, they allow for comparisons between the renter and home owner sub-markets. In both sub-markets, the frequency of noise events and their severity are the main detrimental effects on WTP. Noise insulation provides only partial relief.

The major difference between the two sub-markets is in the effect of overhead flights. While such flights have a significant negative impact on renters' WTP, they do not have a statistically significant effect (even at the 90% confidence level) on homeowners' WTP. In contrast, current noise exposure and level of use of the airport affect home owners' valuations, but do not affect renters' WTP at all.

An additional difference between the two sub-markets, evident from Table 2, is in the functional form of the regressions. While for homeowners, the linear regressions provide the best fit, for renters, the log–log regressions provide the best fit.

Overall, the most important outcome that can be gathered from the full set of regressions, is that the frequency and severity of noise events have significant deleterious effects on both homeowners' and renters' WTP, regardless of regression specification, and that noise insulation only partially mitigates these effects. These findings are significant as they show that frequency and severity of noise events are important, regardless of tenure and the age and income differences between renters and homeowners.*

*Renters' median age was 29, compared with 40 for homeowners. 75% of renters earned less than $40,000 annually, compared with only 47% of homeowners.

7. THE WTP STRUCTURES

In the preceding discussion, it was noted that a significant number of zero valuations were received. This raised the suspicion that preference structures may not be continuous. As each respondent provided 10 observations regarding his/her valuations, it was possible, in the second stage of the analysis, to look at the valuations of individuals so as to gain some insights regarding individuals' WTP structures.

The picture that emerges from looking at individuals' WTP valuations is that many respondents seem to have a certain disturbance threshold above which they are unwilling to consider the residence. These respondents differ, however, in the disturbance level that constitutes the threshold. This observation is perceptible in Table 5.

The first column in Table 5 describes, in an abridged manner, the 10 residential scenarios for whom respondents were asked to state their WTP. The second and fourth columns detail the number of homeowners and renters, respectively, that were not willing to pay anything for the particular scenario. The scenarios are ordered in increasing sequence of number of homeowners not willing to pay for them. However, the differences in sequence between homeowners and renters is insignificant.

Of the total 426 homeowners included in the analysis, 10.8% refused to pay anything for any residence exposed to any level of noise. Almost a third (31.5%) were unwilling to pay anything for a dwelling exposed to occasional severe noise, and 45.1% were unwilling to pay for a residence exposed to frequent severe noise and over which aircraft fly. In comparison, only 4.4% of renters were unwilling to rent a unit exposed to any level of noise, and only slightly more than a third (34.2%) were unwilling to rent, at any price, the standard unit when it was exposed to severe frequent noise with overflights.

Table 5. Unwillingness-to-pay distribution by noise level

	Homeowners (N = 426)		Renters (N = 274)	
Noise level	Unwilling to buy	Mean WTP of those willing to buy ($\$10^3$)	Unwilling to rent	Mean WTP of those willing to rent (in dollars)
No noise	—	121.4	—	628.4
Occasional Minor noise	46 (10.8%)	101.3	12 (4.4%)	557.3
Frequent Minor noise Sound-proofing	75 (17.6%)	98.6	17 (6.2%)	566.4
Frequent Minor noise	110 (25.8%)	89.0	34 (12.4%)	507.8
Occasional Severe noise Sound-proofing	115 (27.0%)	93.6	33 (12.0%)	545.1
Occasional Severe noise	134 (31.5%)	85.8	51 (18.6%)	512.3
Occasional Severe noise Over flights	167 (39.2%)	85.1	81 (29.6%)	491.3
Frequent Severe noise Sound-proofing	143 (33.5%)	86.2	49 (17.9%)	518.6
Frequent Severe noise	164 (38.5%)	77.3	77 (28.1%)	486.8
Frequent Severe noise Overflights	192 (45.1%)	78.6	95 (34.7%)	457.8

The third and fifth columns present the mean WTP of those respondents willing to consider the standard residence with the stated noise scenario. An analysis of variance was conducted to test whether these mean WTP vary across scenarios. When all scenarios are included, the null hypothesis was rejected at the 99% level. However, when the two top scenarios and the scenarios with noise insulation were dropped, the null hypothesis could be rejected only at the 95% confidence level. In other words, the hypothesis that WTP of either renters or homeowners does not increase as we move from the fourth scenario downwards in Table 5 (and skipping scenarios 5 and 8) cannot be rejected at the 99% confidence level. This is indicative of the possibility that the main effect of increasing disturbance due to airport expansion is on the number of respondents unwilling to consider the residence, rather than on the marginal WTP for the residence.

This finding is especially poignant with regards to the effects of overflights on homeowners. While in the regressions presented in Table 4, overflights had no effects on homeowners' WTP, in Table 5 we see that this is only true if we disregard zero valuations. Overflights had significant effects on the number of homeowners unwilling to purchase the standard house, increasing this number by 7–8% (comparing scenarios 6 and 7, and scenario 10 to 9).

Noise insulation is shown, in Table 5, to affect both the number of people willing to buy or rent the respective standard units, as well as the WTP of those willing to buy or rent those units. This finding implies that the effect found in Table 4 is an underestimate of the true value of noise insulation. Still, sound-proofing a residence does not fully mitigate the effects of noise on WTP, as the mitigatory effect in terms of the number willing to buy or rent, and the WTP of those willing to buy or rent, is lower than the effect of increased noise exposure. While the increase in noise from minor to severe levels (from scenario 4 to scenario 9) reduces the number of those willing to consider the residence by 12% and 15% for homeowners and renters, insulation increases these numbers by only 5% and 10%, respectively. In terms of WTP by those willing to consider the residence, sound-proofing has a remarkably constant positive effect. However, this effect is lower than the deleterious effect of increased noise levels. Moreover, noise insulation is the only readily available mitigation action available to homeowners and residents, short of moving (which involves transactions and moving costs, as well as a loss of residence-specific utility).

