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Environmental Quality and Life Satisfaction

EVIDENCE BASED ON MICRO-DATA

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Nick Johnstone

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ENVIRONMENTAL QUALITY AND LIFE SATISFACTION: EVIDENCE BASED ON MICRO-DATA

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Keywords: Air Pollution; Local Environmental Quality; Subjective Well-Being; Life Satisfaction

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ABSTRACT

Environmental conditions are likely to have an effect on people's sense of life satisfaction, both directly and indirectly. In recent years there has been a burgeoning literature assessing the relationship between measures of environmental quality and subjective well-being. This type of studies can be a useful input into the setting of policy priorities. In this paper, the effects of individual and contextual factors on satisfaction with environmental quality and life satisfaction are assessed, using micro-data from a broad cross-section of OECD and non-OECD countries collected in the framework of the Gallup World Poll. In the analysis it is found that actual and perceived environmental quality has a significant effect on life satisfaction, with the magnitude being approximately half that of self-reported health status.

JEL Classifications: Q53, Q51, D60

Keywords: Air Pollution; Local Environmental Quality; Subjective Well-Being; Life Satisfaction

RÉSUMÉ

Les conditions environnementales peuvent affecter, directement et indirectement, la satisfaction individuelle. Durant les dernières années s'est développée une littérature économique explorant les relations entre mesures de la qualité de l'environnement et mesures du bien-être subjectif des populations. Les travaux de ce type peuvent être utiles dans l'élaboration des priorités politiques. Nous explorons dans cet article les effets des facteurs individuels et contextuels sur la satisfaction par rapport à la qualité de l'environnement et au bien être subjectif, en utilisant des données individuelles collectées par Gallup au sein d'un large panel de pays membres et non-membres de l'OCDE. L'analyse montre que la qualité de l'environnement a un effet significatif sur la satisfaction individuelle, dont la magnitude est d'environ la moitié de celle de l'effet de la santé subjective.

Classifications JEL: Q53, Q51, D60

Mots-clés : Pollution de l'air, Qualité de l'environnement, Bien-être subjectif, Satisfaction individuelle.

FOREWORD

This report has been prepared by Jérôme Silva, Nick Johnstone (both OECD Secretariat) and Femke De Keulenaer (Gallup Europe). It assesses the effects of individual and contextual factors on satisfaction with environmental quality and life satisfaction using micro-data from the Gallup World Poll. Following on from the Stiglitz-Sen-Fitoussi report[1], the OECD has launched a horizontal project on measuring well-being and progress of societies.[2] An understanding of the factors that contribute to people's sense of life satisfaction is essential to understanding what contributes to better lives, and therefore how to improve public policy. Several OECD Directorates are investigating different aspects of well-being by looking at how subjective well-being relates to economic, social and other outcomes.

[1] See Stiglitz et al. (2009), "Report by the Commission on the Measurement of Economic Performance and Social Progress" (http://www.stiglitz-sen-fitoussi.fr/documents/rapport_anglais.pdf).

[2] For further information see: www.oecd.org/dataoecd/61/26/48299306.pdf

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EXECUTIVE SUMMARY

There is good empirical evidence that environmental factors affect people's sense of subjective well-being. However, one of the lessons emerging from this literature is that there is no one-to-one relationship between actual pollution concentrations and reported satisfaction with environmental quality. In addition, the relationship between reported satisfaction with environmental quality and life satisfaction varies. It is, therefore, necessary to assess both: A) the factors (including environmental conditions) which affect one's level of satisfaction with environmental quality; and, B) the impact that this has on subjective well being (and how this relationship differs across socio-demographic groups).

In this paper we examine these two sets of relationships. This paper is part of a broader OECD-wide project on "measuring well-being and progress of societies". The analysis is conducted using individual level data from Gallup World Poll survey on satisfaction with air quality combined with more aggregated data on particulate matter (PM_{10}) concentrations in urban areas. Given data availability constraints, multi-level modelling is applied, with country-level and city-level pollution concentrations applied at the upper level.

Preliminary results indicate that higher PM_{10} concentrations do have a significant effect on reported dissatisfaction with air quality; the size of the odds ratios in our models indicates that this effect is pronounced. However, the relationship between these two factors is non-linear, with the relationship being less robust at high levels of pollution. Reported dissatisfaction with health status, being a woman, having a higher income level, higher level of education and being between 26 and 40 years-of-age also increase one's likelihood of being dissatisfied with air quality.

