Local Environmental Quality and Life-Satisfaction in Germany

Katrin Rehdanz[a], and David Maddison[b]*

[a] *Research Unit Sustainability and Global Change, Hamburg University and Centre for Marine and Atmospheric Science, Hamburg, Germany*
[b] *Department of Economics, University of Birmingham, Birmingham, UK*

* Corresponding author: ZMAW, Bundesstrasse 55, 20146 Hamburg, Germany, katrin.rehdanz@zmaw.de

September 22, 2006

Working Paper FNU-119

Abstract

Hitherto the task of valuing differences in environmental quality arising from air pollution and noise nuisance has been carried out mainly by using the hedonic price technique. This paper proposes a different approach to deriving information on individual preferences for local environmental quality. It analyses data drawn from the German socio economic panel in an attempt to explain differences in self-reported levels of well-being in terms of environmental quality. Mindful of existing research a large number of other explanatory variables are included to control for socio-demographic differences, economic circumstances as well as neighbourhood characteristics. Differences in local air quality and noise levels are measured by how much an individual feels affected by air pollution or noise exposure in their residential area. The evidence suggests that even when controlling for a range of other factors higher local air pollution and noise levels significantly diminish subjective well-being. But interestingly differences in perceived air and noise pollution are not capitalised into differences in house prices.

Keywords: air pollution, environmental quality, Germany, life-satisfaction, noise exposure, well-being

JEL Classification: R19, Q53, Q58

1 Introduction

In most developed countries standards for air pollution and noise exposure are an important part of environmental policy to improve local environmental quality. Often these standards are based on expert judgements and do not take into account peoples preferences. Although improvements in air quality or reductions in transportation noise are beneficial, they are nevertheless costly. As this money could be spent elsewhere in an economy, information on the social benefits are needed prior to implementing such standards.

Two valuation techniques have typically been used to derive the welfare benefits from reduced air pollution or noise nuisance. The hedonic price approach relies on data from the housing market while the contingent valuation method derives values by asking people directly about their willingness to pay.

The contingent valuation method is often criticized because of the difficulties related to the construction of a market and its numerous potential biases (see Mitchell and Carson, 1989 or Bateman et al., 2002, for a more recent overview of the method). The majority of studies apply the hedonic price approach to measure the benefits of air quality improvements or to value noise (see Freeman, 2003, for an overview of the method).

All hedonic studies assume that the ability of households to relocate eliminates the net benefits of different locations whilst simultaneously giving rise to compensating house price and in some cases, wage rate differentials.[1] This requires the existence of perfect information, zero moving and transaction costs, as well as perfectly flexible prices. That these assumptions are more realistic for some countries than others is obvious. Perhaps it is not therefore very surprising that most of what is known about societal willingness to pay for improvements in air quality or reductions in noise nuisance comes from hedonic studies carried out in the United States or the United Kingdom. For Germany only one early hedonic study exists.[2] Holm-Müller et al. (1991) analyse data on (self-reported levels of) noise exposure for three cities in Germany (Bielefeld, Bremen and Wuppertal) and find no significant effect of road traffic noise on property prices. For overviews of the empirical literature see Smith and Huang (1995) for air pollution studies and Nelson (2004) for noise pollution studies linked to airports.

This paper proposes a different approach to valuing air and noise pollution using data on subjective well-being (SWB). More specifically, the paper considers the link between perceived levels of noise and air pollution and self reported happiness using individual-level data. We further test the stability of these regressions over both time and space and in addition test the extent to which any welfare impacts caused by noise nuisance and air pollution are also capitalised into hedonic house price regressions.

The remainder of the paper is structured as follows. Section two presents an overview of the economic research into the determinants of happiness focussing in particular on those few studies that have attempted to link happiness with environmental quality. Section three presents the analytical framework underlying the alternative approaches. Section four describes data sources and section five the empirical implementation. Section six discusses the results and the final section concludes.

---

[1] It is difficult to see how highly localised environmental goods such as air quality and noise nuisance can give rise to compensating wage differentials. For a theoretical model in which environmental quality can be capitalised into both house prices and wage rates see Roback (1982).
[2] Three contingent valuation studies exist; Schulz (1985), Holm-Müller et al. (1991) and Weinberger et al., 1991). Schulz (1985) values improvements of air quality in Berlin. Weinberger et al. (1991) analyse noise exposure and Holm-Müller et al. (1991) study a variety of issues including air and water quality, noise exposure, amenity areas.

2 Literature review

One strand of economics is based on analysing people's decisions revealed through their market behaviour. Investigating, e.g., people's choices on the property market, should reveal their preferences for locations including environmental amenities as well as property characteristics. The hedonic price method takes advantage of this kind of information. However, an alternative is to focus on "experienced" utility, stressing the pleasure of consumption, as provided by survey measures of happiness of life-satisfaction.

Research into the determinants of happiness or life-satisfaction was for a long time solely the domain of psychologists and sociologists. In recent years however, it has become increasingly accepted into welfare economics. Today there is the general belief that data on subjective well-being are valid and can be used for formal analyses (Di Tella et al., 2003). Empirical work has furthermore shown that happiness is not a purely personal issue, but that economic conditions like income, unemployment and inflation also have a strong impact on people's subjective well-being (see e.g. Clark and Oswald, 1994; Di Tella et al., 2001; Easterlin, 2001). See, for example, Frey and Stutzer (2002) for a review of the literature.

A handful of studies also attempt to explain differences in SWB as a function of ambient environmental quality. Air pollution was found to reduce happiness in a study using country level data (Welsch, 2002 and 2006). Rehdanz and Maddison (2005) also found climate variables to have a highly significant effect on average self-reported levels of happiness. Van Praag and Baarsma (2005) studied the area around Amsterdam Airport and found exposure to aircraft noise to reduce SWB to a significant extent. Presenting a slightly different type of analysis, Ferrer-i-Carbonell and Gowdy (forthcoming) analyse the relationship between subjective measures of well-being and environmental attitudes.

3 Analytical framework

In the hedonic framework house prices and the levels of environmental attributes are endogenous to the household. The household maximises utility which is a function of the quantity of some composite good and the level of the environmental attribute. This maximisation process is subject to a budget constraint linking household income, expenditure on the composite commodity and expenditure on housing which is itself a function of the level of the environmental attribute.

The household's marginal willingness to pay is revealed by the household's position on the implicit price schedule which plots the gradient of the hedonic price function with respect to the level of the amenity (Rosen, 1974). In the hedonic model calculating the value of non-marginal changes is more involved since the inverse demand function for the environmental amenity is not identified unless the households are observed under different supply and demand conditions.

In the alternative approach presented in this paper the indirect utility function is estimated directly and all prices and levels of environmental attributes are taken as exogenous. In this framework marginal willingness to pay for the environmental attribute is given by the derivative of the indirect utility function with respect to the level of the environmental attribute divided by the derivative of the indirect utility function with respect to income. And unlike with the hedonic approach calculating the value of non-marginal changes in level of the environmental amenity is straightforward.

Which of these alternative frameworks yields the most reliable estimate of the value of environmental amenities? Van Praag and Baarsma (op cit) argue that in the event that both of these approaches yield statistically significant implicit values these benefits should be added

together. Unfortunately it is not straightforward given that hedonic analyses consider the marginal willingness to pay of the household and studies of SWB are undertaken at the level of the individual. It turns out that only one of these approaches yields a statistically significant role for environmental variables.

4 Empirical analysis

Most of the data used in this study is taken from the German Socio-Economic Panel (SOEP) survey. The SOEP is based on a set of pre-tested questionnaires for both households and individuals. Since 1984 the survey has provided annual information on housing, as well as on the occupation, employment history and earnings of individuals. It was extended to include former East Germany in 1990.

In addition to a stable set of core questions, each year the survey focuses on a special topic. In 1994, 1999, and 2004 the questionnaire asked for details of housing and neighbourhood characteristics including information on how strongly the respondent feels affected by air and noise pollution in their place of residence.

One feature of the survey is that the head of the household only answers the questions on housing and neighbourhood characteristics. The head of the household is defined as the person who knows best about the general conditions under which the household operates. However, the questions on air pollution and noise exposure are directed to the individual and should not be answered on behalf of other household members. Tables A1 and A2 in the appendix provide information on the distribution as well as the exact wording of the two questions.

In order to take advantage of this information the analysis relies exclusively on the surveys of 1994, 1999 and 2004 and on information the household head provided and excludes information provided by other household members. Taken together, our dataset contains a total number of about 23,000 observations.

Turning to the analysis of SWB first, SWB is measured on an integer scale of 0-10 with an average SWB of 6.79 for our sample (see Table A3 in the appendix for more detailed information). A feature of the survey is that people living in former East Germany tend to be less happy compared to those in West Germany. One explanation might be the lower income levels and the higher rate of unemployment in the East. Therefore, a dummy variable separating Germany into East and West is included.

Other explanatory variables, generally found significant in models explaining differences in SWB, are individual characteristics such as age, gender, employment status, education level, income, number of children, physical condition or living together with a partner. Note that the income data was adjusted for inflation using information on the consumer price indices (Statistisches Bundesamt, 2005).

