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6 August 2008

Online at <https://mpra.ub.uni-muenchen.de/10660/>

MPRA Paper No. 10660, posted 21 Sep 2008 12:09 UTC

How big a problem is noise pollution?
A brief happiness analysis by a perturbable economist

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August 2008
Preliminary draft, comments welcome

Abstract: This paper approaches the question of the costs of everyday residential noise pollution by examining a series of ‘happiness regressions.’ We control for the possibility that an unobservable characteristic (which we denote ‘complainer type’) may lead people both to complain more and cause them to declare themselves to be less happy. We further control for the possibility that a standard estimate of the marginal utility of income may suffer from endogeneity and will be under-estimated if ‘effort’ is not adequately taken into account. We find perceived noise pollution to exert a negative and highly significant effect on happiness. We then calculate the required income transfer to compensate for the noise and find the costs of noise pollution to be on the order of €106 per month per household.

Key words: happiness, hedonic regression, noise pollution

JEL codes: R21, R41, Q51

Introduction

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1. Introduction

Noise pollution has been a source of concern for doctors, psychologists, and economists for some time. Perhaps due to the broad public policy implications, much of the attention has focussed on noise from roads and especially airports. For example, multiple studies have demonstrated the significant negative physical, psychological and economic effects of chronic aircraft noise exposure (see, for example, Stansfeld *et. al.* (2005), von Praag and Baarsma (2005)). Diaz-Serrano (2006) shows that noise complaints are a significant factor in housing satisfaction.

In economics, there is naturally an interest in calculating the costs of noise pollution and comparing these to the costs of noise abatement policies. While the latter exercise is straightforward, there are a number of difficulties associated with summing up the economic and psychological effects of noise. One set of approaches to this problem includes contingent valuation or 'stated choice' methods where subjects are asked to give their willingness-to-pay for alternative levels of different attributes, or are asked to choose between alternative combinations whose monetary equivalence is known to the researchers (see, for example, Galilea and Ortuzar (2005), Wardman and Bristow (2007)). These methods are prone to various forms of strategic bias, however, and thus remain somewhat controversial (see Carson *et. al.* (2001) for a good review).

Since Walters (1975) it has become more common to use hedonic house price regressions to analyze the relationship between house prices and proximity to noise sources (usually airports) in order to estimate a shadow price of noise from the market data; all else equal, if similar homes sell for less the closer they are to the airport, the conditional difference in price is interpreted as the market discount attributed to the noise problem. The imputed noise costs found by many of these studies are substantial: for example, Nelson (2004) finds a \$200,000 house would sell for \$20,000 to \$24,000 less if exposed to airplane noise.

In theory, with perfect information and free and costless mobility, in equilibrium house prices should completely compensate the noise differentials and the average home-owner should be left observationally indifferent between house X with noise level A and house Y with noise level B. However, von Praag and Baarsma (2005) point out that these assumptions for housing markets are far from realistic as moving costs are relatively high, both economically and socially. Many people who optimally chose a home 10 years ago may find themselves in a suboptimal situation years later for a number of reasons: increases in local traffic, changes in airplane flight paths, or noisy new neighbours next door. Nevertheless, high moving costs combined with the social and psychological costs of re-establishing a social network and leaving one's home of many years¹, many home owners may simply hunker down and stay put. Furthermore, many housing markets are highly regulated with a large amount of

¹ For example, a home owner may have recently renovated their bathroom using Pietra de Luna natural limestone tiles and be loathe to either trade down or go through the ordeal again.

rationing (such as the market studied by von Praag and Baarsma²). If the housing market is not in equilibrium, house prices may not fully compensate for undesirable characteristics and there will be *residual* welfare costs.

A further complication arises when one considers that there may be considerable heterogeneity in individuals' tolerance towards noise. Walters (1975) distinguishes between 'perturbable' and 'imperturbable' people. Arsenio *et. al.* (2006) indeed does find evidence of self-selection, where those with higher marginal values of noise self select into quieter apartments. In the presence of such heterogeneity, noise tolerant people will be more likely to self-select into noisy areas (taking advantage of the lower prices) which in turn leads to a downward bias in any estimate of the average welfare costs of noise; those closest to the noise source are the least bothered by it! Endogenous selection implies that we cannot necessarily interpret the difference in house prices attributed to noise differentials as the total cost that would be imposed on an average individual exposed to that noise.

A third alternative, adopted here, is to use data from the many 'happiness' or life satisfaction surveys that are now available, many of which also ask questions about income and various other relevant things (including noise), making it possible, in principle, to calculate the income transfer required to compensate happiness-reducing factors. For example, Clark and Oswald (2002) use happiness data to generate estimates of the monetized 'costs' of various life events. Van Praag and Baarsma (2005) use a combination of life-satisfaction data (including detailed questions on exposure to different kinds of noise), house prices, and actual objective aircraft noise measurements by postcode to estimate the costs of airport noise around Amsterdam airport. As van Praag and Baarsma do not find any relationship between noise and house price, all of the costs of airport noise in their case are derived from the happiness survey data and they thus use this method to recover the residual costs of noise from the airport.

However the 'happiness regression' approach faces several problems of its own. For example, if people who *generally* complain a lot are less happy³ and also report more noise problems than average, then there will be an omitted variable bias and our estimates of the happiness costs of noise will be overstated. In addition, it may be difficult to estimate the marginal utility of money if we observe income but do not control for unobservable (and happiness decreasing) factors such as the effort that had to be exerted to generate that income. Finally, income and happiness may be endogenous if happier people earn more.

This paper's contribution is thus two-fold. We make a small contribution to the literature on noise pollution by using happiness regressions to impute a monetized value of residential noise complaints. By using data from across Europe that includes

² The Amsterdam market under study was so far out of equilibrium that von Praag and Baarsma found *no* relationship between noise exposure and price!

