DISCUSSION PAPER SERIES

IZA DP No. 6732

Life Satisfaction and Air Quality in Europe

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July 2012

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zur Zukunft der Arbeit
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IZA Discussion Paper No. 6732
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ABSTRACT

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Concerns for environmental quality and its impact on people's welfare are fundamental arguments for the adoption of environmental legislation in most countries. In this paper, we analyse the relationship between air quality and subjective well-being in Europe. We use a unique dataset that merges three waves of the European Social Survey with a new dataset on environmental quality including SO_2 concentrations and climate in Europe at the regional level. We find a robust negative impact of SO_2 concentrations on self-reported life satisfaction.

JEL Classification: I31, Q51, Q53, Q54

Keywords: air quality, SO_2 concentrations, subjective well-being, life satisfaction, Europe, European Social Survey, GIS

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1. Introduction

Concerns for environmental quality and its impact on people's welfare date back, at least, to the industrial revolution. However, conventional welfare measures, Gross Domestic Product (GDP) in particular, ignore many important non-market factors that may explain individual well-being, including environmental quality. In recent years, a broader perspective towards the measurement of welfare is emerging among economists (e.g., Deaton, 2008; Fleurbaey, 2009). Two manifestations of this broader perspective have been an increased interest in using people's subjective well-being as a proxy for utility, and hence a welfare indicator, and the consideration of a rich spectrum of factors (in addition to income) to explain people's well-being.

In economics, the interest in subjective well-being (often measured using "happiness" or "life satisfaction" questions) has increased rapidly over the last decade (for overviews see, e.g., Frey and Stutzer, 2002; Dolan *et al.*, 2008; van Praag and Ferrer-i-Carbonell, 2008; MacKerron, 2011).[1] This new line of research has shown that many factors beyond income significantly affect people's subjective well-being, including health, employment, and marital status. The effect of environmental quality on subjective well-being has also begun to be investigated (for a comprehensive summary see Welsch and Kühling, 2009, and Welsch, 2007, 2009). Research shows that several dimensions of environmental quality: air pollution (e.g., Welsch, 2002, 2006; Luechinger, 2009; Menz and Welsch, 2010), noise (Van Praag and Baarsma, 2005), climate (e.g., Rehdanz and Maddison, 2005) and natural hazards (Luechinger and

[1] Both happiness and life satisfaction are components of subjective well-being. Although slightly different constructs, economists often use them interchangeably to measure overall feelings of well-being. For a discussion on different question modes on subjective well-being and validity see e.g., Kahneman and Krueger (2006).

Raschky, 2009), have a significant influence on subjective well-being in the expected direction.

The main objective of this paper is to analyze how air quality affects people's subjective well-being in Europe. We use survey data collected in the first three rounds of the European Social Survey (ESS)[2] between 2002 and 2007 matched with a uniquely created dataset on sulfur dioxide (SO_2) concentrations at the regional level in Europe. We use Geographic Information Systems (GIS) to interpolate annual mean pollutant concentrations for SO_2 from a network of monitoring stations in 23 European countries between 2002 and 2007, and match them (together with other spatial controls) with individual responses to the ESS during the same period (see Brereton *et al.*, 2011). Overall, our research feeds both into the recent development in subjective well-being research that considers environmental quality as a key determinant of subjective well-being as well as into a more policy-oriented interest in subjective well-being research.

Dolan *et al.* (2011) argue that subjective well-being data can be used in a number of ways by policymakers, and they highlight three areas: (i) monitoring progress, (ii) informing policy design, and (iii) policy appraisal. However, using subjective well-being to inform policy-makers is nothing new. For a long time, Bhutan has used subjective well-being information to both evaluate and plan public policies, and uses Gross National Happiness (GNH) as a national indicator of progress in addition to GDP. Recently, French president Nicholas Sarkozy set up a commission ("Stiglitz Commission"), led by Nobel Prize laureates Joseph Stiglitz and Amartaya Sen to "identify the limits of GDP as an indicator of economic performance and social progress; [...] to consider what additional information might be required for the

[2] For more information about the European Social Survey see Section 2 and www.europeansocialsurvey.org.

production of more relevant indicators of social progress; to assess the feasibility of alternative measurement tools, and to discuss how to present the statistical information in an appropriate way" (Stiglitz *et al.*, 2009, p.3).[3] Moreover, the United Kingdom under the leadership of Prime Minister David Cameron has established the "National Well-being Project," and the Office for National Statistics will publish the UK's first official subjective well-being index in 2012.

