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USING HAPPINESS SURVEYS TO VALUE INTANGIBLES: THE CASE OF AIRPORT NOISE*

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We assess the monetary value of the noise damage, caused by aircraft noise nuisance around Amsterdam Airport, as the sum of hedonic house price differentials and a residual cost component. The residual costs are assessed from a survey, including an ordinal life satisfaction scale, on which individual respondents have scored. The derived compensation scheme depends on, among other things, the objective noise level, income, the degree to which prices account for noise differences, and the presence of noise insulation.

Many city dwellers are painfully aware of a nearby airport, as they suffer from aircraft noise. The area around Amsterdam Airport (Schiphol) is no exception. Air traffic has heavily expanded since the airport started operating in 1926. Since the 1960s, the local population has become noise-conscious as a result of the exponentially growing air traffic and the environmentalist awakening. Similar problems exist for many airports all over the world. In the last years a fierce discussion developed on the question whether Schiphol should be allowed to expand still further, and whether the local inhabitants in the Greater Amsterdam Area should be compensated in money for the growing noise nuisance. A major question is then which money amount seems justified.

This paper proposes a new method of measuring the value of intangibles, the key and normally most controversial element in social cost benefit analysis. The standard procedure is to infer shadow prices from market data. For example, Walters (1975) discusses how to convert the discount in the price of houses in the vicinity of an airport into a valid estimate of the monetary cost of aircraft noise. This approach has its difficulties. Even under ideal conditions, price differentials reflect the cost to the least noise-tolerant of all those affected by the noise. Obtaining reliable estimates of how intra-marginal types are affected is tricky. Moreover, when, as is often true, house prices and rents are controlled the procedure completely breaks down. Its applicability is also questionable if residents face significant switching costs, especially if their ability to make unbiased long-term predictions of their circumstances and preferences is doubtful. Although it is not denied that price differentials may cover part of the value of the intangibles, another part of the cost may not be revealed. Therefore, we need a complementary instrument.

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The complementary instrument developed here is based on the use of happiness surveys, increasingly becoming accepted as a powerful tool of welfare economics. In essence, an equation explaining happiness as a function of income, noise and other variables is estimated. The change in income necessary to compensate for a specified change in noise then drops out immediately. If the strict assumptions of a well-functioning housing market would apply then (ignoring heterogeneity) no relationship should exist between noise and happiness because house prices fully adjust to compensate. However, due to the rationing on the market and the fact that residents face significant switching costs, in practice this equilibrium frequently does not hold and there are still positive *residual* shadow costs. More generally, the appropriate measure is the sum of any noise-created reduction in the market value of the housing stock *plus residual* shadow costs.

The remainder of this paper develops this idea and applies it to estimating the cost of the noise created by Schiphol Airport in Amsterdam. Once obtained, the new measure can be used in standard fashion in decisions on whether to extend runways, reduce the number of flights and, if compensation is to be paid, how much it should be. The novelty in the paper lies in the methodology of measurement.

A political point on which we do not express an opinion is whether such residual costs should be compensated and, if the answer is in the affirmative, whether this should be done by the government, the airport or the airline companies. A special complication is that inhabitants in the area may be heterogeneous with respect to their noise sensitivity. In that case we may expect that the noise-insensitive individuals will move to the noise-exposed houses (mostly near the airport), attracted by the lower prices those houses will bear. This heterogeneity depends on psychological characteristics, which we were unable to observe and which we will henceforth ignore. However, as we will argue later on, it is unlikely that this phenomenon plays an important role in the Amsterdam area.

The noise problem around airports is a special case of the more general problem of how to deal with the difference between private and social costs. Pigou (1920) and Coase (1960) are the pioneers of this subject. There is a considerable empirical literature on this type of problems in general and for aircraft noise in particular. These studies use either revealed preference methods (e.g., the hedonic price method), or *direct* stated preference methods (e.g., the contingent valuation method, willingness to pay). Our method is based on market information *and* on subjective questions. Respondents are asked how they evaluate their 'quality of life' on a (1–10) scale. Such questions are standard instruments in sociological and psychological research. We use a question, which was originally developed by Cantril (1965). It appears that the answers depend on income, exposure to aircraft noise and many other variables.

In Section 1, we give a short critical survey of the literature. In Section 2, we consider the data. In Section 3, we discuss some theoretical aspects of the model used. In Section 4, we formulate and estimate the empirical model for the Schiphol area. In Section 5, we derive the monetary shadow costs and the resulting compensations, which follow from the model, and their policy implications.

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In Section 6, we discuss the model and evaluate the relevance of this study for economic science and policy. In the Appendix, we consider the hedonic relationship between noise and house prices.

1. Short Survey of the Literature

On the basis of our knowledge of the literature, the valuation of aircraft noise has mainly been approached along two roads. The first approach is that of hedonic price studies. The second employs the contingent valuation method (CVM).

1.1. *Hedonic Price Studies*

Attempts to value people's preferences for peace and quiet have centred on the use of the hedonic price method. This method tries to impute a price for an environmental good by examining the effect that its presence has on the value of a relevant market-priced good, such as houses. In the case of aircraft noise nuisance, the method attempts to identify how much of the difference in house prices is due to the level of noise nuisance. Table 1 shows the results of various recent hedonic price surveys that have studied the effect of aircraft noise on residential property values. In most studies, the price sensitivity with respect to aircraft noise is evaluated by the Noise Depreciation Index (NDI), which measures the change in property prices in terms of a percentage for each unit of change in the noise level. The NDI is derived on the basis of a survey of the changes in property values over particular periods or geographical areas (Nelson, 1980, pp. 40–2). A hedonic price equation is specified with the property value (V), on the one hand, and a set of physical and locational housing characteristics (Z) and the level of noise nuisance (N) on the other: $V = V(Z, N)$. The measures of noise nuisance levels N differ between countries. For instance, the US noise descriptor is

Table 1

A Summary of Hedonic Price Studies and Aircraft Noise Nuisance, measured in NDI (%)

Study location	NDI estimate	Study location	NDI estimate
Australia		*US*	
Sydney 1	0.40*	Atlanta	0.65*
Sydney 2	0.22*	Boston	0.83*
Canada		Dallas 1	0.6*
Edmonton	0.51*	Dallas 2	2.3*
Toronto	0.52**	Los Angeles	0.8*
Vancouver 1	0.65*	New York	1.8*
Vancouver 2	0.90*	New Orleans	0.4*
UK		Minneapolis	0.6*
Heathrow 1	0.25**	Rochester	0.55*
Heathrow 2	3.57**	San Francisco	0.5*
Manchester	0.15**	Washington DC	1.06*

*Noise nuisance is measured in NEF.
**Noise nuisance is measured in NNI.
Sources: Nelson (1980, pp. 47–51); Pearce (1993, p. 72); Schipper (1997, p. 6).

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the Noise Exposure Forecast (NEF), the UK noise descriptor is the noise and number index (NNI), whereas the Dutch noise descriptor is the Kosten unit (*Ku*).[1] The NDI is derived from $\partial V/\partial N$. An older list of results has been collected by Walters (1975). Those results are similar to those of more the recent studies presented in Table 1.

