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356

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Berlin, July 2003

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www.diw.de

ISSN 1619-4535

Environment and Happiness: Valuation of Air Pollution in Ten European Countries

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April 2003

Abstract

This paper uses a set of panel data from happiness surveys, jointly with data on per capita income and pollution, to examine how self-reported well-being varies with prosperity and environmental conditions. This approach permits to show that citizens care about prosperity and the environment, and to calculate the trade-off people are willing to make between them. The paper finds that air pollution plays a statistically significant role as a predictor of inter-country and inter-temporal differences in subjective well-being. The effect of air pollution on well-being shows up as a considerable monetary valuation of improved air quality. The air quality improvements achieved in Western Europe in 1990-1997 are valued at almost $900 per capita per year in the case of nitrogen dioxide and more than $1400 per capita per year in the case of lead.

Keywords: pollution; environmental valuation; subjective well-being; marginal rate of substitution

JEL classification: Q2

Acknowledgements: Useful comments were received by Udo Ebert and Carsten Ochsen and an anonymous referee.

1. Introduction

It is well known that the valuation of private (marketable) goods and the underlying preferences can be inferred from observed market data under fairly mild assumptions. In the case of environmental assets, by contrast, public-good characteristics prevent the respective preferences from being identified directly from observation. Instead, it is common in these circumstances to use either contingent valuation and related techniques, or a demand-based, weak-complementarity method such as the travel cost approach and hedonic pricing (see, e.g., Freeman 1993).

Valuation problems may differ in terms of the kind of environmental assets concerned and may require different valuation techniques. If a specific environmental asset or project, such as a local recreation site, is to be evaluated, contingent valuation and the travel cost method are usually contemplated. The situation may be different in the case of more abstract and complex assets like air or water quality. For instance, air quality is a construct that involves several pollutants, having a variety of effects. While some air pollutants mainly affect physical assets like buildings or trees, others have a more direct impact on human well-being, Sulphur dioxide and nitrogen dioxide may serve as examples. While the former substance has been found in hedonic pricing studies to have a significant impact on housing prices, the latter did not (see, e.g., Kim, Phipps and Anselin 2003). One reason may be that nitrogen dioxide has different effects than sulphur dioxide, requiring a different valuation methodology.

This paper is concerned with the direct impact of air pollution on human well-being and explores a valuation approach explicitly designed to capture this effect. The proposed methodology employs the circumstance that environmental valuation is necessarily based on (implicitly) assuming the existence of a preference function over environmental quality and other valued goods (see, e.g., Mäler 1974 for an early statement). The approach of the paper is to estimate this preference function and the implied monetary valuation of environmental characteristics directly. Using a set of panel data on self-reported well-being in 10 European countries, jointly with data on per capita income and air pollution, the paper examines how well-being varies with prosperity and air quality.

It should be emphasized that this technique does not rely on asking people how they value prosperity and environmental conditions. Instead, individuals are asked in surveys how satisfied they are with life, and the paper demonstrates that - possibly unknown to them - their *en masse* answers move systematically with their nation's per capita income and environmental conditions. This approach permits to show that citizens care about prosperity and the environment, and to calculate the trade-off a representative individual is willing to make between them.[1]

Comparable data on average well-being by country have been compiled and used by psychologists and sociologists for almost a decade now.[2] In this literature, well-being is usually referred to as happiness, or life satisfaction.[3] One key finding emerging from reviews of this kind of literature is that there exists a stable relationship between the cross-national pattern of happiness and economic prosperity (Veenhoven 1997, Diener et al. 1999).

The identification of a stable income-happiness relationship is just one indication of the potential usefulness of happiness research for economics. In spite of this potential relevance, happiness surveys have only recently started to be used in economic research. An early study of the economics of happiness is Easterlin (1974). Later contributions examine the relationship between income distribution and self-rated happiness (Morawetz et al. 1977), and between unemployment and happiness (Clark and Oswald 1994, Winkelmann and Winkelmann 1998). Di Tella, McCulloch, and Oswald (2001) use data from happiness surveys to estimate the trade-off between inflation and unemployment in the framework of a macroeconomic social welfare function. Frey and Stutzer (2002) discuss the insights from happiness research which may be important for integrating into economics.

