REM WORKING PAPER SERIES

Subjective well-being and climate change: Evidence for Portugal

Ary José A. Souza-Jr.

REM Working Paper 0213-2022

February 2022

REM – Research in Economics and Mathematics
Rua Miguel Lúpi 20,
1249-078 Lisboa,
Portugal

ISSN 2184-108X

U LISBOA | UNIVERSIDADE DE LISBOA

ISEG LISBON SCHOOL OF ECONOMICS & MANAGEMENT UNIVERSIDADE DE LISBOA

REM RESEARCH IN ECONOMICS AND MATHEMATICS

REM – Research in Economics and Mathematics

Rua Miguel Lupi, 20
1249-078 LISBOA
Portugal

Telephone: +351 - 213 925 912
E-mail: rem@iseg.ulisboa.pt

https://rem.rc.iseg.ulisboa.pt/

https://twitter.com/ResearchRem

https://www.linkedin.com/company/researchrem/

https://www.facebook.com/researchrem/

Subjective well-being and climate change: Evidence for Portugal

Ary José A. Souza-Jr.[1]

Abstract: This paper analyses the impact of air pollution, climate conditions, and extreme weather events on subjective well-being across the Portuguese regions through estimating an ordered probit model. The estimation applies data at the individual level from the 8th and 9th waves of the European Social Survey, along with an air quality indicator, environmental variables, national forest inventory, and a study about the possible future effects of the sea-level rise on vulnerable areas and people living therein. Even after controlling for socio-economic variables and personal traits, the results suggest the existence of differences between regional welfare levels. Air pollution has a negative impact on life satisfaction due to its bad impacts on health (aggravating the condition of individuals with heart and lung diseases). The paper's key finding is to show that at the regional level, both past (forest fires) and «possible» future (floods due to sea-level rise) extreme weather events may impact the current welfare level. Also, assessments of implicit willingness do to pay demonstrate that climate change effects have a relevant impact on their quality of life nowadays.

Keywords: climate, extreme, region, flood, fire.

1. Introduction

Assessments of environmental quality impact on subjective well-being (SWB) commonly use multi-country spatial data (Apergis, 2018; Rehdanz & Maddison, 2005; Welsch, 2002), although analyses at the national level have a relevant role in explaining happiness across regions and may contribute to a successful implementation of environmental policies that take into account the specific characteristics of each region (Cuñado & Gracia, 2013). However, such analyses are frequently limited by data availability (Levinson, 2012; Luechinger, 2009). This paper aims to contribute to filling this gap in the literature by studying the impact of climate conditions, air quality, and extreme weather events (EWEs) on welfare across Portuguese regions.

[1] Pontifical Catholic University of Goiás (PUC-GO - Brazil): ajasouza.jr@gmail.com / ISEG PhD student in Economics – ajasouza-jr@phd.iseg.ulisboa.pt.

The use of environmental quality data at a more spatially disaggregated level can potentially improve the understanding of connections between welfare and the environment (MacKerron & Mourato, 2009), and the SWB literature provides evidence of this relationship at the regional level by NUTS 2 (in a multi-country analysis, Ferreira et al., 2013; or in a single country, Cuñado & Gracia, 2013), at the county level (Luechinger, 2009), and by respondents' location (MacKerron & Mourato, 2009, 2013). Regarding air pollution, Luechinger (2009) estimates the effects of air pollution in German counties, by using panel data at the individual level. His findings demonstrate a negative and highly significant impact of air pollution on SWB. Similarly, Cuñado & Gracia (2013) find the same effect across the Spanish regions. Based on data from Irish regions, one study about climate conditions shows that both the July maximum and January minimum temperatures have a positive and significant influence on life satisfaction, whereas precipitation has a negative effect (Ferreira & Moro, 2010). In addition, there is evidence that both occurred (in Barcelona, see Sekulova & van den Bergh, 2013) and expected (in Germany, Osberghaus & Kühling, 2016); and in several countries, Rehdanz & Maddison, 2005) EWEs impact life satisfaction. Lastly, happiness scores are useful to infer the monetary value of non-marketed goods, by estimating individuals' willingness to pay for changes in environmental factors (Ambrey et al., 2014; Welsch, 2002).

This paper explores three research questions: (1) What is the association between individuals' subjective well-being and environmental quality across Portuguese regions? (2) How may occurred (like forest fires[2]) and expected (like the possible occurrence of floods due to sea-level rise) EWEs influence the current life satisfaction of Portuguese citizens?[3] (3) In Portugal, what is the implicit willingness to pay (IWTP) for environmental variables? The first question seeks to assess the impact of air pollution and climate conditions on the individual level of happiness in the Portuguese regions (Cuñado & Gracia, 2013; Luechinger, 2009), aiming to offer contributions to climate as well as welfare policy. The second aims to show how occurred (past) and expected (future) EWEs might extend their effects to the current happiness level (Osberghaus & Kühling, 2016; Sekulova & van den Bergh, 2013), which may inform policymakers in their choice of strategies to reduce the negative impact of EWEs on the quality of life (such as the delimitation of

[2] Forest fire is a common and frequent event in Portugal's countryside.

[3] "Current" refers to the moment in which individuals answer the questions in each wave of the European Social Survey (ESS).

isolation areas). Following the available evidence in the literature on happiness, this study builds on the hypothesis that expected EWEs may influence the current welfare level (Rehdanz & Maddison, 2005). Finally, the last question concerns measuring the trade-off, across Portuguese regions, between the change in income and the change in the environment variables (air pollution, climate conditions, and EWEs) that will leave people, on average, equally happy (Di Tella et al., 2001). With this purpose in mind, this paper estimates an ordered probit model using data from the 8th and 9th waves of the European Social Survey (ESS), resorting exclusively to information about Portugal.[4]

The findings suggest that air pollution (PM_{10}) and climate variables have an important role in explaining happiness levels across Portuguese regions, which provides an additional argument in favor of public policies aimed at improving quality of life. In addition, the results indicate that when EWEs are seen as a threat to human life, both past and future events may reduce current well-being. The IWTP for reductions in PM_{10} annual emissions is in line with the literature (Cuñado & Gracia, 2013), whereas for EWEs, results reveal sizeable amounts, suggesting that they have a strong impact on life satisfaction.

This research has four relevant contributions to the literature. Firstly, it is the first paper that combines environmental quality variables with Portuguese regional data (NUTS 2) on self-reported happiness. Most of the SWB literature in Portugal explores the impact on specific groups (e.g., veteran athletes in Batista et al., 2019) or within particular topics (education in Pereira & Martins, 2015; macroeconomic fluctuations in Lopes et al., 2014) on welfare. In contrast, Soukiazis & Ramos (2016) assess the main determinants of welfare among Portuguese citizens through a rich cross-section dataset provided by the European Quality of Life Survey (EQLS). They show that satisfaction with material conditions, age, and an optimistic view about the future may affect SWB. However, they do not approach any link with the environment. To my knowledge, this paper is the first to focus on the relationship between environmental quality, EWE, and SWB in Portugal, at a high level of spatial disaggregation. Secondly, the results in this paper have policy implications, by revealing the positive impact that fighting air pollution, forest fires,

[4] The 8th wave of ESS refers to the years 2016/2017. However, 81.02% of observations were collected in 2017. The 9th wave occurred throughout the years 2018/2019.

and avoiding (at least partially) future damages from floods, may have on the quality of life. Thirdly, this study offers estimations of the monetary valuation of non-market goods (such as climate, EWEs, and air pollution) for the Portuguese regions. These estimates allow us to understand how much the individuals would be willing to pay today, if it were possible, for preventing past events (e.g., a forest fire); as well as to measure the willingness to pay for avoiding the occurrence of future events (like a flood). Fourthly, the findings in this paper have fewer shortcomings regarding cultural heterogeneity, since it uses micro-data at the individual level collected from people within the same country. Therefore, results do not suffer from problems related to social and cultural differences (such as language, habits, etc.).

The remainder of the article is organized as follows. Section 2 reviews the related literature. Section 3 explains the data sources, descriptive statistics, and contains details on the explanatory variables. Section 4 discusses the estimation strategy. Section 5 presents the main results. Lastly, some concluding remarks.

2. Literature Review

Subjective well-being approach

In general, the concepts of happiness, subjective well-being, welfare, quality, or life satisfaction are considered to be synonyms, which allow researchers to use them interchangeably. However, psychology suggests that happiness might be an affective state, whereas life satisfaction implies a cognitive process (Peiró, 2006). The SWB approach thereby typically provides a global assessment of all aspects of a person's life (Diener, 2009). Its determinants can be classified into two levels: external conditions and inner processes (Veenhoven, 1997). The first group includes many factors that influence SWB (Diener et al., 1999; Dolan et al., 2008), such as environmental variables (Welsch & Kühling, 2009). As for the second group, strong evidence suggests that personality traits might explain more than half of the differences in SWB (Layard, 2005). Moreover, self-reported well-being works like the product of a final judgment process, which is also highly context-dependent (Schwarz & Strack, 1999). Therefore, measures of SWB may act as a *proxy* to utility (Frey & Stutzer, 2002).

Usually, the relationship between SWB and personality traits has statistical significance (Ambrey et al., 2014).[5] Questions that provide reflections about self-judgment are a useful way of controlling for personality traits. For example, the pleasure from enjoying day-to-day activities, beliefs in oneself, and the feeling of being useful for society (Ferrer-i-Carbonell & Gowdy, 2007).

There is evidence of an association between well-being and a range of personal, economic, and social factors (Dolan et al., 2008). For instance: income (Welsch, 2002), self-reported health level (Cuñado & Gracia, 2013), education (Brereton et al., 2008), being married (MacKerron & Mourato, 2009), having a job (Ferreira & Moro, 2010), and being a woman (Alesina et al., 2004) have a positive effect on SWB. While being separated, divorced, or widowed (Ferreira et al., 2013) has a negative impact.