In addition to the above, we include characteristics of the property the individual is living in (age of the building, type of building, condition of the property) as well neighbourhood characteristics to identify possible factors influencing air pollution or noise exposure. Dummy variables indicate whether the individual is living, for example, in a predominantly residential area, industrial or commercial area. Controls are also included for the size of the town or city as well the distance to the nearest large city or the closest transport link. To capture regional differences on a more disaggregated level dummy variables indicate in which of the Federal State the individual is living. Further dummy variables indicate whether observations are drawn from the 1994, 1999 or the 2004 survey.

Turning to the hedonic regression, the logarithm of monthly rental costs per square metre was regressed on a number of environmental characteristics including air pollution and noise exposure as well as neighbourhood characteristics and structural attributes of the property. Note that for owners the survey provides self-reported imputed rents rather than actual rents. For 2004 no information on rents for owners is provided. The hedonic analysis is, therefore, restricted to data from 1994 and 1999. Also, we excluded from our analysis households living in residential homes, student halls and hostels.

The same set of variables describing the environmental, property and neighbourhood characteristics are used in both the hedonic equations as well as in the equations explaining differences in SWB. In addition, the hedonic model controls for the year the household moved in, whether the house has heating, a garden, a balcony, is owner occupied or is a council house. All those variables are likely to have a significant influence on the rental rate. In line with the demands of theory individuals' socio-economic characteristics are excluded from the hedonic regression.

In order to account for the possible correlation of residuals when observations are taken from the same individual over the different years, the standard errors of both models were adjusted for clustering. The effect is to increase the standard errors of the parameter coefficients. This procedure also leads to robust variance estimates in the face of heteroscedasticity.

A list of variables contained in the dataset is presented in Table 1.

Table 1. Definition of variables included in the two regression models

Variable	Definition
AIR	Adversely affected by level of air pollution (1=not at all, 2=slightly, 3=bearable, 4=strongly,5=very strongly)
NOISE	Adversely affected by noise pollution (1=not at all, 2=slightly, 3=bearable, 4=strongly,5=very strongly)
AGE	Age of the individual
MALE	Unity if the individual is male, zero otherwise
INCOME	Household net income adjusted for inflation (in EURO)
EDUCATION	Institutional years necessary to receive the current degree of education
UNEMPL	Unity if individual is registered unemployed, zero otherwise
CHILDREN	Number of children living in household
DISABLED	Unity if individual is disabled, zero otherwise
HEALTH	Current health status (1=very good, 2=good, 3=satisfactory, 4=poor, 5=bad)
TOGETHER	Unity if individual lives together with a partner, zero otherwise
CONDITION	Condition of property (1=good, 2=needs renovation, 3=needs complete renovation, 4=ready for demolition)
WINDOW	Unity if the property got new windows last year, zero otherwise
AREA	Kind of residential area (1= mostly old houses (built before the war), 2= mostly newer houses, 3= residential and commercial area with flats, houses, shops and businesses, 4= commercial area (shops, banks, offices) with few flats, 5= industrial area with few flats, 6=else)
TYPE	Building type (1=agricultural building, 2=single or double house, 3=terrace house, 4=flat in building with 3 to 4 flats, 5=flat in building with 5 to 8 flats, 6=flat in building with 9 or more flats, 7=flat in high rise building or 8=else)
BUILT	Vintage class (1=before 1919, 2=1919-1948, 3=1949-1971, 4=1972-1980, 5=1981-1990, 6=1991 or later)

CITY	Distance to centre of the nearest city (1=property is in city centre, 2=less than 10 km, 3=10-25 km, 4=25-40 km, 5=40-60 km, 6=60km or more)
TRANSPORT	Walking distance to public transport stop (1=under 10 minutes, 2=10-20 minutes, 3=more than 20 minutes, 4=not in walking distance)
OWNER	Unity if property is owned, zero otherwise
SOCIAL	Unity if the property is a council house, zero otherwise
NO-HEATING	Unity if property has no central heating, zero otherwise
GARDEN	Unity if the property has a garden, zero otherwise
BALCONY	Unity if the property has a balcony, zero otherwise
MOVEIN	Year the household moved in
GGK	Community size (1=less than 2000, 2=2000-20000, 3=20000-100000, 4=100000-500000, 5=more than 500000 inhabitants)
STATE	Federal State (1=Schleswig-Holstein, 2=Hamburg, 3=Lower Saxony, 4=Bremen, 5=North Rhine-Westphalia, 6=Hesse, 7=Rhineland-Palatinate and Saarland, 8=Baden-Wuerttemberg, 9=Bavaria, 10=Berlin, 11=Brandenburg, 12=Mecklenburg Western-Pommerania, 13=Saxony, 14=Saxony-Anhalt, 15=Thuringia)
EAST	Unity if Federal State belongs to Eastern Germany (Berlin is matched to the West German sample), zero otherwise
2004	Unity if the observations are drawn from the 2004 survey, zero otherwise
1999	Unity if the observations are drawn from the 1999 survey, zero otherwise

Source: German socio-economic panel

5 Results

5.1 The SWB model

The SWB data are analysed using an ordered probit model and the results of different model specifications presented in Table 2. These indicate that when all the data is pooled together there is a clearly discernible effect of both perceived noise and air quality on SWB. Note that the inclusion of air and noise quality as categorical rather than continuous variables does not result in a statistically significant increase in fit.[3]

Analysing the data from each year separately does not yield markedly different results. Dividing the data according to whether households are located in former East or West Germany does not alter the regression coefficients either although the statistical significance of the results for former East Germany is much diminished. Therefore, we formally test whether the coefficients describing the impact of higher air pollution or noise exposure are homogenous across space and time. Results of these parameter homogeneity tests are presented in Table A4 in the appendix. The null hypothesis of parameter homogeneity is not rejected for air pollution. The variance weighted estimates are highly significant across space and time. For noise exposure the null hypothesis of parameter homogeneity over time is rejected on the five-percent level of significant. However, when steps are taken to test parameter homogeneity over time for smaller regions (East and West separately), the test is not rejected, but the coefficient is significant for Western Germany only (results are not shown).

---

[3] The $\chi^2(3)$ statistic of the Wald-test ranges from 2.75 (p=0.4311) to 6.83 (p=0.0775) for air pollution and from 0.32 (p=0.9553) to 4.56 (p=0.2066) for noise.

Consistent with earlier analyses we find an inverse U-shaped relationship with age and a diminishing marginal utility of money. Unemployed, sick and single individuals are significantly less happy than their counterparts. Individuals living in poor housing and, as indicated earlier, former East Germany are also less happy.

