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The Shadow Price of Aircraft Noise Nuisance

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A new approach to the internalization of externalities

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Abstract

This paper has a twofold objective. First, we develop a new method to assess the monetary value for individuals of external effects. The method makes use of an ordinal index of life satisfaction as scored by individual respondents who are subjected in varying intensity to the external effect. Our second objective is to assess, with this method, to what extent noise nuisance effects around Amsterdam Airport Schiphol are internalized and what should be the monetary compensation for the nuisance. Such a compensation scheme depends on, among other things, the objective noise level, income and the presence of noise insulation.

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1. Introduction

Many city dwellers are painfully aware of a nearby airport. They suffer from aircraft noise. Amsterdam Airport Schiphol is no exception. The air traffic has heavily expanded since the airport started in 1926. It is now one of the major hub airports in Europe and the only large-scale airport in the Netherlands. The noise is closely monitored per zip code. Noise is measured in Kosten units (Ku), named after the late Professor Kosten, who chaired (from 1961 until 1967) a government-appointed working group, which developed the Dutch official aircraft noise measurement system. Maximum noise norms are given for each zip code area but during the last ten years there are growing difficulties to stay within the noise-limits. As it is impossible to locate the airport elsewhere and it is equally impossible to relocate the inhabitants of the region involved, Dutch political opinion is now tending to the solution of a monetary compensation to the inhabitants, who get a noise overdose. We will postpone a discussion of the political implications of such a 'solution' to the final section. The primary question is what might be an appropriate compensation amount.

Actually, this is a special case of the more general problem *of how to deal with externalities.* We have a negative external effect and we ask for the money value of the damage done. There is a considerable literature on this type of problems. Also a few studies exist that aim at pricing the external effects due to aircraft noise nuisance. These studies either use revealed preference methods (e.g., the hedonic price method), or *direct* stated preference methods (e.g., the contingent valuation method). In this paper we propose an alternative method for evaluating the external effect of aircraft noise damage. The method is based 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 is originally developed by Cantril (1965).

It appears, that the answers depend on income, exposition to aircraft-noise and a lot of other variables. This result provides us with a trade-off ratio between income and exposition to noise. The methodology fits in a “subjective “ literature, which nowadays gets increasing attention among economists (see e.g. Clark and Oswald, 1994; Pradhan and Ravallion, 2000; Frey and Stutzer, 2000; Van Praag, 1971; Van Praag and Frijters, 1999; Plug et al., 1999).

In Section 2, we give a short critical survey of the literature. In Section 3 we consider the data. In Section 4 we discuss some theoretical aspects of the model used. In Section 5 we formulate and estimate the empirical model. In Section 6 we derive the monetary shadow prices, which follow from the model, and their policy implications. In Section 7 we discuss the model and evaluate the relevance of this study for economic science and policy.

2. Short survey of the literature

The valuation of external effects is a famous but difficult problem. Pigou (1920) and Coase (1960) are the pioneers on this subject. An externality is not or inadequately priced in the market. According to our knowledge of the literature the problem has been approached along two roads. The first approach is that of hedonic price studies. The second road employs the contingent valuation method (CVM).

Hedonic price studies

Attempts to value people’s preferences for peace and quiet have centered 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 a relevant market-priced good, like houses. In the case of aircraft noise nuisance, the method attempts to identify –with the use of certain statistical techniques– how much of a difference in housing prices is due to the level of noise nuisance.

Table 1 shows the results of various hedonic price surveys that have studied the effect of aircraft noise on residential property values. The price sensitivity with respect to aircraft noise is in most studies 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. 40-42). 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 hand: $V = V(Z,N)$. The measures of noise nuisance levels *N* differ between countries. For instance, the US noise descriptor is 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 $\partial V/\partial N$.

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. NDI is around 0.6% on average (Collins and Evans, 1994, p. 175; Nelson, 1980, p. 46). This means that a house of, say, $200,000 would sell for 12% less, that is $176,000, if located in a noisier zone with 20 units more noise nuisance.

[1] Recently, the US measure (NEF) has been replaced by the L_{dn} measure, and the UK measure (NNI) has been replaced by the L_{eq}. In the near future, the Dutch measure will probably also be replaced by a new –L_{dn}-like– measure.

Table 1: A summary of hedonic price studies and aircraft noise nuisance

Source: Nelson (1980, p.47-51); Pearce (1993, p. 72); Schipper (1997, p. 6).

Study location	NDI estimate	Study location	NDI estimate
Australia		*USA*	
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.

Looking at table 1, summarizing twenty studies, it is obvious that there is a considerable variation, partly but not wholly caused by differences in the measurement method used and on the choice of the specific location. The use of the hedonic price method has at least two important drawbacks.

Firstly, using property price changes to elicit preferences for reducing noise nuisance does not encompass all the benefits of noise reductions. For instance, noise nuisance could entail health effects, and it is unlikely that individuals will be sufficiently aware of health risks to include those risks when choosing for a house at a certain location. Moreover, it is not obvious that the presence of the airport would only affect *housing* prices. For instance, it may cause a change in the general demand pattern, where families with children will not go to this neighborhood or where individuals living in noise-affected areas will take more holidays abroad.

Secondly, hedonic pricing is dependent on some rather strict assumptions, which are in all probability not valid in the Schiphol region. The two most important assumptions are given below (Bateman, 1993, p. 235):

1. The study area can be treated as a competitive market with freedom of access across the market and perfect information regarding housing prices and environmental characteristics.
2. The housing market in the study area is in equilibrium: individuals continually re-evaluate their location, and adjust their residential choice to changing circumstances.