³ Whether the unhappiness *causes* the increased complaints, or whether the two characteristics, unhappiness and whininess, are simply correlated is a question best left to psychologists and neuroscientists. For the purposes of this study we must assume the latter as the EQLS data leaves us no means to address the causal question.

information on nuisance noise of any origin, we ask a more general (and therefore less precise) question than do van Praag and Baarsma (2005). In particular, we consider what, on average, given the existing disequilibrium in housing markets and the actual distribution of perturbable and imperturbable individuals, is the welfare impact of *all* sources of noise pollution?

Second, in the process of estimating our happiness regressions we address several problems of omitted variable and endogeneity bias in novel ways⁴. In particular, we control for ‘complainer’ personalities among the respondents, and we estimate our marginal utility of income on a sample of housewives, thus de-linking the production of household income from the effort or intrinsic happiness of the respondent.

The paper proceeds as follows. In section 2 we describe the data and in section 3 we outline the method, including our approach to address omitted variable and endogeneity biases. Section 4 discusses the results and section 5 concludes. Tables are presented in the Tables Appendix and detailed information on the data set is presented in the Data Appendix.

2. Data

In order to evaluate the welfare effects of noise we take advantage of a comprehensive stratified random sample survey undertaken by the European Foundation for the Improvement of Living and Working Conditions, set up by the European Council in 1975 to “contribute to the planning and design of better living and working conditions in Europe”. The European quality of life survey (EQLS) was carried out in 2003, covered 28 countries, and involved interviewing 26,000 people. The survey examined a range of issues, such as employment, income, education, housing, family, health, work-life balance, life satisfaction and perceived quality of society. In addition to all the standard socio-economic and housing quality variables, respondents were asked to rank their overall life satisfaction, or happiness as some call it, on a scale of 1 to 10. They were also asked their frequency of exposure to complaint-warranting noise from all sources (from none to very many).

At first blush many economists might rightly be suspicious of surveys asking people how satisfied they are with life. As Di Tella and MacCulloch (2006) so succinctly put it, “economists are trained to infer preferences from observed choices... they watch what people do, rather than listening to what people say” (p. 25). However, since the work of Richard Easterlin (1974), the use of life satisfaction, or happiness, survey data has become increasingly common among economists. Despite some issues of concern⁵, numerous studies have shown these rankings to be surprisingly robust over time and across space, and correlated with the right signs to observables that we might expect to affect happiness (for a nice survey see Di Tella and MacCulloch (2006)).

⁴ To the author’s knowledge!

⁵ For example, the bounded nature of the satisfaction ranking can impose an illusion of diminishing marginal returns.

Our primary dependent variable is the average of two answers from (identical) questions in which respondents were asked to rank their overall life satisfaction on a scale from 1 to 10 (see below for a discussion of why we chose to average the two). The mean 'happiness score' in the usable sample was 6.94, with a standard deviation of 1.96.

Our measure of noise is the response to the question of whether, in the area where the respondent lives, there are 'very many', 'many', 'a few', or no reasons to complain about noise. For most of the analysis we classify respondents who answered 'very many' or 'many' as living in a noisy situation (*noise*)⁶. We do not collect any information about the source of the noise, nor do we have any way of objectively measuring the actual decibel level of the offending noise. In the usable sample 1486 people (7.4% of the sample) claimed to have 'very many' complaints about noise, 2060 (10.2%) had 'many', 5427 (27%) had 'a few' and 11,143 (55.4%) people had no complaints about noise.

Respondents were further asked if they had complaints about air quality, availability of green space and water quality. Although none of these would seem to be correlated with noise pollution, we will exploit their responses to generate a measure of 'complainer personality', as explained further below.

Our measure of income is after-tax household net monthly income, which respondents categorized into one of 19 possible income brackets (see table A2 in the data appendix). Following Layard, Mayraz and Nickell (2008) we assign income to be the mean of each bracket⁷ and include both the log of income and the square of the log of income in all our regressions. We also include average weekly hours worked as one (but ultimately not our primary) measure of 'effort'.

Following the literature, other control variables include sex, age, marital status, parenthood status, education, employment status, family size, and various dwelling characteristics. In addition we include a full set of country fixed effects which will control for the average level of happiness within each country due to both observable and unobservable characteristics. Thus all our overall estimates should be interpreted as a weighted average of the *within* country estimates. A full list of all the variables and their definitions is provided in table A1 in the Appendix.

3. Method

The empirical approach we adopt here is quite straightforward: by including our survey measure of perceived noise pollution in a regression analysis, along with a comprehensive set of control variables that may relate to reported happiness levels, we estimate the marginal effect on reported happiness of different degrees of noise pollution. As we can also measure the effect on happiness of (rough) income level from the same regression, we can then calculate how much income would have to

⁶ We later parse these out for robustness checks.

⁷ For the last open-ended bracket of €4500+ we assign a value of €5000.

increase/decrease to produce the equivalent effect on reported happiness. We call this derived figure the income-equivalent cost of noise pollution.

More specifically, let u_i denote true utility of individual i , X_i denote the vector of individual-specific external factors that effect utility (such as income, sex, marital status etc., as well as exposure to noise pollution), and H_i denote our index measure of happiness. Then, following Layard *et. al.* (2008) we assume that equal intervals on the reported happiness scale reflect equal intervals of true utility⁸, in other words that $f_1(\cdot)$ is linear in equation (1). Thus observed happiness is equal to a linear function of our true utility and a random error:

$$(1) \quad H_i = f_1(u_i) + v_i$$

The conditions under which we can map 'life satisfaction' scores to (unobserved) true utility levels has been explored in depth in the literature (for example, see Layard *et. al.* (2008), Di Tella and MacCulloch (2006)) and we do not revisit the issue here except to note, again, that numerous studies have demonstrated the systematic correspondence between these 'happiness' indices and both observable external conditions as well as neurological brain images (Davidson *et. al.* 2000).