Table 2. Subjective well-being, noise and air quality

	ALL[a]	WEST[a]	EAST[a]	2004	1999	1994
	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient
AIR	-5.93E-02 ***	-5.07E-02 ***	-7.85E-02 ***	-5.00E-02 ***	-6.05E-02 ***	-7.32E-02 ***
NOISE	-3.42E-02 ***	-4.66E-02 ***	-6.41E-04	-6.69E-02 ***	-1.40E-02	-1.07E-02
AGE	-2.43E-02 ***	-1.85E-02 ***	-4.97E-02 ***	-3.10E-02 ***	-2.90E-02 ***	-1.70E-02 ***
AGE^2	3.36E-04 ***	2.74E-04 ***	6.03E-04 ***	3.97E-04 ***	3.81E-04 ***	2.73E-04 ***
MALE	-4.09E-02 **	-5.22E-02 ***	-2.40E-02	-3.02E-02	-9.37E-02 ***	-4.17E-02
INCOME	9.91E-05 ***	8.36E-05 ***	3.26E-04 ***	8.20E-05 ***	2.23E-04 ***	1.97E-04 ***
$INCOME^2$	-1.10E-09 ***	-9.06E-10 ***	-2.07E-08 ***	-8.89E-10 ***	-1.70E-08 ***	-1.19E-08 ***
EDUCATION	-1.93E-03	-2.73E-03	-1.46E-03	1.12E-02 ***	-6.99E-03	-1.97E-02 ***
UNEMPL	-5.03E-01 ***	-5.05E-01 ***	-4.36E-01 ***	-5.53E-01 ***	-4.40E-01 ***	-4.57E-01 ***
CHILDREN	-8.50E-02 ***	-8.46E-02 ***	-1.22E-01 ***	-1.11E-01 ***	-6.77E-02 **	-8.14E-02 ***
$CHILDREN^2$	1.85E-02 ***	1.81E-02 **	2.86E-02 *	3.31E-02 ***	5.45E-03	1.36E-02
DISABLED	-3.03E-02	-1.82E-02	-7.76E-02	-5.75E-02 *	-2.07E-02	1.95E-02
HEALTH	-5.35E-01 ***	-5.34E-01 ***	-5.37E-01 ***	-5.16E-01 ***	-5.59E-01 ***	-5.46E-01 ***
TOGETHER	1.93E-01 ***	2.11E-01 ***	8.67E-02 **	2.38E-01 ***	2.10E-01 ***	1.27E-01 ***
CONDITION	-1.52E-01 ***	-1.76E-01 ***	-8.77E-02 ***	-1.73E-01 ***	-1.40E-01 ***	-1.26E-01 ***
WINDOW	-1.42E-02	-8.01E-04	-1.26E-02	4.07E-02	2.64E-02	-8.33E-02
AREA1	5.82E-02	5.10E-02	-1.62E-02	1.37E-01	1.01E-01	1.09E-02
AREA2	5.54E-02	4.61E-02	-1.69E-04	1.16E-01	1.87E-01	-4.85E-02
AREA3	7.08E-02	6.75E-02	-1.12E-02	1.28E-01	1.80E-01	6.22E-03
AREA4	9.95E-02	9.26E-02	(dropped)	3.43E-01	3.44E-01	-2.86E-01
AREA5	-1.71E-01	-2.03E-01	-2.00E-01	-1.33E-01	-2.15E-01	-7.12E-02
TYPE1	-5.13E-02	-8.87E-02	2.71E-03	-5.00E-02	3.23E-01	-1.25E-01
TYPE2	7.91E-02	8.43E-02	7.23E-02	1.40E-01	3.35E-01	9.58E-03
TYPE3	6.49E-02	7.97E-02	1.38E-02	1.46E-01	2.95E-01	-1.78E-02
TYPE4	3.66E-03	1.86E-03	3.96E-02	8.33E-02	1.83E-01	-3.60E-02
TYPE5	-3.27E-02	-2.68E-02	-4.52E-02	5.93E-02	2.07E-01	-1.37E-01
TYPE6	-7.69E-02	-5.84E-02	-1.09E-01	4.76E-03	1.56E-01	-1.51E-01
TYPE7	-1.79E-02	-3.44E-02	(dropped)	-2.48E-02	1.21E-01	4.39E-02
BUILT	-1.58E-02 ***	-1.82E-02 ***	-1.77E-02	-9.31E-03	-3.31E-02 ***	-1.35E-02
CITY	1.04E-03	2.80E-03	-3.54E-03	3.17E-03	-3.88E-03	3.51E-03
TRANSPORT	-6.05E-02 ***	-3.56E-02 **	-1.34E-01 ***	-6.29E-02 ***	-7.10E-02 ***	-5.16E-02 *
GGK1	-7.60E-02 *	-1.25E-01 **	-1.96E-02	-6.44E-02	-8.86E-02	-6.21E-02
GGK2	-5.08E-02	-4.93E-02	-6.16E-02	-9.19E-02 *	-2.27E-02	-1.93E-02
GGK3	-4.08E-02	-4.73E-02	-2.00E-02	-8.02E-02 *	-4.52E-02	1.71E-02
GGK4	1.22E-04	-1.34E-02	2.49E-02	-2.15E-02	-2.87E-02	5.68E-02
STATE1	-1.27E-01	-1.34E-01	(dropped)	-1.83E-01	-2.70E-01	2.42E-02
STATE2	(dropped)	-1.57E-02	(dropped)	-1.46E-02	-6.32E-02	(dropped)
STATE3	-9.66E-02	-1.11E-01	(dropped)	-1.06E-01	-2.69E-01 *	4.09E-03
STATE4	9.85E-03	(dropped)	(dropped)	(dropped)	(dropped)	-1.36E-02
STATE5	-8.79E-02	-1.01E-01	(dropped)	-9.13E-02	-2.59E-01 *	-1.22E-02
STATE6	-9.88E-03	-2.67E-02	(dropped)	-8.33E-02	-1.52E-01	1.58E-01
STATE7	-4.04E-02	-4.92E-02	(dropped)	-1.06E-01	-1.31E-01	6.97E-02

STATE8	-1.39E-01 *	-1.51E-01	(dropped)	-1.44E-01	-3.29E-01 **	-4.48E-02
STATE9	-1.07E-01	-1.23E-01	(dropped)	-1.20E-01	-2.95E-01 *	4.53E-03
STATE10	-2.26E-01 ***	-2.41E-01 **	(dropped)	-2.74E-01 **	-2.54E-01	-2.04E-01
STATE11	8.21E-02	(dropped)	1.08E-01 *	7.36E-02	(dropped)	3.12E-02
STATE12	(dropped)	(dropped)	(dropped)	-1.22E-01 *	-7.46E-03	(dropped)
STATE13	4.58E-02	(dropped)	5.21E-02	(dropped)	-6.04E-02	3.23E-02
STATE14	-7.16E-02	(dropped)	-6.30E-02	-1.13E-01 *	-1.92E-01 **	-5.47E-02
STATE15	2.09E-02	(dropped)	3.10E-02	-8.17E-03	-5.51E-02	-1.63E-02
EAST	-3.83E-01 ***	(dropped)	(dropped)	-3.74E-01 ***	-3.96E-01 **	-3.02E-01 **
1999	2.19E-01 ***	1.92E-01 ***	3.03E-01 ***	(dropped)	(dropped)	(dropped)
1994	2.59E-01 ***	2.66E-01 ***	2.36E-01 ***	(dropped)	(dropped)	(dropped)
cut1	-5.02E+00	-4.86E+00	-5.21E+00	-5.00E+00	-5.11E+00	-5.14E+00
cut2	-4.77E+00	-4.63E+00	-4.91E+00	-4.75E+00	-4.86E+00	-4.90E+00
cut3	-4.34E+00	-4.22E+00	-4.42E+00	-4.29E+00	-4.45E+00	-4.48E+00
cut4	-3.85E+00	-3.75E+00	-3.89E+00	-3.79E+00	-3.99E+00	-3.99E+00
cut5	-3.50E+00	-3.41E+00	-3.50E+00	-3.42E+00	-3.64E+00	-3.65E+00
cut6	-2.83E+00	-2.77E+00	-2.76E+00	-2.75E+00	-2.97E+00	-2.97E+00
cut7	-2.39E+00	-2.35E+00	-2.28E+00	-2.31E+00	-2.53E+00	-2.53E+00
cut8	-1.71E+00	-1.67E+00	-1.57E+00	-1.63E+00	-1.85E+00	-1.84E+00
cut9	-6.45E-01	-6.16E-01	-4.54E-01	-5.44E-01	-7.77E-01	-8.09E-01
cut10	2.78E-02	6.01E-02	2.16E-01	1.51E-01	-5.66E-02	-2.05E-01
No. Obs.	23,189	17,552	5,637	10,415	6,643	6,131
Log-likelihood	-41,132	-30,977	-10,065	-18,456	-11,664	-10,906
Pseudo-R^2	0.0817	0.0770	0.0774	0.0848	0.0808	0.0841
F-test (P>F)[b]	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000
LR-test (P>χ^2)[c]				0.0000	0.0000	0.0000

Note: Significance at the ten-percent level is indicated by *, significance at the five-percent level is indicated by ** and significance at the one-percent level is indicated by ***.

[a] *These have been adjusted for heteroscedasticity and clustering on the level of the household.*
[b] *F-test on joint significance of AIR and NOISE.*
[c] *A Likelihood ratio test is not applicable if standard errors have been adjusted for heteroscedasticity.*

From table 2 above the estimated coefficients of the ordered probit models are, unfortunately, not intuitiv. To be able to calculate changes in levels of SWB by changes in explanatory variables, we start with deriving the probabilities for an individual to choose one of the 11 scores on life-satisfaction. Using the information on the cutpoints reported in table 2, the chance that a respondent for being least satisfied (score 0) is Prob ("score 0") = F (cut1-H), where F is the standard normal distribution and H is a person's SWB (which is the predicted value of the fitted model from the ordered probit regression). Consequently, the probability to score 1 is Prob ("score 1") = F (cut2-H) - F (cut1-H). Probabilities for other levels of SWB can be computed alike (for more details see Greene, 2003).

Table 3 shows the probabilities derived from our model estimates. They are summarized in steps of three (scores 0 to 2, scores 4 to 6 and score 8 to 10) for all our model specifications. It is evident that the probability to score at the bottom of the scale is very low; mainly less than 1%. Scores of 7 or 8 are dominating (not shown). This corresponds to the original data (compare table A3 in the Appendix).

Table 3: Probability for a person to report a certain score of SWB

Score of life-satisfaction	ALL in %	WEST in %	EAST in %	2004 in %	1999 in %	1994 in %
0 (lowest) to 2	0.91	0.83	1.36	0.93	0.81	0.89
4 to 6	30.93	27.30	42.82	32.23	29.09	30.75
8 to 10 (highest)	39.30	43.81	25.87	37.61	41.88	39.17

Source: Own calculation.

Having computed the probabilities to choose one of the 11 scores on life-satisfaction makes it possible to derive the impact of marginal changes of explanatory variables on changes in a person's SWB. Taking the example from above, they can be derived as follows. The change in ones probability for being, for example, least satisfied is ΔProb ("score 0") = F (cut1-(H+ΔH)) - F (cut1-H). Table 4 shows the calculated changes in probabilities when the quality of air increases or noise exposure decreases. Changes are, again, summarized in steps of three for all our model specifications. In our model, improvements in environmental services imply that respondents move from their current category to the next higher (e.g. from "very strongly affected" to "strongly affected").