In the Amsterdam area, there is an acute housing shortage since World War II, resulting in a continuous rise of housing prices and a severe rationing system in the social housing segment with waiting periods of four to five years. In short, the market since 1945 could and can not be characterized as being in equilibrium. This also holds for the non-applicability to the Amsterdam area of general equilibrium studies like that by Blomquist et al. (1988).

Contingent valuation studies

The contingent valuation method (CVM) to value noise nuisance has not been applied as often as hedonic pricing. The 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. Below only one CVM-study on aircraft noise nuisance is reviewed, since we could only come up with this one study in the literature.

The CVM is associated with some serious problems, which are widely debated in the literature (i.e., Pearce, 1993; Turner, 1993; Hausman, 1993). One of these problems is related to the direct way of questioning in CVM questionnaires which in all probability entails a severe strategic-response bias. For example, respondents are are straightforwardly asked how much compensation they would need to accept an airport nearby (WTA). This invites strategic response. Respondents are not punished in any way if they do not express their true value but a value that is lower of higher, in an attempt to influence the provision or price of the environmental good under valuation. Hence, we can not take the CVM-answer at face value. Moreover, the answers will depend on personal characteristics of the respondent. For instance, the amounts quoted will depend on individual incomes, such that the rich respondent will quote larger money amounts than the poor respondent. Although we do not deny that CVM-analysis is informative, it is frequently rather doubtful whether CVM gives an appropriate assessment of the shadow price of an external effect without application of a number of sophisticate corrections derived from a tested body of theory, which still has to be developed.

The CVM also has an advantage since it measures not just user values, but the total economic value (including non-user values). Non-user values cannot be measured using the hedonic price method. For instance, noise nuisance has no effect in areas without houses, since in these ‘empty’ areas no housing prices exist that may reflect the impact of noise, whereas (non-)user values may be related tot these non-housing areas.

In the case of Schiphol, considered in this study, it would not have been very wise to use the CVM-like way of questioning with the direct relation between the monetary valuation and the noise nuisance. Schiphol Airport and noise nuisance are a hot issue in the Netherlands, and if it would have been known that a survey was sent out with the aim to establish monetary compensation schemes for noise nuisance, it would definitely have led to strategic behavior (e.g., overestimation and/or a boycott of the survey).

A CVM study 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 is 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 when it is located at sites subject to different levels of noise, expressed in yet another noise descriptor, viz. L_{dn}. A similar sequence of WTP questions was conducted for tenants in terms of monthly rent for a three-bedroom residence.

This Israeli study indicates that the difference in valuation for residences with no noise nuisance compared to residences with frequent and severe noise nuisance is 2.4-4.1% of the housing prices per L_{dn} (for home owners) and 1.8-3.0% of the rents per L_{dn} (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. However, due to the nature of the question being asked in this CVM-study, it is unlikely that non-user values are included [2]. 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 residences. Hence, their valuation of (the reduction of) noise nuisance is so high that they are not willing to pay anything for a residence at a noisy location.

3. The data

In 1998 SEO Amsterdam Economics and Intomart carried out a postal survey under the population of the wider Schiphol area an area within 50 kilometers of Schiphol, the Amsterdam airport. Some of the respondents are subject to serious aircraft noise, while

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[2] The manner of questioning in the Feitelson et al. study differs from the traditional CVM question in the sense that noise nuisance is not valued directly. Instead, it is valued indirectly, as the WTP is stated for a different good (viz. Residences, a marketed good) of which noise nuisance is but one attribute.

other respondents in the same area are not subject to such noise at all. This depends on the specific airlanes along which aircrafts are scheduled to arrive at and to leave from Schiphol. The area consists of strongly urbanized areas like the city of Amsterdam, and of many villages and rural areas. The area is closely monitored on aircraft noise. The average noise burden for each zip code is known and monitored in terms of Ku, named after the late Professor Kosten, who devised the measure in the sixties.[3] The measure is a composite formula, built up from the maximum noise in dB, the frequency of that noise level and weighted by the period of the day and night.

The questionnaire consisted of 51 question modules, some of which were rather complex. About 17,000 questionnaires were mailed. After a postal reminder we received about 2,900 valid questionnaires back.[4] Given the content of the questionnaire, the present survey-fatigue in the Netherlands, and the fact that the respondents were not rewarded in any sense, the response rate of about 17% is satisfactory and usual in comparable surveys. The subject of the questionnaire was described to one group as dealing with “satisfaction with the living situation in the Netherlands”, while a second group was approached under the heading “health, well-being and living situation in the Netherlands”. We did not find significant differences in response behavior between the two groups. Although one of the aims of the survey was to investigate the influence of aircraft noise on well-being, this was

[3] In 1961 a Dutch State Commission was installed which was chaired by the late Professor Kosten. Based on aircraft technology and psycho-physical experience, this commission devised a noise measure. The functional specification and the choice of the parameters are partly based on intuition and partly on survey results. The precise formula yields a noise measure in Kosten units (Ku) for each zip code in the specific area. Although the formula is aimed at describing a subjective feeling of inconvenience this aim is clearly not reached. On the other hand it can be used as an ordinal measure of the aircraft noise burden.

[4] The number of observations on which this analysis is based is 1,400 individuals dispersed over the Schiphol area.

not *the* proclaimed objective. On the contrary, in the questionnaire only a very small part is devoted to aircraft aspects. The design was such for two reasons. In the first place, aircraft noise is a sensitive issue. There was a risk of strategic response, such that we would not find the true opinions. The second reason was that the survey should be usable as a multi-purpose data source.

