Subjective Well-Being and Air Quality in Germany

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Abstract

This paper analyses the relation between air quality and subjective well-being in Germany. Life Satisfaction (LS) data from the German Socio-Economic Panel Study (SOEP) is connected with daily county pollution in terms of carbon monoxide (CO), nitrogen dioxide (NO2) and ozone (O3) from 1998 to 2008. The assumed microeconometric happiness function is estimated considering individual time invariant effects. It is observed that O3 has a significant negative impact on life satisfaction. The estimated influence of current CO as well as NO2 is not significant. Moreover, I found that LS of people with environmental worries is 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 daily average county O3 has to be compensated by an increase of €11.33 in monthly net household income to hold an average individual's LS constant.

Key Words: life satisfaction, air pollution, environmental quality

1 Introduction

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. A very popular and distinctive example can be found in South Asia in the state of Bhutan, where the so called *Gross National Happiness* is established even by law. The goal of Bhutan's economic policy is to increase growth in terms of happiness instead of traditional measures like GDP or national income[1]. Following this popular example, UK's government introduced a *Gross Emotional Prosperity Index* in order to measure subjective well-being of the population[2]. In the United States similar activities are initiated. Psychological as well as economic experts are instructed by policy makers to define a measure of well-being that might be integrated in official statistics[3]. Also in Germany policy makers call attention to happiness. For instance, the Federal Ministry of Finance recently has published the *Economics of happiness*[4], in order to describe a possible new guiding principle for financial policy. Another suitable example for the rising relevance of life satisfaction in the German society is the so called *Glücksatlas*. Based on data from the German Socio Economic Panel (GSOEP), the *Glücksatlas* provides detailed information on the socioeconomic determinants of happiness on a generally accessible platform[5].

Economic studies on life satisfaction (LS) can be attributed to the early work of Easterlin (1974). It is assumed, that if we own enough, our satisfaction with life depends on *other variables* than consumption (Easterlin, 2003). Thus, economic studies on LS, try to identify these *other variables*. A growing literature evolved around this goal[6].

The current paper analyses air quality as one determinant of LS. Thus, it connects two very important subjects of today's political discussion: alternative measures of welfare and rising problems induced by man-made air pollution. LS can be affected by air pollution through two different channels: 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[7]. Speaking about an indirect effect means that air pollution has a strong impact on human health which in turn is positively correlated with LS[8]. In conclusion there might be a negative influence on LS. According to the World Health Organization (WHO)[9], it is known that air pollution is even the most dangerous environmental risk. Especially respiratory and heart diseases increase with the level of pollution. For instance, it is estimated that in urban areas, 1.3 million people die due to air pollution. A detailed description of the impact of the considered pollution variables will be given later on in the analysis of this paper.

Moreover, research on subjective well-being provides a new possibility to answer the complicated question on how to evaluate environmental conditions. In previous research two approaches can be found to evaluate the public good *air quality*: firstly, welfare losses can be calculated by a hedonic price approach using housingprices. Secondly, individuals can directly be asked about their willingness to pay for a reduction of pollution. In the framework of happiness research, pollution now can be evaluated using the estimated impact on LS (Frey et al., 2009).

This study contributes to previous research by broadening the range of analyzed pollution variables in Germany. Moreover, the connection of data on LS and air quality is very close in time and geographical distance. This makes it possible to observe the impact of current pollution levels. Additionally, the implemented model controls for weather conditions that might affect the level of current pollution levels. Finally, an estimation approach was implemented, which allows 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 quality and LS in Germany and to evaluate an increase in the pollution variables in monetary terms.

The paper is organized as follows: section 2 provides a short overview of previous empirical research on the determinants of subjective well-being and the impact of air pollution on LS in particular. In the two subsequent sections the data on LS and air pollution is considered in detail. Section 5 begins with a precise description of the data connecting process and the implemented methodological approach. Afterwards observed results are presented and evaluated in monetary terms. In section 6 concluding remarks are given.

2 Empirical Evidence

There is a wide range of empirical studies, analyzing the determinants of LS in industrialized countries. For an introduction to the research field, Frey and Stutzer (2002) provide an appropriate overview. The following cited articles are given examples for the common results listed below.

According to happiness research in economics, subjective well-being is positively influenced by income (Di Tella et al., 2003) and a good health status (Gerdtham and Johannesson, 2001). People living together with children show up higher levels of LS than others (Theodossiou, 1998). This holds also for married people, even if there is evidence that after marriage induced happiness increases, people tend to converge back to their baseline satisfaction levels (Lucas et al., 2003). A negative impact on LS has been observed, for instance, for the variables unemployment (Clark and Oswald, 1994; Knabe and Rätzel, 2010) and inflation (Di Tella et al., 2001). Regarding the influence of the individual's age, effects are not as unique as for the other variables. An often described result in previous research is a U-shaped age specific pattern, i.e. people in middle ages are happier than old and young individuals (Theodossiou, 1998). These standard socio economic variables influencing LS are considered as controls in the empirical analysis of the current paper.