Other factors also are determinants of happiness: income inequality and social mobility (Alesina et al., 2004), the Chernobyl nuclear catastrophe (Berger, 2008), environmental engagement (Choi, 2018), inflation (Di Tella et al., 2001), the business cycle (Wolfers, 2003), the existence of democratic institutions (Frey & Stutzer, 2000), terrorism (Frey & Stutzer, 2005), airport noise (Van Praag & Baarsma, 2005), greenhouse effects (Apergis, 2018), noise pollution (Rehdanz & Maddison, 2008), among others.

In what macroeconomic variables are concerned, Ferreira et al. (2013) show that the regional gross domestic product (GDP) *per capita* has a positive impact on life satisfaction within European countries.[6] Regarding population density and the unemployment rate (at country level or between countries), most studies find a negative effect on SWB (Clark & Oswald, 1994; Cramer et al., 2004; Di Tella et al., 2003; Winkelmann & Winkelmann, 1998).[7] Nevertheless, Clark (2003) shows that unemployment rates at the regional level may have a positive relationship with welfare when the utility depends on social comparisons (for example, against a reference group).

[5] The main five personality traits (Big Five) are openness, conscientiousness, extraversion, agreeableness, and neuroticism (Cummings, J.A. et al., 2019).
[6] GDP per capita in purchasing power parity, by NUTS 2 level (Ferreira et al., 2013).
[7] Unemployed people are substantially more stressed than those individuals that are employed (Clark & Oswald, 1994).

Air Pollution

Bad air quality tends to reduce happiness (Welsch, 2002).[8] Cuñado & Gracia (2013) explore the relationship between air pollution and SWB across the Spanish regions, along with climate conditions, socio-economic, and macro variables. They provide a cross-section analysis using datasets from ESS and other official sources. Regarding air quality indicators, they apply carbon dioxide (CO_2), small particulates (PM_{10}), and nitrogen dioxide (NO_2). Their results show that the first two indicators have a negative impact on welfare, providing evidence of air pollution effects at the regional level.[9]

Luechinger (2009) shows that air pollution may decrease happiness, using panel data at the individual level from the German Socio-Economic Panel (GSOEP) for the period 1985-2003, combined with sulfur dioxide (SO_2) concentrations at the county level, and time-varying predictors of life satisfaction.[10] Ferreira et al. (2013) link SWB to air pollution (SO_2) at regional level (NUTS 2) in a multi-country analysis, with spatial controls and socio-demographic indicators. Their findings also demonstrate that bad air quality reduces individual welfare level.

Climate Conditions

Concerning climate conditions, most studies use the maximum or minimum temperatures, and the level of precipitation (Frijters & Van Praag, 1998; Rehdanz & Maddison, 2005). Ferreira & Moro (2010) discuss the impacts of environmental variables in Irish regions using the hedonic pricing approach. They show that there exists a significant and positive relationship between the January mean daily minimum and the July mean daily maximum air temperatures (in Celsius) with welfare, indicating a higher preference for warmer temperatures, in both seasons. Also in Ireland, Brereton et al. (2008) find that precipitation has a positive impact on SWB, suggesting a correlation between

[8] The most common units of measurement of air pollution are the concentrations of sulfur dioxide (SO_2), sulfur oxide (SO), oxides of nitrogen (NO and NO_2), particulate matter (whose diameter is less than 10 micrometers - PM_{10}), carbon monoxide (CO), and carbon dioxide (CO_2) in ambient air (EEA, 2021).

[9] There are other studies about the effects of air pollution at a more disaggregated spatial level (Levinson, 2012; MacKerron & Mourato, 2009, 2013).

[10] These predictors are age, disability status, marital and partnership status, labor force status, occupational position, type of employment contract, and city or district size (Luechinger, 2009).

rain and scenic beauty. On the other hand, Cuñado & Gracia (2013) show that higher amounts of precipitation tend to decrease happiness in Spain, at the regional level.

Environmental awareness

The *Biophilia* hypothesis explains the inherent human inclination to affiliate with other life features of the nonhuman environment, and there is evidence to support it, such as recovery from illness when having more contact with nature, and fewer social problems (Kellert, 2008; Ulrich, 1984; Wilson, 1984). Ferrer-i-Carbonell & Gowdy (2007) relate this connection with nature through concerns about ozone depletion and biodiversity loss. By extension, this behavior tends to boost environmental awareness (Smyth et al., 2008).

Extreme Weather Events

An EWE is defined as an event that is rare at a particular place and time of the year. Its characteristics may vary from place to place in an absolute sense. Also, if a pattern of extreme weather persists for some time, such as a season, it may be classified as an extreme event (IPCC, 2014).

The SWB literature provides evidence of EWEs effects on SWB for both past and future events. Through an empirical analysis in Barcelona, Sekulova & van den Bergh (2013) appraise the impacts of EWEs (drought, heatwave, and forest fire) on life satisfaction. Only the coefficient on forest fires has a negative and statistically significant relationship with welfare, which is somewhat surprising in an urban context. They explain that forest fires have a more life-threatening character, suggesting that the psychological impact might be substantial, even for the urban population.

Osberghaus & Kühling (2016) discuss the influence of EWEs on well-being, in a study based on cross-section data taken from a survey among German households.[11] Their hypotheses assess the relationship between past damage experience, expectations of impacts from future climate change, and welfare. They find that any financial or health damage experience with EWE impacts negatively on current well-being. At the same time, their results show that the damage expectations coming from climate change on living conditions in the next decades tend to reduce the

[11] They focus on heatwaves, storms, heavy rain, and floods.

respondents' happiness level at the survey's time. In other words, *future* EWEs also might influence the current SWB level, indicating the relevance of the "preoccupation itself" (Ferrer-i-Carbonell and Gowdy, 2007) on the judgment process.

Table 1 – Description of variables

Variable name	Source	Description
Subjective well-being (SWB)	ESS	"Taking all things together, how happy would you say you are?": 0 (extremely unhappy) - 10 (extremely happy).
Socio-economic and demographic variables		
Income	ESS	Net household income from all sources. Ten deciles: 1 (low income) - 10 (high income)
Gender	ESS	Dummy: 1= Female
Age	ESS	Age in years
Main activity	ESS	9 categories: paid work, student, unemployed seeking a job, unemployed not seeking a job (reference), retired, disabled, housework, community/military services (reference), and others.
Health (self-reported)	ESS	5 categories: Very good, good (reference), fair, bad, or very bad.
Education (years)	ESS	Years of education completed (full or part-time)
Marital status	ESS	6 categories: married (reference), civil union, separated, divorced / civil union dissolved, widowed, and none of these.[1]
Personality Traits		
Social meets	ESS	"How often do you meet socially with friends, relatives, or work colleagues?": 1 (Never) - 7 (Every day)
Personal intimacies	ESS	"How many people, if any, are there with whom you discuss intimate and personal matters?": 0 (None) - 6 (10 or more)
Social activities	ESS	"Compared to other people of your age, how often would you say you take part in social activities?": 1 (Much less than most) - 5 (Much more than most)
Religious self-judgment	ESS	"Regardless of whether you belong to a particular religion, how religious would you say you are?": 0 (Not at all religious) - 10 (Very religious)
Sense of insecurity	ESS	"How safe do you – or would you – feel walking alone in this area after dark?": 1 (Very safe) - 4 (Very unsafe)
Size of settlement	ESS	"Which phrase on this card best describes the area where you live?": 1 (big city) – 5 (farm or home in the countryside).
Air Pollution - PM_{10}	PEA	PM_{10} (μm) emissions in ktons per regional area (in km^2) in 2017
Macro Variables (in 2017)		
GDP per capita	NSI	Gross domestic product per capita (at current prices - base 2016 - in euro).
Unemployment rate	NSI	Total unemployment rate in %.
Population Density	NSI	The ratio between the annual average population and the land area (number/km^2).
Climate conditions (in 2017)		
Hottest annual temperature	NSI/PISA	The hottest annual temperature (in Celsius).
Lowest annual temperature	NSI/PISA	The lowest annual temperature (in Celsius).
Precipitation[2]	NSI/PISA	Total volume of precipitation in mm (absolute value).
Environmental awareness	ESS	"How worried are you about climate change?": 1 (Not at all worried) – 5 (Extremely worried).
Extreme Weather Events (EWE)		
Burnt area of forest - Past	ICNF	Total burnt area of forest by 1,000 ha in the years 2017 and 2018.
Floods and its effects – Future		
Vulnerable areas	Rocha (2016)	Total foreseen vulnerable areas (in km^2) in three scenarios: 2025, 2050, and 2100.
People living in vulnerable areas	Rocha (2016)	Expected total number of people living in vulnerable areas (number of residents) in three scenarios: 2025, 2050, and 2100.

1. In both ESS waves used in this paper, the option "civil union" had no observations.
2. Several studies apply the annual mean concentration (see Ferreira and Moro, 2010).

Environmental valuations

Since the SWB measures serve as a proxy to an individual's utility, one can compute the marginal rate of substitution between income and non-marketed goods (Ferreira & Moro, 2010). The common method is to assess the willingness-to-pay (WTP), i.e., how much, theoretically, each individual would be willing to pay for one unit change (e.g., reduction) in a particular variable in a determined period. This technique is useful to measure the effects of past and future events. For instance, Ambrey et al. (2014) and Levinson (2012) use the PM_{10} as the base for evaluating the WTP for less air pollution. Both find a statistically significant WTP, indicating a high disposition of individuals to decrease PM_{10} exceedances.[12] Similarly, this technique can be used to determine monetary value estimations for climate conditions (Ferreira & Moro, 2010).

Rehdanz & Maddison (2005) provide WTP assessments to measure the impact of future events in 67 countries, namely the predictions of temperature and precipitation by computing the change in real GDP per capita necessary to hold happiness at its current levels in the face of predicted changes in climate for two different time slices: 2010–2039 and 2040–2069. They find that most countries would lose from climate change as the temperature is expected to increase over time. Thus, the authors show that the forecast of future events might influence the current SWB level.

