Schmollers Jahrbuch 133 (2013), 275 – 286
Duncker & Humblot, Berlin

Subjective Well-Being and Air Quality in Germany

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Abstract

This paper analyses the relation between air quality and individual life satisfaction in Germany. Life satisfaction data from the German socio-economic panel is connected with daily county pollution in terms of carbon monoxide, nitrogen dioxide and ozone from 1998 to 2008. The assumed microeconometric happiness function is estimated considering individual fixed effects. Ozone has a significant negative impact on life satisfaction. The effect of carbon monoxide as well as nitrogen dioxide is not significant. Moreover, I found that people with environmental worries are more affected by ozone pollution. This was not the case for people with a bad health status. Using the marginal rate of substitution between income and air pollution, it is calculated that an increase of one $\mu g/m^3$ in average county ozone has to be compensated by an increase of € 11.33 in monthly net household income to hold an average individual's life satisfaction constant.

JEL Classifications: Q53; D60

1. Introduction and Empirical Evidence

The analysis of welfare in a non-monetary sense has become an important issue in political discussions as well as in economic research in recent years. Examples where policy makers call attention to happiness can be found in Bhutan, the UK, the US and also in Germany. Economic studies on life satisfaction (LS) can be attributed to the early work of Easterlin (1974). Empirical studies try to identify by which *other variables* than consumption LS is determined. A growing research field evolved around this goal[1].

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* I would like to thank participants at the 2012 SOEP Data Users Conference in Berlin for their helpful comments. A special thank goes to the German Weather Service and the German Environmental Federal Office who provided the data basis of the study, and J. Blankenbach for the great support in the interpolation of the geodesic data. Moreover I want to thank the ediors and M. Karlsson for helpful comments on previous versions of the paper.

[1] Compare for example to Clark et al (2008); Veenhoven (1997); Frey / Stutzer (2002).

The current paper analyses air quality as one determinant of individual LS. Thus, two important issues of today's political discussion are connected: alternative measures of welfare and rising problems induced by man-made air pollution. LS can be affected by air pollution in two ways: the impact can be direct as well as indirect. By the term direct, it is meant that air pollution affects the earth's atmosphere and human mood adjusts to this[2]. Speaking about an indirect effect means that air pollution has a strong impact on human health which in turn is positive correlated with LS[3]. In conclusion there might be a negative influence on LS. According to the World Health Organization (WHO, 2011), it is known that air pollution is even the most dangerous environmental risk. Especially respiratory and heart diseases increase with the level of pollution.

By now, there is only little empirical evidence on the impact of environmental quality on LS in economic research[4]. In this research, the focus is on air pollution as one determinant of environmental quality. Here, a macro as well as a microeconomic perspective can be undertaken to demonstrate constraints in people's LS induced by air pollution[5]. Most economic studies on the relation between LS and air pollution use a macroeconomic approach, i.e. data on aggregated LS and pollution is analyzed. Several of them observed a negative causal impact of pollution on LS. Using multiple regression, for example Welsch (2006) identified pollution as a significant predictor for inter-country differences in LS in Europe. Also Luechinger (2010) observed a negative impact for European countries.

The current paper undertakes a study of individual LS. This approach was only applied by a sparse range of studies in previous research, especially for Germany. In the current context, the most important one is the study of Luechinger (2009). He analyzed the impact of yearly average sulfur dioxide on individual LS. By implementing regression analysis with individual fixed effects, he found a significant negative impact. Coneus / Spiess (2012) also combined pollution and SOEP data. They observed a significant negative impact of pollution on infant health. Another study to be mentioned is the work of Rhedanz / Maddison (2008). Instead of environmental data, they used the answer to the question on how an individual feels affected by pollution and noise as measure of environmental quality. Using regression analysis, they observed that higher levels in both variables significantly decrease individual LS. How-

2 This is known from psychological research Compare for example to Colligan (1981).

3 Compare for Gerdtham / Johannesson (2001).

4 For a general overview see Ferrer-i-Carbonell / Gowdy (2007).

5 A more detailed literature review can be found in the complete discussion paper version under the following link: http://www.diw.de/documents/publikationen/73/diw_01.c.416307.de/diw_sp0541.pdf.

ever, it is to be questioned whether these variables are an adequate indicator for real air pollution.