One of our crucial tools of analysis is the so-called 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'.

It runs as follows:

Figure 1: The Cantril ladder-of-life question

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 you personally stand at the present time?
(Please cross one box only)

Best conceivable →	10 □	2.9%
	9 □	8.6%
	8 □	35.8%
	7 □	28.2%
	6 □	10.4%
	5 □	5.4%
	4 □	2.3%
	3 □	1.2%
	2 □	0.6%
Worst conceivable →	1 □	0.4%
No answer		4.2%

The marginal response distribution is given in the second column (N = 2.852). We notice that only 4.2% is unable to answer the question. Moreover, we see that all categories are filled in with a majority at categories 7 and 8. Only about 10% rates life by 5 or lower.

We shall explain the answer on the quality- of -life-question by some other variables among which 'perceived aircraft noise frequency'. Among the 51 question modules, question 25 is particularly relevant for our study. Question 25 is the following one.

Table 2: Q.25. Would you please indicate the extent to which the following sound sources cause noise nuisance at your place of living?*

Sound sources	never	sometimes	regularly	often	always	no answer
1. Cars, buses, mopeds, trucks	24.6%	44.1%	13.0%	6.3%	5.7%	6.2%
2. Electric trams/subway	79.2%	3.0%	1.0%	0.5%	1.2%	15.1%
3. Trains	71.0%	10.5%	2.1%	1.1%	1.1%	14.3%
4. Airplanes	34.7%	37.6%	10.6%	5.2%	2.0%	10.1%
5. Industry/business	74.9%	7.7%	1.4%	0.7%	0.4%	14.9%
6. Hotels, restaurants, pubs and other places of entertainment	73.0%	10.1%	1.9%	0.7%	0.4%	14.0%
7. Noise nuisance from neighbors	43.3%	32.8%	6.3%	3.9%	1.9%	11.9%
8. Children/youngsters	42.0%	33.5%	6.7%	3.0%	1.4%	13.4%
9. Other sources, viz….	41.7%	4.4%	3.2%	2.1%	1.0%	47.6%

* N = 2.852 dispersed over the Netherlands, not just the Schiphol area.

By asking for nine possible sources aircraft noise is not singled out for special attention. The response rates for the questions are filled out in Table 2. We observe that the aircraft item invites the same non-response rate as the other items (except 'other sources' for obvious reasons).[5]

Apart from those 'subjective' questions we asked for a host of other mostly factual variables like household incomes, age, family composition, education, a typology of the dwelling including owner or non-ownership. We also asked whether the dwelling is insulated. More precisely we ask for three types of insulation: thermal insulation, noise insulation and draught proofing. Finally we had the zip code for each respondent at the finest level. In the Netherlands there are on average twelve households with the same zip code, although there is a considerable variation about that average. Due to that zip code we could lay a link with a list where the aircraft noise level in Ku, to be explained below, is described per zip code. This list exists only for the Schiphol area. Outside that area there is practically no aircraft noise.

Summarizing, the special bits of information we shall use in the sequel are the questions on noise nuisance and general well-being, some demographic characteristics, and housing. We shall complete this information with the noise burden in Ku per zip code.

[5] In question 25 we asked for a more or less factual assessment. In question 28 we asked: which *aspects of your living environment you are satisfied with?* Here we asked for twenty different aspects, not only including traffic, but also including the availability of education and hospital facilities. Comparison of question 25 and 28 reveals that the answers to both questions differ considerably. For instance, about 70% answers that there is no or only incidentally aircraft noise nuisance. However, only 55% states to be (very) satisfied. This implies that both questions ask for different things (*satisfaction* as measured by Q.28 is something different than *perceived frequency,* measured by Q.25).

4. The model

The impact of external effects is best analyzed by means of an ordinal utility function (Deaton and Muellbauer, 1980) with two arguments, viz., income y and the external effect z. In our case, z stands for the level of aircraft noise from which the individual suffers. The utility function reads:

$$W = W(y\,;\,z) \qquad (4.1)$$

If z causes a negative effect, we will have $\partial W/\partial z < 0$. We assume $W(.)$ to be continuously differentiable in both variables. Let us consider the case where initially the income is y_0 with a noise level $z = 0$. If the level increases to z_1, the income compensation or shadow price Δy for the noise is found from the equation:

$$W(y_0\,;\,0) = W(y_0 + \Delta y\,;\,z_1) \qquad (4.2)$$

The money amount Δy is the monetary compensation or *shadow price* we look for. We notice that there is no reason why Δy should be linear in z. We also note that Δy generally will depend on the income level. Finally, we notice that Δy may depend on the utility level as well.

If W depends on other variables, like the age (*age*) of the individual, or his family size (*fs*), it follows that generally speaking the compensation 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., environmentalists.

In economic literature, it is sometimes argued that external effects are ‘internalized’ by the market mechanism. For instance, let the rent of your house be $p(0)$ under ‘no noise’ conditions, and $p(z_1)$ under noise z_1. Using an indirect utility function $W\ (y,\ p\ ;z)$ and assuming internalization by the market, there should hold:

$$W\ (y, p(0)\ ;\ 0) \qquad = W\ (y, p(z)\ ;\ z) \tag{4.3}$$

where the rent difference $p(0) - p(z) > 0$ is actually the shadow price of the external negative effect z. This difference could be assessed by hedonic price analysis. Even more directly, if the rent difference would fully compensate the external effect, we would have:

$$W\ (y\ ;\ 0) = W\ (y\ ;\ z) \tag{4.4}$$

Individuals with the same income would enjoy the same welfare level, irrespective of the external noise effect, as the rent difference would compensate the external effect. If there would be no complete compensation, individuals would move to the better location. Hence, when the effect is fully internalized by the market mechanism, there will hold under *ceteris paribus* conditions:

$$W\ (y\ ;\ 0) = W\ (y\ ;\ z) = W\ (y) \tag{4.5}$$

Assuming that we have an empirically operational definition of well-being, by means of which we could observe well-being per individual household, this would supply us with a test instrument on the hypothesis that effects are fully internalized by the market. If $W\ (y\ ;\ z) \neq W\ (y)$, it would imply that the effect is not fully internalized. If the market is not in equilibrium, we may expect that the external effect is at least *partly* internalized via prices.