Additional analysis was undertaken to study the effect of environmental conditions on subjective well-being. This work indicates that actual observations and perceptions about environmental conditions also affect self-reported subjective well-being, although it must be emphasised that this work is very preliminary. In particular, the effects of both actual and perceived environmental quality on reported life satisfaction relative to changes in household income is implausibly large, although relative to reported health satisfaction, the effect of environmental factors is consistent with previous work.

The effects of perceived and actual environmental conditions, however, are plausible relative to other effects. For example, self-reported dissatisfaction with personal health decreases respondents' life satisfaction score by 0.95 – or, in other words, respondents dissatisfied with their health are roughly one step lower on a 10-point scale than those satisfied with their health. By comparison, reporting dissatisfaction with different measures of environmental quality in our index decreases someone's life satisfaction by 0.48 – i.e. roughly half a step lower on the scale. In summary, the effect of perceived environmental quality on life satisfaction is approximately half the magnitude of the corresponding effect of satisfaction with health status.

ENVIRONMENTAL QUALITY AND LIFE SATISFACTION: EVIDENCE BASED ON MICRO-DATA

1. Introduction

Environmental conditions are likely to have an effect on people's sense of life satisfaction. They can have direct effects through impacts on the aesthetics, visibility, etc. of the local environment, and indirect effects through impacts on people's health, affecting their ability to enjoy other aspects of their welfare. Even if the impacts are not always tangible or apparent to those affected, a general level of concern about environmental conditions may affect people's sense of life satisfaction.[3]

There are, of course, a large number of empirical economic valuation studies which have sought to analyse people's willingness-to-pay for improved local environmental conditions, and similarly willingness-to-accept deterioration in environmental quality.[4] Valuation studies provide a direct means whereby the benefits of policy interventions can be monetised, allowing for a comparison of the costs, and therefore the assessment of whether a given intervention is welfare-improving through a cost-benefit analysis (see Pearce et al. 2006).

More informal analysis of the relationship between measures of environmental quality and subjective well-being is a relatively new area of economic research (Welsch 2005, Levinson 2009). Such studies relax some of the constraints underpinning more formal valuation studies, and do not directly "monetise" the value people place on environmental quality. As such, they cannot be used directly in the context of a cost-benefit analysis. However, some have argued that the results of subjective well-being studies can be used indirectly to generate monetary values via the compensating differentials approach (Blanchflower and Oswald 2004); more work is required to determine if and when this is appropriate.

Irrespective of suitability of subjective well-being studies for the generation of monetary values, these studies can provide a basis upon which governments can assess the relative importance people attach to environmental factors in comparison to other factors that they value. This can be a useful input into the setting of policy priorities, alongside other complementary tools including more formal valuation studies. Their use is likely to be particularly valuable for environmental impacts that are immediately perceptible, that vary widely across space and time, and that relate primarily to "use" values.

This paper is part of a broader OECD-wide project on "measuring well-being and progress of societies". Following on from the Stiglitz-Sen-Fitoussi report[5], the OECD has launched a horizontal project on these issues.[6] An understanding of the factors that contribute to people's sense of life satisfaction is essential to understanding what contributes to better lives, and therefore how to improve public policy. Several OECD Directorates are investigating different aspects of well-being by looking at how subjective well-being relates to economic, social and other outcomes.

The Environment Directorate's contribution to this work focuses on the effect of *actual* and *perceived* environmental quality on subjective well-being. The data used in this study come from the Gallup World

[3] Note – in this paper the terms "life satisfaction", "subjective well-being" and "happiness" are used interchangeably.
[4] Haneman (1994) provides a comprehensive review of the literature published before 1997, while Pearce et al. (2006) provide a more recent review.
[5] See Stiglitz et al. (2009), "Report by the Commission on the Measurement of Economic Performance and Social Progress" (http://www.stiglitz-sen-fitoussi.fr/documents/rapport_anglais.pdf).
[6] For further information see: www.oecd.org/dataoecd/61/26/48299306.pdf

Poll, and covers a broad cross-section of OECD and non-OECD countries. The specific focus of this paper is on the factors that affect respondents' satisfaction with air quality. It is a first step in understanding the consequences of environmental conditions on subjective well-being, and it is in this broader context that the rest of this paper is structured.