If the quality of environmental services increases the distribution of SWB changes. The probability for a respondent to score 8 or higher increases by 2 to 3% for changes in air pollution and by 1 to 3% for improvements in noise exposure. The representation of all other categories diminishes. As a consequence of the estimated coefficients for AIR and NOISE, changes in air quality have more pronounced effects although more people feel negatively effected by noise pollution (compare tables A1 and A2 in the appendix).

Table 4: Change in probability when environmental quality changes

	ALL in %	WEST in %	EAST in %	2004 in %	1999 in %	1994 in %
quality of air increases:						
0 (lowest) to 2	-0.16	-0.12	-0.30	-0.13	-0.14	-0.19
4 to 6	-1.76	-1.46	-2.30	-1.50	-1.80	-2.18
8 to 10 (highest)	2.26	1.99	2.47	1.88	2.35	2.78
noise exposure decreases :						
0 (lowest) to 2	-0.09	-0.11	-0.00[1]	-0.18	-0.03[1]	-0.03[1]
4 to 6	-1.02	-1.34	-0.02[1]	-2.00	-0.41[1]	-0.32[1]
8 to 10 (highest)	1.31	1.83	0.02[1]	2.51	0.55[1]	0.41[1]

[1]*Results are statistically not significant.*

Source: Own calculation.

Similarly, the impact of changes in other explanatory variables like income on SWB can be computed. An increase in household's net income per month of e.g. EUR 100 increases the probability of a respondent to score 8 or higher by only 0.36%.

Taking advantage of this information it is possible to compute the amount of money needed to compensate for a reduction or the willingness to pay for an improvement in environmental quality to attain the same level of utility (SWB). For the first model specification (ALL) about EUR 630 per household and month would be needed to compensate for a reduction from one category to the next lower; for an increase in noise exposure about EUR 360 are needed. Although possible to compute, the significance of those numbers is limited as moving from one category of impairment to the next higher might be particularly difficult (as well as expensive) to achieve; especially for the top categories. More than 70% of all respondents feel only slightly or not at all affected by air or noise pollution. They might not notice improvements or might value them only little. Therefore, it might be more important to improve the quality for those in the last three categories. This might be easier to achieve and also less costly. In our model, improving the quality of air and noise for those in the bottom two categories ("very strongly affected" and "strongly affected") to medium quality ("bearable") costs about 2.3% of all household income for air quality improvements and 1.3% for noise.

5.2 The hedonic model

Turning now to the hedonic analysis reported in Table 5, it is apparent that perceived noise and air pollution are not generally statistically significant. This conclusion is unaltered if data from different years is analysed separately, or if the data are analysed according to whether the household is situated in former East or West Germany.[4] Elsewhere we find that the absence of central heating and poor renovation reduce the logged price per square metre. There are also marked differences according to the type of dwelling (flat, bungalow etc) and according to the size of the community with more expensive properties being located in major urban areas.

The evidence therefore suggests that even though perceived air quality and noise levels contribute to individual welfare, differences in the perceived levels of these environmental variables are not capitalised into house prices. At least in Germany using the hedonic technique to estimate the value of air quality and noise nuisance risks underestimating the extent to which they contribute to SWB.

---

[4] Note that the inclusion of air and noise quality as categorical rather than continuous variables does not result in a statistically significant results.

Table 5. Hedonic house prices, noise and air quality

	ALL[a]	OWNER[a]	RENTER[a]	WEST[a]	EAST[a]	1999	1994
	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient
CONSTANT	1.68E+00 ***	2.44E+00 ***	1.66E+00 ***	1.86E+00 ***	1.77E+00 ***	1.99E+00 ***	1.72E+00 ***
AIR	1.49E-04	2.64E-03	-2.42E-04	1.72E-04	3.67E-03	-6.77E-03	1.07E-02
NOISE	7.08E-03 *	3.13E-03	9.30E-03 *	9.11E-03 *	6.11E-04	3.53E-07	-1.84E-03
OWNER	1.63E-01 ***	(dropped)	(dropped)	1.18E-01 ***	1.74E-01 ***	1.09E-01 ***	3.68E-01 ***
SOCIAL	-6.71E-02 ***	(dropped)	-3.58E-02 ***	-1.24E-01 ***	-9.10E-03	-9.56E-02 ***	1.41E-01 ***
NO-HEATING	-1.79E-01 ***	-1.09E-01 ***	-1.84E-01 ***	-2.12E-01 ***	-7.28E-02 ***	-1.31E-01 ***	-9.36E-02 ***
GARDEN	-1.22E-02	3.59E-02 *	-1.66E-02 *	-1.45E-02	-2.91E-02	-2.41E-02 **	-6.40E-03
BALCONY	2.97E-02 ***	7.91E-02 ***	1.61E-02 *	4.17E-02 ***	1.40E-02	1.65E-02	1.20E-02
MOVEIN	4.93E-03 ***	3.62E-03 ***	6.37E-03 ***	5.51E-03 ***	7.23E-04	2.61E-03 ***	3.82E-03 ***
CONDITION	-1.18E-01 ***	-1.50E-01 ***	-9.69E-02 ***	-1.21E-01 ***	-1.06E-01 ***	-6.39E-02 ***	-4.47E-02 ***
WINDOW	4.22E-02 ***	-8.90E-03	6.93E-02 ***	4.43E-02 **	3.51E-02 *	1.20E-04	2.13E-02
AREA1	3.64E-02	6.98E-02	-2.01E-02	6.78E-03	2.20E-02	-3.34E-02	7.70E-02
AREA2	3.71E-02	9.00E-02	-2.96E-02	3.02E-02	-3.36E-02	-2.31E-02	5.04E-02
AREA3	2.99E-02	3.81E-02	-1.50E-02	1.26E-02	-2.11E-02	-2.97E-02	4.46E-02
AREA4	4.71E-02	8.36E-02	2.52E-04	3.72E-02	-3.22E-03	-3.78E-02	8.45E-02
AREA5	-4.85E-02	-8.40E-02	-7.52E-02	-8.46E-02	(dropped)	-1.20E-01	4.06E-02
TYPE1	7.98E-02	-3.85E-02	1.62E-01 *	8.71E-02	(dropped)	3.74E-01 **	-1.60E-02
TYPE2	1.45E-01 ***	5.95E-02	1.75E-01 ***	1.23E-01 **	1.42E-01 *	4.48E-01 **	8.01E-02
TYPE3	1.99E-01 ***	1.11E-01	2.08E-01 ***	1.87E-01 ***	9.32E-02	4.93E-01 ***	1.33E-01
TYPE4	1.98E-01 ***	2.96E-02	2.57E-01 ***	1.71E-01 ***	1.64E-01 **	4.98E-01 ***	1.29E-01
TYPE5	2.16E-01 ***	1.12E-01	2.73E-01 ***	1.94E-01 ***	1.66E-01 **	5.04E-01 ***	1.47E-01
TYPE6	2.23E-01 ***	1.92E-01 *	2.80E-01 ***	2.33E-01 ***	1.53E-01 *	5.12E-01 ***	1.40E-01
TYPE7	2.67E-01 ***	2.05E-01 *	3.28E-01 ***	2.84E-01 ***	1.78E-01 **	5.20E-01 ***	1.77E-01 *
BUILT	3.21E-02 ***	1.66E-02 ***	4.29E-02 ***	3.51E-02 ***	3.72E-02 ***	2.96E-02 ***	4.52E-02 ***
CITY	-1.64E-02 ***	-2.77E-02 ***	-8.63E-03 ***	-1.60E-02 ***	-1.45E-02 ***	-1.79E-02 ***	-1.57E-02 ***
TRANSPORT	-1.21E-02 *	-8.10E-03	-1.31E-02	-1.32E-02 *	1.72E-02	-1.23E-02	-1.71E-02
GGK1	-2.53E-01 ***	-4.34E-01 ***	-1.52E-01 ***	-3.58E-01 ***	4.70E-02	-3.05E-01 ***	-2.14E-01 ***