Hence, if we find a significant effect of z, this is always assumed to be a *residual* external effect.

Most economists are skeptical on the measurability and interpersonal comparability of well-being. In our sister disciplines of psychology and sociology, but also in health economics, this skepticism is not shared. Actually, the previous analysis in terms of a W-function does not lead to anything, if we do not define an empirical analogue. We suggest to 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. The question is rather easy to answer and most respondents do answer the question. The answer may be explained to a satisfactory degree by utilizing standard econometric models.

This question asks the respondent to evaluate 'his life as a whole' on a (1, 10)-scale, which is the usual scaling used in the Dutch schooling system and hence familiar to all respondents. Ten stands for 'excellent', and one for the 'worst possible situation'. The obvious questions are now whether the answers are interpersonally comparable and whether the resulting function may be considered as a cardinal or ordinal measure of well-being. The question of interpersonal comparability cannot be answered by any a priori theory. Rather, it is an empirical issue. If two individuals are offered the same stimulus and react in the same way, then we may assume that the stimulus has a comparable and similar effect on both individuals. In this case the question is the stimulus and the answer the reaction.

Let us describe the respondent i's objective life situation by (the vector) v_i, his personal characteristics like age and family size by (the vector) x_i, and his subjective evaluation of his life situation (his well-being, for short) by W_i, then we may assume a relationship:

$$W_i = W(v_i, x_i) \tag{4.6}$$

Let us assume two individuals i and j, with $v_i = v_j$ and $x_i = x_j$. When there holds $W_i = W_j$, it follows that i and j, who are in identical circumstances (v, x), evaluate their life identically on this scale. If this is true for all individuals who are in the same circumstances and if W varies with v and x, then it follows that (v, x) is a perfect predictor for the well-being of individuals. This does not imply that individual well-being is really well-measured by the Cantril-question. It only implies that (v, x) is a good predictor of the response to the Cantril-question and that there is a functional relationship $W = W(v, x)$. We also infer then that the answers are then interpersonally comparable. In this case we shall equate well-being with the response on the Cantril-scale. If we find that there is an imperfect fit but that

$$W_i = W(v_i, x_i) + \varepsilon \tag{4.7}$$

where the effects of variables are significant, we will assume interpersonal comparability as well. However, with respect to the imperfect fit we are not sure whether this is caused by an imperfect specification and/or omission of variables, or whether it is caused by imperfect interpersonal comparability. We refer to Van Praag (1993, 1994) for empirical experiments on the translation of verbal labels like ‘good’, ‘bad’ into numerical ranking. It was shown there that most people tend to translate verbal labels into numbers in a similar way and hence that equal *numerical* responses may be translated into equal *verbal* descriptions of feelings. This does not imply that feeling ‘good’ or ‘bad’ means the same to every respondent, but it is highly probable for individuals, living and being brought up in the same language community.

Let us assume that well-being is interpersonally comparable by means of the Cantril-question, then the question arises whether it is a cardinal measure, i.e., equal distances represent equal jumps in well-being. Although we believe this to be a reasonable assumption (ibidem), we do not have means to test that assumption. Hence, it stays as an unproven assumption. However, does it matter in the perspective of this paper whether the measure is ordinal or cardinal? The answer is “no”, since in this paper we are only interested in *the trade-off* between Δz and Δy in $W = W(y, z)$, where income y is a dimension of the personal characteristics vector x, and noise z is a dimension of the objective situation v.

If we look at another ordinal specification of W, say, $W^* = \varphi\ (W\ (z,\ y))$, where φ is a monotonically increasing function, it is obvious that

if $$W\ (z + \Delta z, y + \Delta y) = W\ (z, y) \tag{4.8}$$

then $$\varphi\ [W\ (z + \Delta z, y + \Delta y)] = \varphi\ [W\ (z, y)] \tag{4.9}$$

Hence, our conclusion is that we do not need to assume cardinality to derive trade-off ratios and hence, that we do not have to make a statement on the cardinal or non- cardinal nature of the Cantril well-being measure either. It is only interpersonal comparability in an ordinal sense, which matters here.

5. The empirical model

Consider now the Cantril-question. The answers to the Cantril-question are a discrete and ordinal variable with ten response categories. The usual way to analyze such a variable is by means of Ordered Logit or Ordered Probit Analysis. We assume a latent continuous variable *W* which we observe through a classification procedure. 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[6] 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*)

The Cantril-question has already been used by Plug and Van Praag (1995), Van Praag and Plug (1998), Blanchflower and Oswald (2000). In those studies a noise effect was not included, as the data sets used did not contain such variables. Using the variables listed above, the Cantril measure of well-being *W* is explained in this study by:

$$W = \hat{a}_0 + \hat{a}_1 \ln y + \hat{a}_2 \ln fs + \hat{a}_3 (\ln fs)^2 + \hat{a}_4 \ln y * \ln fs + \hat{a}_5 \ln age + \hat{a}_6 (\ln age)^2 + \hat{a}_7 \ln Ku + \hat{a}_8 Ins * \ln Ku \qquad (5.1)$$