In this context, it is important to improve our understanding of the determinants of subjective well-being, in particular those that, like air quality, can be influenced, directly or indirectly, by public policy. The European Union (EU) has established an extensive body of environmental legislation over the decades to improve individual well-being by ensuring health-based standards for pollutants. For example, Directives 1996/62/EC, 1999/30/EC and 2002/3/EC[4] establish limit values for concentrations of sulphur dioxide (SO_2), oxides of nitrogen (NO and NO_2), particulate matter (PM_{10}), and carbon monoxide (CO) in ambient air. In this paper (as in Luechinger, 2009, 2010), we limit our analysis to SO_2 for a number of reasons; firstly, it has an adverse impact on human health (e.g., Folinsbee, 1992), and, among the pollutants mentioned above, only PM_{10} and SO_2 can be directly noticed by humans. Secondly, the main source of SO_2 emissions is fossil fuel combustion at power plants and other industrial facilities, as opposed to non-stationary emitters (e.g., road transport in the case of CO, NO_2 and PM_{10})[5] and as such it is a regional rather than a local pollutant and hence makes full use of the regional nature of our dataset. In Berlin, for example, PM_{10} concentrations at

[3] In the Commission, we also find Nobel Prize laureates Kenneth Arrow, James Heckman, and Daniel Kahneman, and prominent subject experts (Angus Deaton, Robert Putnam, Nicholas Stern, Andrew Oswald, and Alan Krueger).
[4] http://ec.europa.eu/environment/air/quality/legislation/existing_leg.htm.
[5] In the case of Ireland, for example, over 50% of total SO_2 emissions originate from one location in the West of Ireland (de Kulizenaar *et al*., 2001).

kerbside sites on main streets are up to 40% higher than in the urban background (Lenschow *et al*., 2001).

Previous studies analyzing the impact of environmental amenities on subjective well-being have focused on local areas (e.g., Van Praag and Baarsma, 2005 (noise); Brereton *et al*., 2008; MacKerron and Mourato, 2009 (air quality)) or used macro data aggregated at the national level (e.g., Rehdanz and Maddison 2005, Welsch 2002, 2006). To the best of our knowledge this is the first study that uses regional data on ambient air pollution concentrations (SO_2) coupled with other spatial controls (climate data on temperature and precipitation, and regional indicators of economic performance) to explain individual subjective well-being in Europe. The individual survey data on subjective well-being and socio-demographic characteristics from the ESS are linked to a unique GIS dataset of regional environmental quality in Europe. A recent paper by Murray *et al*. (2011) considers the regional variation of climate across Europe and its impact on life satisfaction for the third wave of the European Values Survey. However, it does not consider air pollution, which, at least in the medium-run, is more amenable to policy intervention than climate.

The rest of the paper is organized as follows. In the next section we describe the data. Section three presents the empirical approach and section four the results. Section five concludes.

2. Data

2.1. Survey data

We use individual survey data from the first three waves of the ESS. The ESS is a biennial, cross-sectional, multi-country survey covering over 30 nations. It was fielded

for the first time in 2002/2003.[6] ESS data are obtained using random (probability) samples, where the sampling strategies, which may vary by country, are designed to ensure representativeness and comparability across European countries. We use the first three waves of the ESS dataset in this paper which include approximately 75,000 observations from 23 European countries.[7]

To capture subjective well-being, we use the answers to the following life-satisfaction question: "All things considered, how satisfied are you with your life as a whole nowadays?" Respondents were shown a card, where 0 means extremely dissatisfied and 10 means extremely satisfied. Figure 1 shows the average life satisfaction levels across the regions covered by the ESS over the three rounds, that is between 2002 and 2007. Overall, Europeans report high levels of life satisfaction (7.12 on average), and the levels are especially high in Nordic countries (from 7.74 in Norway to 8.49 in Denmark). The lowest levels of life satisfaction among the countries in the ESS are found in Portugal (5.47) and in Eastern European countries (5.51 in Hungary and 5.80 in Slovakia). These results are inline with previous findings in cross country studies using other similar datasets (see e.g., World Values Survey, 2011). We summarize average life satisfaction at regional levels in Figure 1, and this figure shows that there are also variations in life satisfaction across regions within countries. For example, average life satisfaction in Italy ranges from 5.57 in Sardinia to 7.80 in Valle d'Aosta.

>>> Figure 1

[6] See www.europeansocialsurvey.org.

[7] The countries included in our analyses are Austria, Belgium, Czech Republic, Switzerland, Germany, Denmark, Estonia, Spain, Finland, France, Greece, Hungary, Ireland, Italy, Luxembourg, Netherlands, Norway, Poland, Portugal, Sweden, Slovenia, Slovakia and the UK.

The explanatory variables at the individual level include socio-economic and socio-demographic characteristics, and we have selected variables that have been found in previous studies to have an impact on subjective well-being (age, sex, marital status, household composition, educational level, employment status, household income, and citizenship of the country of residence) (see e.g., Dolan *et al*., 2008). The ESS also collects information on a number of variables that have been used to proxy for personal functioning/feelings (e.g., self-reported health and religiosity) that also influence subjective well-being and are typically included as additional individual controls in the literature. Table 1 contains the variable descriptions and Table 2 the descriptive statistics of the variables used in our empirical analysis.

>>> Table 1

>>> Table 2

2.2. Measuring air quality

We collected data on the annual mean SO_2 concentrations from a network of monitoring stations in 23 European countries between 2002 and 2007 from AirBase, the public air quality database system of the European Environmental Agency.[8]

In order to convert the point data from the monitoring stations into regional data up to a NUTS 3 level,[9] we used two GIS-based interpolation methods: inverse distance weighting (IDW) and kriging. In IDW, the weight (influence) of a sampled data point is

[8] http://acm.eionet.europa.eu/databases/airbase/index_html.