Sea level rise in Portugal

Following NASA (2021), the sea level rise should reach a rate of 3.3 mm per year, caused mainly by the added water from melting ice sheets (and glaciers) and the expansion of seawater (warming process).[13] Antunes (2016) has a similar forecast based on the Cascais tide gauge (on the Portuguese coast). The potential impact on coastal systems (such as flood damage, erosion, etc.) justifies assessments to decrease the vulnerability and promote adaptation (IPCC, 2014). In Portugal, a country with a large coastal zone spread across all regions, this threat may have significant negative effects on the population (since 75% live near the sea). Rocha (2016) analyses the vulnerability of the Portuguese coast to sea-level rise, which can lead to increased flooding.

[12] WTP is not directly comparable in absolute value across countries, since different authors use distinct levels of domestic income, and deflation techniques.

[13] Satellite sea level observations, from 1993 to today. See:< https://climate.nasa.gov/vital-signs/sea-level/>.

She uses the Digital Terrain Model for elaborating maps of coastal physical vulnerability for the years 2025, 2050, and 2100.[14] Overall, her findings indicate that until 2100, Portugal may have an increase of 71.6% in vulnerable areas and 86.4% of people living in vulnerable areas.[15]

3. Data

This paper uses cross-section data taken from the 8th and 9th waves of the ESS at the regional level, by NUTS 2. The study uses only these two waves due to restrictions on the other datasets (environmental indicators). ESS applies random samples throughout countries, which may change within-country. To ensure representativeness, ESS employs the sample frame with the best coverage on the target population and seeks the design that offers higher statistical precision according to the prescribed level.

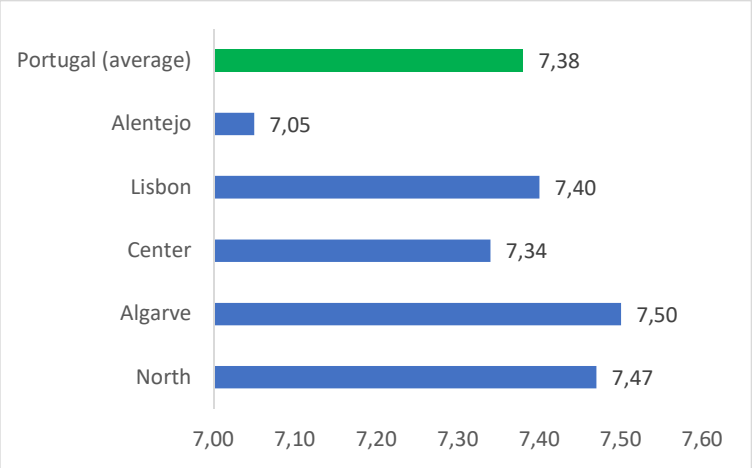

Figure 1. Happiness scores across Portuguese regions
Source: ESS (2021)

The empirical analysis uses micro-data based only on individuals living in Portugal, which includes 2,325 observations, spread across five regions (NUTS 2): Alentejo, Algarve, Center, Lisbon, and North.[16] To capture the SWB level, rated on an 11-point scale in the survey, this study uses the answers to the following question: "Taking all things together, how happy would you say

[14] Antunes (2019) has similar analyses.
[15] Her results are divided into districts. In my paper, these are grouped into NUTS 2.
[16] ESS does not collect data in the Autonomous regions of Madeira and Azores. For sake of simplicity, the region "Lisbon" represents the "Metropolitan Area of Lisbon".

you are?".[17] In those two waves, Figure 1 shows that the average happiness level in all Portuguese regions is higher than 7.3, the lowest one being in Alentejo (7.05) and the highest in Algarve (7.5).[18] Table 1 contains the descriptions of all variables used in this paper. Tables 2 and 3 include the descriptive statistics, all of them at the regional level (NUTS 2).

The set of explanatory variables at the individual level includes demographic and socio-economic data, such as age, gender, self-reported level of health, legal marital status, main activity, years of education, income, and size of the settlement. This selection has been found in previous studies in the SWB literature (Dolan et al., 2008; Ferrer-i-Carbonell & Gowdy, 2007). Following Ferrer-i-Carbonell & Gowdy (2007), this study also controls for individual personality traits.

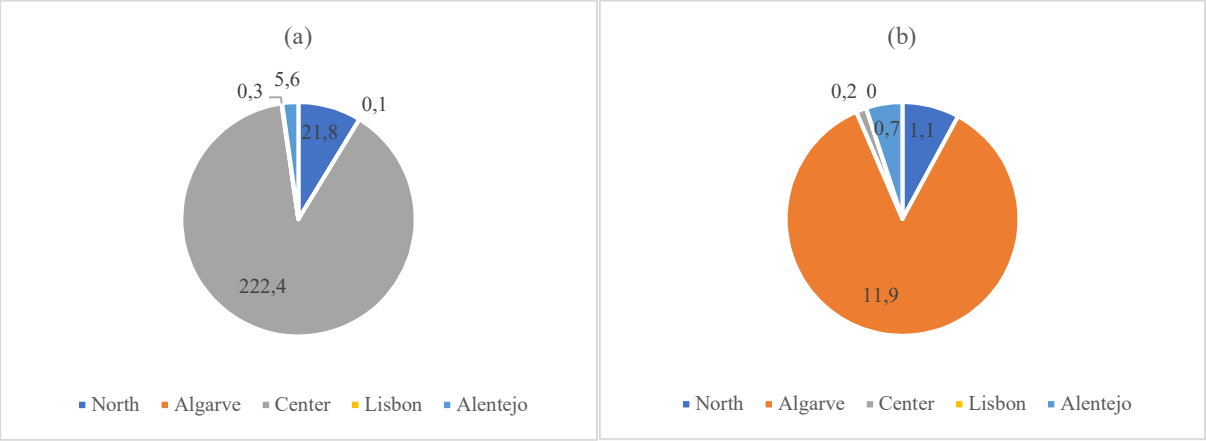

Figure 2. Burnt area of forest across Portuguese regions (in 1,000 ha): (a) Year of 2017; (b) Year of 2018. Source: ICNF (2021)

According to Figure 2, the Center region has the highest share of the burnt area of forest in 2017, while the Algarve reaches this position only in 2018. Most Portuguese households belong to urban areas, mainly in the regions of Lisbon (90%) and Algarve (82%). Through the ANOVA *F* test, I can reject the null hypothesis of no difference among regional levels of welfare, which indicates that the region where the individuals live may affect their happiness. To take advantage of the variation of environmental conditions at the subnational level across Portuguese regions, I do not use any extra adjustments (such as average or weighting).

[17] The answer ranges from 0 (extremely unhappy) to 10 (extremely happy).
[18] The happiness scores per wave, separately, have similar values (with less than a 2% variation).

Table 2 - Descriptive statistics for SWB, socio-economic and demographic variables

Variable / Region	North	Algarve	Center	Lisbon	Alentejo	Portugal (average)
Subjective Well-Being (Happiness)	7.47	7.50	7.34	7.40	7.05	7.38
Socio-economic and demographic variables						
Income (1-10)	4.88	5.87	5.05	6.06	4.88	5.28
Gender (% females)	0.58	0.48	0.59	0.57	0.58	0.58
Age	51.25	53.68	52.94	51.58	54.76	52.19
Health (1-5)	2.50	2.38	2.61	2.33	2.66	2.49
Education (years)	9.44	10.44	9.76	12	9.45	10.26
Marital status (Married - % per region)	0.71	0.59	0.67	0.57	0.66	0.65
Main activity (% per region)						
Paid work	0.50	0.58	0.45	0.52	0.50	0.50
Student	0.07	0.06	0.09	0.11	0.03	0.08
Unemployed seeking a job	0.07	0.04	0.04	0.03	0.04	0.05
Unemployed not seeking a job	0.03	0.20	0.02	0.03	0.03	0.03
Disabled	0.04	0.04	0.06	0.02	0.06	0.04
Retired	0.28	0.35	0.32	0.29	0.29	0.30
Housework	0.19	0.04	0.17	0.15	0.22	0.17
Personal traits						
Social meets (1-7)	5.77	6.03	5.69	5.46	6.00	5.70
Personal intimacies (0-6)	2.45	2.66	2.67	2.95	2.65	2.67
Social activities (1-5)	2.52	2.58	2.66	2.62	2.47	2.58
Religious self-judgment (0-10)	5.91	5.34	5.62	4.96	5.03	5.47
Sense of insecurity (1-4)	1.96	1.90	1.91	1.98	2.04	1.96
Size of settlement (% per region)						
Big city	0.21	0.12	0.09	0.34	0.11	0.21
Suburbs	0.14	0.10	0.06	0.33	0.04	0.16
Town	0.33	0.59	0.36	0.23	0.56	0.34
Village	0.31	0.11	0.47	0.09	0.26	0.27
n	**820**	**98**	**537**	**638**	**232**	**2,325**

Table 3 shows the descriptive statistics for the remaining variables. The air quality indicator was taken from the Portuguese Environment Agency (PEA, 2021). To investigate the effects of air pollution on SWB, this paper uses PM_{10}, which represents the inhalable particulates matter with a diameter of less than 10 micrometers (Ferreira & Moro, 2010; Welsch, 2002). Once inside the lungs, PM_{10} may cause inflammation, aggravating the condition of individuals with heart and lung diseases (EEA, 2021). The most polluted region is the Center, even though the only two Portuguese metropolitan areas do not belong to its territory, which suggests the influence from other sources, such as transport and forest fires (EEA, 2021)

Data on climate conditions are from the National Statistics Institute (NSI, 2021) and the Portuguese Institute of the Sea and the Atmosphere (PISA, 2021), and they follow the availability of data. The lowest and highest annual temperatures are shown in Celsius degrees (similar to Rehdanz &

Maddison, 2005). They correspond to January or February (winter), and July or August (summer), respectively. Portugal has a temperate climate, with high temperatures in the summer (such as 24.9ºC in Alentejo), and not too cold in the winter (as 9.5ºC in Center). Across Portuguese regions, there are huge differences regarding precipitation, ranging from 751 mm in North to 351 mm in Algarve.