We further assume that individual utility is a function of individual external factors X_i and a country-specific term, γ_k , and residual ε_i which is uncorrelated with X_i and γ_k .

$$(2) \quad u_{ik} = f_2(X_i) + \gamma_k + \varepsilon_{ik}$$

$$(3) \quad \text{cov}((X_i, \gamma_k)\varepsilon_{ik}) = 0$$

Following the literature we allow $f_2(\cdot)$ to be nonlinear in some elements of X_i , such as income and age, but assume this can be captured by logarithmic and polynomial transformations of these variables. Thus our basic estimating equation is written:

$$(4) \quad H_{ik} = \gamma_k + \beta_1 \ln(\text{income}) + \beta_2 \text{noise} + \sum_q \beta_q X_{qi} + \omega_{ik}, \quad \text{where } \omega_{ik} = v_i + \varepsilon_{ik}$$

From equation (4) it is straightforward to calculate the additional income necessary to compensate for a decrease in happiness brought about by noise pollution. Clearly, the level of compensation will vary with income level:

$$(5) \quad \text{compensation} = \beta_2 \left(\frac{\hat{\beta}_1}{\text{income}} \right)^{-1}$$

This basic strategy is not novel, for example Clark and Oswald (2002), and Frey, Luechinger and Stutzer (2004) adopt just such an approach for valuing life events such as marriage, illness or unemployment, or terrorism, respectively. Furthermore, our strategy is quite a bit simpler than in van Praag and Baarsma (2005), who isolate

⁸ Layard *et. al.* (2008) test, and reject, the hypothesis that u maps nonlinearly to H .

the utility-compensation costs of *objective* increases in aircraft noise, controlling for other factors that affect perception of noise.

As mentioned above, some of the assumptions underlying equation (4) are problematic, however. In particular, if u is a function of both observable factors, X_i^O , and unobservable factors X_i^U and $\text{cov}(X_i^O, X_i^U) \neq 0$ then our estimates will be biased⁹. The two primary omitted variables of concern here are 'effort,' which may be correlated with both utility (negatively) and income (positively), as well as the possible existence of a 'complaining personality' that is correlated with both a lower level of life satisfaction and with more noise complaints. The former will tend to bias our estimate of β_1 downwards, while the latter will lead us to overestimate the utility costs of noise. Finally, equation (3) will be violated if happiness itself plays a causal role in generating higher income.

We adopt two novel (to the author's knowledge) strategies to control for these possible problems. In the first case, we attempt to address the problem of an unobservable 'complainer' type by exploiting the fact that respondents listed complaints not just about noise, but also about (unrelated to noise) air pollution, green space and water quality. Those respondents who list 'many' or 'very many' complaints about *all three* of these factors are designated as 'complainers'. The **complainer** dummy variable will thus capture the overall lower level of happiness of especially whiny respondents.

To address the problem of unobservable effort in the estimate of the marginal utility of income we attempt to de-link income from effort by separately estimating a happiness regression for a sample of housewives only. As housewives' effort is arguably uncorrelated to household income, this should produce more accurate estimates of the coefficient on income. Using a sample of housewives may also address the possible first-order endogeneity problem that happier people, for a variety of reasons, may command higher incomes¹⁰.

Two possible issues remain that could effect our estimates of β_2 , but these arguably work in opposite directions and thus may partially cancel each other out. Self-selection of imperturbable people towards noisier areas will tend to downward bias our estimate of the costs of noise compared to one that measures the impact of an exogenous noise shock. However, the inclusion of the 'complainer' dummy will capture the average lower happiness of *both* complainers as well as those

⁹ However, unobserved preference heterogeneity by itself is not a problem here. For example, 'perturbable' people may both report more noise and lower happiness, but as long as the lower happiness is due to the fact that they are more perturbed by noise, then as long as we are consistent in interpreting our results as the effect on happiness of perceived noise (not actual noise), our results will not be biased and will in fact capture the overall *average* impact on happiness of the noise that is actually out there on the actual distribution of perturbable and imperturbable people, whatever that may be.

¹⁰ However there could still be a problem if happier women marry richer men, but we consider this possibility to be a second-order issue compared to the happiness-income link.

unfortunates with *legitimate* reasons to complain, thus over-estimating the effect of being whiny but leading to under-estimates of the happiness cost of noise complaints.

Finally, we must settle on a method of estimation. As the dependent variable, a reported level of happiness, is a reported rank from 1 to 10, a common estimator used in the literature is an ordered probit (O-probit). However the EQLS survey asked (in identical fashion) respondents to rank their happiness levels from 1 to 10 *twice* during the course of the survey, presumably for strategic reasons. Thus we have two highly correlated, but often non-identical, happiness rankings for each individual. Averaging these two responses should give us a more robust measure, but it also results in a variable with 19 possible values rather than 10. Thus it was not obvious whether ordered probit or simple OLS would be more suitable.

To further investigate we ran a number of basic happiness regressions using all three measures of happiness and both O-probit and OLS regressions. Results were quantitatively and qualitatively extremely similar regardless of whether we used the first happiness measure, the second happiness measure or the average of the two. They were also similarly comparable whether we used an O-probit or an OLS estimator. Furthermore, we found that the proportional log ratios assumption was rejected for the O-probit specification. One solution is to use a generalized ordered logit (GO-logit) instead, but we found that the GO-logit approach became extremely difficult to estimate and complex to interpret with so many possible outcomes.

Other studies have also examined the question of the most appropriate estimation method for the typical (ranking from 1-10) happiness data. Lu (1999) examines the question of using O-logit or OLS specification in the context of ordered residential satisfaction data. Although he finds the former preferable on first principles, in practice Lu also finds the results derived from the two approaches are the same. Thus our preferred estimation approach is to use the more robust average of the two happiness measures as the dependent variable with a robust OLS estimator¹¹.

4. Results

4a. Estimating happiness regressions

Table 1 presents the results from our 3 baseline happiness regressions. All regressions control for country fixed effects (not reported) and report robust standard errors in parentheses. We follow the happiness literature for guidance on our basic set of control variables, X, and their choice is intuitive (a list of all control variables and definitions is included in the appendix).