GGK2	-2.10E-01 ***	-3.48E-01 ***	-1.75E-01 ***	-2.47E-01 ***	1.00E-01 ***	-2.55E-01 ***	-1.49E-01 ***
GGK3	-1.67E-01 ***	-2.84E-01 ***	-1.43E-01 ***	-1.78E-01 ***	6.98E-02 *	-2.10E-01 ***	-1.27E-01 ***
GGK4	-1.50E-01 ***	-2.49E-01 ***	-1.28E-01 ***	-1.57E-01 ***	7.50E-02 **	-2.01E-01 ***	-1.19E-01 ***
STATE1	2.31E-01 ***	-4.53E-03	(dropped)	1.15E-01 ***	(dropped)	1.18E-01 ***	4.41E-02
STATE2	1.51E-01 ***	(dropped)	-9.85E-02 ***	(dropped)	(dropped)	(dropped)	(dropped)
STATE3	6.01E-02 **	-2.21E-01 ***	-1.51E-01 ***	-6.49E-02 ***	(dropped)	-8.78E-02 ***	-9.70E-02 **
STATE4	(dropped)	-4.18E-01 ***	-1.79E-01 ***	-1.52E-01 ***	(dropped)	-2.12E-01 ***	-1.28E-01 **
STATE5	9.98E-02 ***	-1.45E-01 ***	-1.47E-01 ***	-3.49E-02	(dropped)	-4.32E-02 *	-7.81E-02 *
STATE6	1.52E-01 ***	-9.06E-02	-8.85E-02 ***	2.49E-02	(dropped)	1.65E-02	-2.10E-03
STATE7	7.29E-02 ***	-2.06E-01 ***	-1.37E-01 ***	-2.74E-02	(dropped)	-7.33E-02 **	-1.21E-01 **
STATE8	1.31E-01 ***	-1.11E-01 **	-1.16E-01 ***	1.23E-02	(dropped)	3.50E-03	-1.98E-02
STATE9	1.24E-01 ***	-1.55E-01 ***	-9.66E-02 ***	1.08E-03	(dropped)	-2.76E-02	-4.99E-02
STATE10	-7.94E-02 ***	-1.78E-01 **	-3.15E-01 ***	-2.49E-01 ***	(dropped)	-2.49E-01 ***	-2.25E-01 ***
STATE11	(dropped)	(dropped)	(dropped)	(dropped)	(dropped)	(dropped)	-2.18E-02
STATE12	4.83E-02 *	1.71E-01 ***	3.21E-03	(dropped)	4.23E-02 *	6.40E-02 **	(dropped)
STATE13	-1.40E-02	-5.66E-02	-7.52E-03	(dropped)	-2.56E-02	-4.53E-02 *	-2.72E-02
STATE14	-2.29E-02	-6.51E-02	-2.41E-02	(dropped)	-4.37E-02 *	-7.39E-02 **	-1.88E-02
STATE15	-2.70E-03	-3.04E-02	2.20E-02	(dropped)	6.10E-03	-3.51E-03	-3.41E-02
EAST	3.53E-02	-7.22E-02	-2.42E-01 ***	(dropped)	(dropped)	-6.26E-02 *	-1.79E-01 ***
1999	1.58E-01 ***	8.93E-02 ***	2.07E-01 ***	1.05E-01 ***	2.61E-01 ***	(dropped)	(dropped)
No. Obs.	14,304	5,178	9,126	11,828	2,476	5,391	4,911
R^2	0.3684	0.3467	0.4009	0.3931	0.3541	0.2228	0.3054
F-test (P>F)[b]	0.0778	0.6961	0.0406	0.0324	0.0854	0.3378	0.2201

Note: Significance at the ten-percent level is indicated by *, significance at the five-percent level is indicated by ** and significance at the one-percent level is indicated by ***.

[a] *These have been adjusted for heteroscedasticity and clustering on the level of the household.*
[b] *F-test on joint significance of AIR and NOISE.*

6 Discussion

The current results require us to explain why perceived air quality and noise levels contribute to SWB but are statistically insignificant determinants of house prices, particularly when many other hedonic house price studies have uncovered significant parameter values.

One possibility is that hedonic studies have generally considered much smaller geographical areas, typically cities rather than an entire country. It may be that housing markets in Germany are geographically segmented and that assuming a national market obscures the impact that these variables have on house prices. But defining geographically smaller areas such as Hamburg, Bremen or Berlin does not increase the statistical significance perceived air quality and noise nuisance and neither does distinguishing between communities of differing sizes (results not shown).

Our explanation is that the majority of hedonic studies appear to be undertaken in the United States. In Germany by contrast people are less mobile. Also, the number of individuals renting homes is much greater and the rental sector is subject to regulations governing when and under what circumstances prices can be increased or tenants be evicted (see e.g. Grundmann, 2001, for some recent developments on the regulation of rental housing). These might explain why the price of housing does not appear to reflect variations in the level of environmental attributes. If we are correct then techniques based on SWB might prove to be a useful addition to valuation techniques in contexts where the underlying assumptions of hedonic technique appear unreasonable.

Finally the reader should be aware that variations in self-perceived levels of air pollution and noise nuisance might themselves be correlated with other unobserved characteristics of individuals. Thus unhappy or depressed individuals might perceive noise nuisance or poor air quality more acutely than others. Nonetheless individuals living close to the centre of big cities, close to transport links and in mixed-use or predominantly industrial areas are far more likely to declare themselves strongly affected than individuals living in other locations (see tables 6 and 7). Thus individual assessments of environmental quality are not wholly determined by individual traits.

Of course, objective measures of air pollution and noise nuisance would have been preferred to self-perceived levels. However, local measures are generally unavailable as there are only a limited number of monitoring stations per town or region. Interpolating pollution measures would create errors of its own. Neither is it clear which of a variety of matrix (daily average, peak, night time etc.) is more relevant.

Table 6: Variation in air quality

Affected by air pollution on residential area	living close to the city centre	living in rural area	living close to transport link	no transport link in walking distance	living in industrial area	living in residential area
	in %	in %	in %	in %	in %	in %
1 (not at all)	28.62	46.17	37.61	58.17	20.41	46.24
2	39.57	38.74	40.58	32.69	42.86	39.71
3	21.68	9.98	14.82	5.77	20.41	10.31
4	7.39	4.19	5.31	2.40	11.56	2.89
5 (very strongly)	2.74	0.92	1.68	0.96	4.76	0.85

Source: German socio-economic panel, own calculation.

Table 7: Variation in noise nuisance

Affected by noise pollution on residential area	living close to the city centre	living in rural area	living close to transport link	no transport link in walking distance	living in industrial area	living in residential area
	in %	in %	in %	in %	in %	in %
1 (not at all)	29.28	44.26	35.53	57.42	23.81	44.53
2	39.58	36.03	39.45	31.58	39.46	38.83
3	20.71	12.99	16.35	8.13	24.49	11.84
4	7.19	4.84	6.38	1.44	8.16	3.64
5 (very strongly)	3.24	1.88	2.29	1.44	4.08	1.16

Source: German socio-economic panel, own calculation.

7 Conclusion

This paper compares the extent to which perceived measures or air quality and noise nuisance are reflected in measures of SWB and property prices. At least in the context of Germany it appears that perceived levels of air pollution and noise nuisance are not capitalised into property prices. This is most likely due to the fact that the housing market is highly regulated by the state. By contrast high noise levels and poor air quality markedly diminish SWB.

Future analyses might attempt to apply the same techniques in other countries specifically those in which the hedonic technique has been observed to yield significant results for air pollution and noise nuisance. These analyses might also be able to compare self-perceived measures of air pollution and noise nuisance with their objectively measured counterparts. Further research might also attempt to determine whether individuals sharing the same characteristics reach the same level of well-being irrespective of their geographical location since this is the key assumption underpinning the hedonic technique.

Acknowledgement

References

Bateman, I.T., Carson, R.T., Day, B., Hanemann, M., Hanley, N., Hett, T., Jones-Lee, M., Loomes, G., Mourato, S., Özdemiroglu, E., Pearce, D.W., Sugden, R., Swanson, J., 2002. Economic Valuation with Stated Preference Techniques: A Manual, Cheltenham.

Clark, A.E. and Oswald, A.J., 1994. Unhappiness and Unemployment. The Economic Journal, 104:648-659.

Di Tella, R., MacCulloch, R.J. and Oswald, A.J. (2001) Preferences over Inflation and Unemployment: Evidence from Surveys of Happiness. The American Economic Review, 91:335-341.

Di Tella, R., MacCulloch, R.J. and Oswald, A.J., 2003. The Macroeconomics of Happiness. The Review of Economics and Statistics, 85:809-827.

Easterlin, R.A., 2001. Income and Happiness: Towards a Unified Theory. The Economic Journal, 111:465-484.

Ferrer-i-Carbonell, A. and Gowdy, J.M., forthcoming. Environmental degradation and happiness, Ecological Economics.

Freeman, A.M. III, 2003. The Measurement of Environmental Resource Values, Resources for the Future, Washington, D.C.

Frey, B.S. and Stutzer, A., 2002. Happiness and Economics, Princeton University Press, Princeton.

Greene, W.H., 2003. Econometric Analysis, 3rd edition, New York.

Grundmann, B., 2001. Die Mietrechtsreform, Neue Juristische Wochenschrift, 2498-2505.

Holm-Müller, K., Hansen, H., Klockmann, M. and Luther, P., 1991. Die Nachfrage nach Umweltqualität in der Bundesrepublik Deutschland, Forschungsbericht 10103110/11, Umweltbundesamt, Berlin(1991).

Mitchell, R.C. and Carson, R.T., 1989. Using Surveys to Value Public Goods, Resources for the Future, Washington, D.C.

Nelson, J.P., 2004. Meta-Analysis of Airport Noise and Hedonic Property Values: Problems and Prospects, Journal of Transport Economics and Policy, 38(1), January 2004, pp. 1-27.

Rehdanz, K. and Maddison, D., 2005. Climate and Happiness, Ecological Economics, 52:111-125.

Roback, J., 1982. Wages, Rents, and the Quality of Life. Journal of Political Economy, 90:1257-1278.

Rosen, S., 1974. Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition. Journal of Political Economy, 82:34-55.

Schulz, W., 1985. Der monetäre Wert besserer Luft: Eine empirische Analyse individueller Zahlungsbereitschaften und ihrer Determinanten auf der Basis von Repräsentativumfragen, Berlin.