2. Literature review

The analysis of subjective well-being has enjoyed a recent surge of interest from economists, even those schooled in the more rigorous tradition of welfare economics. In the Stiglitz-Sen-Fitoussi report (2009), the intellectual origins and policy relevance of the approach were set out succinctly:

> *"The ... approach, developed in close connection with psychological research, is based on the notion of subjective well-being. A long philosophical tradition views individuals as the best judges of their own conditions. This approach is closely linked to the utilitarian tradition but has a broader appeal due to the strong presumption in many streams of ancient and modern culture that enabling people to be "happy" and "satisfied" with their life is a universal goal of human existence."*

It is now frequently asserted that subjective well-being – as distinct from utility as applied in welfare economics – should serve as a specific objective of public policy (see Layard 1980 for an early statement of this view). Indeed, Easterlin (1974) showed for the US that there has been a decoupling of the evolution of GDP and the development of self-reported subjective well-being. Studies based on panel and micro-level data, however, find that there is a significant relationship between self-reported well-being and income levels. Clark et al. (2008) developed a model which explains the apparent contradiction in the evidence through the incorporation of relative income – whether in respect to previous states of the individual or in relation to others.

The more specific literature on environmental conditions and subjective well-being is strongly focussed on exposure to "bads" (e.g. air pollution), rather than access to "goods" (e.g. green space). However, in their review of the literature available at that time, Dolan and White (2007) concluded that evidence of the impact of pollution on subjective well-being was very limited. Nonetheless, in recent years, there has been a growing body of literature, much of which supports the existence of such a relationship. For instance, Ferrer-i-Carbonell and Gowdy (2007) concluded that there is a negative relationship between local environmental problems and life satisfaction.

With respect to the effect of air pollution on well-being, the literature is also limited, but growing rapidly. Focusing on urban air pollution in London, MacKerron and Mourato (2008) found a significant and negative association of measured air pollution levels with life satisfaction. Luechinger (2009) used data of SO_2 concentrations at regional level and concluded that there is a statistically robust and significant negative effect of air pollution on life satisfaction. Redhanz and Madison (2008) also found a negative and significant relationship between perceived levels of air pollution and life satisfaction scores in Germany. In addition, the studies undertaken by Welsch (2002, 2005) provided evidence suggesting that nitrogen dioxide concentrations have a detrimental impact on overall happiness.

The most fully-developed study is perhaps the one of Levinson (2009), in which US data from the General Social Survey was merged with data from the Environmental Protection Agency's Air Quality System (AQS), recorded every six days, allowing the author to have fine-grained measures of air pollution and weather conditions (both in time and in geographical terms) corresponding to the location of respondents. This study showed that people reported lower levels of happiness when interviewed on days when air pollution was worse than the local seasonal average.

The role of attitudinal variables was assessed in a study in the UK by Ferrer-i-Carbonell and Gowdy (2007). These authors found that expressed concern about the status of the ozone layer was negatively associated with subjective well-being, while expressed concern about species extinction was positively associated with subjective well-being, suggesting that the role of underlying psychological traits were different in the two cases. Perhaps most interesting is the work of Van Praag and Baarsma (2005); they investigated the effects of aircraft noise around Amsterdam Schiphol Airport and found that objective noise measurements were not related to life satisfaction, but that perceived noise nuisance was negatively related to life satisfaction.

The finding that actual environmental conditions and the perception of environmental quality have different effects on people's subjective well-being highlights the importance of assessing the relationship between the two, and their joint impact on subjective well-being: (1) How closely related are actual and perceived environmental conditions? and (2) do they have distinct effects on well-being?

There are a small number of empirical studies in the epidemiological literature examining the relationship between objective measures and perceptions of air pollution. Rotko et al. (2002) studied the determinants of annoyance by air pollution and compared it to personal exposures to $PM_{2.5}$ and NO_2. They found that 29% of respondents in the cities included in the sample were highly annoyed by air pollution from road traffic, and 14% expressed annoyance associated with indoor air pollution at the workplace. They also observed that women, respondents reporting respiratory symptoms, and those living in the city centre reported a particularly high level of annoyance for a given level of environmental quality.

The results of Day (2007) also highlighted the importance of location in the experience of air quality. Day showed that, while people's judgement of air quality, in general, fitted quite well with the observed data, multiple aspects of location, such as the physical terrain, the presence of trees and greenery, had a mediating impact on the relationship between measured and perceived conditions. In their study on pedestrians' perceptions of particulate matter (PM_{10}) pollution, Nikolopoulou et al. (2011) found that higher PM concentrations were correlated with perceptions of poor air quality, but their results also suggested that visual clues of PM, such as dust, affected the perception of air quality and pollution. Moreover, they found that people's medical or smoking history affected their perception of air quality: people with a medical history of hay fever more frequently judged air quality as poor, whereas current smokers were the least sensitive to ambient air quality conditions.