Table 3 – Descriptive statistics – Environmental, macro, and EWEs variables

Variable / Region	North	Algarve	Center	Lisbon	Alentejo	Portugal (average)
Air Pollution (emissions): PM_{10} (µm) in ktons	26.90	2.70	32.60	14.00	12.90	17.82
Climate conditions						
Hottest annual temperature (Celsius)	21.10	23.70	22.30	23.20	24.90	23.04
Lowest annual temperature (Celsius)	7.70	11.50	9.50	11.60	10.30	10.12
Precipitation (mm)	750.80	351.50	576.30	420.70	362.40	492.34
Environmental awareness (1-5)	3.51	3.47	3.41	3.56	3.46	3.48
Extreme Weather Events	3.51	3.47	3.41	3.56	3.46	3.48
Burnt area of forest (1.000 ha) – Past						
Year 2017	21.80	0.10	222.40	0.30	5.60	50.04
Year 2018	1.10	11.90	0.20	0.00	0.70	2.78
Floods and its effects – Future						
Vulnerable areas – Forecast (km^2)						
Year 2025	8.97	158.65	228.75	269.29	2.23	133.58
Year 2050	24.10	182.30	331.80	358.20	6.60	180.60
Year 2100	44.40	210.90	459.50	423.70	7.30	229.16
People living in vulnerable areas – Forecast (number of residents)						
Year 2025	33,585	1,140	43,122	16,696	25,609	24,030
Year 2050	44,661	922	45,815	27,803	26,366	29,113
Year 2100	71,999	962	64,216	48,703	38,038	44,784
Macro variables						
GDP *per capita* (in euros)	16,102	20,937	16,456	24,884	17,965	19,269
Unemployment rate (%)	9.80%	7.70%	6.90%	9.50%	8.40%	8.46%
Population Density (population/ km^2)	168.00	88.00	79.10	939.80	22.50	259.48
n	**820**	**98**	**537**	**638**	**232**	**2,325**

To assess the impact of forest fires on current well-being, this paper collects data about the burnt area from the 6th National Forest Inventory (NFI), provided by the Institute for the Conservation of Nature and Forests (ICNF, 2021). This report shows data of total burnt forest area (in thousands of hectares) divided by regions and years. Also, this study uses data from a forecast done by Rocha (2016) about vulnerable areas (in km^2) and people living in vulnerable areas (number of residents) for the entire coastal zone of Portugal. Her study has predictions for three different scenarios (2025 – short run, 2050 – middle run, and 2100 – long run), divided by district. Following Figure 3, the sea level rise may generate a high number of vulnerable areas in Lisbon by 2025 (269 km^2),

whereas the North may be the region with more households living in vulnerable areas by 2100 (71,999 inhabitants).

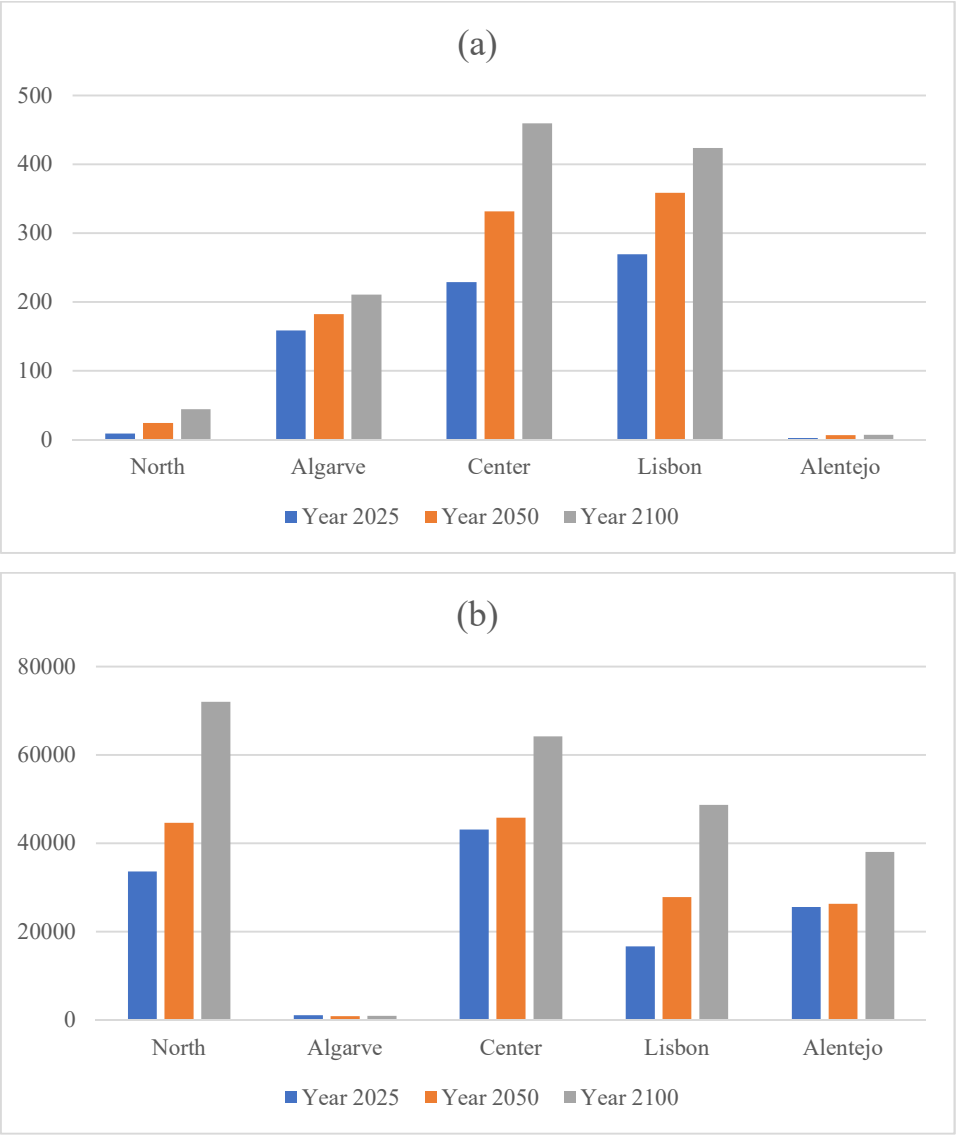

Figure 3. Forecast: (a) vulnerable areas (km^2); (b) people living in vulnerable areas (residents)
Source: Rocha (2016)

It is worth highlighting that for these three variables related to EWEs, this paper aims to discuss if and how each one of them influences the current life satisfaction level of Portuguese citizens, so that their evolution over the years is beyond the scope of this paper.[19] In other words, the EWEs

[19] For this reason, in this study, they have a role similar to any environmental variable on the SWB, and therefore can be part of a cross-section analysis.

coefficients represent the reflection of the possible effect on subjects' well-being today, if they have already experienced EWEs in the past (in case of forest fires) or if they expect to experience them in the future (in case of floods).

Concerning the macro variables, this paper applies the usual approach in the SWB literature, considering the following variables: unemployment rate (Clark, 2003; Di Tella et al., 2003), GDP per capita (Ferreira et al., 2013), and population density (Cramer et al., 2004). Lastly, this paper uses the level of concern of respondents about climate change as a proxy to assess environmental awareness (Smyth et al., 2008). Also, the paper does not control for the geographical variable "coast" since all Portuguese regions have direct access to the sea.

4. Estimation strategy

The personal SWB is a latent and unobserved variable, but it may be expressed by Equation (1). Thus, what is observed is the SWB level, which is an ordered variable that has a relationship with the latent subjective well-being given by Equation (5). Therefore, the estimation may use the ordered probit model (Ambrey et al., 2014; Ferrer-i-Carbonell & Gowdy, 2007).[20] Following Maddala (1983), the $SWB^*_{i,j}$ associates and orders the levels of well-being, from 0 for "extremely unhappy" to 10 for "extremely happy". Ultimately, the latent SWB variable is:

$$SWB^*_{i,j} = \alpha + \omega_j + \delta \ln(Y_{i,j}) + \lambda \boldsymbol{X}_{i,j} + \eta \boldsymbol{ENV}_j + \theta \boldsymbol{REG}_j + e_{i,j} \quad (1)$$

Where the $SWB^*_{i,j}$ is the subjective well-being of individual *i*, in region *j*; $\ln(Y_{i,j})$ is the natural log of the net household income; $\boldsymbol{X}_{i,j}$ stands for a vector of demographic and socio-economic variables (age, gender, health, employment status, and so forth); $\boldsymbol{ENV}_j$ represents the environmental variables (air pollution and climate conditions); $\boldsymbol{REG}_j$ is a vector of characteristics of the region where the citizens live (economic and environmental awareness controls); and, $e_{i,j}$ is the usual error term. The term ω represents the region dummies, which controls unobserved heterogeneity at the regional level. Equation (1) is the base for the estimation of four different specifications. All of them aim to answer the first research question, using data from the 8th wave of the ESS, due to

[20] OLS may offer similar outcomes (Ferrer-i-Carbonell & Frijters, 2004).

restrictions on the availability of data. The distribution of errors is normal to obtain an ordered probit.