The current study contributes to previous research by broadening the range of analyzed pollution variables in Germany. Moreover, the connection of data on individual LS and air quality is very close in time and geographical distance. This makes it possible to observe the impact of indeed current pollution levels. Additionally, the models control for weather conditions that might affect the level of current pollution. Finally, the relation between pollution and LS is estimated with control for individual fixed effects. On all of these aspects insufficient attention was paid on in previous studies. The goal of the current work is to identify the relation between air pollution and LS in Germany and to evaluate an increase in air pollution in monetary terms.

2. Air Pollution in Germany

According to the report of the German Environmental Federal Office, pollutant emissions in Germany had been reduced over the past 20 years by the introduction of new technologies (Umweltbundesamt, 2009). Nevertheless, this trend is not observed for air pollution parameters, i.e. pollution levels in Germany did not decrease proportionally. This might be due to the fact that emissions underly transformations when they are exhausted in the atmosphere. In particular, meteorological conditions strongly affect the distribution of pollutants. For example, weather situations with a high exchange between air layers lead to higher spreading of the particles and thus to less concentration of pollutants and vice versa.

In this research, air quality is measured by three different pollution parameters. These are carbon monoxide (CO), nitrogen dioxide (NO2) and ozone (O3). They are standard variables, by which air quality in Germany is controlled. The impact of fine particles on LS would also be another important research field, but unfortunately there is no data available for the whole period of the analysis. The gaseous pollutants CO and NO2 are mainly produced by combustion processes (e.g. heating or traffic). O3 on the ground level is one of the major types of smog. It is the output of the reaction of sunlight with other pollutants like nitrogen oxides. The pollution data was provided by the German Environmental Federal Office. I use daily averages of the pollutants from all measuring stations within a county. Thereby, stations in urban as well as in rural areas are considered. The approach has the advantage that the generally higher pollution levels measured close to main roads are compensated by observed levels from rural stations that tend to be lower. All observations are outside measurements. Thus, outside pollution is used as a proxy for every pollution people are affected by over the day.

In Table (1) average pollution levels over the whole of Germany are reported. The average level of CO pollution per county was almost 0.7 mg/m^3. NO2 pollution is measured in $\mu g/m^3$ and was on average at a level of around 28. Average O3 levels are closest to the critical threshold, at a value of 45 $\mu g/m^3$ and maximum levels clearly exceed the threshold value.

Table 1

Descriptive Statistics Air Pollution

	CO	NO2	O3
Unit of measure	mg/m^3	$\mu g/m^3$	$\mu g/m^3$
Daily county average	0.6809	27.7088	44.7347
Min	0.0015	0.0278	0.3375
Max	15.5	80.5625	135.787
Std Dev	1.1617	11.1376	22.0321
Threshold for human health protection	10 (max 8h average)	200 (1h average max on 18 days per year)	120 (8h average max on 25 days per year)

Notes: Data source: German Environmental Federal Office. Own calculations. First part describes daily pollution parameters calculated as average per day and county. Measuring stations with rural as well as with urban background were included. Bottom part includes threshold values for protection of public health from the official website of the German Environmental Federal Office18 given by EU Directives 2008. All threshold values based on normalized conditions of a temperature equal to 293 K and pressure of 101,3 kPa.

In addition, all of the pollutants underly a typical seasonal variation. CO and NO2 follow a U-shaped pattern with peaks at the beginning and the end of the year and lowest values during the summer. In the contrary, O3 generally reaches highest levels in the middle of the year and is lower in winter.

3. Life Satisfaction in Germany

Individual data on LS was taken from the socio-economic panel (SOEP)[6]. The main independent variable used in the current study as measure for the latent variable *subjective well-being*, is the answer to the following question:

How satisfied are you with your life, all things considered?

6 More detailed information can be found on the SOEP Web page under the following link: http: //www.diw.de/soep and in the work of Wagner et al (2007). Data from wave o to wave y is used.

Hereto, the interviewee is asked to answer according to a scale from 0 to 10, where 0 means *completely dissatisfied* and 10 stands for *completely satisfied*[7]. Table (2) provides descriptive statistics on LS.