The consensus view that seems to have emerged from the hedonic price studies is that aircraft noise has a negative and statistically significant effect on housing prices, i.e. the NDI is around 0.6% on average (Collins and Evans, 1994, p. 175; Nelson, 1980, p. 46). This means that a dwelling of, say, $200,000 would sell for 12% less, that is $176,000, if located in a zone with 20 units more noise nuisance.

1.2. *Contingent Valuation Studies*

The contingent valuation method (CVM) uses surveys to find the willingness to pay (WTP) or the willingness to accept (WTA) compensation for a change in the level of environmental service flows. Only one CVM study on aircraft noise nuisance is reviewed below, because we could only find this one study in the literature.

There is a lively discussion on CVM in the literature (Pearce, 1993; Hausman, 1993). For a recent defence of CVM, we refer to Carson *et al.* (2001). One of the problems of this approach is related to the direct way of questioning in CVM questionnaires, which may entail a strategic response bias. For example, respondents are asked how much they are willing to pay for a reduction of noise nuisance during the night (WTP). This kind of questioning has an important drawback: strategic response behaviour. Although we do not deny that CVM analysis is informative, in the case of Schiphol, considered in this study, it would not have been very wise to use the CVM way of questioning. Schiphol Airport and noise nuisance are hot issues in the Netherlands and they constitute a playing field for environmental activists. Had it been known that a survey was being carried out with the aim of establishing monetary compensation schemes for noise nuisance, it would definitely have led to strategic behaviour (e.g., overestimation and/or a boycott of the survey). Respondents are not punished in any way if they do not express their true value but a value that is lower or higher than what they really feel in an attempt to influence the provision or price of the environmental good under valuation. Hence, we cannot always take the CVM answer at face value.

[1] A few years ago, the US measure (NEF) was replaced by the L_{den} measure, and the UK measure (NNI) has been replaced by that of the *Leq*. The Dutch Kosten-measure, on which the present study is based, has recently been replaced by the L_{den} measure as well. The Kosten measure is a formula based on the noise level, the frequency and a penalty factor for flying during the evening or during the night. It is based on a consensus between members of a state commission consisting of engineers, psychophysicists and civil servants, chaired by Professor Kosten. The index, denoted by Ku in this paper, is very similar to the Noise Number Index for the UK and the later NEF index. There is a strong positive correlation between the Kosten index and the L_{den} measure. Walters describes such national noise indexes for the UK, the US, France and West Germany. It is remarkable how similar the formulas are, with the exception that they differ with respect to the exogenously fixed values of the parameters.

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The CVM has the advantage that it measures user values and non-user values. A non-user value may be assigned to the existence of natural reserves, which are threatened to become less 'natural' when situated next to a runway. Non-user values cannot be measured by means of the hedonic price method. For instance, noise nuisance has no price effect in areas without houses, since in these 'empty' areas no housing prices exist that may reflect the impact of noise, but (non)user values may be assigned to these non-housing areas. Environmentalists stress that air traffic may cause the living conditions of animals in nature reserves and bird sanctuaries to deteriorate.

One CVM study on aircraft noise was conducted in Israel by Feitelson *et al.* (1996). It estimated the effect of changes in aircraft noise exposure, following an airport expansion, on the WTP for residences. Home owners in three communities near a major airport, where a significant expansion was planned, were asked to state their WTP for a four-bedroom single family residence located in an area with no aircraft noise at all. Next, they were asked to state their WTP for the same residence if it is located at sites subject to different levels of noise (expressed in L_{den} units). A similar sequence of WTP questions was conducted for tenants in terms of monthly rent for a three-bedroom residence.

This Israeli study suggests that the difference in valuation for residences with no noise nuisance compared with residences with frequent and severe noise nuisance is 2.4–4.1% of the housing prices per L_{den} (for home owners) and 1.8–3.0% of the rents per L_{den} (for tenants). These noise depreciation indices (NDI) are higher than the values obtained in most hedonic price studies (around 0.6% on average). This may be partly due to the fact that CVM estimates include the loss of non-use values, whereas the hedonic price estimates only identify market premiums. Feitelson *et al.* also suggest another explanation, viz. the fact that the WTP structures are kinked. This implies that, beyond a certain disturbance threshold, households are unwilling to pay anything for the affected residences. Hence, their valuation of (the reduction of) noise nuisance is so high, because they are not willing to pay anything for a residence in a noisy location.

2. The Data

In recent decades the aircraft noise generated by the Amsterdam Airport Schiphol has been closely monitored by post code. Noise is *evaluated* in Kosten units (*Ku*) named after a government commission, chaired by the late professor Kosten. In 1967 the Kosten Commission derived a formula, based on the noise in decibels, the frequency of the flights, and a correcting factor for day and night traffic. As already said before, this Kosten measure is comparable with the recently introduced L_{den} measure. Maximum annual noise norms are given for each zip-code area but, during the last fifteen years with steadily growing air traffic, it has been increasingly difficult to stay within these noise limits. The public authorities have sometimes threatened the airport with the closure of some specific runways after November in a particular year, as the accumulated annual noise burden for specific zip codes would then exceed the annual amount permitted, but in fact such threats have never been implemented, being too detrimental to the economic

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existence of the airport. Because it is impossible to locate the airport elsewhere, and it is equally impossible to relocate the inhabitants, there is some discussion on the solution of monetary compensation to the inhabitants, who get a noise overdose. The primary question in this paper is whether there is reason to compensate inhabitants and, if so, by what amount. The same information is needed in order to evaluate decisions as to whether a new runway should be built. In the context of a cost-benefit analysis we would have to evaluate the predicted noise damage for inhabitants in terms of money in comparison to the advantages, generated by the new runway.

In 1998 we designed a postal survey[2] of the population, living within a radius of 50 kilometres around the Amsterdam Airport Schiphol. The area is called the Amsterdam Area. Some of the respondents suffer from serious aircraft noise, while others in the same area are not subject to such noise at all. It depends on the specific rather narrow flight paths along which airplanes are scheduled to arrive at and to leave from Schiphol. The area consists of the city of Amsterdam and some twenty other municipalities; some are strongly urbanised and others rural. The aircraft noise in this area is closely monitored. Outside the monitored 50 km radius, the noise nuisance is negligible.

Asking people for their opinion on noise nuisance in an area where there is a public outcry with respect to this issue calls for specific precautions. Explicit questioning, as in a CVM study, is – as we stated earlier – risky, as it would lead to strategic response behaviour and probably a sample selection bias with a heavy over-representation of people with strong views on noise. In order to avoid such problems, we embedded our relevant questions in an elaborate mail questionnaire, which did not focus on aircraft noise, but which dealt with the broad area of 'health, well-being and living situations in the Netherlands'. A second objective was to get some idea of the relative importance of a list of nuisance factors. The questionnaire, which consisted of 51 question modules, was sent by mail to a random sample of households in the area.

When designing the data collection method, one can choose from various modes. At one extreme, we have the 'intensive' mode, with reminders in writing, phone calls, and incentives in the form of gifts of money or in kind. If we do all this, it is obvious to the interviewee that there is no anonymity between him and the data collection agency. This may generate a selection bias if we have a sensitive questionnaire on individual well-being. The most 'extensive' way is to send off the questionnaire, and simply wait for the anonymous response. We decided on a compromise, where we sent out only one reminder. The reminder was sent out to all addressees, because, as a consequence of the strictly kept anonymity, we were unable to identify the addressees who had already responded. It is evident that the response rate depends on the collection method. As a result of the rather extensive collection method our response rate was rather low at 17%, but the sample was representative for the population when compared with the distributions of some characteristics, which are known for the population. The net sample, which is used

[2] This research was commissioned by the Dutch Ministry of Traffic and Transport and carried out by Amsterdam Economics (SEO) and Intomart, Hilversum.