By now, there is only little empirical evidence on the impact of environmental quality on LS in economic research[10]. In the present study, the focus is on air pollution as one determinant of environmental quality. Previous studies might be distinguished into two sections: A macro as well as a microeconomic perspective can be undertaken to demonstrate constraints in people's LS induced by air pollution. Most economic studies on the relation between LS and air pollution use a macroeconomic approach, i.e. data on aggregated LS and pollution is regarded. For instance, Welsch (2006) analyzed ten European countries. Connecting data on LS from the *World Database of happiness*[11] and average levels by country and year on nitrogene dioxide, particulate concentration and lead concentration, he found out that air pollution significantly determines inter-country LS. Luechinger (2010) also observed a negative impact on LS. Using data from 13 European countries, he measured that sulfur dioxide pollution decreases subjective well-being.

The current paper undertakes a study of LS on the individual level. This approach was only applied by a sparse range of studies in previous research, especially in Germany. In the current context, the most important one is the study of Luechinger (2009). He analyzed the impact of yearly averages of sulfur dioxide on individual LS in Germany and found a significant negative effect. Another study also using individual data from the SOEP is the work of Rhedanz and Maddison (2008). They used environmental quality measured in terms of how an individual *feels* affected by pollution and noise. It was observed that higher levels in both variables significantly decrease individual LS. However, it is to be questioned whether these variables are an adequate indicator of real air pollution. Coneus and Spiess (2012) also combined pollution and SOEP data. They observed a significant negative impact of pollution on infant health. In the work of Ferer-i Carbonell and Gowdy (2007) LS data from the British Houshold Panel Survey was analyzed. They found a negative impact of ozone pollution on LS. MacKerron and Mourato (2009) implemented a study on LS of London's population. They also observed a significant loss in LS when the mean nitrogen dioxide concentration increases.

To the best knowledge of the author, at the current state of knowledge, weather conditions are only sparsely considered in previous empirical analysis. But there is evidence that weather significantly determines pollution levels as well as subjective well-being (Umweltbundesamt, 2009; Rhedanz and Maddison, 2005). Thus, weather is an omitted variable when it is excluded from the analysis of the impact of pollution on LS. This is another gap, the current research tries to bridge. A precise discussion of this problem is provided in section 5.

3 How happy is Germany?

The LS data used in this analysis is taken from the German socio-economic panel (SOEP). This is a longitudinal study of German private households which started in 1984. By now every year about 20,000 individuals are sampled. The SOEP consists of 8 subsamples from which 6 are included in the analysis.[12]. The questions deal, for example, with employment, earnings and health[13]. Specific attention is also paid on indicators of LS. 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?

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*[14]. This is a common used indicator for LS[15]. Table (1) provides descriptive statistics on LS.

Table 1: Descriptive Statistics on LS

	Whole Germany			East			West		
	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, version 2011. 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.

N includes the number of observations excluding individuals with non response. The average LS of the entire population over whole Germany was almost 7. This is consistent with previous studies analyzing the SOEP[16]. On average, people living in West Germany are more satisfied with their lives than individuals from East Germany. This coincides with the results of the German *Glücksatlas*, which is also based on information of the SOEP. Regarding the gender no obvious differences in average LS were observed.

4 Air quality 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. These and other determinants lead to the fact that pollution differs between regions. For instance, nitrogen dioxide has higher levels in urban areas, while ozone induced burdens are often harder in rural regions.

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 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[17]. I use daily averages of the pollutants from all measuring stations within a county. Thereby, stations in urban as well as in rural areas were 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. Overall the data used in this study was collected by 765 stations. Of course, the observations are all outside measurements. In the ideal case one should use inroom pollution levels to analyse the effect on LS as well, since most people spend most of their time inside buildings. Unfortunately, information on this is not available at present. Thus, I use outside pollution as a proxy for every pollution people are affected by over the day.

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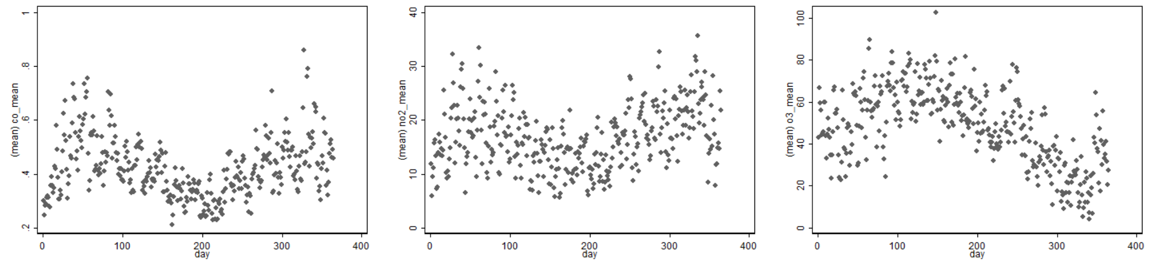
In Table (2) average pollution levels over the whole of Germany are reported[18]. The average level of CO pollution per county was almost 0.68 mg/m^3, which seems not too bad in comparison to the threshold value for human health protection of a maximum eight hour average of 10 mg/m^3 per day. In most European countries, CO concentrations are below the limits[19]. The same holds for NO2 pollution, which was observed at an average of around 27.7 $\mu g/m^3$. Compared to other European countries, NO2 pollution is relatively high in Germany. Average O3 levels are closest to the critical threshold, at a value of almost 45 $\mu g/m^3$, and maximum levels clearly exceed the threshold value. Since O3 highly depends on sunlight, the pollution in Germany is relatively high compared to Scandinavian countries and moderate compared to countries in the Mediterranean region of Europe. Moreover, the standard deviation of all three pollution variables shows sufficient randomness to have an impact on daily values in LS. This phenomenon is also illustrated in Figure (1) at the example of Mecklenburg-West Pomerania in the year 2005. Any other state and year could also have been chosen to illustrate