The effect of income is of course expected to be positive. The family-size effect is ambiguous. For all parents there is a finite optimum, and if the number of children rises

[6] The Kosten unit is based on log(decibels), the flight frequency, while a penalty weight is assigned to evening and night flights.

above that optimum, children become more or less 'undesired'. Using the log-parabolic specification, such an optimum is found as the solution of the equation

$$\hat{a}_2 + \hat{a}_3 \ln fs + \hat{a}_4 \ln y = 0 \quad (5.2)$$

with the explicit solution:

$$\ln fs = \frac{-b_4 \ln y - b_2}{2b_3} \quad (5.3)$$

The solution may be smaller than two, in which case we assume that the optimum number of children is zero.[7] From the equation that specifies 'ln*fs*' it is obvious that the interaction term of 'ln*y*' with 'ln*fs*' is quite important. It presumes 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 for a flexible form by adding a log-quadratic form. We choose for 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 years are perceived as running faster as one grows older.

Next, two variables describing the respondents' living situations 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 and, hence, that

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[7] Family size is defined as follows: 1 + partner + number of children living at home.

well-being is positively affected by the presence of noise insulation. The dummy variable *Ins* equals one when insulation is present and zero otherwise.

The resulting Ordered- Probit estimates for this equation (leaving out the nine threshold values) are presented in table 3.

Table 3: Estimation of the well-being equation with the variable Ku

Variable	Parameter estimate	Standard error
ln*y*	0.5093	0.0849
ln*fs*	- 2.3941	0.8689
$(\ln fs)^2$	- 0.1613	0.1297
ln*y**ln*fs*	0.3274	0.1092
ln*age*	- 4.2372	1.1656
$(\ln age)^2$	0.5681	0.1586
ln*Ku*	- 0.0242	0.0252
*Ins**ln*Ku*	0.0582	0.0241
N = 1,084	Pseudo R^2 = 0.1643	

Significantly different from 0 at a 5% level.
(Top of age at 42)

Looking at these results (on which we shall not comment at this point but later on, when discussing the results in the tables 5 and 6 below), we see that the (external) effect of noise nuisance is not significant. It follows that our first attempt to identify the external effect has not been rewarded.

Actually, different individuals will perceive noise differently. For instance, if an individual is at home during daytime, it stands to reason that noise will have a larger impact than when he or she is working during the day. The same holds for family size. The larger the family, the higher is the family exposition to external factors. In short, the crucial variable is not the *objective* measurement of noise but the *subjective* perception of it. The concept, which explains the subjective well-being is the subjective variable *perceived noise*, which we shall call *noise* for short.

In the survey, a question is posed which may be considered as an index of (perceived) noise. Question 25 asks respondents to indicate the extent to which several sound sources (enumerated in the question) cause noise nuisance at their place of living. These noise sources relate to, among other things, trains, neighbors, industry and airplanes. The answer to this question is given on a discrete 5-value scale, indicating that the respondent "never" experiences noise nuisance up to a situation in which the respondent "always" experiences noise nuisance. In the area around Schiphol, which we considered, we found the following distribution of noise:

Table 4: Aircraft noise nuisance

To what extent do airplanes cause noise nuisance at your place of living?

	Total	No noise insulation	Noise insulation is present
Never	159 (12.0%)	}	}
Sometimes	460 (34.6%)	} ⇒ 647 (73.5%)	} ⇒ 233 (26.5%)
Regularly	261 (19.7%)	}	}
Often	263 (19.8%)	170 (64.6%)	93 (35.4%)
Always	185 (13.9%)	96 (51.9%)	89 (48.1%)
Total	1,328 (100%)	913 (68.8%)	415 (31.2%)
Missing	72		

The table makes clear that in an area of 50 kilometers around the airport there are many sites where aircraft does not pass at all or at least does not cause any noise nuisance. It also shows that 26.5% of the Schiphol respondents who answer "never", "sometimes" or "regularly" to question 25d have noise insulation in their homes. This figure rises to 35.4% for the Schiphol respondents who marked the option "often" in question 25d, and to 48.1% for the respondents who marked the option "always". We note that these percentages cannot be interpreted in an unequivocal way, since in some of these cases the noise insulation may have been installed compulsorily but at zero cost for the house owner or tenant, as part of the insulation program of Schiphol Airport.

Based on the answers presented in table 4, a subjective variable of aircraft noise nuisance is constructed, *noise* for short. This variable will depend on objective circumstances, especially the objectively measurable noise level in Ku *and* individual intervening variables *x*, like family size, housing expenditures et cetera. They influence the perception process.

Now we estimate the relation between noise and Ku. We notice that *noise* stands for subjective evaluations on a discrete [1-5] scale and we model it again by means of Ordered Probit Analysis. The variable *noise* is explained by the following variables:

- family size (ln*fs*)
- 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*)
- objective noise in terms of Kosten units (ln*Ku*)

More exactly, we assume that the latent variable *noise* may be explained by the equation

$$Noise = a_1 \ln fs + a_2 \ln He + a_3 Home + a_4 Bal + a_5 Gar + a_6 \ln Ku + a_0 + h \qquad (5.4)$$

where h stands for the $N(0,1)$-distributed error term. The resulting Ordered Probit estimates for this equation are shown in table 5.

Table 5: 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 0 at a 5% level.