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for this study, consists of 1,400 respondents. Given the fact that this study was a pilot project, it was decided that the sample of 1,400 observations in the Schiphol area was sufficiently large for a first analysis and an evaluation of the method.

One of the crucial tools of analysis is the *well-being question*, originally devised by Cantril (1965) and since then used in hundreds of sociological and psychological surveys all over the world. It asks for an evaluation of general well-being or 'quality of life' (QOL). It runs as follows: Here is a picture of a ladder, representing the ladder of life. Suppose we say that the top of the ladder (step 10) represents the best possible life for you, and the bottom (step 1) represents the worst possible life for you. Where on the ladder do you feel that you personally stand at the present time? (Please put a cross in one box only).

Best conceivable →	10 ☐	2.9%
	9 ☐	9.1%
	8 ☐	34.5%
	7 ☐	29.9%
	6 ☐	10.9%
	5 ☐	4.6%
	4 ☐	2.2%
	3 ☐	1.0%
	2 ☐	0.5%
Worst conceivable →	1 ☐	0.4%
No answer		3.9%

Fig. 1. *The Cantril Ladder-of-life Question.*

Table 2

Q.25. Would You Please Indicate the Frequency at which the Following Sound Sources Cause Noise Nuisance at the Place where you Live? (in %)

Sound sources	Never	Sometimes	Regularly	Often	Always	No answer
Cars, buses, mopeds, trucks	21.2	40.3	13.5	6.4	7.1	11.6
Electric trams/subway	69.4	6.1	1.9	1.0	2.1	19.5
Trains	65.9	9.1	2.1	1.5	1.8	19.6
Airplanes	11.4	32.9	18.6	18.8	13.2	5.1
Industry/business	67.1	9.0	2.0	1.2	0.4	20.4
Hotels, restaurants, pubs and other places of entertainment	67.5	10.6	1.7	0.6	0.5	19.1
Noise nuisance from neighbors	38.9	32.1	7.1	3.8	1.8	16.4
Children/youngsters	43.1	29.8	5.3	2.6	0.9	18.4
Other sources, viz....	39.4	3.2	2.7	1.8	0.9	52.0

*$N = 1{,}400$ for respondents in the Schiphol area.

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The marginal response distribution is given in the second column ($N = 1{,}400$). We note that only 3.9% of the respondents are unable or do not want to answer the question. Moreover, we see that all categories are filled in, with a majority choosing categories 7 and 8. Only about 10% of the respondents rate life quality as 5 or lower.

We shall explain the answer on the quality-of-life question by some other variables, including a constructed variable 'perceived aircraft noise frequency'. Among the 51 question modules, Question 25 is particularly relevant for our study. Question 25 is shown in the title of Table 2.

By asking for nine possible sources of noise, aircraft noise is not singled out for special attention. The response rates for the questions are shown in Table 2. The category 'no answer' includes the category 'non-relevant'.

Apart from those subjective questions, we asked for information concerning a host of other, mostly factual, variables, such as household incomes, age, family composition, education, a typology of the dwelling, including owner or non-ownership. We also asked whether the dwelling was insulated. More precisely, we asked about three types of insulation: thermal insulation, noise insulation, and draught proofing. Finally, we had the post code for each respondent at the finest level. In the Netherlands, there are on average 12 households with the same post code, although there is a considerable variation about that average. Given the post code, we could make a link with the list in which the objective aircraft noise levels in *Ku* are described per post code.

In sum, the special bits of information that we shall use in the remainder of this paper are those derived from the question 25.4 on noise nuisance and the question on general well-being, some demographic characteristics and information on housing. The information is completed with the objective noise burden in *Ku* per zip code.

3. The Model

It is not that easy to find the impact of external effects. Although the theory holds for all types of effects, we shall cast our analysis in terms of air traffic noise in order to make the discussion somewhat less abstract. We assume that any location is subject to a specific noise level $z \geq 0$. We call z the *value* of the externality. If $z = 0$, we have the situation of 'no noise'. We assume that the individual has an indirect utility function $W(y, p; z)$. We shall assume that this utility function is ordinally observable, and that the utilities are interpersonally comparable. That is, if two individuals A and B feel equally satisfied, $W_A = W_B$ holds. In terms of the Cantril question, it implies that an evaluation of '7' corresponds to the same subjectively perceived level of satisfaction for A and B. Evidently, interpersonal comparability can not be proven or refuted; it is a primitive assumption, without which we would be unable to analyse this type of subjective questions. However, the fact that such questions are regularly asked in surveys, covering large and heterogeneous samples, demonstrates that professional survey designers assume that the responses on such questions are interpersonally comparable.

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Two situations can be distinguished: the situation of equilibrium, and the situation of disequilibrium.[3] We will see that this distinction is most relevant when looking at externalities.

3.1. *Equilibrium*

In equilibrium, we assume that the individual can move freely and without transaction costs from one location to another. In general, we may assume that the price vector depends on the external factor, in this case noise z, say $\mathbf{p} = \mathbf{p}(z)$. For instance, houses subject to a lot of noise will be lower priced than identical houses without noise. If prices depend on the external factor, we say that the externality is partly or completely reflected in the price differentials,[4] in a way to be made precise hereafter. In a situation of equilibrium, utility differences between earners of the same income cannot exist; hence the equilibrium condition is

$$W[y, \boldsymbol{p}(z); z] = W[y, \boldsymbol{p}(0); 0] \tag{1}$$

where y stands for income and $\mathbf{p}$ for a price vector. In the case where two individuals have identical houses, except for the noise burden z, we may interpret the price differential $\mathbf{p}_h(0) - \mathbf{p}_h(z)$ for housing as the monetary counter-value of the noise burden z. This is actually the method used in hedonic price analysis, where the effects of z on prices of identical dwellings but at different locations are compared. If we are able to observe the indirect utility function, then we may test whether equilibrium holds. We observe $W[y, \mathbf{p}(z); z] = W(y; z)$, and likewise we observe $W[y, \mathbf{p}(0); 0] = W(y; 0)$. Our test for equilibrium is whether $W(y; z) = W(y; 0)$. We do not even have to know the hedonic price relationship $\mathbf{p}(z)$. Our empirical instrument will be the Cantril ladder question in Figure 1. If we observe $W(y; z) = W(y; 0)$, there is equilibrium; if we observe $W(y; z) \neq W(y; 0)$, there is no equilibrium. If $W[y, \mathbf{p}(z); z] = W[y, \mathbf{p}(0); 0]$, we say that the externality is (completely) reflected in the price differential. If price differences neutralise the differences in z, the value of the damage, which is caused by the externality, is known and can be compensated to the original inhabitants, while the movers-in pay a new lower noise-reflecting price. The difference between an externality and the natural environment (e.g. mountains, climate, drought) is that in the former case the externality can be changed at will by the owner or the authority in control of the externality, while the natural environment cannot be changed at will. In the airport situation, it might be stopping the flights, after which the house prices would eventually recover to their original level.