In a previous paper (Welsch 2002) I have used cross-section data for 54 countries to examine the linkage between well-being, prosperity, and pollution. It was found that the effect of urban air pollution on subjective well-being shows up as a considerable monetary valuation of improved air quality. However, from a methodological point of view the cross-section approach turned out to be rather involved because it crucially relies on finding appropriate controls to deal with unobserved heterogeneity. Therefore, using panel data was recommended as a potentially fruitful alternative research strategy. In the present paper, unobserved heterogeneity is captured by country-specific dummy variables in a panel-data framework.

The paper finds that air pollution plays a statistically significant role as a predictor of inter-country and inter-temporal differences in subjective well-being (even accounting for country and period dummies). The linkage of well-being to income and air pollution implies a substantial value placed on air quality. More specifically, the average (across countries) valuation of the air quality improvements achieved in 1990-1997 amounts to almost $900 per

[1] An alternative methodology - which has been applied with respect to air pollution - combines epidemiological research with techniques for valuing statitistical lives, see European Commission 1993.

[2] A discussion of 'happiness data' is provided in section 2.2.

[3] The corresponding economic terminology is 'experienced utility', see Kahnemann, Wakker and Sarin (1997).

capita per year in the case of nitrogen dioxide and more than $1400 per capita per year in the case of lead.

The paper is organized as follows. Section 2 discusses the data and explains the methodological approach. Section 3 presents the results of estimating several versions of a happiness function with air pollution included. Section 4 calculates the utility-constant marginal valuation of urban air pollution in terms of income. Section 5 concludes.

2. Methodological Approach

2.1 Description of Data

The data set used in this paper comprises annual data, 1990-1997, for the following countries: Belgium, Denmark, France, Germany, Greece, Luxembourg, Netherlands, Portugal, Spain, United Kingdom. The variables and their summary statistics are listed in Table 1.

Table 1: Summary Statistics of Variables Used

	LIFESAT	*INCOME*	*NITROGEN*	*PARTICLES*	*LEAD*
Unit	1-4	1000 $ (PPP)	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$
Mean	3.10	19.243	45.078	45.342	0.178
Median	3.11	19.475	42.650	44.250	0.100
Maximum	3.64	36.629	64.700	81.400	0.800
Minimum	2.44	10.619	31.900	13.200	0.010
Std. Dev.	0.34	5.010	8.238	19.928	0.168

The definitions of variables and the sources of data are as follows.

- The variable *LIFESAT* (average self-reported well-being) comes from the *World Database of Happiness* (Veenhoven 2002). It measures the average level of life satisfaction in a given country. The data are derived from happiness surveys in which the following type of question is asked: "How satisfied are you with the life you lead? (a) very satisfied, (b) fairly satisfied, (c) not very satisfied, (d) not at all satisfied." The responses are rated as follows: "very satisfied" = 4, "fairly satisfied" = 3, "not very satisfied" = 2, "not at all satisfied" = 1. Because *LIFESAT* measures the average well-being across a large sample of respondents, it is a continuous variable.

- *INCOME* (GNP per capita at purchasing power parity) is computed using data on GNP, population, and purchasing power parities (PPP) from OECD (1998). The resulting data are in thousand $ (at PPP and 1990 prices).
- *NITROGEN* (nitrogen dioxide concentration, NO_2), *PARTICLES* (total suspended particulate concentration, TSP) and *LEAD* (lead concentration) are based on time series of indices (1985=100) from OECD (1999). These indices have been converted back to their natural units using information from WEF/YCELP/CIESIN (2002). The pollutant concentrations are expressed in microgram per cubic meter ($\mu g/m^3$).

Our choice of countries and years is largely based on data availability. In addition, the choice of pollutants to be considered is guided by their likely importance for subjective well-being. Nitrogen dioxide is a precursor of photochemical smog and tropospheric (low-level) ozone and as such highly relevant to human health (Cifuentes et al. 2001). Particulates may affect well-being via respiratory problems. Lead is implicated for increased incidence of hypertension, hart attack and general mortality. Whereas only a small proportion of lead intake might actually be due to inhalation, a larger part may actually be related to 'chance ingestion' of lead-rich dust on the hands or in food (Dubourg 1996). Thus, the effects of lead and particles may be complementary to some extent.[4]

With respect to the various pollution variables it may be noted that they occupy quite different ranges and display considerable difference in variability. Whereas *NITROGEN* and *PARTICLES* have mean values of about 45 $\mu g/m^3$ each, the mean value for *LEAD* is less than 0.2 $\mu g/m^3$. *LEAD* also differs from the other two pollutants in that its coefficient of variation (standard deviation divided by mean) is much larger. The largest value observed for *LEAD* is 80 times higher than the smallest one.