Figure 1: Randomness in average air pollution
Example of Mecklenburg-West Pomerania in 2005



(a) CO (b) NO2 (c) O3

Notes: Own Calculations. Data Source: German Environmental Federal Office. Average daily air pollution in Mecklenburg-West Pomerania in 2005. x-axis counts days from Jan 1 to Dec 31. NO2 and O3 levels measured in $\mu g/m^3$, CO levels measured in mg/m^3.

a similar picture.

Table 2: Average pollution degrees over the whole of Germany

	CO	NO2	O3
unit of measure	mg/m^3	$\mu g/m^3$	$\mu g/m^3$
daily average county level	0.6809	27.7088	44.734
min	0.0015	0.0278	0.3375
max	15.5	80.5625	135.787
std. dev.	1.1617	11.1375	22.0320
Threshold value for human health protection	$10mg/m^3$ max 8h average per day	$200\mu g/m^3$ 1h average max on 18 days per year	$120\mu g/m^3$ 8h average max on 25 days per year

Notes: Own calculations. Data Source: German Environmental Federal Office. 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 Office[20] 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.

If the mean pollution of each of the variables is considered separately for each state, it shows up that there is much variation between the geographical regions as well as between the different pollution variables. Figure (2) illustrates average daily air pollution by state. Using variance analysis methods the significance of these varieties can be verified. The highest mean CO level was observed in Schleswig-Holstein at a value of 0.757 mg/m^3 while the minimum average value was measured in Berlin at a level of 0.360 mg/m^3. Average NO2 was highest in Bavaria (33.450 $\mu g/m^3$), whereas the minimum value of 18.894 $\mu g/m^3$ was measured in Lower Saxony. The highest average O3 pollution was observed in Brandenburg, where daily averages exceeded 51 $\mu g/m^3$. The lowest levels occured in North-Rhine Westphalia: the daily O3 average was below 39 $\mu g/m^3$.

Beside the variation between different states, also a clear seasonal variation can be observed for each of the pollutants. Figure (3) illustrates the different pictures for all of them: O3 is highest in the summer and low in the winter, whereas for the other two pollutants a U-shaped pattern is observed with peaks at the beginning and the end of the year. This coincides with the variable descriptions of the German Environmental Federal Office[21]. The same picture evolves, when the seasonal trend of the pollutants is regarded separately for each state.

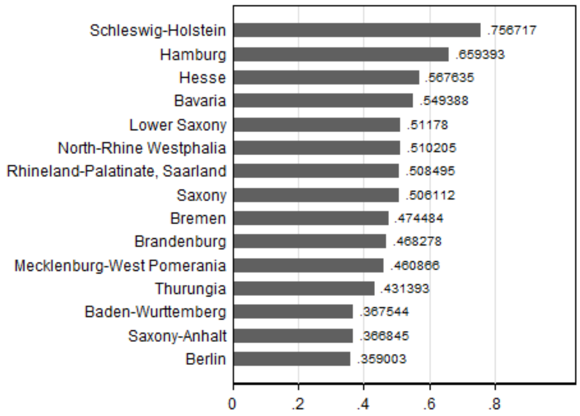
All of the considered pollution variables can be expected to influence LS. Firstly, they determine the environmental atmosphere people live in and it is expected that LS is adjusted to environmental changes. Moreover, following the information of the WHO[22], it is known that each of the parameters influences human health, which in turn implies a negative impact on LS. In the case of NO2 pollution, it was observed that child bronchitis and asthmatic diseases increase with higher long term levels. In addition, reduced lung functions are linked to it. Regarding pollution in terms of O3, a positive impact on breathing problems, asthma, reduced lung functions and lung diseases in general is measured. Finally, CO pollution affects human health in that people poison oneself by breathing the gas. Depending on the degree of poisoning the symptoms reach from headaches and sickness to consciousness disturbance. CO pollution therefore induces the most immediate effects.