As emphasised in the work of Bickerstaff and Walker (2001), awareness of poor air quality is far from universal, a diverse array of spatial, physical and social factors affect the perception of environmental quality. The importance of primary experience is essential, although personal perceptions are not used equally by all. It is, therefore, necessary to take a step backwards and assess the factors (including environmental conditions) that affect people's perception of environmental quality.

As a consequence, in this paper we assess the factors affecting reported satisfaction with local air quality using data from the Gallup World Poll (2006-2010). Although we do not have an objective measure of air quality at the level of the individual respondent, we do have aggregate data on concentrations of particulate matter (PM) for urban residents in a broad cross-section of cities. As such, we undertake a multilevel analysis, in which the effect of actual concentrations at the 'upper' (i.e. spatially aggregated) level is integrated in the regression model. In a second stage, we look at the effects of environmental quality on respondents' sense of life satisfaction, using both data on reported levels of satisfaction with environmental quality and on actual environmental conditions.

3. Conceptual framework

How is subjective well-being measured?

Definitions of subjective well-being used by psychologists are often broader in scope compared to the concepts used by sociologists or economists. Psychologists' terms of "psychological well-being" or "positive mental health" include aspects like having a goal in life, developing one's potential, etc.; a typical definition could be the "combination of feeling good and functioning effectively" (Huppert 2008). These definitions used by psychologists are similar to the concept of mental health/mental functioning defined by the World Health Organization (WHO 2011).

Sociologists and economists define subjective well-being more narrowly, excluding some aspects. A distinction is made between affective and cognitive components of subjective well-being. "While the affective component reflects instantaneous emotional states or instantaneous feelings, the cognitive component is defined as an ex-post, retrospective assessment of the quality of life as a whole" (Fischer 2009); the first component is generally referred to as "emotional well-being" and the second as "life satisfaction".

The advantage of using the component of subjective well-being is that scientific evidence suggests that individuals determine their decisions and choices upon cognitive subjective well-being (SWB) rather than upon emotional SWB (Kahnemann and Krueger 2006). This concept is thought to be particularly relevant for policy evaluations, and it has a closer link to orthodox notions of utility, and it is this definition which is applied in the remainder of the paper.

How does "subjective well-being" differ from "utility"?

While subjective well-being is thought to be a useful and policy relevant complement to utility – as traditionally used in welfare economics – there are important distinctions. Most significantly, SWB is based upon experiences as reflected in actual conditions, and utility is based upon expectations as reflected in the likely consequences of choices and decisions. A necessary, although not sufficient, condition for the two to coincide is that the outcomes from choices and decisions actually lead to utility maximisation.

Outcomes, however, are dependent upon both choice and chance. Utility can then be considered as the outcome of choices when the expected probabilities of chance are actually taken into account when different choices are made (Clark et al. 2008). SWB would, in theory, coincide with utility, if the state of the world assumed ex ante when choices that are made, actually came to be; if not, there will be a wedge between the two.

Moreover, people may make systematic errors in predicting the consequences of different choices on their subjective well-being. The most well-known example is the importance of reference points. Evidence from the psychological and behavioural economics literature has highlighted people's inability to predict how they will adapt to changing conditions, whether positive or negative (see Rabin 1998). If reference points change with conditions, the magnitude of expected changes in utility will be upward biased relative to experienced subjective well-being.

Nonetheless, the empirical evidence does indicate that subjective well-being measures can be a reasonable proxy for utility. According to Ferreira and Moro (2010), the factors which determine SWB are the same as those that are significant in models of utility maximisation (i.e. income, health, etc.). Perhaps more tellingly, SWB is a good predictor of future choices; for instance, if there are certain factors that appear to reduce SWB, the evidence indicates that choices will be made to obviate or remove these factors (see Clark et al. 2008).

What are the implications of SWB for environmental economics?

One of the fields in which the SWB methodology can be applied is environmental economics. If environmental conditions affect SWB, then there is little question that it can inform public policy in terms of the establishment of policy priorities. Some have argued that it can even be used as means of "valuing' changes in environmental conditions, thus complementing (or even supplanting) orthodox valuation techniques based on utility maximisation.

More specifically, in the model of compensating differentials elaborated by Blanchflower and Oswald (2004), it is hypothesised that SWB can be used to value non-market environmental goods. In effect, based on the estimated coefficients from a model with SWB as the dependent variable, it is possible to calculate the income increase necessary to hold SWB constant if the non-market environmental good (i.e. green space) deteriorates in quality or decreases in quantity. This would be analogous to willingness to accept (WTA) in the valuation literature. Flipping the signs, an analogue for willingness to pay (WTP) would be derived (See Dolan and Metcalfe 2008).