Column (1) presents the baseline, classic happiness regression. We include the variable *hours* to try to capture some of the 'effort' required to earn an income. However, this variable is not statistically significant and as its inclusion severely restricts the sample size, it is dropped from all further regressions.

¹¹ As mentioned above, none of our results seem at all sensitive to this choice.

The signs of all other variables are intuitive and we replicate several interesting patterns reported in the literature. In particular, we find a very strong and extremely significant happiness effect of income: richer people are happier, although there is a diminishing marginal impact as income increases.

Figure 1 presents the estimated relationship between happiness and income from our analysis. A striking feature of this curve is the very steep relationship between increasing income and increasing happiness at the lower ends of the socio-economic scale, with a significant flattening out at relatively moderate income levels. This sharply diminishing marginal utility of income could derive either from true declining marginal utility of money, some natural upper bounds on human life satisfaction, or be at least partially an artefact of the boundedness of the happiness rankings and the method of estimation¹².

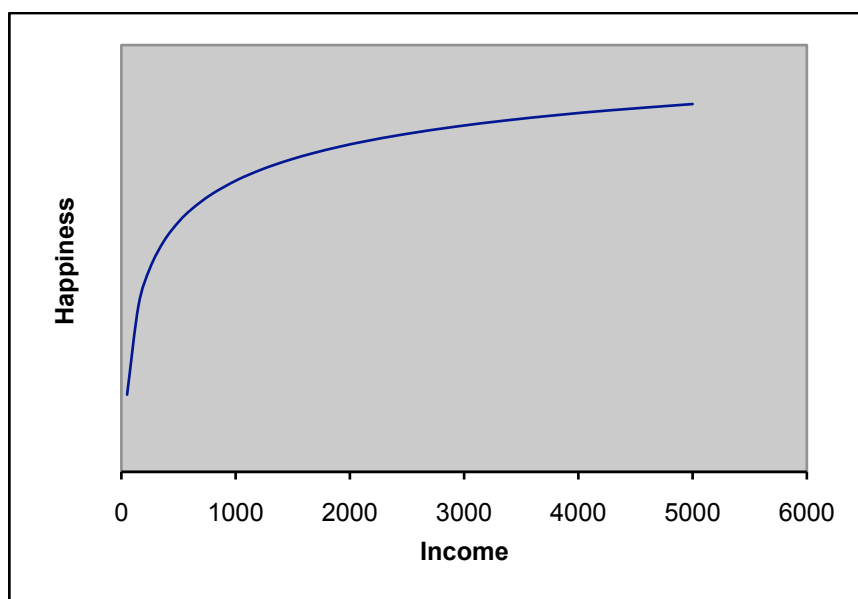


Figure 1: the estimated conditional relationship between household monthly income (€) and life satisfaction.

Besides the econometric concerns discussed above, there are several additional caveats associated with the estimates of the effect of income on happiness. First, this is a cross sectional relationship – that a rich person is happier than a poor person does not automatically imply that the poor person would be made equally happy if they too were as rich. For example, it could be that what really matters is *relative* wealth. In fact, it is much harder to detect an effect of increasing income on happiness in a time series analysis (the famous Easterlin Paradox¹³), although recently Stevenson and Wolfers (2008) present evidence that there is indeed such an effect.

¹² Perhaps a result of either endogeneity or omitted variable bias discussed above, which are only addressed later in regressions 7 and 9 from table 3. For example, if higher income jobs require proportionally more effort this could bias the coefficient downwards as income increases.

¹³ See Easterlin (1974), Stevenson and Wolfers (2008)

A further caveat is that we have data only on total household income, measured relatively roughly. If measurement error is significant, this could bias our estimates downward. Furthermore, household income may not be the correct measure of income in any case when it comes to considering compensating differentials. For example it is arguably plausible that it is individual *disposable* income that is more important. For both these and the reasons cited above, we will want to treat our marginal utility of income estimates with caution and compare them against estimates derived from other data sets and with other methodologies.

Fortunately other studies have also estimated the marginal utility of income and provide a good point of comparison. In particular, Layard *et al.* (2008) also analyze the EQLS, as well as seven other 'happiness' datasets, in order to estimate an elasticity of marginal utility with respect to income, which they denote ρ . Given the focus of their research, in order to focus on 'permanent income' they restrict their analysis to those between the age of 30 and 55, and delete the top and bottom 5% of outliers. Despite the difference in the samples, as with our analysis, Layard *et al.* find that both \log_income and (\log_income) squared have explanatory power¹⁴, and thus reject the hypothesis that happiness depends only linearly on the log of income (i.e. $\rho=1$). Layard *et al.* go on then to estimate ρ using maximum likelihood, and their results suggest values of ρ that are reassuringly similar across countries and time and fall into the region of 1.19-1.34 with an overall average of 1.26. Although we do not directly estimate ρ ourselves, we can use these Layard *et al.* results to compare against our own direct utility-compensating estimates as a robustness check (see discussion below and table 4).

Another interesting relationship that has drawn some attention recently is the correlation between happiness and age. Thus, following some recent research (see, for example, Yang Yang (2008), Oswald and Blanchflower (2008)), we also control for age, age-squared and age-cubed. Mirroring the findings of others, we find a striking dip in happiness around middle age, which then heads upwards again as people age further¹⁵. This relationship holds true controlling for health, income, marital status, country of residence, etc. and has received quite a bit of interest from sociologists, psychologists and economists in the last year. Figure 2 illustrates this estimated cubic inverted-U relationship from our baseline regression.

¹⁴ Although Layard *et al.* (2008) find a much less significant coefficient on the squared log of income for the EQLS data, which is probably due to their much narrower data set.

¹⁵ Thank goodness.