5 Empirical Analysis

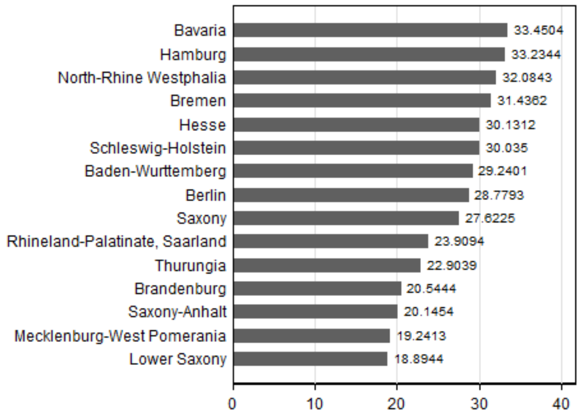
5.1 Connecting the data

One main weakness of previous studies analyzing the relation between air pollution and LS lies in the interpolation of the two data sets. 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:

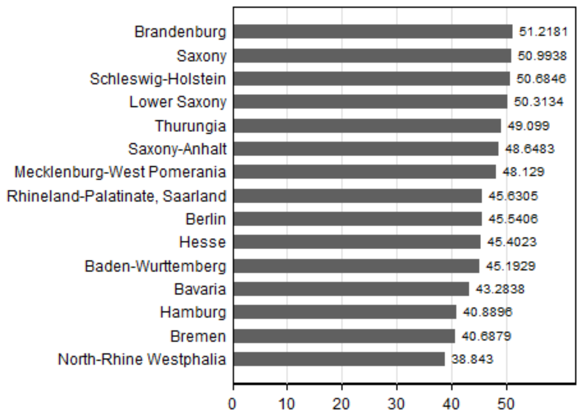
Figure 2: Average Air pollution by State



(a) CO



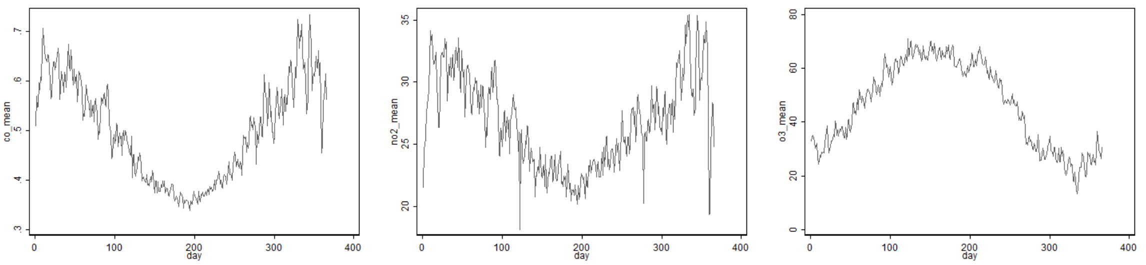
(b) NO2



(c) O3

Notes: Own Calculations. Data Source: German Environmental Federal Office. Average air pollution parameters from 1998 to 2008 for each state separately. NO2 and O3 levels measured in $\mu g/m^3$, CO levels measured in mg/m^3.

Figure 3: Seasonal Air Pollution

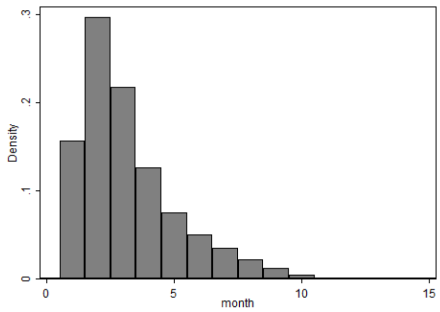


(a) CO (b) NO2 (c) O3

Notes: Own Calculations. Data Source: German Environmental Federal Office. Average seasonal trend for each pollution parameter separately. NO2 and O3 levels measured in $\mu g/m^3$ CO levels measured in mg/m^3.

Firstly, pollution levels underlie a clear seasonal trend as it was shown in the previous section in Figure (3). Also the interview date is unevenly distributed over the year. In Figure (4) the distribution of the interview month is illustrated.

Figure 4: Month of Interview



Notes: Distribution of month of interview over the year. Months counted from 1 to 12.

If yearly averages are used for the analysis, these fluctuations and their influence on LS are not taken into account. Secondly, if pollution is measured in yearly averages, also information which lies in the future from the perspective of the interview date is considered to explain current LS, which makes no sense. 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[23]. Thus, to identify the relation of current pollution and current LS, it is inevitable to interpolate the data close in time. In conclusion, it has to be mentioned, that if a negative impact of current pollution on LS can be observed, this would imply that policymakers should rethink general guidelines of pollution restrictions in order to protect people. By now, all restrictions are at the year level. Another point one might argue about is the unevenly distribution of the interview date. People that are interviewed in the later months of the year perhaps were hardly contactable and therefore have some certain characteristics. In order to control for this, month dummies are included in the empirical analysis later on.

In the current study, LS and pollution data were 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.

5.2 Theoretical Framework

As it is common use in research on LS, 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 equation (1).

$$LS^*_{it} = \alpha + \beta P_t + \gamma W_t + \delta X_{it} + \epsilon_{it} \tag{1}$$

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

LS_{it} : Observed subjective well-being of individual i at time $t = 1, ..., T$. It can take values from 1 to 10.

P_t : Average pollution level at time t in the home county of the individual, consequently β is the parameter of interest

W_t Describes additional weather conditions at time t in the home county of the individual that have an impact on the level of air pollution. A fact that was mainly ignored in previous studies.

X_{it} Includes socioeconomic control variables influencing happiness. A detailed description is given in Table (3)

It is assumed that the individual thresholds ${\lambda_l}^i$ for $l = 1, ..., 10$ are increasing which means ${\lambda_l}^i \leq {\lambda_{l+1}}^i$ and additionally it is supposed that $X_{it} \perp \epsilon_{it}$. Moreover, measurement error and mistakes in the interview are taken as randomly. The ordered probit model was used in most studies in economic research to estimate the relation. For this purpose, it is additionally assumed that LS is ordinal and panel data is treated as cross sectional data.