2.2 Discussion of Happiness Data

As sketched in the Introduction, using happiness surveys seems to gradually become an established approach in economics. Yet, some readers may worry about using answers to questions like "How satisfied are you with the life you lead?" for rigorous statistical work. Therefore, it may be useful to review some of the arguments made in the previous literature in favor of using happiness data (see Frey and Stutzer 2002).[5]

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[4] We do not consider sulphur dioxide because it mainly affects buildings and forests (via acidification), not people (see, e.g., Kim, Phipps and Anselin 2003).

[5] With respect to the conceptual foundations of the happiness approach, Kahnemann, Wakker and Sarin (1997) provide an axiomatic defense of what they call experienced utility (happiness). Ng (1997) discusses the measurability of happiness.

First, it should be noted that the main purpose of using happiness surveys in economic analysis is not to compare levels of well-being in an absolute sense but rather to seek to identify its determinants and to measure the rate at which several determinants trade off against each other. For this purpose it is sufficient that the data be ordinal in character, i.e. higher levels of the data reflect higher well-being independent of the chosen cardinalization (as long as cardinalizations differ only by monotone increasing transformations).

Second, whether happiness measures meet this condition has been widely assessed in psychological validation exercises. In these studies measures of happiness are generally found to have a high scientific standard in terms of internal consistency, reliability and validity, and a high degree of stability over time (Diener et al. 1999). Different happiness measures correlate well with each other and, according to factor analyses, represent a single unitary construct. Happiness responses are correlated with physical reactions that can be thought of as describing true, internal happiness: People reporting to be happy tend to smile more and show lower levels of stress responses (heart rate, blood pressure). They are more frequently described by others a being happy and they are less likely to commit suicide. As concerns the comparability across nations, no indication has been found that cultural or linguistic bias may prevent a comparison of happiness across nations (Veenhoven 1993).

2.3 Empirical Strategy

Using *POLLUTION* to refer to the various pollutants discussed in section 2.1 (*NITROGEN*, *PARTICLES*, *LEAD*) the equations to be estimated can be written as follows:

$$\log(LIFESAT_{it}) = \alpha_i + \beta_t + \gamma \log(INCOME)_{it} + \delta \log(POLLUTION_{it}) + u_{it}, \qquad (1)$$

The coefficient relating to *INCOME* is expected to be positive while the *POLLUTION* coefficients should be negative. As an alternative to the specification in logarithms we will also consider the corresponding specification in level variables.

The parameters α_i and β_t are country and period dummies. The country dummies are included to control for time-invariant omitted-variable bias, and the period dummies are included to control for global shocks, which might affect well-being in any period but are not otherwise captured by the explanatory variables.

As mentioned above, the dependent variable *LIFESAT* is the average of self-reported well-being taken across all respondents in a particular country and year. Thus, even though the individual responses are categorical data - cardinalized on a four-point integer scale -

LIFESAT is a continuous variable. Therefore, estimation techniques for discrete variables are not applicable. Instead, standard continuous-variable methods will be used.

Standard methods of estimating eq. (1) are fixed effects or random effects.[6] In contrast to the fixed effects technique, the random effects estimation requires that the number of cross sections is larger than the number of coefficients to be estimated. This condition is not met by our data because of the period-specific effects. Applying the random effects method would thus require to drop the period dummies. Since these turn out highly significant in fixed-effects estimates, the random effects method is not pursued. Instead, the fixed effects method will be used throughout. To account for cross-section heteroskedasticity, generalized least squares (GLS) will be used.

It may be added that issues of simultaneity are ignored in this paper because it is unclear what kind of variable could serve as a persuasive instrument for environmental quality in a happiness regression equation.