In a sense, such an approach has elements of both revealed preferences (i.e. hedonics) and stated preferences (i.e. contingent valuation or CV) techniques used in orthodox valuation studies. On the one hand, the data are "stated" rather than revealed (as in CV), and, on the other hand, the value is derived indirectly, with the trade-off being implicit rather than explicit (as in hedonics). As a consequence, it shares some of the shortcomings of orthodox valuation techniques; it may, however, also have some advantages. Firstly, relative to CV studies, there may be less scope for strategic and focussing bias since the trade-off between income and the non-market good is never presented directly. Secondly, relative to hedonic studies, it does not assume perfect markets – a particular problem given that the two markets most commonly used in hedonic studies (labour and real estate) are particularly "sticky".

A number of studies – including some of those listed above – have used SWB measures to place a monetary value on environmental factors, including airport noise (van Praag and Baarsma 2005), flood and disasters (Luechinger and Raschy 2009), climatic conditions (Redhanz and Madison 2005) and pollution (Welsch 2002, 2005). In general, the values found when using SWB measures are much higher than those arising out of WTP studies (Dolan and Metcalfe 2008). One possible reason for this may be the difficulties associated with "bounding" the changes temporally. Over what period should the change in the environmental state be considered to affect reported SWB? This is less of a problem in CV or hedonic studies, where temporal conditions are generally clearly defined in either the hypothetical scenario or the market transaction.

It is clear that more work is required to assess when SWB-based "valuation" can be used as a complement, or even a substitute for utility-based valuation techniques. Nonetheless, it is likely that its suitability will be greater for "perceptible" environmental conditions, which exhibit large variation, and for which non-use values are not important. Air pollution with perceptible health impacts would be one such example; another example would be access to green space used for recreational purposes.

How does air quality affect subjective well-being?

In the context of analysing pollution effects on SWB, PM_{10} is an appropriate measure, both because it is easily perceived and because the health impacts are (relatively) well-known. Numerous scientific studies have linked PM_{10} pollution exposure to a variety of problems, including:

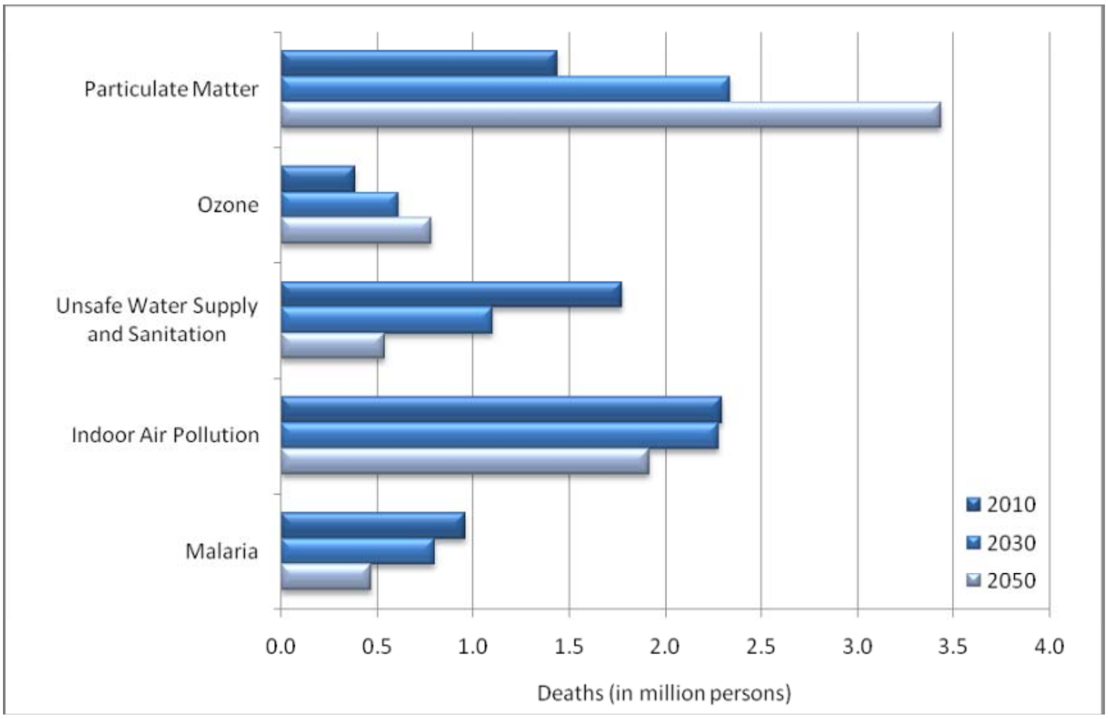
- decreased lung function,
- aggravated asthma,
- development of chronic bronchitis,

- irregular heartbeat,
- nonfatal heart attacks, and
- premature death in people with heart or lung disease.