For the second research question, I consider the two following equations:

$$SWB_{i,j}^{*} = \alpha + \delta \ln(Y_{i,j}) + \lambda \boldsymbol{X}_{i,j} + \vartheta \boldsymbol{BUR}_{j} + e_{i,j} \quad (2)$$

$$SWB_{i,j}^{*} = \alpha + \delta \ln(Y_{i,j}) + \lambda \boldsymbol{X}_{i,j} + \rho \boldsymbol{FLO}_{j} + e_{i,j} \quad (3)$$

In comparison to Equation (1), Equations (2) and (3) also consider the $\ln(Y_{i,j})$, and the vector $X_{i,j}$, but each equation adds an extra specific element. In Equation (2), $\boldsymbol{BUR}_{j}$ is a vector of total burnt forest area per region, including the years 2017 and 2018. While in Equation (3), $\boldsymbol{FLO}_{j}$ is a vector for forecasting vulnerable areas and the people who live in them, in three distinct scenarios (2025, 2050, and 2100). As aforementioned in the section "Data", I am not interested in the evolution of the vectors $\boldsymbol{BUR}_{j}$ and $\boldsymbol{FLO}_{j}$ over the years. Therefore, I do not apply the subscript "*t*" for time since the coefficients represent the impact of those events on the current well-being of the Portuguese citizens. Equations (2) and (3) only use the data from the 9th wave of ESS since it may capture the full effects of the massive fires that happened in 2017, which generated more than 100 deaths and 500 thousand hectares of burnt area (encompassing all types of fires) in Portugal. Also, following previous studies (Osberghaus & Kühling, 2016; Sekulova & van den Bergh, 2013), I consider only socio-economic and demographic variables, to isolate the effect of each EWE on SWB.[21]

In this study, where $SWB \in J = \{0,1,2,\dots,10\}$, the unknown parameters α_m with $m = 0,1,2,\dots,9$ are considered such that:

$$\alpha_0 < \alpha_1 , \dots , < \alpha_9 \quad (4)$$

[21] The aim is to avoid any possible influence coming from the relationship between environmental variables (such as air pollution, climate conditions) and welfare on the relationship between EWEs and happiness.

While the ordinal dependent variable satisfies:

$$SWB = \begin{cases} 0, if\ y^* \leq \alpha_0 \\ 1, if\ \alpha_0 < y^* \leq \alpha_1 \\ \dots \\ 9, if\ \alpha_8 < y^* \leq \alpha_9 \\ 10, if\ y^* > \alpha_9 \end{cases} \quad (5)$$

The unknown parameters α_m and $\omega, \delta, \lambda, \eta, \theta, \vartheta, \rho$ are estimated by the Maximum Likelihood Method (Maddala, 1983). Additionally, since the data is spread across regions, it is expected that, within a region, the observations are not independent. For this reason, the models were estimated with robust cluster variance (Cameron & Miller, 2015), which respects the fact that the observations are independent between regions but not necessarily within.

For the valuation of infra-marginal changes of non-market goods, I compute the implicit willingness-to-pay (IWTP) for a one-unit change in each variable at the regional level (Ambrey et al., 2014; Welsch, 2006), using the partial derivatives of SWB with respect to PM_{10}, climate conditions, forest fires, or floods and the partial derivative of SWB with respect to net household income, as follows: [22]

$$IWTP_{PM_{10}} = \frac{\frac{\partial SWB^*_{i,j}}{\partial PM_{10}j}}{\frac{\partial SWB^*_{i,j}}{\partial Y_{i,j}}} = -\bar{y}\frac{\hat{\eta}}{\hat{\delta}} \quad (6)$$

$$IWTP_{BUR_j} = \frac{\frac{\partial SWB^*_{i,j}}{\partial BUR_j}}{\frac{\partial SWB^*_{i,j}}{\partial Y_{i,j}}} = -\bar{y}\frac{\hat{\vartheta}}{\hat{\delta}} \quad (7)$$

[22] Following Ambrey et al. (2014), the partial derivatives were taken from the likelihood of an individual reporting a happiness score of 10 (extremely happy).

$$IWTP_{FLO_j} = \frac{\frac{\partial SWB^*_{i,j}}{\partial FLO_j}}{\frac{\partial SWB^*_{i,j}}{\partial Y_{i,j}}} = -\bar{y}\frac{\hat{\rho}}{\hat{\delta}} \quad (8)$$

where $\bar{y}$ is the average value of household income. Even though ordinary least squares (OLS) has been widely used to estimate WTP (Cuñado & Gracia, 2013), an ordered probit may also be used for the same purpose since it offers a consistent estimation of the parameters (Frey et al., 2010). Moreover, other papers in the literature compute WTP estimates based on ordinal models (Ambrey et al., 2014).

5. Outcomes

Table 4 shows the results from the specifications of Equation (1). Model 1 represents the standard SWB regression. Overall, the effects of socio-economic and demographic variables are similar to those in the current literature (Dolan et al., 2008), with few variations throughout the models. Being a woman and having a higher income have a significant and positive association with welfare (Alesina et al., 2004; Welsch, 2002). Following previous studies, happiness is U-shaped with age (Ferreira et al., 2013). Students and retired people are less happy. Only those in very good health have a higher level of well-being, whereas bad health is associated with less life satisfaction (Cuñado & Gracia, 2013). The coefficient on education has a negative and statistically significant relationship with welfare (at the 1% level), and it indicates that highly-educated individuals distress more than others (Clark & Oswald, 1994). People who are widowed report to be less satisfied with life (Diener et al., 1999). Regarding personal traits, three out of five have a statistically significant relationship with well-being (Layard, 2005). People who consider themselves more religious and more often meet others are happier; while those who feel insecure walking alone at night tend to be less happy. When controlling for socio-economic variables, a global significance test on region dummy coefficients indicates the existence of differences in the levels of self-reported SWB across regions. This finding implies that the place where the respondent lives matters. When comparing regions, the citizens from Centro are the most satisfied with life. Next, Model 2 excludes regional dummy variables and includes air pollution and macro variables.[23]

[23] The four models were built according to the multicollinearity restrictions.

Table 4 - Environmental quality and SWB across Portuguese regions[1]

Variables	Model (1)	Model (2)	Model (3)	Model (4)
Socio-economic characteristics				
Ln (Income)	0.217*	0.217*	0.220*	0.199
	(0.127)	(0.127)	(0.126)	(0.141)
Gender	0.114**	0.114**	0.120***	0.144***
	(0.047)	(0.047)	(0.045)	(0.052)
Age	-0.069***	-0.069***	-0.071***	-0.073***
	(0.011)	(0.011)	(0.011)	(0.011)
Age^2	6.15e-04***	6.15e-04***	6.37e-04***	6.58e-04***
	(1.40e-04)	(1.40e-04)	(1.35e-04)	(1.46e-04)
Main activity				
Paid work	-0.612	-0.612	-0.619	-0.608
	(0.426)	(0.426)	(0.427)	(0.424)
Student	-1.133**	-1.133**	-1.108**	-1.058**
	(0.452)	(0.452)	(0.458)	(0.461)
Unemployed seeking	-0.588	-0.588	-0.616	-0.607
	(0.428)	(0.428)	(0.445)	(0.447)
Retired	-0.589**	-0.589**	-0.599**	-0.604**
	(0.275)	(0.275)	(0.278)	(0.268)
Disabled	-0.500	-0.500	-0.502	-0.355
	(0.338)	(0.338)	(0.335)	(0.287)
Housework	-0.329	-0.329	-0.344	-0.344
	(0.438)	(0.438)	(0.443)	(0.441)
Others	-0.673	-0.673	-0.666	-0.700
	(0.597)	(0.597)	(0.597)	(0.589)
Health				
Very good	0.294***	0.294***	0.290***	0.283***
	(0.054)	(0.054)	(0.053)	(0.050)
Fair	-0.097	-0.097	-0.093	-0.120
	(0.075)	(0.075)	(0.075)	(0.076)
Bad	-0.771***	-0.771***	-0.776***	-0.835***
	(0.172)	(0.172)	(0.171)	(0.224)
Very bad	-0.785	-0.785	-0.779	-0.670
	(0.490)	(0.490)	(0.487)	(0.427)
Education	-0.027***	-0.027***	-0.027***	-0.031***
	(0.009)	(0.009)	(0.009)	(0.010)
Marital status				
Separated	-0.336	-0.336	-0.311	-0.252
	(0.494)	(0.494)	(0.484)	(0.528)
Divorced	-0.258	-0.258	-0.259	-0.284
	(0.214)	(0.214)	(0.212)	(0.204)
Widowed	-1.335***	-1.335***	-1.276***	
	(0.072)	(0.072)	(0.078)	
None	-0.131	-0.131	-0.130	-0.116
	(0.152)	(0.152)	(0.151)	(0.144)
Personality traits				
Social meets	0.077***	0.077***	0.075***	0.072***
	(0.008)	(0.008)	(0.009)	(0.011)
Personal intimacies	0.014	0.014	0.013	0.010
	(0.022)	(0.022)	(0.021)	(0.028)
Social activities	0.013	0.013	0.018	-0.001
	(0.056)	(0.056)	(0.057)	(0.053)
Religious self-judgment	0.070***	0.070***	0.070***	0.073***
	(0.008)	(0.008)	(0.008)	(0.011)
Sense of insecurity	-0.179**	-0.179**	-0.182**	-0.204**
	(0.089)	(0.089)	(0.088)	(0.081)
Size of settlement	-0.043	-0.043	-0.035	-0.046
	(0.038)	(0.038)	(0.041)	(0.034)

Table 4 - Environmental Quality and SWB across Portuguese regions (continued)[1]

Variables	Model (1)	Model (2)	Model (3)	Model (4)
Region				
Algarve	-0.233***			
	(0.011)			
Centro	0.057*			
	(0.034)			
Lisboa	-0.004			
	(0.020)			
Alentejo	-0.077***			
	(0.024)			
Air Pollution - PM_{10}		-0.052**		
		(0.021)		
Macro variables				
GDP per capita		-3.70e-04***		
		(1.28e-04)		
Ln (unemployment rate)		-2.21***		
		(0.802)		
Population density		0.003***		
		(0.001)		
Climate conditions				
Hottest annual temperature			0.272*	
			(0.150)	
Lowest annual temperature			0.222**	
			(0.110)	
Precipitation			0.004**	
			(0.002)	
Environmental awareness				0.098***
				(0.014)
IWTP				
Pollution (PM_{10})		€ 381		
Hottest annual temperature			€ (1,939)	
Lowest annual temperature			€ (1,585)	
Log likehood	-1,155	-1,155	-1,156	-1,131
Pseudo R^2	0.0433	0.0433	0.0429	0.0439

Note: Standard errors in parentheses. Significance: *** p<0.01; ** p<0.05; * p<0.1. The intercepts are not shown.
1. Due to multicollinearity restrictions, several models are estimated. Omitted case: variable "widowed" in Model 4.