Having estimated the parameters of the happiness equation, it will be possible to compute the marginal rate of substitution (MRS) of (reduced) pollution for income:

$$MRS = -\frac{\partial LIFESAT \;/\; \partial POLLUTION}{\partial LIFESAT \;/\; \partial INCOME}, \qquad (2)$$

It should be noted that in order to determine the MRS it is not necessary to check for alternative cardinalizations of *LIFESAT*: The MRS is an ordinal concept, i.e., it is invariant with respect to the cardinalization of utility (happiness).

3. Empirical Results

3.1 Basic Estimation Results

We first consider univariate regressions of log(*LIFESAT*) on the various explanatory variables, see Table 2. These regressions provide some information on the structure of the data and will be used below as a background to our discussion of the multivariate happiness regressions we are actually interested in. In this perspective, we note that well-being is

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[6] The major difference between these two techniques is the information utilized to calculate the coefficients. The fixed effects estimates are calculated from differences within each country across time; the random effects estimates are more efficient, since they incorporate information across individual countries as well as across periods. The major drawback with the random effects method is that it is consistent only if the country-specific effects are uncorrelated with the other explanatory variables. A Hausman specification test can evaluate whether this independence assumption is satisfied.

positively and significantly related to prosperity and negatively and significantly related to the various pollutants.

Table 2: Univariate Happiness Regressions. Dependent Variable: log*(LIFESAT)*

	coefficient	t-statistic
log(*INCOME*)	0.398	4.90
log(*NITROGEN*)	-0.035	3.41
log(*PARTICLES*)	-0.032	2.81
log(*LEAD*)	-0.012	4.18

Note: Regressions include country and year dummies; method: GLS.

In order to understand several of the results presented below it is also useful to examine how the various air pollutants are related to the level of prosperity. Table 3 reports the results of regressing the pollutant concentrations on per capita income. The result is that the concentration of all three air pollutants is negatively linked to the level of prosperity. In other words, the countries considered in this paper are on the downward-sloping part of the environmental Kuznets curve. The negative association is particularly strong and highly significant in the case of *PARTICLES*: An increase of per capita income by one percent is associated with a reduction in urban particulate concentration by more than 2.5 percent. In the case of *LEAD* the relationship is of a similar strength, but insignificant. For *NITROGEN*, the linkage is significant, but much weaker.

Table 3: Univariate Regression of Various Pollutants on log(*INCOME*)

Dependent Variable	coefficient	t-statistic
Log(*NITROGEN*)	-0.248	2.01
Log(*PARTICLES*)	-2.584	4.65
Log(*LEAD*)	-2.543	0.99

Note: Regressions include country and year dummies; method: GLS.

3.2 The Happiness-Prosperity-Pollution Relationship

These preliminary regressions provide the starting point for the multivariate happiness regressions shown in Table 4. With respect to these regressions it should be noted in the first place that the coefficient of determination (adjusted R2) is unanimously rather high (above 0.95) in all regressions. An exploratory regression on the country and year dummies alone (not shown) reveals that they represent a major portion of the overall explanatory power. The R2 statistics of the regressions which include prosperity and pollution thus yield little insight and are not reported in the table. Rather, we focus on the question of whether prosperity and pollution make a significant contribution over and above the dummy variables.

Table 4: Multivariate Regressions. Dependent Variable: log*(LIFESAT)*

	(A)	(B)	(C)	(D)	(E)
log(*INCOME*)	0.308 (3.86)	0.259 (2.09)	0.262 (2.34)	0.191 (1.15)	0.208 (1.80)
log(*NITROGEN*)	-0.044 (4.47)			-0.085 (1.61)	-0.057 (2.27)
log(*PARTICLES*)		-0.022 (1.22)		0.028 (0.71)	
log(*LEAD*)			-0.011 (2.26)	-0.020 (2.52)	-0.012 (2.23)

Note: Regressions include country and year dummies; method: GLS. Figures in parenthesis are t-statistics.

Regressions (A) - (C) combine income with each of the pollutants separately. It can be seen that the coefficient of *INCOME* is positive and significant in each of these cases. The coefficients of the pollutants are negative and significant for *NITROGEN* and *LEAD* while being negative and insignificant in the case of *PARTICLES.* The result that *PARTICLES* becomes insignificant when *INCOME* is included while being significant on its own (see Table 2) is obviously related to the circumstance that the two variables exhibit a strong and highly significant (negative) association, as shown in Table 3.