The 2009 report of the UK Committee on the Medical Effects of Air Pollutants (COMEAP) provides a summary of evidence and quantitative estimates of the impact of the long-term effects of PM pollution on mortality. The report concluded, in the following terms, about the impact of long-term air pollution exposure at the level of the population as a whole: "*We are left with little doubt that long-term exposure to air pollutants has an effect on mortality and thus decreases life expectancy*."

PM includes particulate matter emitted directly to the atmosphere, such as black carbon (primary particulates), and particulates formed in the atmosphere from the reaction of precursor gases, primarily ammonia, NO_X, SO_2 and, to some degree, VOCs (secondary particulates). According to the forecasts reported in the OECD Environmental Outlook, the number of premature deaths from exposure to PM worldwide is likely to more than double to 3.5 million by 2050 – mostly in China and India. Despite the decrease in emissions, the joint effects of an increasing size of urban populations (where air pollution is concentrated) and the ageing of the population (elderly people are more susceptible) outweigh the benefits from lower average concentrations (OECD 2011).

Figure 1. Global premature deaths from selected environmental risks (2010 to 2050)

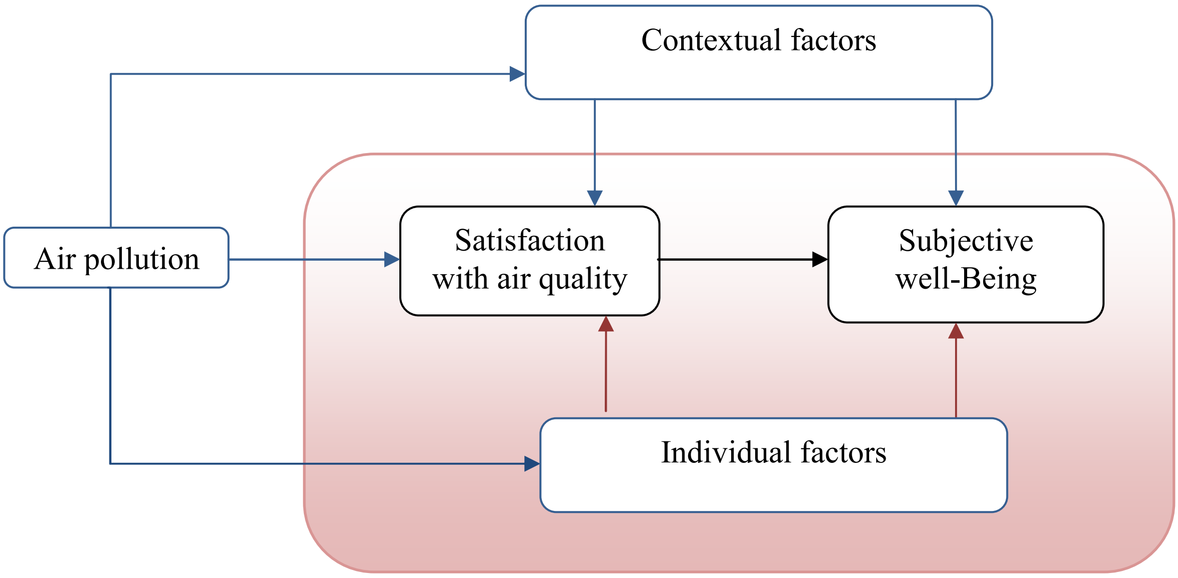


Source: Environmental Outlook Baseline projections; output from IMAGE Suite of models (PBL)

The particles of most concern are in the finer fractions, PM_{10} and especially $PM_{2.5}$, as these particles are sufficiently small to be able to penetrate deeply into the lungs. Globally, 8% of lung cancer deaths, 5% of cardiopulmonary deaths and around 3% of respiratory infection deaths can be attributed to exposure to fine particulate matter alone (WHO, 2009a). The WHO estimates that there are each year approximately 299,400 premature deaths in China and 119,900 in India from exposure to PM_{10} (WHO, 2009b).