[9] The Nomenclature of Territorial Units (NUTS after the French Nomenclature d'Unites Territoriales Statistiques) is a geocode standard for referencing the subdivisions of countries for statistical purposes.

inversely proportional to its distance from the estimated value. Kriging permits the variogram (i.e., the spatial dependence of the data) to assume different functional forms that include directional dependence. The variables used in the estimation are based on IDW interpolation. IDW is suitable for rapid interpolation of in-situ air quality data, and retains a larger number of the original data after interpolation than kriging. Results based on kriging-interpolation based variables were similar.[10] The final level of regional aggregation in the analysis (NUTS 1, NUTS 2 or NUTS 3), varies by country and is determined by the level of spatial disaggregation in the ESS.[11]

Figure 2 shows average SO_2 concentrations across Europe in 2006. In addition to between-country variation, there is much within-country variation in pollution levels. For example, for Poland, the country with the second highest average concentration of SO_2 (at 10.60 μg/m^3), concentrations range between 4.8 μg/m^3 in the region of Zachodniopomorskie and 21.22 μg/m^3 in Slaskie. Interestingly, the "greener" countries in Figure 2, Norway and Denmark (with average concentrations of 1.09 and 2.19 μg/m^3, respectively) are also among the most satisfied in Figure 1.

>>> Figure 2

2.3. Other regional characteristics

In order to prevent omitted variable bias (for example, pollutant concentrations are correlated with congestion and the latter might have a negative impact on life

There is a 3-level hierarchy for each EU member country with NUTS 3 referring to the smallest subdivision.

[10] For more details on the interpolation methodology and more detailed information about the dataset see Brereton *et al*. (2011).

[11] Austria (NUTS 2), Belgium (NUTS 1), Czech Republic (NUTS 3), Switzerland (NUTS 2), Germany (NUTS 1), Denmark (NUTS 3), Estonia (NUTS 3), Spain (NUTS 2), Finland (NUTS 2), France (NUTS 2), Greece (NUTS 2), Hungary (NUTS 2), Ireland (NUTS 3), Italy (NUTS 2), Luxembourg (NUTS 1),

satisfaction as it is associated with longer commutes (Stutzer and Frey, 2008)), we control for a number of variables that proxy for the economic and demographic characteristics of the area where the respondent lives as well as for the climate conditions. The first is the size of the settlement where the respondent lives as stated by the respondent (big city, suburbs, town, small village, or farm/country side). We also collected regional information on population density, GDP per capita and the unemployment rate for the population 15 and above from the European Commission's Eurostat database.[12,13]

Finally, we control for regional climatic conditions. Climate variables, from the European Climate Assessment & Dataset,[14] include maximum temperature in July, minimum temperature in January, and mean annual precipitation. We used similar interpolation techniques as for the pollution data.[15]

3. Econometric methods

We estimate the following hybrid subjective well-being function (which merges individual and regional level information in the same equation):

$$LS_{ijk,t} = \alpha_k + \delta_t + \boldsymbol{\beta}'_1 \mathbf{X}_{ijk,t} + \boldsymbol{\beta}'_2 \mathbf{Z}_{jk,t} + e_{ijk,t} \ , \qquad (1)$$

Netherlands (NUTS 3), Norway (NUTS 2), Poland (NUTS 2), Portugal (NUTS 2), Sweden (NUTS 3), Slovenia (NUTS 3), Slovakia (NUTS 3) and the UK (NUTS 1).

[12] See http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database

[13] In addition, because the regional macroeconomic variables contain many missing values, and when included in the regression, reduce the sample size by almost half, we analyzed the robustness of the results to two alternative variables using ESS data: average of the income reported by other respondents in the respondent's region (as a proxy for regional income), and the ratio of the number of unemployed actively seeking work to those in a paid work in the respondent's region (as a proxy for regional unemployment).

[14] See http://eca.knmi.nl/

[15] In addition, we used Climate Data Operators (CDO) software to extract the relevant files and to obtain the values for the relevant variable from daily data. CDO is a collection of tools developed by the Max-Planck Institute to manipulate, analyze and forecast climate data (see http://www.unidata.ucar.edu/software/netcdf/software.html#CDO).

where the self-reported life satisfaction, *LS*, of individual *i*, in region *j*, at country *k*, in year *t* depends on a vector of individual socio-demographic and economic characteristics ($\mathbf{X}_{ijk,t}$), and the characteristics of the region where s/he resides, which include annual indicators of pollution, climate, and demographic and economic controls ($\mathbf{Z}_{jk,t}$). In addition, in equation (1) we control for unobserved country-level and temporal heterogeneity by introducing country (α_k) and time (δ_t) dummies.

It should be noted that ESS is a repeated cross-section, not a panel. Hence, we do not control for unobserved individual heterogeneity. Previous studies have addressed unobserved individual heterogeneity by averaging observations across individuals in a country (for example, Welsch 2002, 2006, and Luechinger, 2010), at the cost of ignoring intra-country variability in environmental conditions. While the averaging approach is viable at the national level since the ESS samples at the country level are representative, it is not appropriate at the regional level. ESS samples are not representative at this finer level of spatial disaggregation.[16] In this paper, we do not fully address individual unobserved heterogeneity in order to take advantage of the rich variation of environmental conditions at the regional level across Europe.