Table 3: Definition of variables

Variable	Description
age	Age of individual in years
hhinc	Aggregated monthly net income of all household members in €
unempl	Dummy variable equals one if individual is currently registered as unemployed
good health	Dummy variable equals one if individuals self assessed health is good or very good
disabl	Dummy variable equals one if individual is disabled, unabled to work
married	Dummy variable equals one if individual is married and lives together with partner
child	Dummy variable equals one if children under 16 years live in the household
CO	CO level in $\mu g/m^3$
NO2	NO2 level in $\mu g/m^3$
O3	O3 level in $\mu g/m^3$
Rainfall	Cumulative rainfall in milliliter per day
Windspeed	Classified in levels of the Beaufort scale
Sunshine	Sunshine duration in hours per day
Air temperature	Air temperature measured in degree centigrade

Notes: Pollution and weather variables all measured as average over the county the individual lives in on the day of the interview.

5.3 Estimation approach

Considering the results of Ferer-i Carbonell and Fritjers (2004), the commonly used ordered probit model to identify equation (1), leads to biased results in the coefficients of the happiness determinants. This is caused by ignoring time-invariant individual factors. Thus, in the current analysis, the impact of air pollution on individual LS is estimated by the use of a methodological approach that allows for individual time-constant effects. A conditional fixed effects logistic regression is undertaken. This approach will be described in the following.

For the purpose of using a conditional fixed effects logistic regression, the dependent variable first has to be collapsed into binary format. This was implemented by the use of individual specific thresholds of LS[24].

$$\text{ls}_{it} = \begin{cases} 1 & if \quad LS_{it} \quad > \quad \bar{LS_i} \\ 0 & if \quad LS_{it} \quad \leq \quad \bar{LS_i} \end{cases}$$

$$\bar{LS_i} = \frac{1}{T} \sum_{t=1}^{T} LS_{it}$$

The generated dummy variable ls_{it} equals one if person i has stated a value of subjective well-being at time t which is higher than the individual mean value over the whole period. Consequently, for each person there is an individual quantity of k_{1i} ones and $T_i - k_{1i}$ zeros in the variable ls_{it}. The reason why individual instead of overall thresholds are used lays in the fact that in this way less individuals are lost for the analysis, because individuals might switch there LS but do not exceed the overall mean LS. Moreover, in this way it is assumed that a switch from LS=1 to LS=2 is worth equal as a change in LS from 7 to 8.

Using standard Maximum-Likelihood techniques to solve the resulting problem would lead to inconsistent estimates (Chamberlain, 1980). A solution to this difficulty is given by considering the probability of $ls_i = (ls_{i1}, ..., ls_{i1})$ conditioned on the observed number of ones for person i ($k_{1i} = \sum_{t=1}^{T_i} ls_{it}$). This is given by equation (2):

$$Pr(ls_i = 1|k_{1i}) = \frac{exp(\sum_{t=1}^{T_i} ls_{it}\, x_{it}\, \beta)}{f_i(T_i, k_{1i})} = \frac{exp(\sum_{t=1}^{T_i} ls_{it}\, x_{it}\, \beta)}{\sum_{q_i \in Q_i} exp(\sum_{t=1}^{T_i} q_{it}\, x_{it}\, \beta)} \qquad (2)$$

x_{it} now includes all regressors of equation (1). Q_i denotes the set of all possible combinations of k_{1i} ones and $T_i - k_{1i}$ zeros. q_{it} equals to 0 or 1 with $\sum_{t=1}^{T_i} q_{it} = k_{1i}$. Thus, individual fixed effects are no longer considered for the estimation. Consequently, all time constant impacts cancel out, i.e. no intercept is estimated by the implementation of this methodology. Equation (3) describes the resulting Log-Likelihood function, which can be maximized by standard programms using conditional fixed effects logistic regression[25]. In the estimating process only individuals are included, whose LS is not constant over the whole period. This means that at least one switch in the dummy variable ls_{it} is neccessary. Using this approach makes it possible to exclude all static effects of the living environment of the individuals like for example labour market conditions or green areas from the analysis of the relation between air pollution and LS.

$$LL = \sum_{i}^{n} \left\{ \sum_{t=1}^{T_i} ls_{it}\, x_{it}\, \beta - ln(f_i(T_i, k_{1i})) \right\} \quad (3)$$

5.4 Results

Before the results of the regression analysis will be presented, the correlations between LS and pollution variables are considered. As reported in Table (4), only for O3 pollution a negative correlation with LS is observed. The negative correlation between O3 and the other pollutants might be induced by the fact of different seasonal variation as discussed in section 4. The correlation is positive between LS and CO, NO2 respectively.

Table 4: Correlation Coefficients

	LS	CO	NO2	O3
CO	0.023	1.000		
NO2	0.036	0.587	1.000	
O3	-0.013	-0.453	-0.586	1.000

Notes: Data Source: SOEP and German Environmental Federal Office. Correlation coefficients between LS and each of the pollution variables.