Using air pollution as an example, the relationship between actual environmental conditions, reported satisfaction with environmental conditions and life satisfaction can be presented as in Figure 2 below.

Figure 2. From air pollution to subjective well-being – conceptual model



In the first step, we suppose that air quality (defined as concentrations of air pollution in the atmosphere) constitutes an aspect of the natural environment, the importance of which can be more or less perceived by individuals who report different levels of satisfaction with air quality. Satisfaction with air quality will also depend on individual and contextual factors. Secondly, the level of reported satisfaction with air quality can affect subjective well-being, which in turn also depends on individual and contextual factors. And finally, air pollution may affect subjective well-being without being mediated through satisfaction with air quality; for instance, pollution may affect health conditions, without the individual being aware of the causal factors at work (Welsch 2005) – we are not concerned with the latter relationship in this study.

In order to test these relationships we focus on the case of PM_{10}. Therefore, our hypotheses are the following:

H1: PM10 ↑ → Satisfaction with Air Quality ↓
H2: Satisfaction with Air Quality ↓ →SWB ↓

We suppose that higher pollution levels in a local area (measured in terms of PM_{10} concentrations) affect the satisfaction with air quality of persons living in this area. In turn, we expect that satisfaction with air quality affects subjective well-being.

4. Bivariate relationship between PM_{10} and reported satisfaction with air quality

We first explore the relationship between PM_{10} concentrations and reported satisfaction with air quality at an aggregate level. Across different locations (here countries or cities) where data are available, we look at the bivariate relationship between two aggregate-level variables: (1) the proportion of respondents who were satisfied with air quality and (2) actual levels of PM_{10} concentrations.

Objective measures of environmental quality: World Bank PM_{10} concentration data

The data on PM_{10} concentrations are provided by the GMAPS project database of World Bank.[7] These values are calculated for urban areas in the largest cities, usually with a population greater than 100,000; unfortunately, there are a large number of urban areas for which there is no monitoring facility. The data are provided in two ways: (1) average annual PM_{10} concentrations (micro grams per cubic meter) in residential urban areas, and (2) global country urban population weighted average PM_{10} concentrations (micro grams per cubic meter).

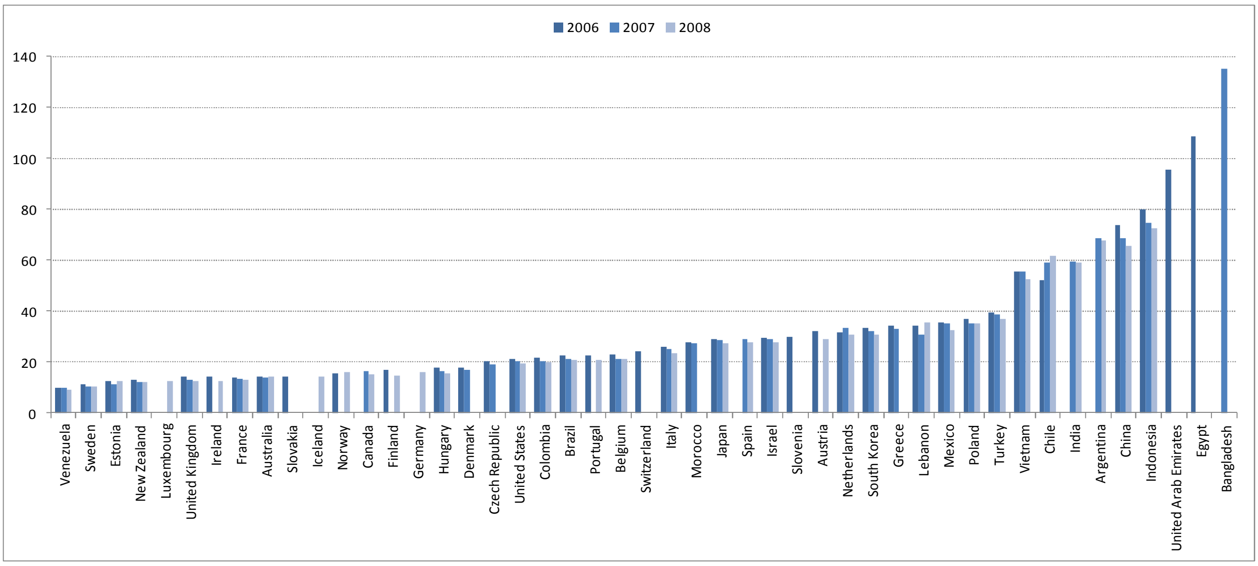
> *"The Global Model of Ambient Particulates (GMAPS) is an attempt to bridge this information gap through an econometrically estimated model for predicting PM levels in world cities (Pandey et al. 2006). The estimation model is based on the latest available monitored PM pollution data from the World Health Organization, supplemented by data from other reliable sources. The current model can be used to estimate PM levels in urban residential areas and non-residential pollution hotspots. The results of the model are used to project annual average ambient PM concentrations for residential and non-residential areas in 3,226 world cities with populations larger than 100,000, as well as national capitals."*