Table 2

Descriptive Statistics LS

	Germany			East Germany			West Germany		
	all	male	female	All	male	Female	all	male	Female
N	110,481	52,919	57,562	29,050	13,977	15,073	81,431	38,942	42,489
Mean	6.821	6.825	6.818	6.388	6.397	6.381	6.976	6.979	6.973
Std dev	1.769	1.760	1.777	1.740	1.737	1.743	1.753	1.742	1.763

Notes: Data source: SOEP. Own calculations. Columns report descriptive statistics on average LS for the whole of Germany and distinguished by East and West Germany. Statistics calculated for the entire population as well as separately for each gender.

The average LS over whole Germany is almost 7. This is consistent with previous studies analyzing the SOEP[8]. On average, people living in West Germany are more satisfied with their lives than individuals from East Germany. Regarding the gender, no obvious differences in average LS occurred.

4. Empirical Analysis

4.1 Data Connecting Process

One main weakness of previous studies analyzing the relation between air pollution and LS lies in the data connecting process. To the best knowledge of the author, by now there is no study using the SOEP, in which the interpolation of pollution data is close in time. Generally air pollution is measured in yearly averages, which leads to criticism in three points: Firstly, pollution levels underlie a clear seasonal trend as it was mentioned in the previous section. This is not taken into account if yearly averages are used. Secondly, yearly averages include also information lying in the future from the perspective of the interview date and is considered to explain current LS. Finally, from psychological research it is known that LS itself underlies fluctuations in short time windows because the answer to the question on how happy the respondent is, strongly depends on his or her current mood[9].

7 This is a common used indicator for LS, compare for example Frey / Stutzer, 2002.

8 Compare for example to Rhedanz / Maddison (2008).

9 Compare for example to Kahneman and Krueger (2006).

In the present study, LS and pollution data was connected on the county level from 1998 to 2008. First, an inverse distance weighted average of all measured pollution levels within a circle of 60 km around the county centroid was calculated for each day. Afterwards, this data was merged to the individual data of the SOEP by interview date and home county.

4.2 Methodology

As it is common use in research, the current analysis is based on a microeconometric happiness function. This is an appropriate approach, given that the subjective well-being is a valid measure for the latent variable Life Satisfaction (LS*) (Frey and Stutzer, 2002). The relation is described by the following equation:

$$LS^*_{it} = \alpha + \beta P_t + \gamma W_t + \delta \chi_{it} + \varepsilon_{it}$$

$$LS_{it} = l \Leftrightarrow \lambda^i_l \leq LS^*_{it} \leq \lambda^i_{l+1}$$

LS_{it}: Observed subjective well-being of individual i at time $t = 1, \ldots, T$.

P_t: Average pollution level at time t in the home county of the individual

W_t: Weather conditions at time t in the home county of the individual

χ_{it}: Socioeconomic control variables influencing happiness

The ordered probit model was used in many studies in economic research to estimate this relation. But considering the results of Ferer-i Carbonell/Fritjers (2004), this approach leads to biased results in the coefficients of the LS determinants. This is caused by ignored time-invariant individual factors. Thus, in the current analysis, the impact of air pollution on LS is estimated by the use of a conditional fixed effects logistic regression. For this purpose the dependent variable has to be collapsed into binary format. This was implemented by the use of individual specific thresholds of LS, i.e. for each individual a dummy variable ls_{it} is generated which equals one if person i has stated a value of LS at time t that is higher than the individual mean value over the whole period. Following the approach of Chamberlain (1980), the resulting Maximum Likelihood is estimated conditioned on the number of observed ones for individual i over the whole period. Implementing this methodology allows to exclude all static individual effects of the individuals.[10]

[10] A more detailed description of the estimation approach can be found in the full discussion paper version under the following link: http://www.diw.de/documents/publikationen/73/diw_01.c.416307.de/diw_sp0541.pdf.

4.3 Results

Results of the conditional fixed effects logistic regression are reported in Table (3). The estimation was implemented including all pollution variables simultaneously, with as well as without controlling for weather conditions. It is to be mentioned, that there is correlation between the pollution variables[11]. This induces a bias in the results due to omitted variables, if the effect is estimated excludingly for one of the pollutants. Nevertheless, it should be mentioned that there also could be a problem of multicolinearity, if correlation between the pollutants was too high.[12]

Overall, the results show the typical signs for the socioeconomic determinants. The p-Values of the χ^2-test show overall explanatory power of the model for each estimation. The relatively small values for the Pseudo R^2 are caused by the conditional fixed effects methodology and are consistent with earlier studies, that used the same approach[13].