Smith, V.K. and Huang J.C., 1995. Can Markets Value Air Quality? A Meta-analysis of Hedonic Property Value Models. Journal of Political Economy, 103:209–227.

Statisitsches Bundesamt (2006) Verbraucherpreisindex und Index der Einzelhandelspreise: Jahresdurchschnitte ab 1948, Statistisitsches Bundesamt, Wiesbaden.

Van Praag, B.M.S. and Baarsma, B.E., 2005. Using happiness surveys to value intangibles: The case of airport noise, The Economic Journal, 115:224-246.

Welsch, H., 2002. Preferences over Prosperity and Pollution: Environmental Valuation based on Happiness Surveys, Kyklos, 55:473-494.

Welsch, H., 2006. Environment and happiness: Valuation of air pollution using life-satisfaction data, Ecological Economics, 58:801-813.

Appendix

Table A1. How strongly do you feel you are affected by air pollution on your residential area?

	ALL in %	WEST in %	EAST in %	2004 in %	1999 in %	1994 in %
not at all	38.44	41.11	30.12	47.32	35.59	26.46
slightly	40.61	39.20	45.01	39.15	42.69	40.84
bearable	14.22	13.61	16.14	9.76	15.02	20.94
strongly	5.18	4.69	6.69	3.11	5.12	8.76
very strongly	1.55	1.39	2.04	0.67	1.58	3.00

Source: German socio-economic panel, own calculation.

Table A2. How strongly do you feel you are affected by noise pollution on your residential area?

	ALL in %	WEST in %	EAST in %	2004 in %	1999 in %	1994 in %
not at all	36.57	39.38	27.82	42.39	33.69	29.80
slightly	39.25	38.14	42.72	38.02	42.24	38.10
bearable	15.93	15.12	18.45	13.09	16.36	20.27
strongly	6.10	5.61	7.63	4.97	5.68	8.47
very strongly	2.16	1.76	3.39	1.53	2.03	3.36

Source: German socio-economic panel, own calculation.

Table A3. How satisfied are you with your life, all things considered? "0" means completely dissatisfied ,"10" means completely satisfied?

	ALL in %	WEST in %	EAST in %	2004 in %	1999 in %	1994 in %
0	0.56	0.56	0.59	0.58	0.53	0.59
1	0.44	0.39	0.59	0.45	0.42	0.44
2	1.45	1.29	1.95	1.56	1.29	1.44
3	3.42	2.99	4.75	3.67	3.01	3.44
4	4.30	3.81	5.82	4.70	3.91	4.05
5	13.31	11.74	18.20	13.79	12.40	13.47
6	12.37	11.40	15.40	12.50	12.19	12.35
7	22.67	22.44	23.38	22.66	22.53	22.83
8	28.61	30.42	22.97	28.22	29.85	27.92
9	8.68	9.98	4.65	8.28	9.63	8.33
10	4.19	4.99	1.7	3.61	4.21	5.14

Source: German socio-economic panel, own calculation.

Table A4. Parameter Homogeneity among the Coefficients

Model	AIR	NOISE		Model	AIR	NOISE
WEST	-5.07E-02 ***	-4.66E-02 ***		2004	-5.00E-02 ***	-6.69E-02 ***
EAST	-7.85E-02 ***	-6.41E-04		1999	-6.05E-02 ***	-1.40E-02
				1994	-7.32E-02 ***	-1.07E-02
Parameter homogeneity test Variance weighted estimate	$\chi^2(1) = 1.08$ -0.058 ***	$\chi^2(1) = 3.61$ * -0.034 ***		Parameter homogeneity test Variance weighted estimate	$\chi^2(2) = 0.82$ -0.061 ***	$\chi^2(2) = 7.48$ ** -0.036 ***

Note: Significance at the ten-percent level is indicated by *, significance at the five-percent level is indicated by ** and significance at the one-percent level is indicated by ***.

Working Papers
Research Unit Sustainability and Global Change
Hamburg University and Centre for Marine and Atmospheric Science

Rehdanz, K. and D. Maddison (2006), *Local Environmental Quality and Life-Satisfaction in Germany,* **FNU-119** (submitted)

Tanaka, K., Tol, R.S.J., Rokityanskiy, D., O'Neill, B.C. and M. Obersteiner (2006), *Evaluating Global Warming Potentials as Historical Temperature Proxies: an application of ACC2 Inverse Calculation*, **FNU-118** (submitted)

Berrittella, M., K. Rehdanz and R.S.J. Tol (2006), *The Economic Impact of the South-North Water Transfer Project in China: A Computable General Equilibrium Analysis*, **FNU-117** (submitted)

Tol, R.S.J. (2006), *Why Worry about Climate Change? A Research Agenda*, **FNU-116** (submitted)

Hamilton, J.M. and R.S.J. Tol (2006), *The Impact of Climate Change on Tourism in Germany, the UK and Ireland: A Simulation Study*, **FNU-115** (submitted)

Schwoon, M., F. Alkemade, K. Frenken and M.P. Hekkert (2006), *Flexible transition strategies towards future well-to-wheel chains: an evolutionary modelling approach*, **FNU-114** (submitted).

Ronneberger, K., L. Criscuolo, W. Knorr and R.S.J. Tol (2006), *KLUM@LPJ: Integrating dynamic land-use decisions into a dynamic global vegetation and crop growth model to assess the impacts of a changing climate. A feasibility study for Europe,* **FNU-113** (submitted)

Schwoon, M. (2006), *Learning-by-doing, Learning Spillovers and the Diffusion of Fuel Cell Vehicles*, **FNU-112** (submitted).

Strzepek, K.M., G.W. Yohe, R.S.J. Tol and M. Rosegrant (2006), *The Value of the High Aswan Dam to the Egyptian Economy*, **FNU-111** (submitted).

Schwoon, M. (2006), *A Tool to Optimize the Initial Distribution of Hydrogen Filling Stations*, **FNU-110** (submitted).

Tol, R.S.J., K.L. Ebi and G.W. Yohe (2006), *Infectious Disease, Development, and Climate Change: A Scenario Analysis*, **FNU-109** (submitted).

Lau, M.A. (2006), *An analysis of the travel motivation of tourists from the People's Republic of China,* **FNU-108** (submitted).

Lau, M.A. and R.S.J. Tol (2006), *The Chinese are coming – An analysis of the preferences of Chinese holiday makers at home and abroad*, **FNU-107** (submitted).

Röckmann, C., R.S.J. Tol, U.A. Schneider, and M.A. St.John (2006), *Rebuilding the Eastern Baltic cod stock under environmental change - Part II: The economic viability of a marine protected area.* **FNU-106** (submitted)

Ronneberger, K., M. Berrittella, F. Bosello and R.S.J. Tol (2006), *KLUM@GTAP: Introducing biophysical aspects of land-use decisions into a general equilibrium model. A coupling experiment,* **FNU-105** (submitted).

Link, P.M. and Tol, R.S.J. (2006), *Economic impacts on key Barents Sea fisheries arising from changes in the strength of the Atlantic thermohaline circulation*, **FNU-104** (submitted).

Link, P.M. and Tol, R.S.J. (2006), *The economic impact of a shutdown of the Thermohaline Circulation: an application of FUND*, **FNU-103** (submitted).

Tol, R.S.J. (2006), *Integrated Assessment Modelling*, **FNU-102** (submitted).

Tol, R.S.J. (2006), *Carbon Dioxide Emission Scenarios for the USA*, **FNU-101** (submitted, *Energy Policy*).

Tol, R.S.J., S.W. Pacala and R.H. Socolow (2006), *Understanding Long-Term Energy Use and Carbon Dioxide Emissions in the USA*, **FNU-100** (submitted).

Sesabo, J.K, H. Lang and R.S.J. Tol (2006), *Perceived Attitude and Marine Protected Areas (MPAs) establishment: Why households' characteristics matters in Coastal resources conservation initiatives in Tanzania*, **FNU-99** (submitted).

Tol, R.S.J. (2006), *The Polluter Pays Principle and Cost-Benefit Analysis of Climate Change: An Application of* FUND, **FNU-98** (submitted)

Tol, R.S.J. and G.W. Yohe (2006), *The Weakest Link Hypothesis for Adaptive Capacity: An Empirical Test*, **FNU-97** (submitted, *Global Environmental Change*)

Berrittella, M., K. Rehdanz, R.Roson and R.S.J. Tol (2005), *The Economic Impact of Water Pricing: A Computable General Equilibrium Analysis*, **FNU-96** (submitted)

Sesabo, J.K. and R. S. J. Tol (2005), *Technical Efficiency and Small-scale Fishing Households in Tanzanian coastal Villages: An Empirical Analysis*, **FNU-95** (submitted)

Lau, M.A. (2005), *Adaptation to Sea-level Rise in the People's Republic of China – Assessing the Institutional Dimension of Alternative Organisational Frameworks*, **FNU-94** (submitted)

Berrittella, M., A.Y. Hoekstra, K. Rehdanz, R. Roson and R.S.J. Tol (2005), *The Economic Impact of Restricted Water Supply: A Computable General Equilibrium Analysis*, **FNU-93** (submitted)

Tol, R.S.J. (2005), *Europe's Long Term Climate Target: A Critical Evaluation*, **FNU-92** (forthcoming, *Energy Policy*)

Hamilton, J.M. (2005), *Coastal Landscape and the Hedonic Price of Accomodation*, **FNU-91** (submitted)

Hamilton, J.M., D.J. Maddison and R.S.J. Tol (2005), *Climate Preferences and Destination Choice: A Segmentation Approach*, **FNU-90** (submitted)

Zhou, Y. and R.S.J. Tol (2005), *Valuing the Health Impacts from Particulate Air Pollution in Tianjin*, **FNU-89** (submitted)

Röckmann, C. (2005), *International Cooperation for Sustainable Fisheries in the Baltic Sea,* **FNU-88** (forthcoming, in Ehlers,P./Lagoni,R. (Eds.): *International Maritime Organisations and their Contribution towards a Sustainable Marine Development*.)