Table 5 thus suggests that the WTP valuation is actually the outcome of a two-stage process. First, the respondent determines whether he, or she, is willing to consider the residence. Only if the answer is affirmative do respondents offer a positive assessment of their WTP for it. This implies that a respondent's bid curves are kinked, where, above a certain noise threshold, their marginal bid for a residence is zero. However, the noise attributes that comprise this threshold vary across households.

No significant differences were found between households with different thresholds, in terms of income or situation in life cycle, for either homeowners or renters. One possible explanation for this finding is that such differences are a function of life style choices, rather than income or life cycle. Support for this hypothesis can be found in Feitelson's (1993) findings that life style is a more robust long-term segmentation base for residential demand. Regrettably, data limitations precluded the testing of this hypothesis in this study, and it is thus left for future research.

8. DISCUSSION AND IMPLICATIONS

This paper presents a contingent valuation method for analyzing the noise costs of airport expansion. This approach provides direct estimates of the noise cost of airport expansion for residents. These costs are significantly higher than those derived from hedonic price studies. If we assume that the difference between a no-noise scenario and a frequent severe noise scenario is somewhere between 15 and 25 Ldn, then the difference in valuation of those willing to pay (without zero valuations), based on Table 5, is between 1.5% and 2.4% of house prices for home owners and 0.9–1.5% of rents for renters.* When the zero valuations are included (as they should be), the noise premium rises to 2.4–4.1% for home owners and 1.8–3.0% for renters (as the mean WTP for noisy residences drops while the mean WTP for quiet residences remains unchanged). These results compare with the 0.4–1.1% premiums reported by Nelson (1980, 1981), and the even lower premiums in most recent studies.

This wide difference between the results obtained by the CVM and HPM studies should not come as a surprise, as, in this study, the estimates include loss of use value, while the HPM studies identify only market premiums.† Moreover, these differences conform to what we would expect from the theoretical discussion summarized in Fig. 2, as the CVM estimates the dW measure, while the HPM estimates the dR.

This paper also shows that the use of average peak noise indexes (such as Ldn) as the basis of valuation understates the disturbance caused by airport expansion, as the actual disturbance also includes frequency of overhead flights. Thus premiums calculated as a percentage effect per Ldn, are an underestimate of the actual welfare loss.

On a more general level, the results of this paper provide new insights as to household WTP structures with regard to noise. Specifically, they indicate that household WTP functions for residences are kinked, whereby, above a certain disturbance level, households are not willing to consider the residence, and thus their WTP drops to zero.

There are two possible explanations for this kink. Firstly, household preferences are kinked, and thus, above a certain noise threshold, their utility drops precipitously. Two, it is the outcome of the residential choice context of the valuations. In a residential choice framework, as used in this study, households perhaps compare the hypothetical residence to some base residence (probably a function of their current residence). As the noise (or total disturbance) rises above a certain level, the residential unit becomes less attractive than the base unit, and thus the household's WTP for the hypothetical unit drops to zero. In both cases, households would differ in terms of the disturbance level at which this kink occurs. However, tests of the two possible explanations, and of the household attributes that determine the threshold levels, are beyond the scope of this paper and are left for future research.

The findings of this study have several policy implications. The most important finding from a policy perspective is that most current compensation schemes do not fully address the welfare loss due to aircraft noise suffered by the airport's neighbors due to its expansion. It is not surprising, therefore, that these programs have proved to be inadequate, and do not mitigate community opposition.

This paper has shown clearly that the most popular type of compensation program, noise insulation, does not fully compensate for noise disturbance. Thus, airport authorities should strive to provide additional compensations, if they are to purchase the right to increase noise above the levels considered socially acceptable.‡

In identifying the level and nature of more comprehensive compensation schemes, airport authorities should not rely solely on HPM studies to identify loss of property value. If they do, they are likely to find that the compensation which they offer is still inadequate. Rather, they should try to differentiate between households who would like to relocate, and those who would stay in place and sustain the welfare loss. To compensate the first group, the full relocation and place-surplus loss would have to be offered.§ To estimate the minimal compensation for the second group, the airport authority may use the CVM approach as presented in this paper. By providing a basis for estimating the

*The 15 Ldn difference is between 55 Ldn for no noise and 70 Ldn for the severe noise scenario. The 25 Ldn difference is between 50 Ldn in the suburban setting without any aircraft noise and 75 Ldn with aircraft noise. This latter possibility is very remote, as it is unlikely that any new runway will be allowed to expose a population to 75 Ldn. The scenarios chosen were the ones with the lowest noise (no aircraft noise) and the highest noise without overflights, as overflights represent a nuisance not accounted for in the Ldn measure.

†Verhoef (1994) suggests, on the basis of European studies, that CVM studies can obtain estimates up to 8 times higher than HPM studies for road noise.

‡This issue is detailed in Feitelson (1989a), and applied to the airport noise case in Feitelson (1989b).

§This point was raised already by Walters (1975). However, the techniques he discussed for estimating the compensation were cumbersome and inaccurate, and thus precluded the implementation of this approach.

full welfare loss, the CVM approach advanced here may facilitate the implementation of property rights and fee schemes to airport noise issues.

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