Regarding the impact of air pollution, it was observed that only O3 has a significant negative impact on LS. The estimated coefficients of CO and NO2 pollution are also negative but not significant. The result holds for estimations including as well as excluding additional weather conditions. Nevertheless, it should be mentioned that leaving out the weather variables induces a less negative effect of O3. This might be caused by the fact that sunshine and temperature are positively correlated with the pollutant and in addition have a positive impact on LS itself. Thus, the estimated negative impact of O3 pollution on LS might be downward biased if weather is not considered as well.

11 Correlations between the pollution variables are reported in the full discussion paper version under the following link: http://www.diw.de/documents/publikationen/73/diw_01.c.416307.de/diw_sp0541.pdf.

12 Estimation results if only one of the pollutants is included in the model as well as a more detailed discussion of problems induced by omitted variables are reported in the full discussion paper version under the following link: http://www.diw.de/documents/publikationen/73/diw_01.c.416307.de/diw_sp0541.pdf.

13 Compare for example to Kassenboehmer/Haisken-DeNew (2009).

Table 3

Results Conditional Logistic Regression

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable	Binary LS	Binary LS	Binary LS	Good Health	Binary LS	Binary LS
age	–0.0841***	–0.0836***	–0.0803***	–0.1211***	–0.0751***	–0.0839***
hhinc	0.0001***	0.0001***	0.0001***	0.0001***	0.0001***	0.0001***
unemployed	–0.6933***	–0.6954***	–0.6825***	–0.3127***	–0.6746***	–0.6931***
disabled	–0.3420***	–0.3429***	–0.3466***	–0.6160***	–0.2311***	–0.3429***
married	0.2744***	0.2734***	0.2648***	0.0386	0.2652***	0.2749***
children	0.0064	0.0060	0.0267	–0.0551	0.0141	0.00612
bad health					–1.0313***	
environ. worries						0.0338
Co_mean	–0.0239	–0.0089	–0.0180	–0.0357		
No2_mean	–0.0010	0.0001	–0.0013	–0.0055*		
O3_mean	–0.0015*	–0.0014*	–0.0019**	–0.0027*		
Co_interact					0.0534	–0.0018
No2_interact					–0.0033	–0.0010
O3_interact					0.0008	–0.0007*
rainfall	0.0036		0.0038	0.0024	0.0033	0.0036
windspeed	–0.0144**		–0.0106*	–0.0181	–0.0176***	–0.0159***
sunshine	0.0032		0.0035	0.0086	0.0011	0.0033
temperature	0.0050**		0.0043*	–0.0038	0.0052**	0.0050**
Pseudo R^2	0.0212	0.0210	0.0201	0.0372	0.0421	0.0212
Prob $> \chi^2$	0.000	0.000	0.000	0.000	0.000	0.000
Log Likelihood	–2.155e+08	–2.155e+08	–1.910e+08	–79,194,393	–2.104e+08	–2.154e+08

Notes: Data source: SOEP, German Environmental Federal Office, German Weather Service. N = 105,575. Conditional Fixed Effects Logistic regression using Stata command clogit. First and second column show results with and without weather. In column (3) people who moved are excluded. In column (4) the estimated effect on good health is presented. Last two columns include results for interaction of pollution and bad health (5) and environmental worries (6). The interaction variables are defined as pollution variable times the dummy variables *bad health* and *person has environmental worries*, respectively. The group variable is the individual. Standard errors are clustered on the individual. Groups without switch in LS are excluded from the analysis (4,906 observations dropped). Monthdummies included to control for seasonal effects Significance level: * $p < 0 : 1$, ** $p < 0 : 05$, *** $p < 0 : 01$.

4.4 Monetary Valuation

The observed effect of air pollution on LS can further be used to evaluate increasing pollution levels in monetary terms. An adequate approach is the calculation of the marginal rate of substitution (MRS) between pollution and income of a representative individual. This can be computed as the negative value of the marginal effect of the pollution variable divided by the marginal effect of income[14]. In the case of the conditional fixed effects logit model, it has to be considered, that marginal effects are not constant. Thus, they are calculated for an average individual. Since the individual fixed effects cancel out in the chosen estimation model and are not estimated themselves, it is necessary to assume that they are equal to zero[15]. Following this approach it is observed that an increase of one $\mu g/m^3$ in average daily county ozone induces a necessary compensation payment of € 11.33 in monthly net household income to hold an average individual's LS constant.