Regression (D) includes all pollutants jointly with *INCOME*. The result is that all explanatory variables except *LEAD* become insignificant. The lowest t-statistic is obtained for *PARTICLES* and the coefficient turns positive. Eliminating this insignificant regressor yields regression (E). The result is that all remaining coefficients have the expected sign and the two pollutants are significant at confidence levels of about 3 percent; *INCOME* is significant at a level of 8 percent.

If one compares the estimated coefficients from these multivariate regressions with the univariate results from Table 2, one conclusion is that omitting the pollution variables from the income-happiness relationship implies a considerable omitted-variable bias: While the elasticity of *LIFESAT* with respect to *INCOME* is estimated at almost 0.4 when pollution is omitted (first line of Table 2), it drops by almost half when pollution is included (regression (E) in Table 4). The reason is that, since higher prosperity is strongly associated with lower pollution (see Table 3), the beneficial effect of reduced pollution levels is attributed to increased prosperity when pollution is omitted from the regression.

Similar reasoning helps to explain why it is difficult to identify a linkage between *PARTICLES* and well-being when *INCOME* is included in the regression: Due to the strong negative association between *PARTICLES* and *INCOME*, the beneficial effect of reduced levels of the former is attributed to higher levels of the latter. With respect to the other two pollutants there is also a negative association with *INCOME*, but it is weaker or more fragile than in the case of *PARTICLES* and therefore does not prevent their effect on well-being from being identified.

With respect to the effect of *PARTICLES* it should also be noted that there is a strong positive linkage of this pollutant to *NITROGEN* and *LEAD*: In a log-linear regression of *PARTICLES* on *NITROGEN* and *LEAD*, the coefficients are 0.733 and 0.107, respectively (with associated t-statistics of 7.09 and 4.58). Thus, a 1-percent change in *NITROGEN* goes along with a change in *PARTICLES* by more than 0.7 percent. This (multi)collinearity adds to the difficulty of establishing an explicit relationship between *LIFESAT* and *PARTICLES* in the multivariate framework, though it is clearly visible in the univariate setup.

Overall, regression (E) can be considered a satisfactory representation of the linkage of subjective well-being to prosperity and air pollution. Even though it fails to capture the role of *PARTICLES* explicitly, their effect may be thought of as being represented by the coefficients of *NITROGEN* and *LEAD* in an implicit fashion, due to the strong association between *PARTICLES* and these other two pollutants.

3.3 Alternative Specifications

In addition to the linear-in-logaritms specification considered above, a linear-in-levels formulation of the happiness regression has been examined. Results are reported in Table 5.

Table 5: Multivariate Regressions. Dependent Variable: *LIFESAT*

	(A)	(B)	(C)	(D)	(E)
INCOME	0.030 (2.03)	0.030 (2.34)	0.022 (0.93)	0.027 (1.01)	0.022 (0.87)
NITROGEN	-0.004 (3.49)			-0.007 (1.14)	-0.006 (1.74)
PARTICLES		-0.01 (1.28)		0.000 (0.01)	
LEAD			0.052 (0.67)	-0.104 (0.98	-0.003 (0.03)

Note: Regressions include country and year dummies; method: GLS. Figures in parenthesis are t-statistics.

In comparison with the logarithmic specification we find several of our previous results confirmed: *LIFESAT* exhibits a positive association with *INCOME* and a negative association with *NITROGEN*, whereas a linkage between *LIFESAT* and *PARTICLES* is again hard to establish. In contrast to the logarithmic specification, however, there does not seem to exist a link between *LIFESAT* and *LEAD*, and the relationships of *LIFESAT* to *INCOME* and *NITROGEN* are now insignificant in several of the specifications examined. The only specification which is satisfactory from a statistical point of view is regression (A), but this fails to capture the impact of *LEAD* on *LIFESAT*.

We thus conclude that the logarithmic specification provides the preferred framework for investigating the linkage between air pollution and subjective well-being

4. Evaluating Air Pollution

4.1 Effects on Well-Being

Our preferred specification, regression (E) from Table 4, can be used as the basis for computing the marginal disutility of air pollution. The result will provide an answer to the question: "How many happiness categories - on a scale from 1 to 4 - is a representative individual shifted downwards (upwards) when the ambient concentration of pollutant *X* increases (decreases) by 1 $\mu g/m^3$?"