Equation (1) can be estimated by ordinary least squares (OLS) or, given the ordinal nature of the dependent variable, life satisfaction, by using either ordered-probit or ordered-logit models. As in previous studies that have applied both approaches, we find little qualitative difference between the results of the two (see e.g., Ferrer-i-Carbonell and Frijters, 2004, or Angrist and Pischke, 2009). Our discussion below focuses on the OLS results as their interpretation is more straightforward.[17] In all the regressions, standard errors are clustered at the regional level to account for biases

[16] www.europeansocialsurvey.org/index.php?option=com_content&view=article&id=80&Itemid=365.

arising from potential intra-correlation of responses (e.g., Moulton, 1990; Williams, 2000).

4. Results

We estimate six different specifications of the model presented in equation (1). The simplest version, in the first column of Table 3, is a standard subjective well-being regression that includes only individual characteristics ($\mathbf{X}_{ijk,t}$) as explanatory variables without inclusion of region-specific variables ($\mathbf{Z}_{jk,t}$).

The impacts of individual socio-economic characteristics on subjective well-being are similar to those typically found in the literature (e.g. Dolan *et al*., 2008; Blanchflower and Oswald, 2008). Age has a non-linear, U-shaped, effect on well-being. Being a female, having a higher income and better health, all have a positive and significant impact on life satisfaction. People who are married or in a civil partnership report to be more satisfied with life than singles, while separated and divorced are less content. Regarding employment status, students and retired people report the highest levels of life satisfaction, while those unemployed report the lowest. As we would expect, results in Table 3 indicate that people who report to be in good health are substantially more satisfied with life than those who are in poor health.

The other five specifications of the model presented in equation (1) expand the standard subjective well-being regression by incorporating the spatial variables. In column 2 of Table 3, SO_2 emerges with a negative and statistically significant coefficient. An increase of 1 $\mu g/m^3$ in SO_2 concentrations is associated with a reduction in life satisfaction of 0.016 point on the life satisfaction scale. In order to put this

[17] The results of the ordered probit estimation are available upon request.

number into perspective, it lies the estimated coefficients of the impact of country-level SO_2 concentrations on subjective well-being in Luechinger (2010) range between -0.001 and -0.002 with life satisfaction elicited in a 4-point scale (i.e. our estimates using regional instead of country-level data are about three to four times larger). In column 3 of Table 3, we re-estimate the results, but exclude the health status variables. Compared to column 2, the coefficient of SO_2 increases in both size and significance (it is now significant at the 5% level). This suggests that SO_2 has indeed an impact on life satisfaction through health, but combined with the results in column 2, it seems that much of the negative impact of SO_2 on life satisfaction that we find in our regressions is a direct effect, not captured by the health-status dummies.[18]

>>> Table 3

In column 4 of Table 3, we control for the size of settlement where the respondent lives and for regional differences in climate. Results shown in column 4 are robust to the inclusion of these additional variables. Regarding the impacts of pollution concentrations on life satisfaction, SO_2 remains statistically significant, and if anything, its negative effect on life satisfaction is larger than in column 3 in terms of both magnitude and significance, increasing to 0.0212 and significant at the 1% level. Turning to the size of settlement variables, living in urban areas is associated with lower life satisfaction than living in rural areas; life satisfaction tends to be monotonically

[18] The negative impact of SO_2 on life satisfaction does not seem to be due to differences in environmental attitudes among respondents either. In regressions not reported in the paper but available upon request, we find that people who report that "the environment" is important also tend to report higher levels of life satisfaction. This is similar to the effect that Ferrer-i-Carbonell and Gowdy (2007) who find for concern about species extinction. However, the size and significance of the SO_2 pollution coefficient in column 3 of Table 3 does not change.

reduced as the size of the dwelling area of the respondent increases. Of the climate variables, the coefficients on the January minimum and July maximum temperatures are consistent with preferences for milder climates (although these coefficients are not statistically significant at the conventional levels). Precipitation has a positive and significant impact on life satisfaction, in line with findings in Rehdanz and Maddison (2005) which they explain as possibly due to landscape effects.

In column 5 of Table 3, we complete the list of spatial controls by also including regional macroeconomic variables: unemployment rate, GDP per capita and population density. In this specification, the regional unemployment rate has a negative and significant impact on well-being (as in Clark and Oswald, 1994 and Luechinger *et al*., 2010). Results for SO_2 remain robust, although due to missing observations of the macroeconomic variables, the number of observations is reduced by about one third. For robustness, in column 6 we include alternative indicators of unemployment rate and average income constructed from ESS data (see Table 1 for exact definitions) and thus without having the same problem of losing many observations as in the previous model. The result for SO_2 is similar to what is presented in column 4.