The results of the conditional fixed effects logistic regression are reported in Table (5). Five different specifications of the model were implemented: the estimation was undertaken including all pollution variables simultaneously, with as well as without controlling for weather conditions. Moreover, the relation was estimated separately for each of the pollution variables. Overall, the results show the typical sign for the socioeconomic control variables[26]. Age has a significant negative impact on LS. The observed effect of the net value of aggregated houshold income per month is very weak but positive. This was found in the majority of studies on LS. The very small estimated coefficient is consistent with the results of Ferer-i Carbonell and Fritjers (2004). They found out, that allowing for individual fixed effects leads to less importance of income for subjective well-being. This result is another reason, why more attention should be paid on nonmonetary measures of welfare in economic research. As expected, unemployed and disabled people are less happy than others, whereas married persons are more satisfied with their lifes. For the variable living together with children, a positive but insignificant coefficient was estimated. The p-Values of the χ^2 test show overall explanatory power of the model for each of the estimations. The relatively small values for the Pseudo R^2 are caused by the conditional fixed effects methodology and consistent with earlier studies, that used the same approach[27].

Table 5: Estimated Effect of Air Pollution on LS

	All Pollution weather	All Pollution no weather	CO	NO2	O3
age	-0.0841***	-0.0836***	-0.0848***	-0.0846***	-0.0839***
hhinc	0.0001***	0.0001***	0.0001***	0.0001***	0.0001***
unempl	-0.6934***	-0.6954***	-0.6936***	-0.6938***	-0.6940***
disabl	-0.3420***	-0.3429***	-0.3423***	-0.3424***	-0.3422***
married	0.2744***	0.2734***	0.2734***	0.2734***	0.2740***
child	0.0064	0.0060	0.0069	0.0069	0.0065
CO	-0.0239	-0.0089	-0.0097		
NO2	-0.0010	0.0001		0.0001	
O3	-0.0015*	-0.0014*			-0.0010
Rainfall	0.0036		0.0036	0.0036	0.0036
Windspeed	-0.0144**		-0.0174***	-0.0168***	-0.0131**
Sunshine	0.0033		0.0012	0.0011	0.0023
Air temperature	0.0050**		0.0050**	0.0050**	0.0050**
Pseudo R^2	0.0212	0.0210	0.0211	0.0211	0.0211
Prob χ^2	0.000	0.0000	0.0000	0.0000	0.0000
-log(Likelihood)	2.155e+08	2.155e+08	2.155e+08	2.155e+08	2.155e+08

Notes: Data Source: SOEP and German Environmental Federal Office. N = 105,575. Conditional Fixed Effects Logistic regression using Stata command clogit. Dependent variable is binary LS. First and second column show estimation results when all pollutants are included. Columns three to five report results for seperate estimations including only one pollution variable. The groupvariable is the individual. Standard errors are clustered on the individual. Groups without switch in LS are excluded from the analysis (4,906 observations droppped). All estimations include month dummies to control for seasonal effects. χ^2 tests for joint significance of all explaining variables. Significance level: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Regarding the impact of air pollution, it was observed that one of the three variables has a significant negative impact on LS. People are less satisfied with their lives, if O3 pollution increases. No significant effect was measured for pollution in terms of CO and NO2. Regarding the inclusion of weather conditions, it shows up that the estimated impact of pollution is less negative if weather controls are excluded from the analysis. Thus, there is a positive bias induced by omitted variables. Assuming zero correlation between weather and the socioeconomic controls, this in turn implies that the pollution variables are positively correlated with weather variables that have a positive impact on LS and negatively correlated with those that have a negative impact on LS. As discussed in section 4, different weather variables have a different impact on the pollutants. Hence, there might be a varying importance of the weather variables for the bias as well.

O3 is especially determined by sunshine duration and high air temperatures. The higher both variables are, the more O3 is in the atmosphere and thus there is a positive correlation. Moreover, for both of these variables a positive impact on LS was estimated. In conclusion there is a positive bias in the estimated effect of O3 pollution, when weather is not considered in the analysis. Overall, weather determinants that affect air pollution are important control variables when the relation between air quality and LS is analyzed and they are included in al following estimations.

In addition, estimations were undertaken only including one of the pollution variables instead of all three simultaneously. The estimated negative coefficient of O3 pollution remains but is no longer significant. This might be explained by the fact that for O3, CO pollution is an omitted variable. Since both variables are negatively correlated, people might be happier because of less CO pollution which seems to weaken the negative O3 impact. This result leads to the conclusion that the effect of different pollution variables on LS should be analyzed simultaneously. Nevertheless, it should be mentioned that there also could be a problem of multicolinearity, if correlation between the pollutants was too high.

5.5 Extensions

The estimated negative impact of O3 pollution on LS and the fact that pollution leads to a variety of health problems, raises the question whether LS of individuals who have a bad self-assessed health status, are more affected by current air pollution. Thus, an extension of the initial model was undertaken, in the sense that interaction terms of the pollution levels and the variable *self-assessed health* was used. Therefore, the generated dummy variable *bad health* equals one if the individual defined his or her health status as *not so good* or *bad*. The first column in Table (6) includes the observed results.