The problem with expressing the effects on well-being in this way is - obviously - that the measurement units of the pollutants ($\mu g/m^3$) are not very vivid. Moreover, as shown in Table 1, typical concentrations of *NITROGEN* and *LEAD* differ by a factor of more than 100. Hence, a comparison of the effects of the two pollutants - if expressed in this way - is not straightforward.

For these reasons we choose to describe the effects of air pollution on well-being (and likewise its monetary valuation) differently: We ask (a) How is well-being affected by a 1-standard-deviation change[7] of pollution? and (b) How is it affected by the observed changes over the sample period 1990-1997?

Table 6 presents the results. In computing the figures displayed, the average across 1990-1997 of each country's marginal disutility of pollution has been multiplied (a) by the standard deviation (SD) of the pollutant concentrations in the complete sample, and (b) by the difference between the pollutant concentration in 1990 and 1997 in each respective country.

[7] The standard deviations are reported in Table 1.

The table reports the summary statistics of the figures so obtained. More specific comments are provided in the text.

Before interpreting these results, a few comments on the development of air pollution in the countries considered may be helpful. In 1990-1997 the urban NO_2 concentration decreased in all countries except Portugal. The rates of decrease were between 9 percent in France and the UK and 41 percent in Spain, whereas Portugal experienced an increase by 58 percent. Among the reasons for the variance in the rates of change are differences in the growth of electricity generation and of car traffic. With respect to power generation it is also important to note that by 1990 the countries considered (which are all members of the European Union) had achieved varying degrees of completing the denitrification programs for power stations prescribed by the European Unions's regulation. As a result, some of the countries, especially the poorer ones, had to undertake more abatement than others in the 1990s. As concerns car traffic, a factor that influenced NO_2 emissions was the market penetration of catalytic converters, which was different in the various countries by 1990 and thereafter.

The reasoning with respect to car traffic also applies to lead, since catalytic converters require unleaded gasoline (whereas the converse is not true). As a result of the introduction of unleaded gas, urban lead concentrations dropped by up to 80 percent in 1990-1997. However, in one of the countries considered (Luxembourg) the lead concentration in 1997 was practically the same as in 1990, probably because the diffusion of unleaded gas had already been largely completed by the beginning of the 1990s.

Table 6: Effects on Well-Being of Changes in Air Pollution

	1-SD change in *NITROGEN*	Observed change in *NITROGEN*	1-SD change in *LEAD*	Observed change in *LEAD*
Mean	0.035	0.030	0.067	0.047
Median	0.035	0.021	0.050	0.048
Maximum	0.055	0.070	0.155	0.074
Minimum	0.020	0.012	0.015	0.019
Std. Dev.	0.011	0.021	0.058	0.024

From the first column of Table 6 it can be seen that on average a 1-SD drop in *NITROGEN* entails an increase in subjective well-being by 0.035 categories. This could also be expressed by saying that on average 3.5 percent of the people are lifted up one happiness category. The corresponding minimum and maximum effects are 2 percent and 5.5 percent.

The average effect of the *observed* decreases in *NITROGEN* is 0.030 or 3 percent, with a minimum of 1.2 and a maximum of 7 percent. The average figure corresponds approximately to the figure for Belgium. In Belgium, the NO_2 concentration dropped by about 14 percent in 1990-1997 and, according to our estimate, this lifted about 3 percent of the citizens up one category of happiness. In Portugal, the NO_2 concentration increased by 58 percent, shifting 7 percent of the people downwards by one happiness category.

With respect to *LEAD* concentrations we find the average effect of a 1-SD change to be 0.067, the inter-country range being 0.015 to 0.155. The larger range of effects in comparison with *NITROGEN* is due to the larger range of *LEAD* concentrations (see Table 1) which implies a larger variation in the marginal effects of any given change in concentrations.