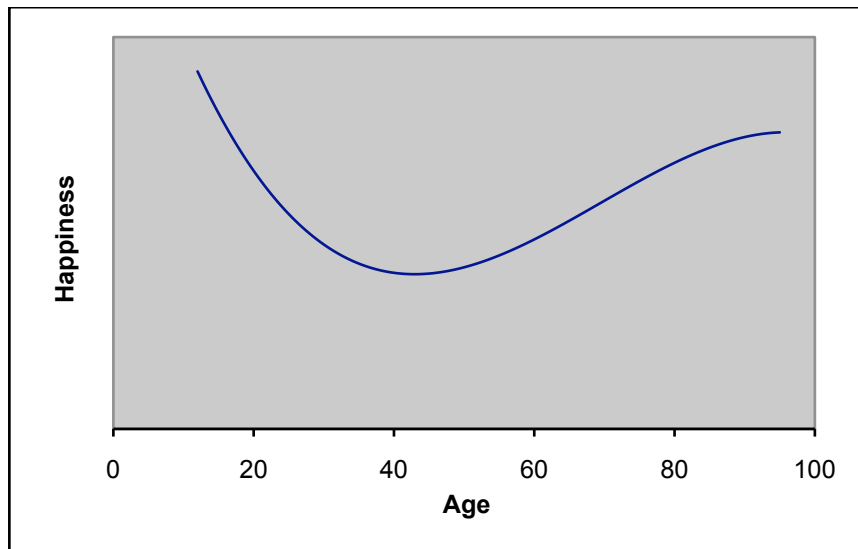


Figure 2: the estimated conditional relationship between reported life satisfaction and age

In Column (3) we introduce our noise variable, *noise*, to the baseline regression. Respondents who report ‘very many’ or ‘many’ reasons to complain about noise in the area where they live are much less happy than others, and this is highly statistically significant. The coefficient estimate of -0.260 is similar in magnitude to reported effects of noise on housing satisfaction by Diaz-Serrano (2006)¹⁶, and approximately of the same order of magnitude as the coefficient on being disabled (≈ 0.30).

Finally, it is interesting to note that in regressions (1) and (2) *Urban* is negative and significant. However, once we control for noise pollution in regression (3), the significance of this variable disappears. Thus it seems that a primary disutility of living in urban areas comes from noise pollution – and in fact people are indifferent between rural and urban areas once noise is taken into account.

In table 2 we further explore the robustness of the estimate of the coefficient on *noise*. To control for the possibility that some people may complain more about everything and also be less happy, in column (4) we include our variable *complainer*. As expected, complainer is negatively related to happiness and is highly statistically significant. The inclusion of complainer also lowers our estimate of the effect of *noise*, to -0.215.

In column (5) we parse out our *noise* variable into its component parts: *noise1* corresponds to ‘very many’ noise complaints, *noise2* ‘many’, and *noise3* denotes only

¹⁶ Diaz-Serrano reports 12 country-specific regressions explaining ‘satisfaction with housing’ (also ranked from 1-10) from the European Community Household Panel from 1994-2001, split between owners and renters, for a total of 24 regressions. Coefficient estimates on ‘neighborhood noise’ ranged from a highly significant -0.348 (renters in the UK) to an insignificant -0.004 (owners in Italy). The overall (unweighted) average ‘noisy neighborhood’ coefficient is -0.182. Excluding the apparently imperturbable countries of Ireland and Italy, where noise is not statistically significant, yields an estimate of -0.219.

'a few' complaints (the excluded category is 'no complaints'). As expected, the coefficients on the three variables declines monotonically from -0.329 (worse than being disabled!) for the most noise to -0.230 for relatively fewer complaints (the omitted category is 'no complaints').

In column (6) of table 2 we consider whether our noise variable could be proxying for other characteristics of the respondent's dwelling. For example, poorly constructed housing can lack acoustic insulation, causing more noise complaints, as well as decrease happiness more directly. Thus in regression (6) we control for the state of the dwelling: whether it is considered too small, how high the density (family size/number of rooms) is, whether it is in bad shape (with rot or no indoor plumbing), and whether the respondent owns the property, privately rents or lives in public housing. Once we have controlled for all these housing factors, the magnitude of the coefficient estimate on *noise* falls to -0.158, but is still negative and highly statistically significant.

4b. Utility compensating income estimates

We have found noise pollution to have a relatively large and statistically significantly negative effect on life satisfaction. However we would also like to calculate the monetary equivalent impact: by how much would income have to increase to compensate for the negative effect on happiness that noise pollution creates? To generate estimates of the happiness-compensating money (income) value of noise pollution, it is essential to generate estimates of the marginal happiness of income. However, as discussed above, these estimates can be difficult. In particular there are two primary problems that we will address in this analysis. First, if happier people command higher incomes there will be endogeneity bias. Second, if we fail to control for the (happiness reducing) effort required to earn that income, we will understate the true happiness benefit of extra income.

In table 3 we address both these problems by re-estimating our baseline happiness regression in a sample of housewives. As discussed above, housewives' effort level is arguably uncorrelated with household income. Furthermore, by de-linking the respondent from the source of the income, we also address the first-order endogeneity of happiness and income. Figure 3 graphically represents the income-happiness relationship based on this restricted sample.

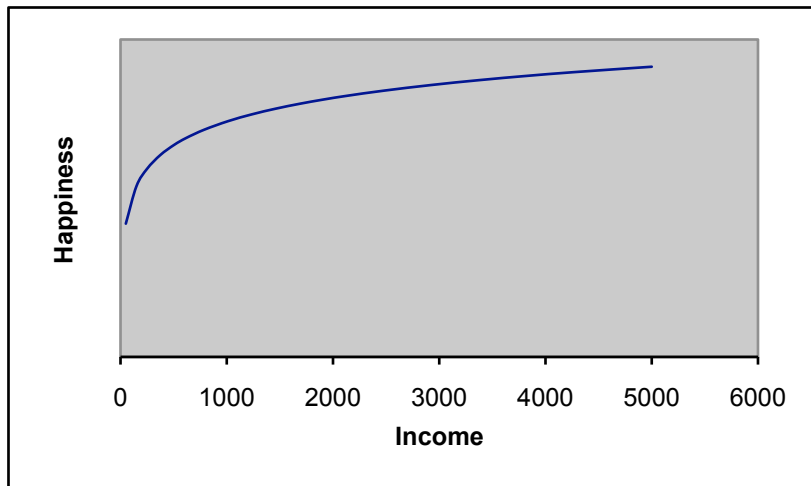


Figure 3: The relationship between income and happiness in housewife-only sample.