[3] By its nature, a disequilibrium is always temporary if economic subjects are free to move. However, it may take a long time (some years) to restore equilibrium adapted to the new value of the externality. If, in the meantime, the value of the externality is changed again and again, a final equilibrium is not reached.

[4] In a similar way, it may be that income y depends on z, say $y = y(z)$. In the case of the Amsterdam area, this is inconceivable, but it is realistic if we think about salaries in Florida compared with those in Alaska, or about the income differences needed to attract workers from unpolluted areas to industrial or mining regions. We shall assume, for the Amsterdam area, that incomes do not depend on air traffic noise.

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3.2. *Disequilibrium, the Case of Amsterdam*

In our neo-classical world, the basic assumption is that equilibrium prevails; price differentials compensate for differences in noise exposure. Above, we made it clear that this assumption may be empirically tested by means of the Cantril question. Hence, we no longer assume neo-classical equilibrium for granted, but we will test whether it prevails. Our hunch is that, for long-term investments in consumer goods, the equilibrium situation is not very probable. For instance, I buy a house for € 200,000 when I am 25. At 50 I am still living in the same house, although my income has doubled, my children have left home, housing prices have quadrupled and for 15 years there has been a runway nearby. It is not very likely that I would choose this house again, if I were now in the position to buy a new house. However, as the monetary cost of moving out is relatively large, housing prices have soared during the last 25 years and the psychic cost of leaving my neighbourhood and my neighbours is considerable, I prefer to stay in my house, even though in my present situation I would not have chosen to buy it again. Equilibrium, in the sense that marginal utilities are proportional to prices according to Gossen's Second Law, is probable for non-durables but not for durables, where switching is difficult and costly.

Let us now look in more detail at the subject of our paper, since most readers will not be familiar with the Amsterdam circumstances. The Amsterdam, or even the Dutch housing market as a whole, can definitely not be characterised as being in equilibrium. This statement will sound commonplace to most Dutch people, but it requires some explanation for an international readership. First, we should know that the respondents in the sample to be analysed below have lived in their present dwelling in the Greater Amsterdam Area on average for about 13 years. We note that this is actually an underestimate of the total duration, because we observe unfinished spells. It is doubtful whether most owners and tenants would have chosen today the same housing, which they chose 20 years ago. They stay where they are, given the considerable monetary and non-monetary switching costs. Apart from this general reason for being sceptical about an equilibrium, there are special reasons to believe that the Amsterdam Area is not in equilibrium. The Dutch housing situation in general, and in the Amsterdam area in particular, may be considered as being in a situation of significant disequilibrium, at least since 1945 at the end of World War II. At that time, there was a tremendous housing shortage, triggered by war damage, the backlog of marriages after the war, changes in the minimum quality standards for housing and the baby boom. The Dutch government tried to solve the problem by a strict regulation policy, which has changed several times in the period since 1945, but which in fact is still mostly in force. It is probably this regulation policy, geared to a 'decent housing for all'-principle, which has blocked the Dutch market mechanism up to the present day.

The main ingredients of this policy were, and are, the following. First, the building of all new houses and apartments is subject to permission by the local and national authorities. Hence, the number, the size and the price of new houses or rents of rented units to be built is planned; during this period of more than 50 years the link between demand and supply was weak, to put it mildly. Second,

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the stock is split up into 'social housing' and a 'free sector' with a heavy accent on social housing. In the Amsterdam area, the social housing sector, consisting of rented houses and apartments, is about 70% of the market and it is only accessible for households below a certain income. The fraction of owner occupied housing is of the order of 10% in Amsterdam. In the suburbs that fraction varies between 10% and 50%. In the 'social' sector a severe policy of rationing reigns, resulting in a waiting time of about 8.5 years in 2002. Third, permanent rent control prevails in both the social and the free sector, where existing rents are increased annually by a fixed percentage, which is set by Parliament, mostly in line with general inflation. Finally, rent contracts in both the private and social sectors are more or less permanent; the house owners have no right to break the contract, even if they want to sell the house empty. In most cases, even heirs who live in the house as housemates of the deceased tenant, have an automatic right to continue the tenancy agreement. In the social sector, this leads to a situation where tenants who no longer qualify for entrance because their income has grown far above the limit for such housing can still keep on living in their subsidised house. As a consequence, a sizeable fraction of the social sector is occupied by households that would not qualify for a new tenancy agreement. Only in very special cases is it possible to break the contractual relation by a Court decision. In contrast, the tenant can terminate the relation at any time. The reader will not be surprised, that in those conditions, we do not find the equilibrium assumption appropriate. Actually, the greater part of the market is subject to rationing. This does not, however, exclude the fact that some individuals will be in an equilibrium situation at given prices.

Although in this paper we consider the Amsterdam market in particular, we suspect that many housing markets, e.g. in London or Paris, are also not in equilibrium when closely investigated and that similar observations may hold for other markets, such as that for health care insurance where the privately insured elderly virtually have no opportunity to change insurance. Hence, we do not think that the case dealt with here is a unique case of a persistent dis-equilibrium, but rather one example of a frequently encountered situation.

3.3. *Disequilibrium, the Theory*

We assume that income and commodity prices (except possibly those for housing and rents) have nothing to do with air traffic noise. We write the price vector as $\mathbf{p} = (p_{-}, p_h)$, where p_h stands for the house price and we assume[5] that $p_h = p_h(z)$. It follows that utility may be written as $W[y, p_{-}, p_h(z); z] = W(y, z)$.

We assume $W(.)$ to be continuously differentiable in both variables y and z. There are two possibilities. The first is the equilibrium situation as explained before, where $W[y, p_{-}, p_h(z); z] = W[y, p_{-}, p_h(0); 0]$. The noise effect is completely reflected in the house price. We may rewrite the equality as $W(y; z) = W(y; 0)$. Individuals with the same income enjoy equal utility at either location.

[5] We notice that houses differ in many respects in reality. For ease of explanation, we assume here that all houses are identical except for differences in their noise burden.

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The second situation, which we assume to be the usual situation in the Amsterdam area, yields $W[y, p_-, p_h(z); z] \neq W[y, p_-, p_h(0); 0]$ or, in short, $W(y; z) \neq W(y; 0)$. In that case, there may be some difference between $p_h(0)$ and $p_h(z)$, but not enough to achieve equality. As a rule, we will have

$$W[y, p_-, p_h(0); z] \leq W[y, p_-, p_h(z); z] \leq W[y, p_-, p_h(0); 0]. \tag{2}$$

There is an additional income compensation Δy needed to achieve utility equality between both locations. The income compensation is found by solving the equation

$$W[y + \Delta y, p_-, p_h(z); z] = W[y, p_-, p_h(0); 0]. \tag{3}$$

The money amount Δy is the *residual shadow cost* that we are looking for. It is this amount that should be compensated for, if authorities decide to compensate. We notice that Δy will, in general, depend on the income level. The compensation Δy may also depend on the utility level. We stress that the shadow cost Δy will be zero, if the noise effect is completely reflected in prices. If the noise effect is not completely reflected, the compensation Δy will be a *residual* compensation. If $p_h(0) = p_h(z)$, the compensation will have to be total, as prices do not differentiate with respect to z. We define the *total* shadow cost of noise z as

$$\text{Shadow cost of noise } z = [p_h(0) - p_h(z)] + \Delta y. \tag{4}$$

This is the sum of the hedonic price differential and the residual income compensation.