5. Conclusions

In recent years there has been a rapidly increasing interest in subjective well-being data among policy-makers for uses ranging from monitoring progress to direct use in policy design. The analysis of the impact of environmental factors on subjective well-being at a sub-national level has in the past been limited by data availability, except for studies in local areas (e.g., Van Praag and Baarsma, 2005, study of noise in Amsterdam, or MacKerron and Mourato, 2009, study on air quality in London).

This paper combines rich European data on air pollution, climate and macroeconomic controls using GIS to create a detailed spatially-referenced dataset at the regional level to feed analyses investigating the importance of air quality on individual welfare. This is along the suggested line of research in the overview paper by Welsch and Kühling (2009) when they wrote "Another difficulty is that the spatial and temporal matching between happiness and income on the one hand and environmental conditions on the other is sometimes rather crude. In the light of this, improvements in available data sets may be expected to enhance the precision of results" (p. 403).

Our dataset matches regional concentrations of SO_2, a pollutant amenable to regional analysis, and that has received considerable attention from policy makers, as well as other spatial controls to individual data from the first three waves of the European Social Survey. This allows us to investigate the relationship between people's subjective well-being levels and air quality at the regional level in Europe. Previous analyses that have analyzed the role of SO_2 concentrations on life satisfaction (e.g., Di Tella and MacCulloch, 2008, Luechinger, 2009, 2010, Menz and Welsch 2012) find that pollution negatively affects subjective well-being, but they use country level data or concentrate on one country only (Luechinger, 2009).

Consistent with previous studies, when using detailed regional data, we find a negative and significant relationship between air pollution and individual self-reported life satisfaction. An increase in SO_2 concentrations by 1 $\mu g/m^3$ is associated with a reduction in life satisfaction of between 0.016 and 0.021 points on the 11-point life satisfaction scale. The sign, significance and magnitude of this effect are robust to using different model specifications. We warn, however, that while our analysis, at the

regional level, may be appropriate for a regional pollutant such as SO_2, it may not extend to other, more local, air pollutants.

Acknowledgements

We would like to thank Richard Howarth, Heinz Welsch for very helpful comments. Financial support from the European Science Foundation (Cross-National and Multi-level Analysis of Human Values, Institutions and Behaviour (HumVIB)) and from Formas through the program Human Cooperation to Manage Natural Resources (COMMONS) is gratefully acknowledged. We would like to thank Tine Ningal and Oana Borcan for excellent research assistance.

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Table 1: List of variables

VARIABLE	SOURCE	DESCRIPTION
Individual variables (Xijt)		
Socio-demographic Indicators	ESS	
Subjective Well-Being		"How satisfied with life as a whole?": 0 (extremely dissatisfied) - 10 (extremely satisfied)
Sex		Dummy: 1= Female
Age		Age of respondent in years
Marital Status		4 categories: married or in civil partnership; separated, divorced; widowed; never married nor in civil partnership (reference)
Household Income		Household's total net income (all sources).
Employment Status		8 categories: paid work; in education; unemployed and actively looking for job; unemployed and not actively looking for job; permanently sick or disabled; retired; housework; other (reference category).
Educational Level		Years of full-time education completed
Household size		Number of people living regularly as member of household
Children		Dummy: 1= Children in the household
Citizenship		Dummy: 1=Citizen of country of residence
Born in country		Dummy: 1=Born in country of residence
Size of settlement		5 categories: big city, suburbs, town/small city, village, farm/country side
Personal and interpersonal feelings and functionings	ESS	
Health Status (self-reported)		Discrete: 1 (very good) - 5 (very bad)
Religiosity		Dummy: 1 = Belonging to a particular religion or denomination
Important to care for nature and environment		Discrete: 1 (very much like me) – 6 (not like me at all)
Regional variables (up to NUTS3 level) (Zjt)		
Pollution	EEA AirBase/Authors	
SO2		SO2 mean annual concentration (µg/m3)
Climate	ECA/Authors	
July max temperature		Mean of daily max. temperature in July (°C)
Jan min temperature		Mean of daily min. temperature in January (°C)
Mean annual precipitation		Annual mean precipitation (mm)
Socioeconomic structure	Eurostat + ESS/Authors	
GDP per capita		Regional gross domestic product (PPP per inhabitant) by NUTS 2 regions
Population density		Population density by NUTS 2 region
Unemployment rate		Unemployment rate by NUTS 2 region
Sample average regional household income		Ln(average income reported by other respondents in respondent's region)
Sample regional unemployment rate		Ratio of number of unemployed actively seeking work to those in a paid work in the respondent's region

Note. For more information on pollution and climate variables see Brereton *et al*. (2011).