In column (7) of table 3 we reproduce our baseline regression in the housewife-only sample. The sample size is greatly reduced, but still sizable at 1815. We find that squared (log income) is not statistically significant, so the variable is dropped. In regressions (8) and (9) we directly compare our baseline regression using only **Log of Income** from the whole sample and housewife-only sample. As predicted, the coefficient on the **Log of Income** increases significantly for the housewife sample, from 0.375 to 0.483.

From equation (5) we can derive the increase in income required to compensate for a loss of happiness due to noise pollution. We take our estimate of $\hat{\beta}_1$ from regression (9), 0.483. For $\hat{\beta}_2$ we adopt the most conservative of our estimates, -0.158, from regression (6). Table 4 presents the required compensatory income for each of the 19 income levels in the EQLS survey. The amount varies from €16/month for the lowest income bracket, up to €1636 for the top group.

There are several interesting points to note. First, the general relationship outlined in table 4 is not overly sensitive to the choice of functional form for the happiness-income parameterization. In separate robustness checks using level income brackets (1-19), dividing the sample into three income groups, and allowing separate intercepts and slope coefficients for each, we found very similar results (not reported but available upon request).

Second, taking the compensation amounts presented in columns 3 and 4 of table 4 as the amount required to compensate for *noise pollution* assumes that a noisy environment reduces happiness in equal amounts for all income cohorts. For wealthy people, spending to reduce noise pollution is a good deal in happiness terms, so we would expect them to 'buy' themselves out of a lot of the noise (and other) problems that less wealthy individuals face. In fact, if we break up the noise variable, **noise**, by income bracket, we find that the wealthiest third do not suffer¹⁷ from noise (even if

¹⁷ The coefficient on **noisy** for the top 6 income brackets was -0.07 with a robust t-statistic of -1.01. Full results available upon request.

they complain about it), suggesting that what they consider to be 'noise' is not the same as it is for the lower income classes.

If we thus omit the top third of the income scale from consideration (they do not suffer from noise pollution!), we are still faced with relatively high compensation rates for the middle-income group. This of course is simply a direct result of the declining marginal returns to income reflected in the estimated happiness-income curve. However, it is probably politically, and possibly ethically, infeasible to consider making larger compensation payments to wealthier individuals for noise pollution (although this is routinely done in wrongful death cases, for different reasons). Thus on the basis of our results for the lowest third of income levels (taking the average of the six lowest brackets), given the estimates for the (conservative) utility costs of noise from regression (6) we adopt a very rough estimate of a monetary equivalent cost of relatively severe noise pollution to be on the order of €106 per month for a household.

Finally, as we have discussed above, Layard, Mayraz and Nickell (2008) calculate the elasticity of happiness with respect to income (ρ) for 8 different data sets, and column 4 of table 4 presents the implied compensation for each income bracket from their mean overall estimate of $\rho=1.26$. As is apparent, the Layard *et. al* estimates, which do not control for effort and are subject to endogeneity biases discussed above, are quite a bit higher than ours. This is to be expected as their estimate for the EQLS of $\rho=1.19$ was the lowest of all the datasets. However, estimates of the compensating income required at $\rho=1.19$ are still higher than ours. This in turn suggests that omitted variable bias from unobservable effort, as well as possibly endogeneity, may account for some of the difference¹⁸.

5. Discussion

This paper presents a simple empirical exercise to raise awareness of a single point: noise pollution can have a serious detrimental affect on people's life satisfaction. As urbanization rates increase dramatically around the globe and high housing costs compel people to live in ever closer quarters, overall welfare will suffer if builders and policy makers do not pay sufficient attention to acoustic insulation of dwellings. However, noise pollution is often an externality and not easily priced in the market, leaving it to be easily under-considered in the planning process. We approach the problem of quantifying the lost utility of noise by examining a series of 'happiness regressions' in which we use a range of socio-economic data to explain respondent's declared level of life satisfaction on a scale from 1 to 10. In the process we replicate the observed patterns from other studies of this type and find that noise complaints significantly decrease declared levels of life satisfaction.

In the process of estimating our happiness regressions we address several major problems with previous attempts to use this kind of data to evaluate monetary costs of non-market phenomena. First, previous analyses have failed to control for the

¹⁸ Layard *et. al* also restrict the sample to people between 30 and 55 years old and omit the top and bottom 5% of outliers.

possibility that an unobservable characteristic (which we denote 'complainer type') may lead people both to complain more and cause them to be less happy. Second, estimates of the marginal utility of income may suffer from endogeneity and will be under-estimated if 'effort' is not adequately controlled for. By including a dummy variable for 'complainers' and estimating the marginal utility of income on a sample of housewives, we make some progress in addressing both of these problems. Furthermore, while a number of other studies have used hedonic methods to monetize the costs of traffic and airport noise (which are substantial), this paper makes a stab at monetizing the costs of everyday neighbourhood noise of *all* types (even imaginary noise!).

Consistent with the literature, we find a substantial decline in the marginal impact of income on happiness at very moderate levels of income, even after attempting to control for omitted variables and endogeneity. While this could be a true reflection of people's underlying preferences, it may also be due to estimation bias or be an artefact of the bounded nature of the happiness rankings themselves. At any rate, taken at face value a low elasticity of happiness with respect to income automatically implies that quite large monetary transfers must be made to compensate a given fall in 'happiness,' leading to infeasible estimates of the value of noise abatement for higher income individuals.