If W depends on other variables, such as the age (*age*) of the individual, or his family size (*fs*), it follows that, generally speaking, the compensation according to (2) may depend on those other variables as well. Whether such variables are taken into account as a basis for compensation is a question of politics, the administration costs, and the negotiation power of the action group representing the interests of inhabitants and other parties, e.g. the airport authority and environmentalists.

A final point is that individuals may vary in noise sensitivity. Walters (1975) distinguished between 'perturbable' and 'imperturbable' individuals. 'Imperturbables' are immune with respect to aircraft noise. It is obvious that in this case the imperturbables prefer to live at the edge of the airport or below a flight path, because this would give them a premium of $p_h(0) - p_h(z)$. This would yield the pathological effect that life satisfaction would increase instead of decrease with noise exposure. In the econometric estimates in the next section we find that noise has a negative effect on life satisfaction, which implies that noise heterogeneity coupled with the choice of noise-exposed housing cannot be a regular phenomenon around Amsterdam. We can only state that a refined theory on individualised shadow costs would come out with shadow costs, which vary with the individual's noise aversion, and a price system, which becomes more or less noise sensitive as the proportion of 'perturbability' in the population rises or falls. Without a specified demand *and* supply model it is impossible to draw more specific conclusions. For practical purposes and political relevance it seems preferable to assume a

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homogeneous population consisting of *average* individuals. This is also in line with the idea that 'citizens are equal before the law' and, consequently, official policy cannot, and should not, take into account psychological differences between citizens for differentiating with respect to compensation.

Assuming that we have an empirically operational index of ordinal well-being, by means of which we can observe well-being per individual household, this would provide us with a test instrument for the hypothesis that price differentials fully compensate for noise exposure differentials. If $W(y; z)$ is constant in z, it implies that price differentials compensate for the noise differentials, including the case that individuals are noise insensitive in which case no compensation is needed. If $W(y; z)$ is not constant in z, it implies that the noise effect is not fully compensated by price differentials. In that case, we may calculate the additional monetary compensation needed to neutralise noise differences. Most economists are sceptical about the measurability and interpersonal comparability of well-being. In our sister disciplines of psychology and sociology, and also in health economics, this scepticism is not shared. The previous analysis in terms of a W-function does not actually lead to anything, unless we define an empirical analogue. We use the Cantril ladder-of-life question as shown in Figure 1. This question module (or a modification of it as a horizontal scale) is since 1965 included as a matter of routine in many sociological and psychological surveys all over the world.[6] The question is quite easy to answer, and most respondents do answer the question.

4. Estimation

The usual way to analyse a categorical question like the Cantril question is by means of Ordered Logit or Ordered Probit Analysis. We assume a latent continuous variable W, which we observe through a classification procedure with ordered categories 1,…,10. The latent variable may be explained by some observable objective variables. We selected the following explanatory variables:

- net monthly household income ($\ln y$)
- family size ($\ln fs$ and $(\ln fs)^2$)
- interaction term of income and family size ($\ln y \ln fs$)
- age of the respondent ($\ln age$ and $(\ln age)^2$)
- noise in terms of Kosten units ($\ln Ku$)
- interaction term of a dummy for noise insulation (Ins) and noise, in terms of Ku ($Ins \ln Ku$).

Although the Cantril question has already been used in many economic studies,[7] In those studies a noise effect was never included, quite probably because the data sets used did not contain such variables. Using the variables listed above, we start by explaining the Cantril measure of well-being W by the equation:

[6] For example, during the period 1996–2000 in the *British Household Panel Survey* (BHPS). It has recently been re-introduced.

[7] For instance, Clark and Oswald (1994), Plug and Van Praag (1995), Van Praag and Plug (1998), Blanchflower and Oswald (2004). See also Vaa Praag and Ferrer-i-Carbonell (2004).

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$$W = \beta_0 + \beta_1 \ln y + \beta_2 \ln fs + \beta_3 (\ln fs)^2 + \beta_4 \ln y \ln fs + \beta_5 \ln age + \beta_6 (\ln age)^2 + \beta_7 \ln Ku + \beta_8 Ins \ln Ku. \quad (5)$$

The effect of income is, of course, expected to be positive. As we do not have clear expectations on the family size effect, and there may be an optimum number of children, we introduce a squared term in $\ln(fs)$. We also add an interaction term between $\ln(y)$ and $\ln(fs)$, since we assume that the optimum number of children depends on the financial situation of the household.

Furthermore, it seems safe to assume that well-being is age dependent. As we do not know the relationship, we choose a flexible form by adding a log-quadratic term. We choose the logarithm of *age* instead of *age*, although *age* is used in much of the literature (Mincer, 1963). In our view, $\ln(age)$ is more reasonable, as the years seem to go faster, as one grows older.

Next, two variables describing the respondent's living situation are included in the model, viz. the level of aircraft noise nuisance in *Ku*, and the presence of noise insulation. Obviously, the effect of aircraft noise nuisance on well-being is expected to be negative. The interaction term $Ins \ln Ku$ is included in the model, since we assume that the size of the negative noise effect will do less harm if the house has noise insulation ($Ins = 1$) and, hence, that well-being will be positively affected by the presence of noise insulation. The resulting Ordered Probit estimates for this equation (leaving out the nine threshold values) are presented in Table 3.

Looking at the results in the second and fourth columns of Table 3, we see that the effect of noise nuisance is not significant. It follows that our first attempt to identify the externality effect has not been rewarded. We may think that additional variables might improve things. We added the following variables:

Table 3

Estimation of the Well-being Equation with the Variable Ku

	First equation		First equation extended with other variables	
Variable	Parameter estimate	Standard error	Parameter estimate	Standard error
$\ln y$	0.5093*	0.0849	0.5107*	0.0933
$\ln fs$	−2.3941*	0.8689	−1.8870*	0.9048
$(\ln fs)^2$	−0.1613	0.1297	−0.1787	0.1313
$\ln y \ln fs$	0.3274*	0.1092	0.2582*	0.1154
$\ln age$	−4.2372*	1.1656	−3.7262*	1.2057
$(\ln age)^2$	0.5681*	0.1586	0.4896*	0.1656
$\ln Ku$	−0.0242	0.0252	−0.0213	0.0256
$Ins \ln Ku$	0.0582*	0.0241	0.0546*	0.0244
$\ln(He)$			0.0443	0.0646
Home			0.0375	0.0980
Bal			−0.0633	0.0745
Gar			0.1650	0.0891
	$N = 1{,}067$	Pseudo $R^2 = 0.1614$	$N = 1{,}067$	Pseudo $R^2 = 0.1654$

*Significantly different from 0 at a 5% level. The number of observations is less than 1,400 due to missing information. (The maximum in *age* is reached at the age of 42)

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- monthly housing expenses ($\ln He$)
- dummy for presence at home during the day (*Home*)
- dummy for presence of balcony (*Bal*)
- dummy for presence of garden (*Gar*).