The average effect of *observed* changes in *LEAD* is 0.047. This indicates that, on average, the effect on subjective well-being of the reduction of lead concentrations in 1990-1997 was about 1.5 times that of the reduction of NO_2. One reason for this stronger effect is the circumstance that the decrease in lead concentrations was in general more pronounced than the decrease in NO_2. An example of the strong decrease is provided by Germany, where atmospheric lead dropped by 70 percent. The implied increase in well-being is 0.048, a figure very similar to the average effect of the observed changes (0.047).

The result for Germany means basically that the increased penetration of unleaded gas shifted almost 5 percent of the Germans up one happiness category. The smallest effect occurred in Belgium, where the drop in lead concentration amounted to 40 percent, lifting just under 2 percent of the citizens up one category.

4.2 Monetary Valuation of Air Pollution

We are now able to calculate the utility-constant trade-off, or marginal rate of substitution (MRS), between income and air pollution. The MRS of pollution for income is the amount of income that the representative individual must be given to compensate her for a one-unit increase in pollution (see equ. (2)).

The results are displayed in Table 7. Similar as in the preceding section, the method of obtaining the shown figures is to apply the average across 1990-1997 of each country's MRS to (a) the standard deviation of the pollutant concentrations in the complete sample, and (b) the difference between the pollutant concentration in 1990 and 1997 in each respective country

With respect to *NITROGEN* the representative person values a 1-SD decrease at about \$1000 on average, the range across countries being roughly \$400 to \$1800. The observed decrease

1990-1997 is valued at about $880 p.a. on average, with a minimum of somewhat more than $500 and a maximum of almost $1900. To provide a more specific benchmark, the average valuation ($880 p.a.) may be compared to the somewhat less than $950 p.a. at which a representative Belgian citizen values the fact that concentrations in 1997 are 14 percent below those in 1990. A representative person in the Netherlands values the observed 9 percent decrease at $540 p.a.

Table 7:Marginal Rates of Substitution of Air Pollution for Income

	1-SD change in *NITROGEN*	Observed change in *NITROGEN*	1-SD change in *LEAD*	Observed change in *LEAD*
Mean	1024	879	1798	1413
Median	1038	539	755	1527
Maximum	1837	1896	4361	2358
Minimum	420	372	312	558
Std. Dev.	391	597	1949	815

With respect to *LEAD* we find higher valuations throughout. A 1-SD change is valued at almost $1800 on average, whereas the average valuation of observed changes is $1400. As in the case of marginal disutility (see preceding section), these averages mask considerable dispersion. The average figure is similar to the figure for Germany (about $1500), where the reduction amounted to 70 percent. The lowest figure (roughly $560) refers to Greece, where the reduction was 60 percent.

The latter comparison provides just one illustration of a more general finding, namely that differences in the valuation of observed changes are not proportional to the size of these changes. Since (in our preferred formulation of the happiness regression) higher per capita income implies a lower marginal utility of income, a representative citizen of a richer country (such as Germany) is prepared to sacrifice more income in exchange for better air quality than a citizen in a less prosperous country (such as Greece).

5. Conclusions

This paper has used a set of panel data on average self-reported well-being (happiness) in 10 European countries, jointly with data on per capita income and air pollution, to examine how subjective well-being varies with prosperity and air quality. The estimates obtained were used to measure the slope of indifference curves, i.e. the rate at which a representative citizen is willing to trade off income against air pollution. Thus, by direct estimation of the preference function over prosperity and air pollution, a new approach to environmental valuation has been demonstrated.

The proposed methodology should be viewed as a complement rather than a substitute for standard valuation techniques such as contingent valuation, or demand-based, weak-complementarity methods. These approaches continue to be indispensable with respect to single environmental assets and specific measures to improve their quality (e.g. maintenance of local recreation sites) since these assets are rather unlikely to be empirically identifiable as arguments in an individual's happiness function. By contrast, with respect to aggregate phenomena, such as air pollution, empirical identification of their linkage to subjective well-being is more plausible.

In fact, the paper has found that air pollution plays a statistically significant role as a predictor of inter-country and inter-temporal differences in subjective well-being and that the effect of air pollution on well-being shows up as a considerable monetary valuation of improved air quality. More specifically, the average (across countries) valuation of air quality improvements achieved in 1990-1997 amounts to almost $900 per capita per year in the case of nitrogen dioxide and more than $1400 per capita per year in the case of lead.

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