4.5 Extensions and Robustness Checks

To test the validity of the observed results, three robustness checks were undertaken[16]. Firstly, one could think of selection bias in the sense that people who lived in areas with very high pollution might search for less polluted places and therefore move. Thus, the full model additionally was estimated with a sample in which individuals that switched their home states were dropped. Results are reported in column three of Table (3). Again it is observed that O3 has a significant negative effect on LS.

Secondly, in order to describe the indirect impact of pollution on LS through its negative effect on health, the estimation was implemented with self-assessed health as dependent variable. The considered dummy variable *good health* is defined as one, if the respondent stated his or her health status as very good, good or at least satisfactory. Results are presented in column four of Table (3). As it can be seen, CO as well as O3 has a significant negative impact on self-assessed health. This confirms the thesis that there is an indirect negative impact of pollution on LS.

Another sensitivity test lies in the definition of the pollution average. Instead of using daily levels, the analysis was also implemented with average pollution of the previous month. It was observed that O3 has still a significant negative impact on LS. In addition for CO pollution in the last month, a significant negative effect was estimated[17].

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14 Compare to Welsch (2006).

15 A more detailed description of the calculation of the MRS can be found in the full discussion paper version under the following link: http://www.diw.de/documents/publikationen/73/diw_01.c.416307.de/diw_sp0541.pdf.

16 Further extensions can be found in the full discussion paper version under the following link: http://www.diw.de/documents/publikationen/73/diw_01.c.416307.de/diw_sp0541.pdf.

17 Results can be found in full discussion paper version under the following link: http://www.diw.de/documents/publikationen/73/diw_01.c.416307.de/diw_sp0541.pdf.

Finally, it is questioned, whether LS of people with a bad health status or with environmental worries is more affected by air pollution. This is analyzed by including appropriate interaction terms with the pollutants in the model. Results can be found in the last two columns of Table (3). It was observed that a bad health status itself has a significant negative impact on LS. But since the coefficients of the interaction terms of bad health and pollution are not significant, there is no indication, that LS of ill people is more affected. Regarding people with environmental worries, it was found that in the case of O3 pollution there is a stronger negative impact on LS.

5. Conclusions

The current paper analyses the relation between air quality and individual LS in Germany. The impact of three pollution parameters on LS was estimated, by the use of a conditional fixed effects estimation approach. It was observed that O3 pollution significantly decreases individual LS. The estimated coefficients of CO and NO2 pollution were not significant. The reason, why only O3 has a significant effect might be the fact that the pollution levels are closest to its critical thresholds. Moreover, it was not found that people with worse self-assessed health have a higher O3 pollution induced loss in their LS. However, LS of individuals with environmental worries is more affected by air pollution. Evaluating the measured effects by the use of the marginal rate of substitution between income and air pollution, it was observed that an increase of one $\mu g/m^3$ O3 pollution has to be compensated by an increase of € 11.33 in monthly net household income. Nevertheless, it has to be considered, that air pollution parameters might underlie synergies, such that the impact of several pollution variables could be weakened even if only one of them is dammed. In conclusion, the current results give reason, to pay more attention on the control of air pollution. Especially in the case of O3 pollution, it was observed that on average pollution does not exceed critical thresholds for public health, but anyhow, the measured impact on individual LS is considerably large. Thus, it is to be questioned, whether prevailing legal norms should be adjusted to lower levels. Future analysis might use the same estimation approach to identify the relation in comparable countries. Another extension would be merging the data using zip codes, which would lead to even more precise results. Furthermore, it is to be questioned whether there is a lagged effect through health. The question would be, if pollution induced health problems in the previous time leads to a negative impact on LS today. Finally, it would be an appropriate alternative to estimate the impact of current pollution on LS also using a linear fixed effects approach. All of these possible extensions would bring evidence for current results and could build a basis for a global discussion on the set of pollution induced problems and help to identify policy plans for the protection of population and nature from man-made air pollution.

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