The signs of the socioeconomic variables remain the same compared to the initial implementation.

A bad self-assessed health status itself has a significant negative impact on LS. But the interaction variables of bad health with all three pollutants did not show a significant effect. Thus, ill people do not seem to be more affected by air pollution. Nevertheless, it should be mentioned,

Table 6: Interaction of bad health and environmental worries with air pollution

	(1)	(2)
age	-0.0751***	-0.0839***
hhinc	0.0001***	0.0001***
unempl	-0.6746***	-0.6931***
disabl	-0.2311***	-0.3429***
married	0.2652***	0.2749***
child	0.0141	0.0061
bad health	-1.0313***	
chron$_{i}ll$		
environ$_{w}orries$		0.0338
CO$_{interact}$	0.0534	-0.0018
NO2$_{interact}$	-0.0033	-0.0009
O3$_{interact}$	0.0008	-0.00074*
N	105,415	105,575
Pseudo R^2	0.0421	0.0212
Prob χ^2	0.0000	0.0000
-log(Likelihood)	2.104e+08	2.154e+08

Notes: Results of conditional fixed effects logistic regression. Data Source: SOEP and German Environmental Federal Office. Dependent variable is binary LS. The group variable is the individual. First column includes model with interaction of pollution and a bad health status. Second column reports results for interaction with environmental worries. The interaction variables are defined as pollution variable times the dummy variables bad health and person has environmental worries, respectively. Standard errors clustered on the individual. Additional control for weather and month of interview. χ^2 tests for joint significance of all explaining variables. Significance level: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

that this might be induced by the unpricise indicator for illness and should be considered in more detail in further research.

Another extension of the model is founded by the question, whether LS of individuals with environmental worries is more affected by air pollution. Thus, in a next step the interaction effect of pollution and environmental worries on LS was included in the empirical model. Results are reported in the second column of Table (6). I found that LS of people with environmental worries is significantly more affected by O3 pollution. This result is consistent with the findings of Luechinger (2009), who analyzed the impact of sulfur dioxide on LS.

5.6 Robustness Checks

To test the validity of the observed results, three robustness checks were implemented. Firstly, the time window of considered pollution was extended. Therefore, the pollution variables were redefined, in the sense that average county pollution in the last month before the interview was used instead of the daily average level. As the first column of Table (7) reports, again a significant negative effect of O3 pollution is observed. In addition, also CO has a significant negative impact on LS. This means that effectively longer holding high CO levels determine LS and a single day with much CO pollution is compensated for. The estimated impact of NO2 remains insignificant.

Secondly, one could think of selection bias in the sense that people that lived in areas with very high pollution might search for less polluted places and therefore move. Thus, the empirical analysis additionally was undertaken with a sample in which individuals that switched their home county from one period to another were excluded. Results are reported in the second column of Table (7). The significant negative impact of O3 on LS is also observed for the subsample.

Finally, in order to describe the indirect impact of pollution on LS through its negative effect on health as mentioned in section 4, 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

Table 7: Results of implemented Robustness Checks

dependent var	(1) binary LS	(2) binary LS	(3) good health
age	-0.0855***	-0.0803***	-0.1211***
hhinc	0.0001***	0.0001***	0.0001***
unempl	-0.6924***	-0.6825***	-0.3127***
disabl	-0.3429***	-0.3467***	-0.6160***
married	0.2739***	0.2648***	0.0386
child	0.0065	0.0267	-0.0551
CO		-0.0181	-0.0357
NO2		-0.0013	-0.0055*
O3		-0.0019*	-0.0027*
$CO_{lastmonth}$	-0.1932*		
$NO2_{lastmonth}$	-0.0008		
$O3_{lastmonth}$	-0.0042**		
N	105,574	94,756	46,120
Pseudo R^2	0.0213	0.0201	0.0372
Prob χ^2	0.0000	0.0000	0.0000
-log(Likelihood)	2.154e+08	1.910e+08	79,194,393

Notes: Conditional fixed effects logistic regression. Data Source: SOEP and German Environmental Federal Office. Dependent variable is binary LS in columns one and two. The group variable is the individual. First column reports results using average pollution in the home county in the previous month before the interview date. Second column presents results when movers are excluded from the sample. Third column reports estimated effects on good self-assessed health. Standard errors are clustered on the individual in all models. χ^2 tests for joint significance of all independent variables. Additional control for weather and month of interview. Significance level: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

are presented in the last column Table (7). As it can be seen, NO2 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 and approves the observed negative impact of O3 pollution.

5.7 Monetary Valuation

The observed effects of air pollution on LS further can 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. The marginal rate of substitution can be computed as the negative value of the marginal effect of the pollution parameter divided by the marginal effect of income[28]:

$$MRS = -\frac{\partial LS/\partial x_{pol}}{\partial LS/\partial hhinc} \tag{4}$$

In case of the conditional fixed effects logit model, it has to be considered, that marginal effects are not constant. In this approach, they are defined as follows:

$$\frac{\partial LS}{\partial x_{pol}} = \frac{\partial Pr(ls_i = 1|k_{1i})}{\partial x_{pol}} = \frac{exp(\sum_{t=1}^{T_i} ls_{it}\, x_{it}\, \beta)/f_i(T_i, k_{1i})}{\partial x_{pol}} \tag{5}$$

Thus, the marginal effect of one independent variable varies with the specific degree of all other parameters and thus differs for every individual. In this study marginal effects are calculated for an average individual using standard statistical software. One weakness of the approach is, that individual fixed effects have to be set to zero since they can not be estimated using the methodology. Results for all three pollution variables are reported in Table (8).