The coefficient on the amount of air pollutants has a negative and statistical relationship with individual SWB at the 5% level (Ambrey et al., 2014), suggesting that, at the regional level, the harmful effects of PM_{10} emissions on health may reduce happiness. Turning to macro variables, the coefficient on GDP per capita is negative and statistically significant. Despite being uncommon, there is evidence of this result in the literature (Ding et al., 2021; Welsch & Kühling, 2018). One possible explanation for this intriguing result is the simultaneous control for income at the individual level and GDP per capita, where the coefficient for the second suggests playing a role as comparison income (Clark et al., 2008).[24] Following the usual findings, the unemployment

[24] Clark & Oswald (1996) show that comparison income has a negative and statistically significant impact on workers' life satisfaction level.

rate at the regional level also affects happiness negatively (Di Tella et al., 2001; Winkelmann & Winkelmann, 1998). However, population density has a positive and statistically significant effect on welfare at the 1% level, suggesting a beneficial effect coming from governmental efforts devoted to reducing the negative migratory balance.[25]

Table 5 – EWEs and SWB across Portuguese regions[1]

Variable	Area of burnt forest – Equation 2	Vulnerable areas and people living therein – Equation 3	
	Model (1)	Model (1)	Model (2)
Socio-economic and demographic variables	Included	Included	Included
Extreme Weather Events (EWE)			
Burnt area of forest - Past			
Year 2017	-1.50e-04		
	(3.72e-04)		
Year 2018	-0.015***		
	(0.005)		
Floods and its effects – Future			
Vulnerable areas			
Ln (Year 2025)		-0.315	
		(0.198)	
Ln (Year 2050)		0.073	
		(0.382)	
Ln (Year 2100)		0.343**	
		(0.142)	
People living in vulnerable areas			
Ln (Year 2025)			-1.383**
			(0.705)
Ln (Year 2050)			-3.692*
			(2.196)
Ln (Year 2100)			-2.182
			(1.430)
IWTP			
Burnt area of forest – Year 2018	€ 263		
Vulnerable area – Year 2100		€ (5,624)	
People living in vulnerable areas – Year 2025			€ 23.997
Log likehood	-1,409	-1,407	-1,407
Pseudo R^2	0.0636	0.0652	0.0649

Note: Standard errors in parentheses. Significance: *** p<0.01; ** p<0.05; * p<0.1. The intercepts are not shown.
1. Due to multicollinearity restrictions, several models are estimated. The full version of these estimations is in Appendix I.

In Model 3, Table 4, the coefficient on the hottest annual temperature is positive and significant at a 10% level, indicating that warmer days increase happiness in summer. The coefficient on the lowest annual temperature is also positive and significant at a 5% level, suggesting the preference towards a warmer climate in winter. Ferreira & Moro (2010) find similar results for Ireland.

[25] In Portugal, the migratory movement has generated the emptying of small towns and villages in the country's most remote areas (NSI, 2021).

Precipitation tends to increase happiness in Portugal, which indicates a possible correlation between rain and scenic beauty (Brereton et al., 2008). Lastly, in Model 4, Table 4, serving as a proxy to environmental awareness, the level of concern about climate change has a positive effect on well-being, which may express a kind of affiliation with nature (Kellert, 2008; Wilson, 1984).

Table 5 shows the regression results for Equations (2) and (3), which aim to answer the second research question. Socio-economic and demographic variables show similar results. In what the burnt forest area is concerned (Model 1 – second column), there is a negative relationship with SWB in 2018, which follows the previous results in the happiness literature, indicating that forest fires have a negative influence on welfare. Since the largest part of the Portuguese population lives in urban areas, such result suggests that forest fires have lasting psychological or physical impacts, probably due to the high frequency of health problems and negative emotional status among those individuals who experienced such events (Sekulova & van den Bergh, 2013).

The results from Equation (3) are set forth in columns 3 and 4 of Table 5. The coefficient on vulnerable areas in 2100 has a positive and statistically relationship with well-being at the 5% level, suggesting that in the long run, people may (possibly) have time for adjusting their lives as well as the affected economic activities, in face of the expected changes. On the other hand, the coefficients of people living in vulnerable areas show that a forecast of an increase in the short (2025) or middle run (2050) may be understood as a threat since it tends to reduce current well-being. In my opinion, a possible explanation for this result is that the Portuguese citizens fear not being able to make all the necessary adjustments in the short and middle run, in a way to avoid the damage coming from sea level rise. Thus, the paper's key finding is that at the regional level, both past and (possible) future EWEs may decrease the current level of welfare, when these events are seen as a threat to human life.

Lastly, at the bottom of Tables 4 and 5 one can see the monetary valuations of non-marketable goods, such as air pollution, climate conditions, and EWEs. First, the estimations indicate that an individual has an IWTP of 381 euros per year to decrease one kton of PM_{10} annual emissions. Just to compare with previous results, respecting the differences for each study, Cuñado & Gracia (2013) find monetary valuations to the Spanish case of 325 euros, for the 4th wave of ESS. It is

worth noting that in the case of Spain, the citizens were willing to pay for one day less per year that exceeds the PM_{10} index (50 μg / m^3), whereas the present study assesses the decrease in one kton emission. Thus, each study applies different measurement units. For the hottest annual temperature, the subjects are likely to gain 1,939 euros from an increase of one degree Celsius in the summer, and 1,585 euros in the winter. This result makes sense for Portugal, due to the high weight of the tourism activities on its GDP (mainly in the coastal zone).

Concerning the EWEs, the IWTP in 2018 for the burnt forest area is equal to 263 euros, which means that citizens are willing to pay 263 euros per a thousand hectares reduction in the burnt forest area. Although, this amount is low if one considers all negative effects that forest fires may cause to citizens as well as to the whole economy. In the short run (2025), the coefficient on people living in vulnerable areas shows an IWTP of around 24,000 euros for having one less person who lives in (future) vulnerable areas due to sea-level rise. Such a high amount might be an expression of the level of concern for each human being that will be directly affected by climate change.

6. Concluding remarks

Assessments of environmental quality at the regional level contribute to improving the understanding of life satisfaction by taking into account the specific characteristics of each region. This paper uses a set of explanatory variables for analyzing the effects of air pollution, climate conditions, and the occurrence of EWEs across Portuguese regions. Among its findings, there is a clear difference in happiness level between regions, indicating that the place where the individuals live may affect their well-being. Having knowledge at a more disaggregated spatial level allows for the conception of environmental public policies oriented at mitigating economic restrictions that are due to natural regional features while respecting the differences between regions. This is relevant since environmental conditions may influence subjective well-being, even though the individuals are not consciously aware of the cause-effect relationship (Welsch & Kühling, 2009).

Following previous results (Ambrey et al., 2014; Ferreira et al., 2013), when using regional data, the findings in this paper show a negative impact of PM_{10} emissions on life satisfaction. From a public policy perspective, this result is useful to inspire governmental initiatives towards the

reduction of air pollution at the Portuguese regional level, simultaneously promoting higher environmental quality and improvements in welfare.

This research also offers a contribution to ecological economics for providing an assessment of environmental quality across Portuguese regions, by using data from the ESS survey, air pollution indicators, and climate conditions. To my knowledge, this is the first paper devoted to the Portuguese case, combining those environment factors at the NUTS 2 level along with individual socio-economic and demographic characteristics. The results obtained are in line with the SWB literature, offering a suitable frame for the environmental policy in Portugal.

Regarding EWEs, namely forest fires and floods, most coefficients show a negative impact on welfare, regardless of whether they happened in the past or if it is just a simple forecast. In addition, the IWTP suggests that the households are prone to give up a part of their income to avoid those EWEs effects. In my opinion, the influence of past and future EWEs, at the regional level and for a single country, on current well-being is the key finding of this paper, indicating that not only experienced events, but also predicted events, may disturb individuals' mental health. In what forecasted floods are concerned, another interesting finding is that only expected events in the short and middle run negatively affect the current happiness level, suggesting a fear of not being able to handle the consequences of climate change on time. Ferrer-i-Carbonell & Gowdy (2007) also claim that the "preoccupation itself" can reduce individual well-being. These findings may be useful to the Portuguese policymakers by providing elements to build public policies suitable to balance the negative impacts coming from climate change, its effects on quality of life, and economic costs. For instance, in the case of the increase of people living in vulnerable areas due to the sea-level rise, the ideal solution may encompass the removal of these households from their homes, which implies public spending (when the Government assumes this responsibility).

Future research may expand this analysis in several ways. First, adding data from the autonomous regions of Azores and Madeira (currently not covered by ESS), which may offer assessments based on a higher level of heterogeneity, since these are insular regions, with different features in comparison with the mainland. Second, considering data at a more spatial disaggregated level (such as NUTS 3) may highlight the distinctions across districts, even for a small country like

Portugal. For example, a dummy variable might identify those areas with a coastal zone, high altitudes, or better transport infrastructure. Third, the application of surveys in areas with a higher frequency of forest fires might allow us to better understand the extension to which EWEs lead to reductions in the happiness level locally. This type of analysis may map in detail the most affected areas and help to improve the efficiency of public policies.