Ceronsky, M., D. Anthoff, C. Hepburn and R.S.J. Tol (2005), *Checking the price tag on catastrophe: The social cost of carbon under non-linear climate response* **FNU-87** (submitted, *Climatic Change*)

Zandersen, M. and R.S.J. Tol (2005), *A Meta-analysis of Forest Recreation Values in Europe,* **FNU-86** (submitted, *Journal of Environmental Management*)

Heinzow, T., R.S.J. Tol and B. Brümmer (2005), Offshore-Windstromerzeugung in der Nordsee -eine ökonomische und ökologische Sackgasse? **FNU-85** (*Energiewirtschaftliche Tagesfragen*, **56** (3), 68-73)

Röckmann, C., U.A. Schneider, M.A. St.John, and R.S.J. Tol (2005), *Rebuilding the Eastern Baltic cod stock under environmental change - a preliminary approach using stock, environmental, and management constraints,* **FNU-84** (forthcoming, *Natural Resource Modeling*)

Tol, R.S.J. and G.W. Yohe (2005), *Infinite uncertainty, forgotten feedbacks, and cost-benefit analysis of climate policy,* **FNU-83** (submitted, *Climatic Change*)

Osmani, D. and R.S.J. Tol (2005), *The case of two self-enforcing international agreements for environmental protection*, **FNU-82** (submitted)

Schneider, U.A. and B.A. McCarl, (2005), *Appraising Agricultural Greenhouse Gas Mitigation Potentials: Effects of Alternative Assumptions*, **FNU-81** (submitted)

Zandersen, M., M. Termansen, and F.S. Jensen, (2005), *Valuing new forest sites over time: the case of afforestation and recreation in Denmark,* **FNU-80** (submitted)

Guilletminet, M.-L. and R.S.J. Tol (2005), *Decision making under catastrophic risk and learning: the case of the possible collapse of the West Antarctic Ice Sheet*, **FNU-79** (submitted, *Climatic Change*)

Nicholls, R.J., R.S.J. Tol and A.T. Vafeidis (2005), *Global estimates of the impact of a collapse of the West Antarctic Ice Sheet: An application of FUND,* **FNU-78** (submitted, *Climatic Change*)

Lonsdale, K., T.E. Downing, R.J. Nicholls, D. Parker, A.T. Vafeidis, R. Dawson and J.W. Hall (2005), *Plausible responses to the threat of rapid sea-level rise for the Thames Estuary,* **FNU-77** (submitted, *Climatic Change*)

Poumadère, M., C. Mays, G. Pfeifle with A.T. Vafeidis (2005), *Worst Case Scenario and Stakeholder Group Decision: A 5-6 Meter Sea Level Rise in the Rhone Delta, France,* **FNU-76** (submitted, *Climatic Change*)

Olsthoorn, A.A., P.E. van der Werff, L.M. Bouwer and D. Huitema (2005), *Neo-Atlantis: Dutch Responses to Five Meter Sea Level Rise,* **FNU-75** (submitted, *Climatic Change*)

Toth, F.L. and E. Hizsnyik (2005), *Managing the inconceivable: Participatory assessments of impacts and responses to extreme climate change*, **FNU-74** (submitted)

Kasperson, R.E. M.T. Bohn and R. Goble (2005), *Assessing the risks of a future rapid large sea level rise: A review,* **FNU-73** (submitted, *Climatic Change*)

Schleupner, C. (2005), *Evaluation of coastal squeeze and beach reduction and its consequences for the Caribbean island Martinique,* **FNU-72** (submitted)

Schleupner, C. (2005), *Spatial Analysis As Tool for Sensitivity Assessment of Sea Level Rise Impacts on Martinique,* **FNU-71** (submitted)

Sesabo, J.K. and R.S.J. Tol (2005), *Factors affecting Income Strategies among households in Tanzanian Coastal Villages: Implication for Development-Conservation Initiatives,* **FNU-70** (submitted)

Fisher, B.S., G. Jakeman, H.M. Pant, M. Schwoon. and R.S.J. Tol (2005), *CHIMP: A Simple Population Model for Use in Integrated Assessment of Global Environmental Change*, **FNU-69** (forthcoming, *Integrated Assessment Journal*)

Rehdanz, K. and R.S.J. Tol (2005), *A No Cap But Trade Proposal for Greenhouse Gas Emission Reduction Targets for Brazil, China and India*, **FNU-68** (submitted)

Zhou, Y. and R.S.J. Tol (2005), *Water Use in China's Domestic, Industrial and Agricultural Sectors: An Empirical Analysis*, **FNU-67** (*Water Science and Technoloy: Water Supply*, **5** (6), 85-93)

Rehdanz, K. (2005), *Determinants of Residential Space Heating Expenditures in Germany*, **FNU-66** (forthcoming, *Energy Economics*)

Ronneberger, K., R.S.J. Tol and U.A. Schneider (2005), *KLUM: A Simple Model of Global Agricultural Land Use as a Coupling Tool of Economy and Vegetation,* **FNU-65** (submitted, *Climatic Change*)

Tol, R.S.J. (2005), *The Benefits of Greenhouse Gas Emission Reduction: An Application of* FUND, **FNU-64** (submitted, *Global Environmental Change*)

Röckmann, C., M.A. St.John, U.A. Schneider, F.W. Köster, F.W. and R.S.J. Tol (2006), *Testing the implications of a permanent or seasonal marine reserve on the population dynamics of Eastern Baltic cod under varying environmental conditions,* **FNU-63-revised** (submitted)

Letsoalo, A., J. Blignaut, T. de Wet, M. de Wit, S. Hess, R.S.J. Tol and J. van Heerden (2005), *Triple Dividends of Water Consumption Charges in South Africa*, **FNU-62** (submitted, *Water Resources Research*)

Zandersen, M., Termansen, M., Jensen,F.S. (2005), *Benefit Transfer over Time of Ecosystem Values: the Case of Forest Recreation,* **FNU-61** (submitted)

Rehdanz, K., Jung, M., Tol, R.S.J. and Wetzel, P. (2005), *Ocean Carbon Sinks and International Climate Policy*, **FNU-60** (forthcoming, *Energy Policy*)

Schwoon, M. (2005), *Simulating the Adoption of Fuel Cell Vehicles*, **FNU-59** (submitted)

Bigano, A., J.M. Hamilton and R.S.J. Tol (2005), *The Impact of Climate Change on Domestic and International Tourism: A Simulation Study*, **FNU-58** (submitted)

Bosello, F., R. Roson and R.S.J. Tol (2004), *Economy-wide estimates of the implications of climate change: Human health*, **FNU-57** (*Ecological Economics*, **58**, 579-591)

Hamilton, J.M. and M.A. Lau (2004) *The role of climate information in tourist destination choice decision-making,* **FNU-56** (forthcoming, Gössling, S. and C.M. Hall (eds.), Tourism and Global Environmental Change. London: Routledge)

Bigano, A., J.M. Hamilton and R.S.J. Tol (2004), *The impact of climate on holiday destination choice*, **FNU-55** (forthcoming, *Climatic Change*)

Bigano, A., J.M. Hamilton, M. Lau, R.S.J. Tol and Y. Zhou (2004), *A global database of domestic and international tourist numbers at national and subnational level*, **FNU-54** (submitted)

Susandi, A. and R.S.J. Tol (2004), *Impact of international emission reduction on energy and forestry sector of Indonesia*, **FNU-53** (submitted)

Hamilton, J.M. and R.S.J. Tol (2004), *The Impact of Climate Change on Tourism and Recreation*, **FNU-52** (forthcoming, Schlesinger et al. (eds.), Cambridge University Press)

Schneider, U.A. (2004), *Land Use Decision Modelling with Soil Status Dependent Emission Rates*, **FNU-51** (submitted)

Link, P.M., U.A. Schneider and R.S.J. Tol (2004), *Economic impacts of changes in fish population dynamics: the role of the fishermen's harvesting strategies*, **FNU-50** (submitted)

Berritella, M., A. Bigano, R. Roson and R.S.J. Tol (2004), *A General Equilibrium Analysis of Climate Change Impacts on Tourism*, **FNU-49** (forthcoming, *Tourism Management*)

Tol, R.S.J. (2004), *The Double Trade-Off between Adaptation and Mitigation for Sea Level Rise: An Application of* FUND, **FNU-48** (forthcoming, *Mitigation and Adaptation Strategies for Global Change*)