The influence of family size on *noise* is positive: the larger the household, the more annoyance by the aircraft noise. Furthermore, the results indicate that the higher the housing expenses, the more aircraft noise nuisance annoys someone. Obviously, when the house is more expensive, one expects a higher housing quality and absence of noise nuisance is one of the relevant quality dimensions. In addition, individuals who are at home during the day on weekdays experience more aircraft noise nuisance than people who leave the home during daytime.

The next two variables describe the respondents' living situation, viz. the presence of a balcony and the presence of a garden. 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. 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. Our conclusion is that perceived noise does not only depend on the objective noise level, but that the perception is 'colored' by intervening variables.

Respondents, who are exposed to the same subjective *noise* level, will be characterized by the same value of the latent variable *noise*. By means of Table 5 we may evaluate the expected noise level for each respondent by substituting his own values of the explanatory variables in eq.(5.4). 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 (see Terza, 1987).

If we include in eq.(5.1) the intermediate variable *noise* (specified in eq.(5.4)) instead of Ku, the specification of well-being reads as follows:

$$W = \hat{a}_0 + \hat{a}_1 \ln y + \hat{a}_2 \ln fs + \hat{a}_3 (\ln fs)^2 + \hat{a}_4 \ln y * \ln fs + \hat{a}_5 \ln age + \hat{a}_6 (\ln age)^2 + \hat{a}_7 noise + \hat{a}_8 lns * noise \qquad (5.5)$$

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 nuisance depends on objective noise Ku *and* on individual characteristics.

The resulting estimates for this equation are presented in table 6.

Table 6: 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
*lns*noise*	0.0736	0.0270

N = 1,031	Pseudo R^2 = 0.1662

Significantly different from 0 at a 5% level.
(Top of age at 40)

Let us start to notice that the coefficients in tables 6 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 combined effect of all three variables referring to family size indicates that an optimal family size exists and that this size increases with income. The age effect is quadratic with a minimum at 40 years.

The variable *noise* has now a significant and negative influence on well-being. The positive and significant interaction term of noise insulation with noise nuisance (*Ins***noise*) indicates that, if the house does *not* have noise insulation, the effect of noise nuisance on well-being is -0.1126, whereas this effect reduces by more than half to -0.0390 (-0.1126 + 0.0736), if the house does have noise insulation. However, noise insulation does not fully mitigate the effects of aircraft noise on well-being.[8]

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 monetary compensations for changes in the noise level in Ku.

[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 2. In a study of the Dutch consultants Regioplan on the nature and the extent of the complaints about aircraft noise nuisance in the Schiphol region, a similar incomplete effect of noise insulation has been found (Hulshof and Noyon, 1997, p. 73).

6. The resulting shadow prices

6.1. A compensation schedule differentiated to net monthly income

We are now able to derive shadow prices for changes in the noise level measured in Ku on the basis of tables 5 and 6. Considering tables 5 and 6 we may write schematically $W = W\,(y,\ noise\,(Ku,\ x),\ z)$, 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 *x*, and finally a vector *z*, including family size (*fs*) and age. The shadow price Δy, needed to compensate for an increase of ΔKu, is now calculated from the equation

$$W\,(y + \Delta y,\ noise\,(Ku + \Delta Ku,\ x),\ z) = W\,(y,\ noise\,(Ku,\ x),\ z) \tag{6.1}$$

Dropping all non-relevant terms in (4.5), 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

$$(\beta_1 + \beta_4 \ln fs) * \Delta \ln y = - (\beta_7 + \beta_8 Ins) * 0.3445(\Delta \ln Ku)) \tag{6.2}$$

where β_1, β_4, β_7, β_8 are given in table 6 and the coefficient 0.3445 is taken from table 5. Equation (6.2) may be rewritten as

$$\frac{\partial \ln y}{\partial \ln Ku} = -\frac{(b_7 + b_8 Ins)}{(b_1 + b_4 \ln fs)} * 0.3445 \tag{6.3}$$

The first point, which follows from (6.3), is that the price is not a constant, i.e., the compensation 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. So, it is the relative changes that count. This is not surprising as nearly every psychophysical stimulus is translated on a logarithmic scale.

Similarly, the compensation in money depends on the initial income level. Here, it is also found that the relative changes count. The expression ∂ln*y*/∂ln*Ku* is an elasticity. Politically, this implies that the compensation for noise nuisance depends on income, where richer people are entitled to a 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 *ƒ*100 is smaller if someone has an income of *ƒ*2,000, than if one earns an income of *ƒ*1,000. Similarly, a compensation of *ƒ*100 means less to somebody with *ƒ*2,000 than for an individual earning *ƒ*1,000.

From equation (6.3) it is obvious that the compensation (elasticity) depends on the fact whether or not the house is insulated against noise. The compensation needed is much smaller when the house 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.

There result two values for the elasticity (∂ln*y*/∂ln*Ku*), viz., a noise elasticity without noise insulation

$$-\frac{(b_7)}{\left(b_1 + b_4 \overline{\ln fs}\right)} * 0.3445 = -\frac{(-0.1126)}{(0.5039 + 0.3061 * 0.6743)} * 0.3445 = 0.0546$$

and a noise elasticity with noise insulation

$$-\frac{(b_7 + b_8)}{(b_1 + b_4 \overline{\ln fs})} * 0.3445 = -\frac{(-0.1126 + 0.0736)}{(0.5039 + 0.3061 * 0.6743)} * 0.3445 = 0.0189$$

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 well - being equivalent *y* has to increase by b%. The percentages b have been tabulated below both for the case *without* and *with* noise insulation.