References

Alesina, A., Di Tella, R., & MacCulloch, R. (2004). Inequality and happiness: Are Europeans and Americans different? Journal of Public Economics. Vol. 88, pp: 2009–2042. https://doi.org/10.1016/j.jpubeco.2003.07.006

Ambrey, C.L., Fleming, C.M. & Chan, A.Y.C. (2014). Estimating the cost of air pollution in South East Queensland: An application of the life satisfaction non-market valuation approach. Ecological Economics. Vol. 97, pp: 172–181. https://doi.org/10.1016/j.ecolecon.2013.11.007

Antunes, C.M.C. (2016). Rising Average Sea Level in Cascais, revision of the current rate. 4th Journey of Hydrographic Engineering, Lisbon, pp: 21-23. https://doi.org/10.1175/2010JCLI4045.1

Antunes, C.M.C. (2019). Assessment of sea level rise at west coast of Portugal mainland and its projection for the 21st century. Journal of Marine Science and Engineering, 7(3). Vol. 61, pp.1-17. https://doi.org/10.3390/jmse7030061

Apergis, N. (2018). The Impact of Greenhouse Gas Emissions on Personal Well-Being: Evidence from a Panel of 58 Countries and Aggregate and Regional Country Samples. Journal of Happiness Studies. Vol. 19, pp:69-80. https://doi.org/10.1007/s10902-016-9809-y

Batista, M.; Leyton, M.; Serrano, J.; Petrica, J.; Honório, S.; Rocha, J.; Santos, J.; Silveira, P.; Jimenez, R. (2019) Self-determined motivation and subjective well- being in Portuguese veteran athletes in different sports. JHSE Supplementary Issue: International Seminar of Physical Education, Leisure and Health. Castelo Branco, Portugal. https://doi.org/10.14198/jhse.2019.14.Proc4.82

Berger, E.M. (2008) A note on the high stability of happiness: the minimal effects of a nuclear catastrophe on life satisfaction. Discussion Papers of DIW Berlin 803, DIW Berlin, German Institute for Economic Research.

Brereton, F.; Clinch, J.P. and Ferreira, S. (2008). Happiness, Geography and the Environment. Ecological Economics. Vol. 56, pp: 386-396. https://doi.org/10.1016/j.ecolecon.2007.07.008

Cameron, A. and Miller, D. (2015). A practitioner's guide to cluster-robust inference. Journal of Human Resources. Vol. 50 (2): 317–372, 2015.

Choi, J. (2018). Structural Relationships among Environmental Engagement, Sustainable Behavior, and Happiness in University Students. Opción. Vol. 15, pp: 924-940.

Clark, A.E. (2003). Unemployment as a Social Norm: Psychological Evidence from Panel Data. Journal of Labor Economics. Vol. 21, No. 2 (April 2003), pp: 323-351. https://doi.org/10.1086/345560

Clark, A.E., Frijters, P. and Shields, M. (2008). Relative income, happiness and utility: an explanation for the Easterlin paradox and other puzzles. Journal of Economic Literature. Vol. 46, issue 1, pp: 95–144. https://doi.org/10.1257/jel.46.1.95

Clark, A.E. and Oswald, A.J. (1994). Unhappiness and unemployment. Economic Journal. Vol. 104, pp: 648–659.

https://doi.org/10.2307/2234639

Clark, A.E. and Oswald, A.J. (1996). Satisfaction and comparison income. Journal of Public Economics. Vol. 61, pp: 359–381. https://doi.org/10.1016/0047-2727(95)01564-7

Cramer, V., Torgersen, S. and Kringlen, E. (2004). Quality of life in a city: the effect of population density. Social Indicators Research. Vol. 69, pp: 103–116. https://doi.org/10.1023/B:SOCI.0000032663.59079.0b

Cummings, J. A.; Diener, E. and Lucas, R. A. (ed.). (2019). Personal Traits. In: Cummings, J.A.; Sanders, L. (Org.). Introduction to Psychology. University of Saskatchewan, 2019. Chapter 16. Available in: https://openpress.usask.ca/introductiontopsychology/front-matter/about-the-book/. Acess in: Mar/2021.

Cuñado, J. and Gracia, F.P. (2013). Environment and Happiness: New Evidence for Spain. Social Indicators Research. Vol. 112, pp: 549-567. https://doi.org/10.1007/s11205-012-0038-4

Di Tella, R., MacCulloch, R.J. and Oswald, A.J. (2001). Preferences over Inflation and Unemployment: Evidence from Surveys of Happiness. The American Economic Review. Vol. 91, pp: 335–341. https://doi.org/10.1257/aer.91.1.335

Di Tella, R., MacCulloch, R. J. and Oswald, A. (2003). The macroeconomics of happiness. The Review of Economics and Statistics. Vol. 85, pp: 809–827. https://doi.org/10.1162/003465303772815745

Diener, E. (2009). Subjective well-being. In: Diener, E. (Ed.), The science of well-being: The collected works of Ed Diener. Social indicators research series. Vol. 37. Springer Science + Business Media. https://doi.org/10.1007/978-90-481-2350-6

Diener, E., Suh, E.M., Lucas, R.E. and Smith, H.L. (1999). Subjective well-being: three decades of progress. Psychological Bulletin. Vol. 125, pp: 276–302. https://doi.org/10.1037/0033-2909.125.2.276

Ding, J., Salinas-Jiménez, J. and Salinas-Jiménez, M. del M. (2021). The impact of income inequality on subjective well-being: the case of China. Journal of Happiness Studies. Vol. 22, pp: 845–866. https://doi.org/10.1007/s10902-020-00254-4

Dolan, P., Peasgood, T. and White, M. (2008). Do we really know what makes us happy? A review of the economic literature on the factors associated with subjective well-being. Journal of Economic Psychology. Vol. 29(1), pp: 94–122. https://doi.org/10.1016/j.joep.2007.09.001

EEA – European Environment Agency. (2021). Air quality index. Available in: <https://www.eea.europa.eu/themes/air/air-quality-index>. Access in: March/2021.

ESS – European Social Survey. (2021). NSD - Norwegian Centre for Research Data, Norway – Data Archive and distributor of ESS data for ESS ERIC. Available in:<https:// https://www.europeansocialsurvey.org/>. Access in: February/2021.

Ferreira, S., Akay, A., Brereton, F., Cuñado, J. and Martinsson, P. (2013). Life satisfaction and air quality in Europe. Ecological Economics. Vol. 88, pp.1–10. https://doi.org/10.1016/j.ecolecon.2012.12.027

Ferreira, S. and Moro, M. (2010). On the use of subjective well-being data for environmental valuation. Environmental and Resource Economics. Vol. 46(3), pp: 249–273. https://doi.org/10.1007/s10640-009-9339-8

Ferrer-i-Carbonell, A. and Frijters, P. (2004). How important is methodology for the estimates of the determinants of happiness? Economic Journal. Vol. 114, pp:641–659. https://doi.org/10.1111/j.1468-0297.2004.00235.x

Ferrer-i-Carbonell, A. and Gowdy, J.M. (2007). Environmental Degradation and Happiness. Ecological Economics. Vol. 60, pp: 509-516. https://doi.org/10.1016/j.ecolecon.2005.12.005

Frey, B., Luechinger, S. and Stutzer, A. (2010). The life satisfaction approach to environmental valuation. Ann. Rev. Resour. Econ. 2, pp:139–160.

Frey, B.S. and Stutzer, A. (2000). Happiness, Economy and Institutions. The Economic Journal. Vol. 110, pp: 918-938. https://doi.org/10.1111/1468-0297.00570

Frey, B.S. and Stutzer, A. (2002). What can economists learn from happiness research? Journal of Economic Literature. Vol. 40, pp: 402–435.

Frey, B.S. and Stutzer, A. (2005). Happiness Research: State and Prospects. Review of Social Economy, LXII, n. 2, pp: 207-228. https://doi.org/10.1080/00346760500130366

Frijters, P. and van Praag, B.M.S. (1998). The Effects of Climate on Well-Being and Welfare in Russia, Climate Change. Vol. 39, pp:61-81. https://doi.org/10.1023/A:1005347721963

ICNF - Institute for the Conservation of Nature and Forests. (2021). Available in: <https://www.incf.pt/>. Access in: March/2021.

IPCC: Intergovernmental Panel on Climate Change (2014). Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1132 pp.

Kellert, S.R. (2008). In: Dimensions, elements, and attributes of Biophilic design. Kellert, S.R., Heerwagen, J.H. and Mador, M.L. (Eds.), Biophilic Design: The theory, Science, and Practice of Bringing Buildings to Life. John Wiley and Sons, New Jersey, U.S.A.

Layard, R. (2005). Happiness: Lessons from a new science. London: Allen Lane.

Levinson, A. (2012). Valuing public goods using happiness data: The case of air quality. Journal of Public Economics, 96, pp.869–880. https://doi.org/10.1016/j.jpubeco.2012.06.007

Lopes, H., Calapez, T. and Porto, C. (2014). Does the macroeconomic context influence subjective well-being in Europe and Portugal? The puzzling case of the 2008 crisis. Portuguese Journal of Social Science. Vol. 13(1), pp: 3–19. https://doi.org/10.1386/pjss.13.1.3_1

Luechinger, S. (2009). Valuing Air Quality Using the Life Satisfaction Approach. The Economic Journal, 119 (536), pp:482–515. https://doi.org/10.1111/j.1468-0297.2008.02241.x

MacKerron, G. and Mourato, S. (2009). Life satisfaction and air quality in London. Ecological Economics. Vol. 68, pp:1441-1453. https://doi.org/10.1016/j.ecolecon.2008.10.004

MacKerron, G. and Mourato, S. (2013). Happiness is greater in natural environments. Global Environmental Change. Vol. 23, pp:992-1000. https://doi.org/10.1016/j.gloenvcha.2013.03.010

Maddala, G. 1983. Limited Dependent and Qualitative Variables in Econometrics. New York, Cambridge University Press.