Erdil, Erkan and Yetkiner, I. Hakan (2004), *A Panel Data Approach for Income-Health Causality,* **FNU-47**

Tol, R.S.J. (2004), *Multi-Gas Emission Reduction for Climate Change Policy: An Application of* FUND, **FNU-46** (forthcoming, *Energy Journal*)

Tol, R.S.J. (2004), *Exchange Rates and Climate Change: An Application of* FUND, **FNU-45** (forthcoming, *Climatic Change*)

Gaitan, B., Tol, R.S.J, and Yetkiner, I. Hakan (2004), *The Hotelling's Rule Revisited in a Dynamic General Equilibrium Model*, **FNU-44** (submitted)

Rehdanz, K. and Tol, R.S.J (2004), *On Multi-Period Allocation of Tradable Emission Permits*, **FNU-43** (submitted)

Link, P.M. and Tol, R.S.J. (2004), *Possible Economic Impacts of a Shutdown of the Thermohaline Circulation: An Application of* FUND, **FNU-42** (*Portuguese Economic Journal*, **3**, 99-114)

Zhou, Y. and Tol, R.S.J. (2004), *Evaluating the costs of desalination and water transport,* **FNU-41** (f*Water Resources Research,* **41** (3), W03003)

Lau, M. (2004), *Küstenzonenmanagement in der Volksrepublik China und Anpassungsstrategien an den Meeresspiegelanstieg,***FNU-40** (*Coastline Reports*, Issue 1, pp.213-224.)

Rehdanz, K. and Maddison, D. (2004), *The Amenity Value of Climate to German Households*, **FNU-39** (submitted)

Bosello, F., Lazzarin, M., Roson, R. and Tol, R.S.J. (2004), *Economy-wide Estimates of the Implications of Climate Change: Sea Level Rise*, **FNU-38** (submitted, *Environmental and Resource Economics*)

Schwoon, M. and Tol, R.S.J. (2004), *Optimal CO_2-abatement with socio-economic inertia and induced technological change*, **FNU-37** (submitted, *Energy Journal*)

Hamilton, J.M., Maddison, D.J. and Tol, R.S.J. (2004), *The Effects of Climate Change on International Tourism,* **FNU-36** (*Climate Research*, **29**, 255-268)

Hansen, O. and R.S.J. Tol (2003), *A Refined Inglehart Index of Materialism and Postmaterialism*, **FNU-35** (submitted)

Heinzow, T. and R.S.J. Tol (2003), *Prediction of Crop Yields across four Climate Zones in Germany: An Artificial Neural Network Approach,* **FNU-34** (submitted, *Climate Research*)

Tol, R.S.J. (2003), *Adaptation and Mitigation: Trade-offs in Substance and Methods,* **FNU-33** (*Environmental Science and Policy*, **8** (6), 572-578)

Tol, R.S.J. and T. Heinzow (2003), *Estimates of the External and Sustainability Costs of Climate Change*, **FNU-32** (submitted)

Hamilton, J.M., Maddison, D.J. and Tol, R.S.J. (2003), *Climate change and international tourism: a simulation study,* **FNU-31** (*Global Environmental Change,* **15** (3), 253-266)

Link, P.M. and R.S.J. Tol (2003), *Economic impacts of changes in population dynamics of fish on the fisheries in the Barents Sea*, **FNU-30** (*ICES Journal of Marine Science*, **63** (4), 611-625)

Link, P.M. (2003), *Auswirkungen populationsdynamischer Veränderungen in Fischbeständen auf die Fischereiwirtschaft in der Barentssee*, **FNU-29** (*Essener Geographische Arbeiten*, **35**, 179-202)

Lau, M. (2003), *Coastal Zone Management in the People's Republic of China – An Assessment of Structural Impacts on Decision-making Processes*, **FNU-28** (*Ocean & Coastal Management*, No. 48 (2005), pp. 115-159.)

Lau, M. (2003), *Coastal Zone Management in the People's Republic of China – A Unique Approach?*, **FNU-27** (*China Environment Series,* Issue 6, pp. 120-124; http://www.wilsoncenter.org/topics/pubs/7-commentaries.pdf)

Roson, R. and R.S.J. Tol (2003), *An Integrated Assessment Model of Economy-Energy-Climate – The Model Wiagem: A Comment*, **FNU-26** (*Integrated Assessment,* **6** (1), 75-82)

Yetkiner, I.H. (2003), *Is There An Indispensable Role For Government During Recovery From An Earthquake? A Theoretical Elaboration*, **FNU-25**

Yetkiner, I.H. (2003), *A Short Note On The Solution Procedure Of Barro And Sala-i-Martin for Restoring Constancy Conditions*, **FNU-24**

Schneider, U.A. and B.A. McCarl (2003), *Measuring Abatement Potentials When Multiple Change is Present: The Case of Greenhouse Gas Mitigation in U.S. Agriculture and Forestry*, **FNU-23** (submitted)

Zhou, Y. and Tol, R.S.J. (2003), *The Implications of Desalination to Water Resources in China - an Economic Perspective*, **FNU-22** (*Desalination*, **163** (4), 225-240)

Yetkiner, I.H., de Vaal, A., and van Zon, A. (2003), *The Cyclical Advancement of Drastic Technologies*, **FNU-21**

Rehdanz, K. and Maddison, D. (2003) *Climate and Happiness*, **FNU-20** (*Ecological Economics,* **52** 111-125)

Tol, R.S.J., (2003), *The Marginal Costs of Carbon Dioxide Emissions: An Assessment of the Uncertainties*, **FNU-19** (*Energy Policy,* **33** (16), 2064-2074).

Lee, H.C., B.A. McCarl, U.A. Schneider, and C.C. Chen (2003), *Leakage and Comparative Advantage Implications of Agricultural Participation in Greenhouse Gas Emission Mitigation*, **FNU-18** (submitted).

Schneider, U.A. and B.A. McCarl (2003), *Implications of a Carbon Based Energy Tax for U.S. Agriculture*, **FNU-17** (submitted).

Tol, R.S.J. (2002), *Climate, Development, and Malaria: An Application of* FUND, **FNU-16** (forthcoming, *Climatic Change*).

Hamilton, J.M. (2003), *Climate and the Destination Choice of German Tourists,* **FNU-15** (revised and submitted).

Tol, R.S.J. (2002), *Technology Protocols for Climate Change: An Application of* FUND, **FNU-14** (*Climate Policy,* **4**, 269-287).

Rehdanz, K (2002), *Hedonic Pricing of Climate Change Impacts to Households in Great Britain*, **FNU-13** (*Climatic Change* **74** (4), 413-434).

Tol, R.S.J. (2002), *Emission Abatement Versus Development As Strategies To Reduce Vulnerability To Climate Change: An Application Of* FUND, **FNU-12** (forthcoming, *Environment and Development Economics*).

Rehdanz, K. and Tol, R.S.J. (2002), *On National and International Trade in Greenhouse Gas Emission Permits*, **FNU-11** (*Ecological Economics*, **54**, 397-416).

Fankhauser, S. and Tol, R.S.J. (2001), *On Climate Change and Growth*, **FNU-10** (*Resource and Energy Economics*, **27**, 1-17).

Tol, R.S.J.and Verheyen, R. (2001), *Liability and Compensation for Climate Change Damages – A Legal and Economic Assessment*, **FNU-9** (*Energy Policy*, **32** (9), 1109-1130).

Yohe, G. and R.S.J. Tol (2001), *Indicators for Social and Economic Coping Capacity – Moving Toward a Working Definition of Adaptive Capacity*, **FNU-8** (*Global Environmental Change*, **12** (1), 25-40).

Kemfert, C., W. Lise and R.S.J. Tol (2001), *Games of Climate Change with International Trade*, **FNU-7** (*Environmental and Resource Economics*, **28**, 209-232).

Tol, R.S.J., W. Lise, B. Morel and B.C.C. van der Zwaan (2001), *Technology Development and Diffusion and Incentives to Abate Greenhouse Gas Emissions*, **FNU-6** (submitted).

Kemfert, C. and R.S.J. Tol (2001), *Equity, International Trade and Climate Policy*, **FNU-5** (*International Environmental Agreements*, **2**, 23-48).

Tol, R.S.J., Downing T.E., Fankhauser S., Richels R.G. and Smith J.B. (2001), *Progress in Estimating the Marginal Costs of Greenhouse Gas Emissions*, **FNU-4**. (*Pollution Atmosphérique – Numéro Spécial: Combien Vaut l'Air Propre?*, 155-179).

Tol, R.S.J. (2000), *How Large is the Uncertainty about Climate Change?*, **FNU-3** (*Climatic Change*, **56** (3), 265-289).

Tol, R.S.J., S. Fankhauser, R.G. Richels and J.B. Smith (2000), *How Much Damage Will Climate Change Do? Recent Estimates*, **FNU-2** (*World Economics,* **1** (4), 179-206)

Lise, W. and R.S.J. Tol (2000), *Impact of Climate on Tourism Demand*, **FNU-1** (*Climatic Change*, **55** (4), 429-449).