Regarding the whole of Germany, it was observed that the monthly household net income has to rise by €11.33 for each additional $\mu g/m^3$ O3 to hold an average individual's LS constant.

Table 8: Marginal Effects after Conditional Logit Estimation

	hhinc	O3	-MRS_{CO}
marginal effect	2.18e-06	-.0000247	11.33

Notes: Marginal effects for probability of discrete change in ls from 0 to 1. Effects are calculated at the mean of the independent variables. Individual fixed effects set to zero. MRS calculated as the negative value of the marginal effect of pollution divided by the marginal effect of income. MRS(O3) in €per $\mu g/m^3$

6 Conclusion

In the current paper the relation between air quality and LS in Germany was analyzed. The impact of three pollution parameters on LS was estimated, by the use of a conditional fixed effects estimation approach. It was observed that current O3 pollution significantly decreases individual LS. The estimated coefficient of current CO and NO2 pollution was 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 and even exceeds them. If a longer time window is considered, i.e. if the effect of average pollution in the last month is estimated, also a negative impact of CO on LS was observed. Moreover, it was not found that ill people have a higher O3 pollution induced loss in their LS, whereas subjective well-being of individuals with environmental worries is stronger affected by O3 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 $\mu g/m^3$ in daily average 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 underly synergies, such that the impact of several pollution variables could be weakened even if only one of them is dammed. Further, it has to be considered that negative effects of pollution are even underestimated, since people might adapt to bad environmental quality.

In conclusion, the current results give reason, to pay more attention on the control of air pollution. Especially in the case of CO pollution, it was observed that on average pollution does not exceed critical thresholds for public health, but anyhow, the measured impact on LS was 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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Notes

[1]Further information can be found under the following link: http://spreadtheword-online.de/?p=1226

[2]Further information can be found on the official homepage of the Office of UK's National Statistics: http://www.statistics.gov.uk

[3]Corresponding newspaper articles can be found for example at the *Washington Post*: http://www.washingtonpost.com/business/economy/if-youre-happy-and-you-know-it–let-the—–government-know/2012/03/29/gIQAlSL2jS$_{s}tory_{2}.html$

[4]The full article can be downloaded from the web page of the Federal Ministry of Finance: http://www.bundesfinanzministerium.de

[5]More information about the study can be found under the following link: http://www.gluecksatlas.de/cms/index.html

[6]For example, Clark et al. (2008), Veenhoven (1997) or Frey and Stutzer (2002) provide an appropriate overview of the literature.

[7]This is known from psychological research Compare for example to Colligan (1981)

[8]Compare for example to Gerdtham and Johannesson (2001)

[9]Compare to WHO, 2011

[10]For a general overview see Ferer-i Carbonell and Gowdy (2007)

[11]For further information see http://www2.eur.nl/fsw/research/veenhoven/Pub2000s/2004f-full.pdf

[12]These are the subsamples A (West German Households since 1984), B (Foreign West German Households since 1984), C (East German Households since 1990), D (Immigrants Germany since 1994), E (German households completion sample since 1998)and F (German households completion sample since 2000)

[13]More detailed information can be found on the SOEP Web page under the following link: http://www.diw.de/soep, or in the work of Wagner et al. (2007)

[14]Questionnaires can be inspected on the SOEPinfo webpage under the following link: http://panel.gsoep.de/soepinfo2009/

[15]Compare for example Frey and Stutzer (2002)

[16]Compare for example to Rhedanz and Maddison (2008)

[17]Homepage *Umwelt Bundesamt*: http://www.env-it.de/umweltbundesamt/luftdaten/pollutants.fwd

[18]Due to the fact, that there is measurement error in the pollution data, outliers were excluded from the analysis. An outlier was defined as observation that was greater than the median plus twice the interquartile distance over all stations and the whole period. As robustnesscheck, all analysis where implemented with an outlier defined as a value that exceeded the 99-percentile or that was lower than the 1-percentile of the pollutant. No considerable changes in the results occured

[19]Compare to information provided by the European Environment Agency, EEA (2011)

[20]Homepage *Umwelt Bundesamt*: http://www.env-it.de/umweltbundesamt/luftdaten/pollutants.fwd

[21]Information about the pollution variables can be found under the following link: http://www.umweltbundesamt.de/luft/schadstoffe/index.htm

[22]Compare to WHO, 2011

[23]Compare for example to Kahneman and Krueger (2006)

[24]This approach was used in the work of Kassenboehmer and Haisken-DeNew (2009) and is based on the concept of Ferer-i Carbonell and Fritjers (2004) where a detailed description of the methodology can be found.

[25]Compare to Chamberlain (1980).

[26]Compare to section 2

[27]Compare for example to Kassenboehmer and Haisken-DeNew (2009)

[28]Compare to Welsch (2006)