However our results also suggest that higher income households make those trade-offs they see as worthwhile and 'buy' themselves out of serious noise problems¹⁹. Among the wealthiest cohort of our sample, even those having 'many' or 'very many' reasons to complain about noise did not experience lower happiness by a statistically significant amount as a result, suggesting that their perception of noise is quite different from those with less income.

In the end, we adopt the estimates from the bottom third income cohort of the sample. For this group, we estimate that the monetary equivalent of relatively severe noise pollution would be on average about €106 per month per household. Clearly these are large costs, which, if taken at face value, can easily justify significant investment in noise abatement policies and infrastructure.

How do our estimates of the costs of noise compare with those generated using other methods? Van Praag and Baarsma (2005) find that an Amsterdam-area household with monthly income of €1500 would require (monthly) compensation of €57 for an increase in aircraft noise from 20 to 40 *Ku*. As mentioned earlier, Nelson (2004) finds a US\$200,000 house would sell for \$20,000 to \$24,000 less if exposed to airplane noise. \$24,000 amortized over 20 years at 4% comes to about \$145/month. Galilea and Ortuzar (2005) use a stated preference approach and find a (conservative) estimate of willingness-to-pay (WTP) of US\$2.12 per decibel (dB(A)) per month. Double glazing reduces noise levels by approximately 30 dB(A), so their results suggest a WTP of \$64/month to reduce noise to a degree equivalent to that achieved by double glazing.

¹⁹ This strategy turns out to be much more difficult in extraordinarily expensive cities, such as central London.

It is difficult to see how to directly compare these disparate estimates, but the general order of magnitude does not seem too out of line. Our estimates are a bit higher, but other studies have focussed on single sources of noise, whereas here we attempt to capture the effect of *all* sources of irritating neighbourhood noise. Furthermore, psychological studies suggest that people often under-predict how unhappy a future bad event will make them (see Gilbert (2006)), suggesting that the WTP estimates be considered lower bounds²⁰. In sum, then, our primary conclusion is that noise pollution seems to be a cause of significant personal dissatisfaction (especially in urban areas) and that this disutility is not wholly immune from quantification. Clearly, more research would be welcome.

²⁰ Many thanks to Guy Mayraz who helpfully pointed this out.

Tables Appendix

Table 1: Happiness OLS Regressions

	(1) LHS=Happy	(2) LHS=Happy	(3) LHS=Happy
Noise			-0.260*** (0.032)
Log income	0.661*** (0.111)	0.727*** (0.103)	0.736*** (0.103)
(Log income) ²	-0.023*** (0.009)	-0.028*** (0.008)	-0.029*** (0.008)
Sex	-0.136*** (0.025)	-0.130*** (0.024)	-0.129*** (0.024)
Age	-0.125*** (0.020)	-0.120*** (0.018)	-0.118*** (0.018)
Age ²	0.002*** (0.000)	0.002*** (0.000)	0.002*** (0.000)
Age ³	-0.000*** (0.000)	-0.000*** (0.000)	-0.000*** (0.000)
Family size	-0.027** (0.012)	-0.029*** (0.011)	-0.029*** (0.011)
Got kid	0.080** (0.039)	0.079** (0.037)	0.076** (0.037)
Married	0.573*** (0.036)	0.577*** (0.034)	0.576*** (0.034)
Single	0.138*** (0.052)	0.154*** (0.050)	0.151*** (0.049)
Urban	-0.045* (0.025)	-0.047** (0.024)	-0.020 (0.024)
University	0.220*** (0.031)	0.218*** (0.030)	0.217*** (0.030)
Employed	0.083 (0.103)	-0.139* (0.084)	-0.138* (0.083)
Unemployed	-0.609*** (0.116)	-0.790*** (0.097)	-0.787*** (0.096)
In school	-0.038 (0.101)	0.020 (0.085)	0.021 (0.085)
Retired	0.162 (0.111)	0.002 (0.092)	0.005 (0.092)
Housewife	0.077 (0.118)	-0.116 (0.094)	-0.108 (0.094)
Disabled	-0.108 (0.144)	-0.320** (0.126)	-0.318** (0.126)
Healthy	0.744*** (0.031)	0.801*** (0.030)	0.794*** (0.030)
Unhealthy	-0.882*** (0.053)	-0.880*** (0.049)	-0.872*** (0.049)
Hours	0.005 (0.009)		
Constant	5.385*** (0.481)	5.292*** (0.432)	5.273*** (0.432)
Country Fixed Effects	yes	yes	yes
Observations	17119	20113	20113
R-squared	0.352	0.346	0.349

Note: Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 2: Estimating the happiness cost of noise pollution

	(4) LHS= Happy	(5) LHS= Happy	(6) LHS= Happy
Noise	-0.215*** (0.034)		-0.158*** (0.033)
Complainer	-0.280*** (0.061)	-0.263*** (0.061)	-0.236*** (0.061)
Noise1		-0.329*** (0.052)	
Noise2		-0.283*** (0.041)	
Noise3		-0.230*** (0.026)	
Small			-0.198*** (0.031)
Bad shape			-0.384*** (0.029)
Density			-0.179*** (0.031)
Owner occupied			0.080 (0.052)
Rent private			-0.147** (0.060)
Rent public			-0.015 (0.060)
Log income	0.741*** (0.102)	0.756*** (0.102)	0.709*** (0.102)
(Log income) ²	-0.030*** (0.008)	-0.031*** (0.008)	-0.033*** (0.008)
Constant	5.263*** (0.431)	5.276*** (0.431)	5.750*** (0.430)
Country Fixed Effects	yes	yes	Yes
Observations	20113	20113	20016
R-squared	0.349	0.352	0.364

Note:

- Robust standard errors in parentheses
- *** p<0.01, ** p<0.05, * p<0.1
- All regressions additionally control for Sex, Age, Age², Age³, Family size, Got kid, Married, Single, Urban, Employed, Unemployed, In school, Retired, Housewife, Disabled, Healthy, Unhealthy (not reported)