As we see from the last two columns in Table 3, the results do not improve at all. Consequently, we might decide that the noise effect is compensated by prices. However, there is still another possibility. It may be that the *objective Ku* measure does not adequately describe *subjectively* perceived noise nuisance and the latter is, after all, the relevant variable. The index *Ku* is a measure that does not include non-acoustic factors. Actually, it is quite possible that different individuals perceive the same level of noise differently. For instance, if an individual is at home during the daytime, noise will have a greater impact than if he or she works outside the home during the day. The same holds for family size. The larger the family, the higher is the family exposure to external factors. In short, the crucial information is not the *objective* measurement of noise but the *subjective* perception of it. The concept, which explains *subjective* well-being, is the subjective variable *perceived noise*, which we shall call *noise* for short. As a matter of fact the *Ku* measure and comparable measures, such as those used in the UK and elsewhere, have been constructed to reflect the subjective perception of noise by using log-transformations and a trade-off between the number of flights and the loudness of the noise per flight. But such measures are not corrected for *individual* characteristics. Given the objective for which they have been constructed, this is not meant as an objection. The method of measurement of noise nuisance, caused by an airport or a plane, cannot be made dependent on the specific inhabitants who dwell underneath the flight path.

Fortunately, in the survey, a question was also asked about the respondent's subjective noise perception. We define the aircraft noise nuisance by means of Question 25.4 in the dataset (see Table 2). Subjectively perceived noise is measured by subjective evaluations on a discrete [1–5] scale. We assume that the latent variable noise may be explained by the equation:

$$Noise = \alpha_1 \ln fs + \alpha_2 \ln He + \alpha_3 Home + \alpha_4 Bal + \alpha_5 Gar + \alpha_6 \ln Ku + \alpha_0 + \eta \qquad (6)$$

where η stands for the N(0,1)-distributed error term. We observe that five of the six variables in this specification are 'individual'. The resulting Ordered Probit estimates for this equation are shown in Table 4.

The influence of family size on *noise* is positive: the larger the household, the more annoyance is perceived. Furthermore, the results indicate that the higher the housing expenses, the more aircraft noise nuisance is perceived as annoying. Obviously, if the dwelling is more expensive, one expects better housing quality and absence of noise nuisance is one of the relevant quality dimensions. It may also be that richer people are more sensitive to the negative factors that influence their living quality. In addition, individuals (e.g. housewives) who are at home ($Home = 1$) during the day on weekdays experience more aircraft noise nuisance than people who are away from the home in the daytime.

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Table 4

Estimation of the Intermediate Variable 'Noise'

Variable	Parameter estimate	Standard error
ln*fs*	0.1578*	0.0665
ln*He*	0.1457*	0.0543
Home	0.2120*	0.0805
Bal	0.0458	0.0685
Gar	0.2718*	0.0792
ln*Ku*	0.3445*	0.0229
	$N = 1{,}281$	Pseudo $R^2 = 0.2251$

*Significantly different from zero at a 5% level.

The next two variables describe noise-relevant aspects of the respondents' living situation, viz. the presence of a balcony, and the presence of a garden. The dummy variable *Bal* is 1 if a balcony is present, and 0 otherwise. The same applies to the dummy variable *Gar* for garden. It appears that the presence of a garden significantly increases the extent to which individuals are annoyed by aircraft noise. The effect of the presence of a balcony is also positive, but not significant, at a 5% level. Finally, we include the core variable: the level of aircraft noise nuisance. Of course, the effect of aircraft noise nuisance on *noise* is strongly positive. Our conclusion is that perceived noise not only depends on the objective noise level, but also is strongly coloured by intervening, non-acoustic variables. This may also be the reason why *Ku* by itself did not have a significant effect (see Table 3) in the original equation (5).

Respondents who are exposed to the same subjective *noise* level will be characterised by the same value of the latent variable *noise*. We may evaluate the expected noise level for each respondent by substituting his own values for the explanatory variables in (5). We can even reach a finer approximation if we take account of the specific response category of Question 25 which the respondent has chosen. Then we may also assess the perceived *noise* by the conditional expectation of *noise*, given that the respondent has chosen a specific response category $i\,(i = 1,\ldots,5)$. For the explicit expression for this conditional expectation, see Maddala (1983) and Terza (1987).

$$\begin{aligned}\mathrm{E}(Noise|\mu_{i-1} < Noise \leq \mu_{i-1}) = {} & \alpha_1 \ln(fs) + \alpha_2 \ln(He) + \alpha_3 Home + \alpha_4 Bal + \alpha_5 Gar \\ & + \alpha_6 \ln(Ku) + \alpha_0 + \mathrm{E}[\eta|\mu_{i-1} - \mathrm{E}(Noise) \\ & < \eta \leq \mu_i - \mathrm{E}(Noise)] \end{aligned} \tag{7}$$

The variable *noise*, which we operationalise by (7), is an ordinal index of subjective noise nuisance. If we replace *Ku* in (5) by the intermediate variable *noise* (specified in (7)), the specification of the well-being equation reads as follows:

$$\begin{aligned} W = {} & \beta_0 + \beta_1 \ln y + \beta_2 \ln fs + \beta_3 (\ln fs)^2 + \beta_4 \ln y \ln fs + \beta_5 \ln age + \beta_6 (\ln age)^2 \\ & + \beta_7 noise + \beta_8 Ins\ noise. \end{aligned} \tag{8}$$

In this specification, we suppose that well-being is indirectly, and not directly, influenced by changes in the level of *Ku*, viz. via the intermediate variable *noise*. We replace the objective variable *Ku* by a subjective translation of it. The *perceived* noise

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nuisance depends on objective noise *Ku* and on individual characteristics. The resulting estimates for this equation are presented in Table 5.

Let us begin by noting that the coefficients in Table 5 and 3 hardly differ, except for the *noise* coefficient. Net monthly income has a positive and significant impact on well-being. The family size effects ln*fs* and $(\ln fs)^2$ are negative but the latter is not significant. The coefficient of the interaction term with income (ln*fs*ln*y*) is positive and significant. The age effect is quadratic with a minimum at 40 years.

The variable *noise* now has a significant and negative influence on well-being. The positive and significant interaction term of noise insulation with noise nuisance (*Insnoise*) indicates that, if the house is *not* noise insulated, the effect of noise nuisance on well-being is −0.1126, whereas this effect falls by almost two-thirds to −0.0390 (−0.1126 + 0.0736) if the house does have noise insulation.[8] It should be noted that insulation and *Ku*-exposure are correlated. However, insulation is not purely endogenous. Schiphol Airport has the formal obligation to insulate *all* the houses in the most exposed residential quarters at no cost to the inhabitants. The majority of houses to be insulated have not been insulated yet. We see therefore that replacing the objective measure *Ku* by an ordinal subjective analogue was worthwhile.

Since *noise* is positively related to the noise level in *Ku*, well-being is negatively related to the noise level in *Ku*. Using this specification of well-being, it is now possible to compute residual shadow costs for changes in the noise level in *Ku*.