Table 2: Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Life Satisfaction	81326	7.12	2.17	0	10
Income	81326	34980.62	29860.71	900	150000
Marital status					
Paid work	81326	0.55	0.50	0	1
Student	81326	0.08	0.27	0	1
Unemployed seeking	81326	0.04	0.19	0	1
Unemployed not seeking	81326	0.02	0.14	0	1
Disabled	81326	0.03	0.17	0	1
Retired	81326	0.24	0.43	0	1
Housework	81326	0.23	0.42	0	1
Years of education	81326	12.03	4.09	0	56
Marital status					
Married/partner	81326	0.55	0.50	0	1
Separated/divorced	81326	0.10	0.29	0	1
Widowed	81326	0.09	0.29	0	1
Sex: female	81326	0.52	0.50	0	1
Age	81326	47.75	17.69	14	110
Household size	81326	2.70	1.40	1	15
Children	81326	0.40	0.49	0	1
Religiosity	81326	0.61	0.49	0	1
Born in country	81326	0.92	0.27	0	1
Citizen of country	81326	0.96	0.19	0	1
Health status					
Very good health	81326	0.23	0.42	0	1
Good health	81326	0.44	0.50	0	1
Fair health	81326	0.25	0.43	0	1
Environment important	76116	2.13	1.00	1	6
Pollution					
SO_2	77316	5.37	3.74	0.48	27.17
Size of settlement					
Big city	81162	0.17	0.38	0	1
Suburbs	81162	0.14	0.35	0	1
Town	81162	0.31	0.46	0	1
Village	81162	0.31	0.46	0	1
Climate					
Max temperature	77232	24.01	4.01	5.67	35
Min temperature	77316	-1.94	4.99	-43	10
Precipitation	71419	2.26	0.90	0	6
Macroeconomic variables					
Unemployment rate	60440	8.30	5.24	1.3	26.7
GDP per capita	49444	23117.26	10036.04	6900	57100
Population density	57871	416.96	798.04	4.3	6458.7

In sample Macroeconomic variables					
Unemployment rate	81253	7.85	15.44	0	5.83
Average income	81326	34933.4	15826.5	5478.3	98666.7

Table 3: Life satisfaction and air pollution

Variables	Standard LS	Including SO2 pollution variable				
		With health controls	No health controls	No health controls+ spatial controls	No health controls+ spatial controls + macro controls	No health controls+ spatial controls + (in sample) macro controls
	(1)	(2)	(3)	(4)	(5)	(6)
Ln(Income)	0.298***	0.294***	0.355***	0.372***	0.383***	0.362***
	(0.0195)	(0.0201)	(0.0211)	(0.0222)	(0.0249)	(0.0216)
Employment Status						
Paid work	-0.0177	-0.0245	0.0454	0.0346	0.0170	0.0359
	(0.0264)	(0.0269)	(0.0291)	(0.0309)	(0.0402)	(0.0305)
Student	0.202***	0.216***	0.271***	0.289***	0.340***	0.287***
	(0.0356)	(0.0362)	(0.0376)	(0.0391)	(0.0535)	(0.0383)
Unemployed seeking	-1.046***	-1.059***	-1.066***	-1.080***	-1.147***	-1.091***
	(0.0693)	(0.0718)	(0.0737)	(0.0770)	(0.0897)	(0.0762)
Unemployed not seeking	-0.628***	-0.613***	-0.664***	-0.683***	-0.664***	-0.682***
	(0.0914)	(0.0933)	(0.0971)	(0.0986)	(0.113)	(0.0985)
Disabled	-0.305***	-0.337***	-1.117***	-1.118***	-1.069***	-1.118***
	(0.0522)	(0.0524)	(0.0564)	(0.0582)	(0.0645)	(0.0579)
Retired	0.197***	0.185***	0.0813**	0.0636	0.0298	0.0650
	(0.0344)	(0.0345)	(0.0403)	(0.0407)	(0.0530)	(0.0411)
Housework	0.0369*	0.0342	0.0425*	0.0453*	0.0217	0.0438*
	(0.0208)	(0.0214)	(0.0234)	(0.0236)	(0.0326)	(0.0233)
Education	0.0144***	0.0159***	0.0308***	0.0335***	0.0399***	0.0329***
	(0.00335)	(0.00342)	(0.00360)	(0.00355)	(0.00427)	(0.00348)
Marital Status						
Married/partner	0.373***	0.376***	0.417***	0.405***	0.457***	0.403***
	(0.0234)	(0.0248)	(0.0265)	(0.0267)	(0.0337)	(0.0264)
Separated/divorced	-0.158***	-0.156***	-0.136***	-0.132***	-0.117**	-0.134***
	(0.0335)	(0.0343)	(0.0361)	(0.0378)	(0.0490)	(0.0373)
Widowed	-0.0540	-0.0464	-0.0601	-0.0596	-0.0572	-0.0616
	(0.0370)	(0.0383)	(0.0410)	(0.0441)	(0.0518)	(0.0436)
Sex (female=1)	0.146***	0.145***	0.109***	0.107***	0.118***	0.108***
	(0.0146)	(0.0151)	(0.0166)	(0.0170)	(0.0209)	(0.0170)
Age	-0.0467***	-0.0464***	-0.0586***	-0.0613***	-0.0672***	-0.0609***
	(0.00386)	(0.00395)	(0.00451)	(0.00489)	(0.00648)	(0.00488)
Age squared /100	0.0525***	0.0523***	0.0577***	0.0607***	0.0660***	0.0603***
	(0.00393)	(0.00403)	(0.00459)	(0.00500)	(0.00647)	(0.00500)
Household size	0.0267***	0.0278***	0.0310***	0.0188**	0.0206*	0.0202**
	(0.00833)	(0.00848)	(0.00863)	(0.00890)	(0.0113)	(0.00870)
Children	-0.135***	-0.142***	-0.162***	-0.153***	-0.173***	-0.153***
	(0.0233)	(0.0237)	(0.0243)	(0.0253)	(0.0343)	(0.0248)
Religiosity	0.190***	0.193***	0.202***	0.193***	0.232***	0.192***
	(0.0216)	(0.0225)	(0.0235)	(0.0244)	(0.0305)	(0.0234)
Born in country	0.202***	0.202***	0.229***	0.194***	0.218***	0.200***
	(0.0343)	(0.0347)	(0.0364)	(0.0377)	(0.0480)	(0.0375)
Citizen in country	0.107**	0.106**	0.0898*	0.0812	0.0688	0.0816
	(0.0457)	(0.0474)	(0.0487)	(0.0498)	(0.0667)	(0.0497)
Health Status						
Very good health	2.202***	2.188***				
	(0.0500)	(0.0516)				
Good health	1.707***	1.701***				
	(0.0447)	(0.0459)				
Fair health	1.109***	1.106***				
	(0.0413)	(0.0422)				
Pollution						
SO_2		**-0.0160***	**-0.0174****	**-0.0212*****	**-0.0185****	**-0.0213*****
		(0.00814)	**(0.00805)**	**(0.00764)**	**(0.00753)**	**(0.00817)**
Size of settlement						
Big city				-0.254***	-0.147**	-0.263***
				(0.0514)	(0.0672)	(0.0515)
Suburbs				-0.244***	-0.133**	-0.259***
				(0.0474)	(0.0650)	(0.0478)
Town				-0.230***	-0.153**	-0.235***
				(0.0463)	(0.0614)	(0.0462)
Village				-0.114***	-0.0348	-0.120***
				(0.0413)	(0.0549)	(0.0413)
Climate variables						