Table 3: Estimating the marginal happiness of income using Housewives

	(7) Housewives Only Sample LHS = Happy	(8) Whole sample LHS = Happy	(9) Housewives Only Sample LHS = Happy
Log Income	0.944** (0.405)	0.375*** (0.018)	0.483*** (0.066)
(Log Income) ²	-0.037 (0.031)		
Complainer	-0.144 (0.181)	-0.388*** (0.059)	-0.133 (0.181)
Sex	0.020 (0.263)	-0.130*** (0.024)	0.016 (0.264)
Age	0.053 (0.068)	-0.119*** (0.018)	0.056 (0.068)
Age ²	-0.001 (0.001)	0.002*** (0.000)	-0.001 (0.001)
Age ³	0.000 (0.000)	-0.000*** (0.000)	0.000 (0.000)
Family size	-0.112*** (0.035)	-0.032*** (0.011)	-0.114*** (0.035)
Got kid	-0.285* (0.170)	0.087** (0.037)	-0.276 (0.170)
Married	0.775*** (0.139)	0.577*** (0.034)	0.765*** (0.140)
Single	-0.233 (0.276)	0.159*** (0.049)	-0.213 (0.275)
Urban	-0.147* (0.088)	-0.028 (0.024)	-0.141 (0.088)
University	-0.045 (0.133)	0.209*** (0.030)	-0.056 (0.133)
Disabled	0.000 (0.000)	-0.316** (0.126)	0.000 (0.000)
Healthy	0.974*** (0.103)	0.795*** (0.030)	0.970*** (0.103)
Unhealthy	-0.708*** (0.191)	-0.892*** (0.048)	-0.717*** (0.191)
Constant	1.986 (1.698)	6.335*** (0.304)	3.320*** (1.138)
Country Fixed Effects	yes	yes	yes
Observations	1815	20113	1815
R-squared	0.294	0.347	0.293

Note:

- Robust standard errors in parentheses
- *** p<0.01, ** p<0.05, * p<0.1
- Regression 8 additionally controls for employed, unemployed, Inschool, retired, housewife (not reported)

Table 4: Utility compensating income transfers

Mean monthly household income (€)	Slope of the happiness-income curve (dH/di) from Housewives Only Sample	Necessary income transfer to compensate for 0.158 happiness units (€/month)	Layard et. al. (2008) estimate of compensation for $\rho=1.26$ (€/month)
50	0.00966	16	22
150	0.00322	49	87
250	0.00193	82	166
375	0.00129	123	277
505	0.00096	165	403
617	0.00078	202	518
787	0.00061	257	704
1012	0.00048	331	966
1237	0.00039	405	1245
1462	0.00033	478	1536
1687	0.00029	552	1840
1912	0.00025	625	2154
2137	0.00023	699	2479
2475	0.00020	810	2982
2925	0.00017	957	3681
3375	0.00014	1104	4408
3825	0.00013	1251	5161
4274	0.00011	1398	5936
5000	0.00010	1636	7234

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Data Appendix

Table A1: The EQLS variables used in the analysis

Variable Name	Variable Definition
Happy	The average of the two responses ranking overall life satisfaction on a scale from 1-10
Noise	Respondant has 'many' or 'very many' reasons to complain about noise in the area where the respondent lives
Noise1	there are 'very many' reasons to complain about noise
Noise2	there are 'many' reasons to complain about noise
Noise3	there are 'a few' reasons to complain about noise
Complainer	Respondent has 'many' or 'very many' reasons to complain about air quality <i>AND</i> availability of green space <i>AND</i> water quality
Sex	Sex=1 if respondent is male
Age	Age of the respondent
Income	Net household monthly income bracket (see table A2)
Hours	Number of hours worked per week
Family size	Household size
Got kid	Respondent has at least one child
Married	Respondent is married
Single	Respondent is single
University	Highest level of education attained is university
Employed	Respondent is employed
Unemployed	Respondent is unemployed
In school	Respondent is currently in education
Retired	Respondent is retired
Housewife	Respondent is a housewife
Disabled	Respondent is classified as disabled
Healthy	Respondent reports health to be excellent, very good, or good
Unhealthy	Respondent reports health as poor
Urban	Respondent lives in a city, city suburb, or a medium to large town
Small	Respondent's dwelling is short on space
Bad shape	Respondent's dwelling has rot in windows, doors or floors, damp or leaks, or lack of indoor flushing toilet
Density	Density = family size / number of rooms
Owner occupier	Respondent is an owner-occupier of dwelling
Rent private	Respondent is a private renter of dwelling
Rent public	Respondent rents from the state (i.e. public housing)

Excluded categories include:

- Employment status: Other
- Marital status: Divorced or Widowed, don't know/no answer
- Ownership status: accommodation is provided free, Other, Don't Know
- Health: 'health is fair' and 'don't know'
- Education: highest level of education attained is primary or secondary

Appendix (cont.)

Table A2: Income brackets

Income is net monthly household income, divided into 19 non-uniform brackets:

<u>Value</u>	<u>Income bracket</u>
1	Less than 100 euro
2	100 to 199 euro
3	200 to 299 euro
4	300 to 449 euro
5	450 to 559 euro
6	560 to 674 euro
7	675 to 899 euro
8	900 to 1124 euro
9	1125 to 1349 euro
10	1350 to 1574 euro
11	1575 to 1799 euro
12	1800 to 2024 euro
13	2025 to 2249 euro
14	2250 to 2699 euro
15	2700 to 3149 euro
16	3150 to 3599 euro
17	3600 to 4049 euro
18	4050 to 4499 euro
19	4500 euro or more

Table A3: Countries in EQLS Sample

Austria	Italy
Belgium	Latvia
Bulgaria	Lithuania
Cyprus	Luxembourg
Czech Republic	Malta
Denmark	Netherlands
Estonia	Poland
Finland	Romania
France	Slovakia
Germany	Slovenia
UK	Spain
Greece	Sweden
Hungary	Turkey
Ireland	Portugal