5. The Resulting Shadow Costs

5.1. *A Compensation Schedule Differentiated with Respect to Net Monthly Income*

As seen above, the *total* shadow costs can be decomposed into a price component and a residual cost component. When prices are constant in *z*, that is,

Table 5

Estimation of the Well-being Equation with the Intermediate Variable Noise

Variable	Parameter estimate	Standard error
ln*y*	0.5039*	0.0885
ln*fs*	−2.1450*	0.8990
$(\ln fs)^2$	−0.1758	0.1326
ln*y*ln *fs*	0.3061*	0.1129
ln*age*	−4.2718*	1.2025
$(\ln age)^2$	0.5788*	0.1636
noise	−0.1126*	0.0331
Insnoise	0.0736*	0.0270
	$N = 1{,}031$	Pseudo $R^2 = 0.1662$

*Significantly different from zero at a 5% level.

[8] This result: that insulation does not fully mitigate the effect of noise, was also found in the contingent valuation study conducted by Feitelson *et al.* (1996, p. 11), discussed in Section 1 above. A similar incomplete effect of noise insulation was found in a study by the Dutch consulting agency Regioplan on the nature and extent of the complaints about aircraft noise nuisance in the Schiphol area (Hulshof and Noyon, 1997, p. 73).

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they do not reflect differences in noise exposure, the total cost will equal residual cost. We find, in the Appendix, that prices in the Amsterdam area are not significantly related to the *Ku* burden, due to the disequilibrium in the housing market. It follows that residual costs are equal to total costs in the present context.

We are now able to derive the residual shadow costs for changes in the noise level measured in *Ku* on the basis of Table 4 and 5. Considering Table 4 and 5 we may write schematically $W = W[y, noise(Ku, \mathbf{x}), \mathbf{z}]$, where y stands for income, *noise* is the perceived noise nuisance (which is a function of the objective noise level in *Ku* and of other intervening variables $\mathbf{x}$, including family size (*fs*) and age), and, where $\mathbf{z}$ stands for a vector of other variables. The compensation Δy, needed to compensate for an increase ΔKu, is now calculated from the equation:

$$W[y + \Delta y, noise(Ku + \Delta Ku, \mathbf{x}), \mathbf{z}] = W[y, noise(Ku, \mathbf{x}), \mathbf{z}]. \tag{9}$$

Dropping all non-relevant terms, this boils down to the equation:

$$(\beta_1 + \beta_4 \ln fs)(\ln y + \Delta \ln y) + (\beta_7 + \beta_8 Ins)[noise(Ku + \Delta Ku)] \\ = (\beta_1 + \beta_4 \ln fs) \ln y + (\beta_7 + \beta_8 Ins) noise(Ku)$$

or

$$(\beta_1 + \beta_4 \ln fs)\Delta \ln y = -(\beta_7 + \beta_8 Ins)[0.3445(\Delta \ln Ku)] \tag{10}$$

where β_1, β_4, β_7, β_8 are given in Table 5, and the coefficient 0.3445 is taken from Table 4. Equation (10) may be rewritten as:

$$\frac{\partial \ln y}{\partial \ln Ku} = -\frac{(\beta_7 + \beta_8 Ins)}{(\beta_1 + \beta_4 \ln fs)} \times 0.3445. \tag{11}$$

The first point, which follows from (11), is that the residual shadow cost is not linear in *Ku*, but it depends on the level of *Ku*. The change from 20 *Ku* to 30 *Ku* is equivalent to the change from 30 *Ku* to 45 *Ku*. It is the relative change that counts. This is not surprising as nearly every psychophysical stimulus is translated on a logarithmic scale.

Similarly, the monetary compensation depends on the initial income level. Here, it is also found that it is the relative change that counts. The expression $\partial \ln y / \partial \ln Ku$ is an elasticity. Politically, this implies that the compensation for noise nuisance depends on income, where richer people are entitled to higher compensation in money terms. Politically, this is hard to defend but not impossible. It is actually the same mechanism which makes a progressive income tax acceptable. The pain of an income loss of €100 is smaller if one has an income of €2,000 than if one earns an income of €1,000. Similarly, a compensation of €100 means less to somebody with €2,000 than to an individual earning €1,000. An alternative compensation scheme which may be acceptable to politicians is a scheme that differentiates for housing expenses. Although housing expenses may be more neutral in a political sense, the results are found to be similar, since housing expenses and income are strongly and positively correlated.

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From (11) it appears that the compensation (elasticity) depends on whether or not the dwelling is noise-insulated. The compensation needed is much smaller if the dwelling is insulated ($Ins = 1$).

Finally, the compensation depends on the family size. As this is not a politically relevant parameter, we fix the value of ln *fs* at the sample average of 0.6743. This results in two values for the elasticity ($\partial \ln y / \partial \ln Ku$), viz. a noise elasticity *without* noise insulation:

$$-\frac{(\beta_7)}{(\beta_1 + \beta_4 \overline{\ln fs})} \times 0.3445 = -\frac{(-0.1126)}{(0.5039 + 0.3061 \times 0.6743)} \times 0.3445 = 0.0546$$

and a noise elasticity *with* noise insulation:

$$-\frac{(\beta_7 + \beta_8)}{(\beta_1 + \beta_4 \overline{\ln fs})} \times 0.3445 = -\frac{(-0.1126 + 0.0736)}{(0.5039 + 0.3061 \times 0.6743)} \times 0.3445 = 0.0189.$$

The constant elasticities imply that there is a log-linear relationship between *Ku* and income *y*. That is, if *Ku* increases by *a*%, then the income *y* has to be increased by *b*% to hold well-being constant. The percentages *b* have been tabulated below, both for the case *without* and the case *with* noise insulation.

We see that at a monthly net income of €1,500 a household would have to be compensated with 2.24% of its income, that is €33.6 per month, for a noise increase from 20 to 30 *Ku*.[9] A change from 20 to 40 *Ku* would require compensation of €33.6 + €23.7 = €57.3 per month, approximately. The compensation amounts needed for houses *with* insulation are much smaller, but still not equal to zero. For instance, at the same income level of €1,500, the compensation would be only €11.55 per month. This also implies that the monthly value of insulation at that level would be € 33.6 − €11.55 = €22.05. Under pressure of both public opinion and the government, the Schiphol Airport authorities have accepted the obligation to insulate dwellings which are in high *Ku* areas (>45*Ku*). Now the question arises: would it be cheaper to *pay* the compensation or to *insulate* the house? By subtracting the second row from the first row in Table 6, we find the value of the insulation. Clearly, noise insulation is a capital investment. Using an interest rate of 5%, a monthly amount of €22.05 is equivalent to a capital expenditure of 20 × 12 × € 22.05 = €5,292. It follows that authorities should insulate the dwellings of households, earning €1,500 per month, which experience

Table 6

Monetary Compensation Amounts as a Fraction of Net Income for Selected Changes in Noise Level

Noise level changes (%)	20 → 30 *Ku*	30 → 40 *Ku*	40 → 50 *Ku*
Without insulation	2.24	1.58	1.23
With insulation	0.77	0.54	0.43
Value of noise insulation	1.47	1.04	0.80

[9] The exchange rate at the time of the survey was approximately US$ 1 = € 1.

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a noise increase from 20 to 30 *Ku*, if the once-only costs of insulation are below this amount of €5,292. It should be noticed that the amounts are rather small.