Avg min temperature Jan				0.00270	0.00732	0.00122
				(0.00832)	(0.0128)	(0.00845)
Avg max temperature July				-0.00788	-0.00823	-0.0106
				(0.00824)	(0.0101)	(0.00809)
Precipitation				0.0687**	0.0621*	0.0690***
Macro variables Eurostat						
Unemployment rate					-0.0404***	
					(0.00641)	
GDP per capita					5.43e-07	
					(3.25e-06)	
Population density					-2.05e-05	
					(2.34e-05)	
Macro variables (in sample)						
Ln(average income)						0.294***
						(0.107)
Unemployment rate						0.150
						(0.159)
Country F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Observations	81326	77316	77348	71301	43882	71232
R-squared	0.252	0.251	0.201	0.200	0.188	0.200

Note: Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

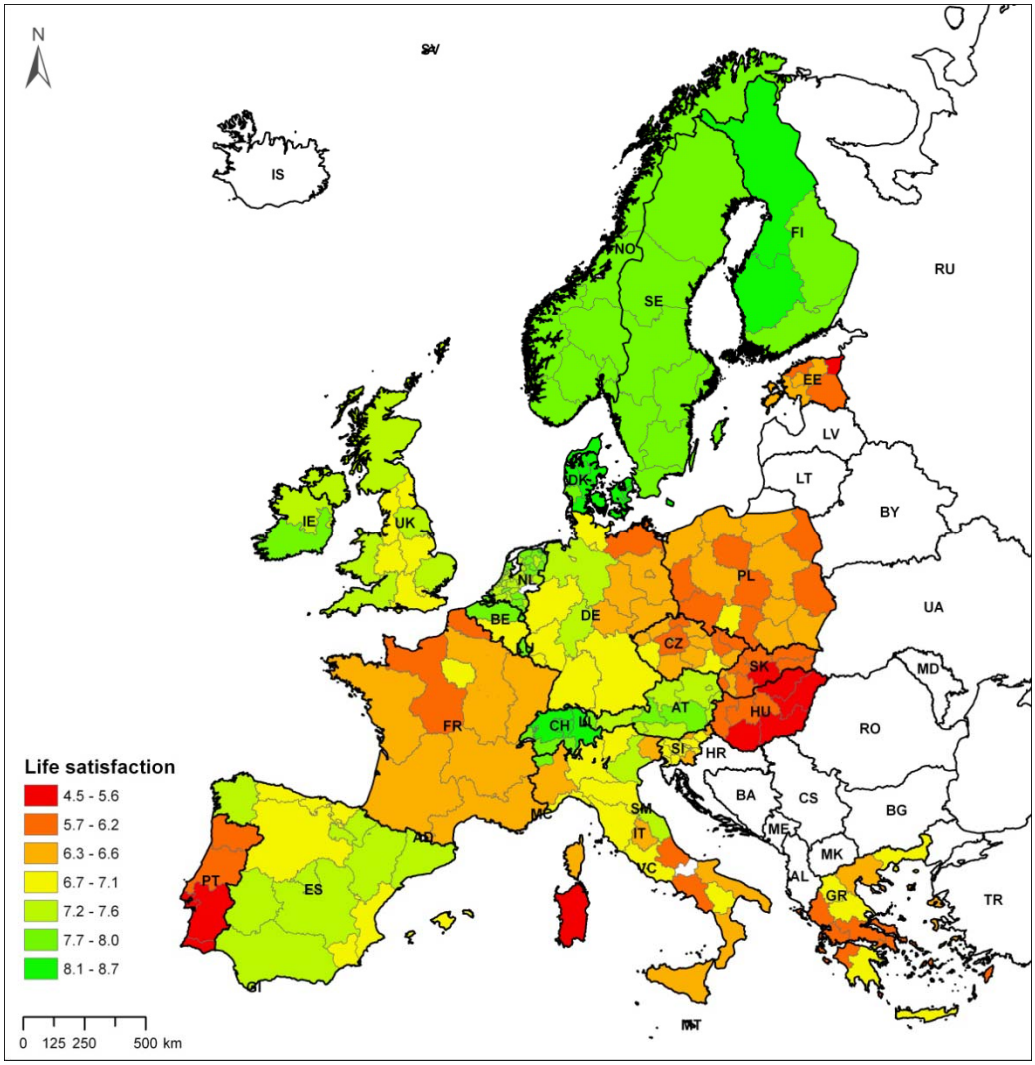

Figure 1: Life Satisfaction in Europe (2002-2007)

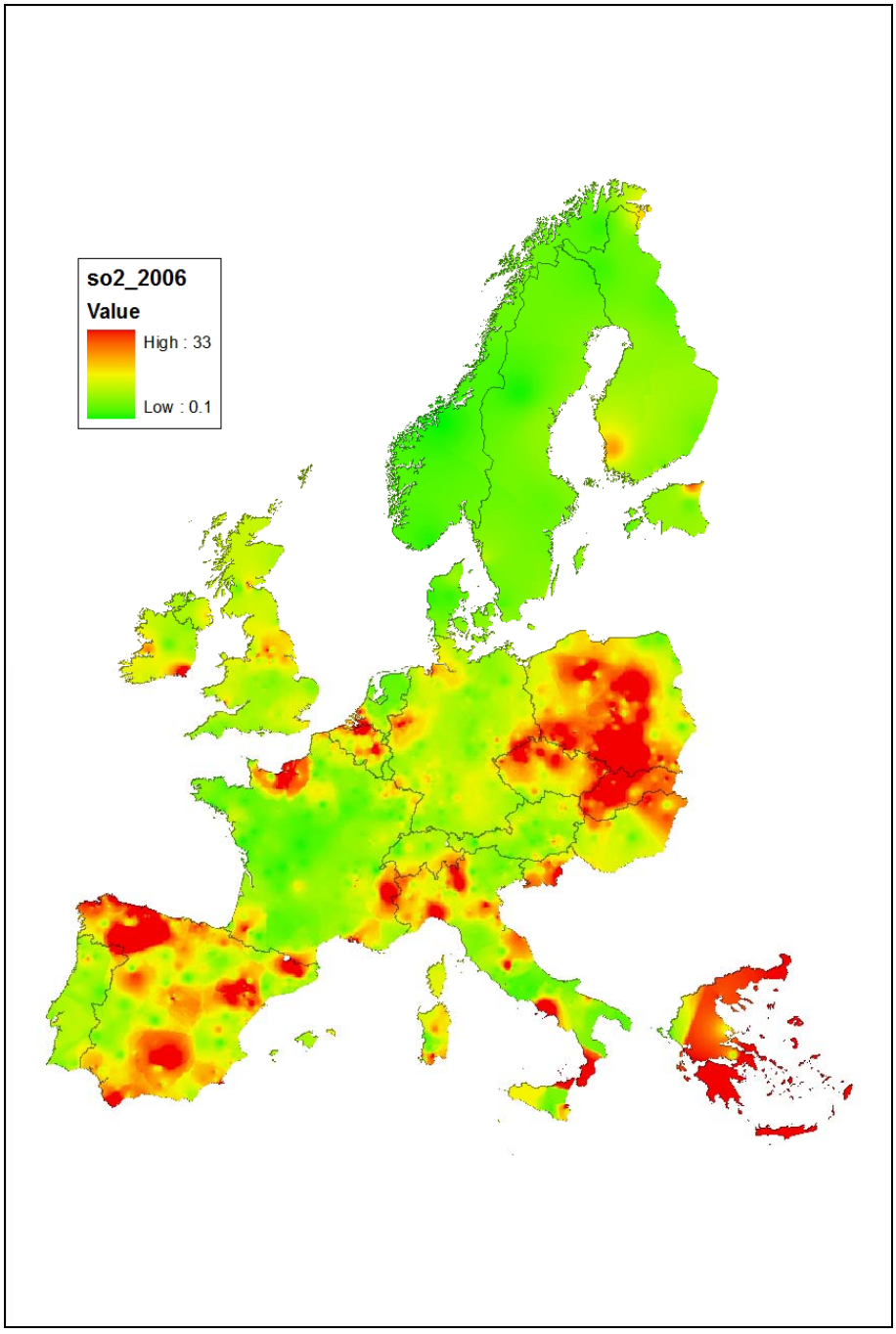

Figure 2: SO2 concentrations in Europe in 2006