Table 7: Monetary compensations as a fraction of net income for selected changes in noise level

	20 → 30 Ku	30 → 40 Ku	40 → 45 Ku	40 → 50 Ku
Without isolation	2.15%	1.53%	0.63%	1.20%
With isolation	0.74%	0.53%	0.22%	0.41%
Value of noise insulation	1.41%	1.00%	0.41%	0.79%

We see that at a monthly income of ƒ1,500 a household would have to be compensated with 2.15%, that is ƒ32.24 per month, for a noise increase from 20 to 30 Ku.[9] A change from 20 to 40 Ku would require ƒ32.24 + ƒ23.07 = ƒ55.31 per month approximately.

The compensation amounts for houses *with* insulation are much smaller. For instance, at the same income level of ƒ1,500 the compensation would be only ƒ 11.08. This implies also that the value of insulation at that level would be ƒ32.24 - ƒ11.08 = ƒ21.16. Under pressure of public opinion and of the government the Amsterdam airport authorities have accepted the obligation to insulate dwellings which are in high Ku areas (> 45 Ku). Now the question arises whether it

[9] The present exchange rate is USA$ 1 = ƒ2.50.

would be cheaper to *pay* the compensation or to *insulate* the house. By subtracting the second row from the first row in table 7 we find the value of the insulation. Clearly, noise insulation is a capital investment. Using an interest-rate of 5%, a monthly amount of ƒ21.16 is equivalent to a capital expenditure of 20*12*ƒ21.16 = ƒ5,078.40. It follows that authorities should insulate the dwellings of households earning ƒ1,500 per month experiencing a noise increase from 20 to 30 Ku, if the once- only costs of insulation are below this amount of ƒ5,078.40.

6.2. A compensation schedule differentiated to housing expenditures

It was already hinted at that a compensation scheme, which depends on the household income level, might not be politically acceptable. An alternative way to set such a scheme uses the housing expenses (*housing exp.*) as a key variable. Here we have to distinguish between home owners and tenants. For home owners in the Schiphol region, we found the following relationship:

$$\ln(\textit{housing exp}) = \underset{}{0.3680} + \underset{(8.41)}{0.3889\ln y} - \underset{(-13.61)}{0.2657\ln \textit{Tor}} + \underset{(6.14)}{0.3019\ln(\textit{asking price})} \qquad (6.4)$$

$R^2 = 0.3904$; N = 625

We assume that housing expenses will depend on income and on the current market price of the house if sold empty. The current market value of the house is denoted by *asking price*. In the Netherlands, houses are in very short supply and it follows that prices rise by 5 to 20% per year during the last 15 years. There is also an annual general inflation fluctuating between 2 and 10% over that period. The housing expenses are for a good deal based on *historical* costs, since mortgage loan costs are an important component of housing expenses in the Netherlands. It follows that nominal housing expenses of homeowners tend to fall with the time of residence.

We have to correct for that effect, if we want to predict income from housing housing expenses. We find

$$\ln y_{pred} = (0.3889)^{-1}[\ln(\textit{housing exp}) - 0.3680 + 0.2657\ln \textit{Tor} - 0.3019\ln(\textit{asking price}) \qquad (6.5)$$

Departing from table 7 and replacing the income by predicted income y_{pred} we find tables 8 (insulation not present) and 9 (insulation present). These tables are calculated on the assumption that the household has lived in the house for five years (*Tor* = 5).

Table 8: Monthly Compensation for home owners if noise insulation is not present (differentiated for net monthly housing expenses and asking price)

	20 → 30 Ku	30 → 40 Ku	40 → 45 Ku	40 → 50 Ku
Asking price: ƒ150,000				
Housing expenses				
ƒ 500	ƒ 20.93	ƒ 14.98	ƒ 6.14	ƒ 11.67
ƒ 750	ƒ 59.36	ƒ 42.49	ƒ 17.41	ƒ 33.11
ƒ1,000	ƒ 124.39	ƒ 89.03	ƒ 36.48	ƒ 69.38
Asking price: ƒ400,000				
Housing expenses				
ƒ1,000	ƒ 58.09	ƒ 41.58	ƒ 17.03	ƒ 32.40
ƒ1,500	ƒ 164.78	ƒ 117.93	ƒ 48.32	ƒ 91.91
ƒ2,000	ƒ 345.27	ƒ 247.11	ƒ 101.25	ƒ 192.58

Table 9: Monthly Compensation for homeowners if noise insulation is present (differentiated for net monthly housing expenses and asking price)

	20 → 30 Ku	30 → 40 Ku	40 → 45 Ku	40 → 50 Ku
Asking price: ƒ150,000				
Housing expenses				
ƒ 500	ƒ 7.19	ƒ 5.16	ƒ 2.12	ƒ 4.02
ƒ 750	ƒ 20.41	ƒ 14.63	ƒ 6.01	ƒ 11.42
ƒ1,000	ƒ 42.76	ƒ 30.66	ƒ 12.60	ƒ 23.92
Asking price: ƒ400,000				
Housing expenses				
ƒ1,000	ƒ 19.97	ƒ 14.32	ƒ 5.88	ƒ 11.17
ƒ1,500	ƒ 56.64	ƒ 40.62	ƒ 16.69	ƒ 31.69
ƒ2,000	ƒ 118.69	ƒ 85.11	ƒ 34.98	ƒ 66.40

Similarly, we may 'predict' household incomes from monthly rents. For tenants we find

$$\ln(\textit{housing exp}) = 4.0687 + 0.3045\ln y - 0.0081\ln Tor \qquad (6.6)$$

$$(10.62) \qquad (-0.55)$$

$R^2 = 0.1802$; N = 516

$$\ln y_{pred} = (0.3045)^{-1}[\ln(\textit{housing exp}) - 4.0687 + 0.0081\ln Tor] \qquad (6.7)$$

The effect of *Tor* on housing rents is not significant. The main reason for this non-significance is that all Dutch rents are fixed per housing unit. The initial rent level of the housing unit is multiplied each year according to law by a national index α, which approximately equals the nominal growth rate of income. Hence, staying in one apartment for a long time does not automatically reduce the relative rent/income ratio, apart from incidental cases where the income grows considerably.