These amounts refer to residual effects. Total shadow costs have been defined as the sum of the price differential and the residual compensation. In the present case we see from the Appendix that house prices in the Greater Amsterdam Area do not significantly depend on noise nuisance. Undoubtedly, this has to be explained by the chaotic situation in the Amsterdam housing market. It follows that, in this case, the estimated residual effect will approximately equal the total noise effect, as there is no price differential observed.

5.2. *Cost of Compensation to Society*

An important policy question now is what the total amount of compensation would be if all the population living around Schiphol were to be compensated for the noise nuisance which they suffer. This means that we have to compute the residual cost compensation per household in the area involved, taking into account that different households have different incomes, and experience different levels of *Ku*. Subsequently, the compensation amounts for all households concerned have to be aggregated.

Suppose we set a critical *Ku* limit of *x Ku*, for example. What is the percentage of households having a noise nuisance level higher than *x Ku*? And, what would be the amount needed in order to compensate them for the excess nuisance? In Table 7 below, we have calculated these figures for five threshold levels.

To be precise, we have computed the accumulated compensation necessary to compensate the nuisance level for all people suffering from a damage level of $y\ Ku(y > x)$ over the chosen level of *x Ku*. Table 7 shows that the average monthly amount of compensation per household for a bottom level of 20 *Ku* is higher than the average amounts for higher critical levels. That is logical, because the lower the critical level is laid, the higher the number of *Ku* that have to be compensated. This is shown even more clearly in column 4 of the Table, where the total amount of annual compensation is given. To put the amounts in Table 7 into the right perspective, we have to relate them to the number of commercial flights (about 397,000 in 1999 at Schiphol) or to the number of passengers (about 36.8 million in 1999). Consequently, if we suppose that the government were to choose 20 *Ku*

Table 7

Total Yearly Amount of Compensation

Ku	Number of households concerned*	Average monthly compensation per household concerned €	Total yearly amount of compensation € mn
>20	148,063 (17.9%)	56.63	100.62
>25	80,478 (9.7%)	41.46	40.04
>30	26,734 (3.2%)	29.90	9.59
>35	11,851 (1.4%)	20.90	2.97
>40	6,030 (0.7%)	17.13	1.24

*In absolute numbers and (in parenthesis) as a percentage of the total population in the Schiphol region.

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as the critical level, the compensation per flight would amount to €253.45 and the compensation to be paid per passenger would be €2.73.

6. Discussion and Conclusions

In this paper we developed a novel methodological extension to assess the effect of an externality. It may be applied in cost benefit analysis to assess the value of intangibles. The problem with an externality is that it is frequently not completely accounted for by market price differentials. If prices fully reflect the externality differences, the costs are readily assessed by the hedonic price method where prices in externality affected situations are compared with not affected situations. However, there are many cases where prices only partly compensate for the influence of the externality. This is especially probable when individuals are in a situation, where the physical and/or emotional transaction costs attached to changing that situation are high. The Amsterdam housing market and its painful relationship with Amsterdam Airport are a case in point.

We estimated the residual shadow cost of aircraft noise nuisance on the basis of subjective questions about the satisfaction with 'life as a whole' and the subjective perception of aircraft noise. A significant non-zero noise effect estimate is a positive test for the hypothesis that price differentials are not noise-compensating. We assessed the monetary counter-value of that residual effect. Since in the Amsterdam case (see Appendix) prices appear not to correlate with noise differences, in this case the value of the residual cost component equals the total cost of the externality.

The monetary compensation amounts found are derived from a model including both well-being and the subjectively perceived noise nuisance. The compensation amounts differ according to whether or not the dwelling is noise-insulated. This result gives the tool for a cost-benefit analysis to compare the value of once-for-all noise – insulation with permanent monthly compensation to inhabitants.

To our knowledge this is the first time that (residual) noise nuisance effects have been monetarily evaluated by means of the Cantril question. It is obvious that this external effect could only be measured due to the fact that noise nuisance varies a lot over the Amsterdam area and that the noise burden is pretty accurately registered according to zip codes, making it possible to link objective noise nuisance with the subjective feelings of the individuals living there. The same model may be used to evaluate air traffic noise at other places in the world.

The advantage of this extended model, compared to traditional hedonic price analysis, is that it does not assume equilibrium on the housing market as a starting point. Although almost always postulated, equilibrium is a rather restrictive assumption, and, as our empirical findings in this paper suggest, not maintainable for the greater Amsterdam Area. The advantage of satisfaction questions compared to the CVM approach is that the respondent is not aware or made to believe that his or her responses may have any influence on decisions or compensations in which he or she has an interest. Hence, strategic response behaviour is highly unlikely in our study. As we need only a few questions, it will be easy to include them in routine surveys or opinion polls, which may imply a major cost reduction

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on data collection. The final point, which should be mentioned, is that the method effectually tests whether the externality is completely reflected in market prices or not.

One question, which falls outside the scope of this study, is whether a noise compensation schedule is politically desirable. For reasons of justice there is much to say for the polluter pays principle. It might be that the compensation is family size-dependent. For political reasons this seems unacceptable in the Dutch circumstances.

The method is clearly applicable on other situations as well. First, we may look at other airports all over the world. We leave it to the fantasy of the reader to invent other externality types where the method would be valuable. We mention other types of traffic, e.g. road traffic, the effects of traffic regulation policies, environmental damages, creation of nature resorts, public transport effects, supply of free education or childcare, and so on.

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Appendix. The Relation Between Housing Costs and Noise Nuisance.

We did some additional regressions, where we attempted to find a relationship between ln(*housing costs*) and noise, as measured by the Kosten – unit. Housing costs are defined as the rent or the cost of mortgage. The latter is somewhat difficult as older loans may be amortised. We tried a number of equations, for tenants and for owners and for the two subsamples taken together. We were not able to find a sensible (that is negative significant) noise effect. We present the simplest estimates in Table A1.

This Table shows that the most important determinant of housing costs is the length of the period one has been living in the house, or in other words the date one started living there. The longer the person lives in the house, the lower the housing costs are. This is the immediate effect of the rent control, described in Section 3, coupled with the soaring building prices for new houses. Hence, rents are basically determined by historical building

Table A1
ln(*housing costs*) *Explained*

Variable	Estimate	t-value
Constant	7.23	93.05
Dummies for housing type (def. House in a row)		
Detached family home	0.16	2.31
Two under one roof	0.12	1.58
Corner family home	0.04	0.62
Flat	−0.29	−6.71
Other	−0.21	−2.08
ln(age of the house)	−0.02	−0.81
ln(years lived in the house)	−0.17	−9.97
ln(*Ku*)	0.02	1.56

$R^2 = 0.143$, $N = 1{,}017$

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prices. For owners of houses their mortgage costs are based on the historical purchase price in a similar way. Given the advantage of staying in your house and the existence of a considerable sales tax, it is no surprise that Dutchmen do not move easily from one house to another. The noise effect is insignificant, which indicates that we are near the point of 'no compensation. The dummy effects are reasonable, although most are insignificant.

We tried about 20 other specifications including some with interactions between *Ku* and 'years lived in the house' and with the subjective variable noise. We also tried those specifications on the two sub-samples of owners and renters. All those specifications yielded similar results. Apart from the housing types only 'years lived in the house' yielded a major effect, while the noise effect remained non-significant. We conclude that, referring to the reasons listed before, the noise burden is hardly or not at all reflected in prices in the Schiphol area.

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