NASA: National Aeronautics and Space Administration (2021). Global Climate Change. Vital signs of the planet, Sea Level. Available in: < https://climate.nasa.gov/vital-signs/sea-level/> Acess in: March/2021.

National Statistics Institute - NSI. (2021). Available in:<https://www.ine.pt/>. Access in: March/2021.

Osberghaus, D. and Kühling, J. (2016). Direct and indirect effects of weather experiences on life satisfaction – which

role for climate change expectations? Journal of Environmental Planning and Management. Vol. 59, n. 12, pp: 2198-2230. https://doi.org/10.1080/09640568.2016.1139490

Portuguese Environment Agency - PEA. (2021). Available in:<https://www.apambiente.pt/>. Access in: March/2021.

Peiró, A. (2006). Happiness, satisfaction and socio-economic conditions: Some international evidence. The Journal of Socio-Economic. Vol. 35, pp: 348–365. https://doi.org/10.1016/j.socec.2005.11.042

Pereira, M.C. and Martins, D. (2015). Assessing the effect of education on subjective well-being in Portugal: a study of mediating effects. In: Godinho, P.; Dias, J. (Edi.). Assessment Methodologies. Energy, mobility and other real world application. Coimbra University Press. Coimbra, Portugal. Available in: <https://digitalis.uc.pt/en/livro/assessing_effect_education_subjective_well_being_portugal_study_mediating_effects>. Access in: Mar/2021.

Portuguese Institute of the Sea and the Atmosphere - PISA. (2021). Available in:<https://www.ipma.pt/>. Access in: March/2021.

Rehdanz, K. and Maddison, D. (2005). Climate and Happiness. Ecological Economics. Vol. 52, pp: 111-125. https://doi.org/10.1016/j.ecolecon.2004.06.015

Rehdanz, K. and Maddison, D. (2008). Local Environmental Quality and Life-Satisfaction in Germany". Ecological Economics. Vol 64, pp:787-797. https://doi.org/10.1016/j.ecolecon.2007.04.016

Rocha, C. S. (2016). Study and analysis of coastal vulnerability in the face of scenarios of rising average sea level and extreme events due to the effect of climate changes. 112 p. Dissertation. Supervisors: Antunes, C.M.C. and Catita, C.M.S. Master in Geographic Engineering, Faculty of Sciences, Department of Geographic Engineering, Geophysics and Energy, University of Lisbon, Lisbon. Available in:<https://repositorio.ul.pt/handle/10451/2632>. Access in: March/2021.

Schwarz, N. and Strack, F. (1999). Reports of Subjective Well-Being: Judgmental Processes and Their Methodological Implications. In: Kahneman, D., Diener, E., Schwarz, N. (Eds.), Well-being: The Foundations of Hedonic Psychology. Russell Sage Foundation, New York.

Sekulova, F. and van den Bergh, J.C.J.M (2013). Climate change, income and happiness: An empirical study for Barcelona. Global Environmental Change. Vol. 23, pp:1467–1475. https://doi.org/10.1016/j.gloenvcha.2013.07.025

Smyth, R., Mishra, V. and Qian, X. (2008). The Environment and Well-Being in Urban China. Ecological Economics. Vol. 68, pp:547-555. https://doi.org/10.1016/j.ecolecon.2008.05.017

Soukiaviz, E. and Ramos, S. (2016). The Structure of Subjective Well-Being and Its Determinants: A Micro-Data Study for Portugal. Social Indicators Research. Vol. 126, pp:1375–1399. https://doi.org/10.1007/s11205-015-0938-1

Ulrich, R.S. (1984). View through a window may influence recovery from surgery. Science, New Series. Vol. 224, Issue 4647, pp: 420-421. https://doi.org/10.1126/science.6143402

Van Praag, B.M.S. and Baarsma, B.E. (2005). Using happiness surveys to value intangibles: the case of airport noise. Economic Journal. Vol. 115, pp: 224–246. https://doi.org/10.1111/j.1468-0297.2004.00967.x

Veenhoven, R. (1997). Advances in understanding happiness. Revue Québécoise de Psychologie. Vol. 18, pp 29-74.

Welsch, H. (2002). Preferences over Prosperity and Pollution: Environmental Valuation based on Happiness Surveys. Kyklos. Vol. 55, pp:473-494. https://doi.org/10.1111/1467-6435.00198

Welsch, H. (2006). Environment and happiness: Valuation of air pollution using life satisfaction data. Ecological

Economics. Vol. 58, pp: 801-813. https://doi.org/10.1016/j.ecolecon.2005.09.006

Welsch, H. and Kühling, J. (2009). Using happiness data for environmental valuation: Issues and applications. Journal of Economic Surveys. Vol. 23, pp: 385–406. https://doi.org/10.1111/j.1467-6419.2008.00566.x

Welsch, H. and Kühling, J. (2018). How green self-image is related to subjective well-being: Pro- Environmental Values as a Social Norm. Ecological Economics. Vol. 149, pp: 105–119. https://doi.org/10.1016/j.ecolecon.2018.03.002

Wilson, E.O. (1984). Biophilia. Harvard University Press, Massachusetts.

Winkelmann, L. and Winkelmann, R. (1998). Why are the unemployed so unhappy? Evidence from panel data. Economica. Vol. 65 (257), pp: 1–15. https://doi.org/10.1111/1468-0335.00111

Wolfers, J. (2003). Is business cycle volatility costly. Evidence from surveys of subjective well-being. International Finance. Vol. 6, pp: 1–26.

Appendix I - EWEs and SWB across Portuguese regions[1]

Variable	Burnt area of forest – Equation 2	Vulnerable areas and people living in them – Equation 3	
	Model (1)	Model (1)	Model (2)
Socio-economic and demographic variables			
Ln (Income)	0.094**	0.101**	0.095**
	(0.041)	(0.042)	(0.043)
Gender	0.027	0.039	0.029
	(0.055)	(0.054)	(0.055)
Age	-0.035***	-0.032**	-0.034***
	(0.012)	(0.012)	(0.013)
Age^2	3.11e-04**	2.90e-04**	3.01e-04**
	(1.26e-04)	(1.21e-04)	(1.27e-04)
Main activity			
Paid work	0.082	0.101	0.098
	(0.155)	(0.167)	(0.168)
Student	0.040	0.049	0.031
	(0.144)	(0.143)	(0.149)
Unemployed seeking	0.058	0.052	0.065
	(0.151)	(0.127)	(0.135)
Retired	0.050	0.059	0.059
	(0.225)	(0.218)	(0.215)
Disabled	-0.408	-0.405*	-0.389
	(0.263)	(0.236)	(0.246)
Housework	-0.110	-0.093	-0.091
	(0.293)	(0.291)	(0.305)
Others	-0.516***	-0.488***	-0.513***
	(0.161)	(0.177)	(0.182)
Health			
Very good	0.382***	0.388***	0.376***
	(0.087)	(0.090)	(0.085)
Fair	-0.099	-0.097	-0.103
	(0.122)	(0.127)	(0.123)
Bad	-0.449***	-0.460***	-0.458***
	(0.157)	(0.155)	(0.154)
Very bad	-1.026*	-1.021*	-1.036*
	(0.574)	(0.578)	(0.582)
Education	-0.026***	-0.026**	-0.027***
	(0.010)	(0.011)	(0.010)
Marital status			
Separated	-0.894**	-0.899**	-0.922**
	(0.428)	(0.441)	(0.430)
Divorced	-0.398***	-0.381***	-0.403***
	(0.117)	(0.113)	(0.115)
Widowed	-0.976***	-0.978***	-0.969***
	(0.209)	(0.206)	(0.208)
None	-0.426***	-0.404***	-0.416***
	(0.064)	(0.069)	(0.067)
Personality traits			
Social meets	0.128***	0.130***	0.135***
	(0.011)	(0.011)	(0.011)
Personal intimacies	-0.011	-0.006	-0.012
	(0.034)	(0.036)	(0.035)
Social activities	0.083***	0.083***	0.082***
	(0.024)	(0.024)	(0.024)
Religious self-judgment	0.046***	0.045***	0.046***
	(0.010)	(0.009)	(0.010)
Sense of security	-0.217***	-0.202***	-0.217***
	(0.023)	(0.020)	(0.019)
Size of settlement	-0.066**	-0.071***	-0.058*
	(0.033)	(0.021)	(0.032)

Appendix I - EWEs and SWB across Portuguese regions (continued)[1]

Variable	Burnt area of forest – Equation 2	Vulnerable areas and people living in them – Equation 3	
	Model (1)	Model (1)	Model (2)
Extreme Weather Events (EWE)			
Burnt area of forest - Past			
Year 2017	-1.50e-04		
	(3.72e-04)		
Year 2018	-0.015***		
	(0.005)		
Floods and its effects – Future			
Vulnerable areas			
Ln (Year 2025)		-0.315	
		(0.198)	
Ln (Year 2050)		0.073	
		(0.382)	
Ln (Year 2100)		0.343**	
		(0.142)	
People living in vulnerable areas			
Ln (Year 2025)			-1.383**
			(0.705)
Ln (Year 2050)			-3.692*
			(2.196)
Ln (Year 2100)			-2.182
			(1.430)
IWTP			
Burnt area of forest – Year 2018	€ 263		
Vulnerable area – Year 2100		€ (5,624)	
People living in vulnerable areas – Year 2025			€ 23.997
Log likehood	-1,409	-1,407	-1,407
Pseudo R^2	0.0636	0.0652	0.0649

Note: Standard errors in parentheses. Significance: *** p<0.01; ** p<0.05; * p<0.1. The intercepts are not shown.
1. Due to multicollinearity restrictions, several models are estimated.