On the basis of these results, we can now compute the amounts of compensation differentiated for rent (tenants). Table 10 gives the compensations if noise insulation is not present, and table 11 if noise insulation is present.

Table 10: Compensation for tenants if noise insulation is not present (differentiated for net monthly rent)

	20 → 30 Ku	30 → 40 Ku	40 → 45 Ku	40 → 50 Ku
Rent:				
ƒ300	ƒ 4.82	ƒ 3.45	ƒ 1.41	ƒ 2.69
ƒ500	ƒ 25.79	ƒ 18.46	ƒ 7.56	ƒ 14.39
ƒ750	ƒ 97.68	ƒ 69.91	ƒ 28.64	ƒ 54.48

Table 11: Compensation for tenants if noise insulation is present (differentiated for net monthly rent)

	20 → 30 Ku	30 → 40 Ku	40 → 45 Ku	40 → 50 Ku
Rent:				
ƒ300	ƒ 1.66	ƒ 1.19	ƒ 0.49	ƒ 0.93
ƒ500	ƒ 8.87	ƒ 6.36	ƒ 2.61	ƒ 4.96
ƒ750	ƒ 33.58	ƒ 24.08	ƒ 9.89	ƒ 18.79

6.3. The costs of compensation to society

An important policy question is now what the total amount of compensation would be for compensating the population living around Schiphol for the noise nuisance they suffer. This means that we have to compute the 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 added together.

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 to compensate for the exceeding nuisance? In table 12 below, we have done this for a number of critical levels.

Table 12: Total yearly amount of compensation

x Ku	Number of households concerned[1]	Average monthly compensation per household concerned	Total yearly amount of compensation
> 20 Ku	148,063 (17.9%)	ƒ 13.69	ƒ 24.33 million
> 25 Ku	80,478 (9.7%)	ƒ 10.52	ƒ 10.16 million
> 30 Ku	26,734 (3.2%)	ƒ 8.17	ƒ 2.62 million
> 35 Ku	11,851 (1.4%)	ƒ 6.11	ƒ 0.87 million
> 40 Ku	6,030 (0.7%)	ƒ 5.47	ƒ 0.40 million

[1] Of the total population in the Schiphol region.

To be precise, we have computed the total monthly compensation necessary to compensate the nuisance level for all people suffering from a damage level of over x Ku, to the chosen level of *x* Ku. Table 12 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 higher the critical level, the smaller 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. This is because the number of households exposed to over 20 Ku is much higher than the number of households exposed to higher critical levels.

To put the amounts in Table 12 into the right perspective we have to relate them to the number of commercial flights (which equals about 397,000 in 1999 at Schiphol) or to the number of passengers (which equals about 36,8 million in 1999). Consequently, if we suppose that the government would choose 20 Ku as the critical level, the compensation per flight would amount to ƒ61,- and the compensation per passenger would be ƒ0.66.

7. Discussion and conclusions

In this paper, we estimated the shadow price of an external effect, viz., of aircraft noise nuisance. An external effect is always a residual effect which is left after taking into account that prices, in this case housing prices and rents, partially reflect the impact of the external effect. We estimated the shadow price of this residual effect on the basis of a subjective question about the satisfaction with 'life as a whole'. On the basis of our empirical estimates we conclude that the answers are interpersonally comparable for practical purposes. Our second finding is that housing prices and rents do not appear to internalize the external effect completely. There is a residual effect.

Methodologically, the paper is innovating, as it uses the Cantril ladder-of-life question as information on well-being, while recognizing the ordinal character of the Cantril index. It also estimates a two-equation model, where both variables to be explained are ordinal and one of the two variables figures as explanatory variable for the other. The monetary tariffs found, say shadow prices, are derived from that model and they differ according to whether or not the house is insulated against noise. The tariffs may depend either on household income, reflecting the falling marginal utility of income (Gossen's first law), or on the housing expenses.

We do believe that this is the first time that external effects have been monetarily measured by means of the Cantril-question. It is obvious that this external effect could only be measured by the circumstance that noise nuisance varies a lot over the Amsterdam area and that the noise burden is pretty well registered according to zip codes, making it possible to link objective noise nuisance with the subjective feelings of the individuals living there.

The advantage of this model compared to hedonic price analysis is that it does not assume equilibrium on the housing market and that it does not only include the external effect as far as it concerns housing inconveniences but that it includes all aspects. The advantage to CVM studies is that the respondent is not aware that his or her responses may have any influence on decisions or compensations in which he or she has an interest. Hence, strategic response behavior is highly unlikely in our study.

One question, which falls outside the scope of this study, is the question whether a noise compensation schedule is politically to be desired. At the one hand it does right to the idea that the polluter pays for the damage and accordingly will reduce the pollution in line with a cost-benefit analysis. On the other hand it affects housing prices, where the compensated locations are becoming subsidized and hence will demand a higher selling price than before. Given the fact that the Amsterdam housing market is characterized by soaring prices and a permanent housing shortage and that the size of the effects found is rather small, we do not believe that the compensation schedule derived in this study will affect or disturb the housing market to any significant extent. For reasons of justice the polluter-pays-principle should be maintained.

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