Measurements of the PM_{10} urban concentrations reveal wide variation across countries, as illustrated in Figure 3. The WHO guideline for maximum average annual pollutant concentrations is 20 $\mu g/m^3$ for PM_{10}; this maximum value was exceeded, on average, in about 60% of the countries (27 out of 47) for the period 2006-2008. Measurements of the PM_{10} urban concentrations were mostly stable during this period.

While measured PM_{10} urban concentrations were lower than 30 $\mu g/m^3$, on average, in European countries, the South-East Asian countries in our sample often had much higher concentrations, i.e. around 60 $\mu g/m^3$. In countries like Egypt or Bangladesh, average annual concentrations were higher than 100 $\mu g/m^3$. One has to keep in mind, however, that these differences in annual averages across countries may hide huge discrepancies in concentrations both across cities' annual averages in one country and across daily concentrations, during the year, in one city.

[7] Esther Lee and Kirk Hamilton (World Bank) are gratefully acknowledged for providing the 2008 data. Data for previous years is publicly available at http://go.worldbank.org/3RDFO7T6M0 .

Figure 3. Global country urban population weighted average PM_{10} concentrations (2006-2008)



Measure: Data for countries are urban-population weighted PM_{10} levels in residential areas of cities with more than 100,000 residents; the estimates represent the average annual exposure level of the average urban resident to outdoor particulate matter.
Source: World Bank GMAPS (2006 – 2008)

Subjective measures of satisfaction with air quality: the Gallup World Poll

The Gallup World Poll continually surveys residents in more than 150 countries, representing more than 98% of the world's adult population. Gallup typically surveys 1,000 individuals in each country. All samples are probability based and nationally representative of the resident population aged 15 and older; the coverage area is the entire country including rural areas, and the sampling frame represents the entire civilian, non-institutionalized, aged 15 and older population of the entire country.[8] Respondents are randomly selected within the selected households (by using either a Kish grid or the most recent birthday method).

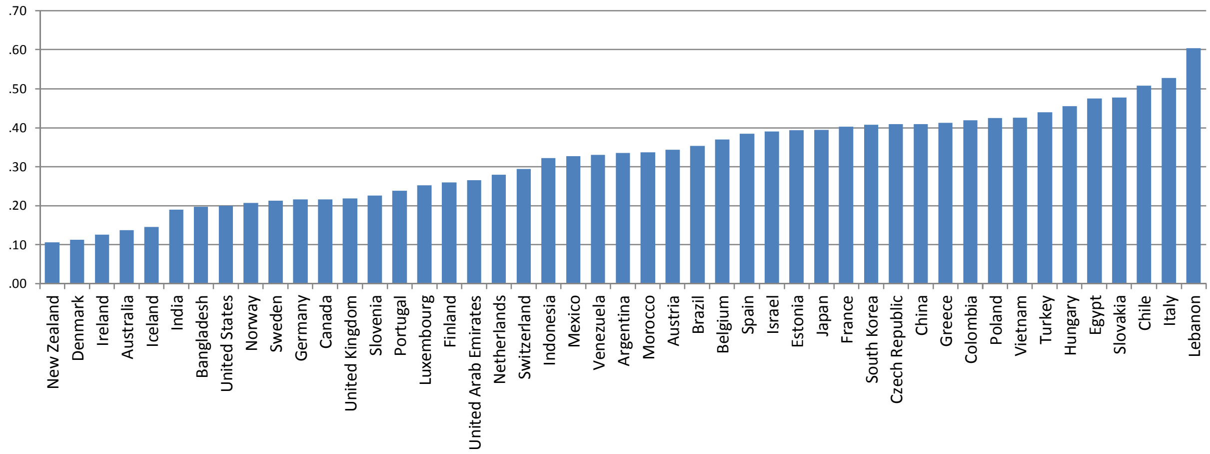
The survey includes a standard set of core questions that has been translated into the major languages of the respective country. Telephone surveys are used in countries where telephone coverage represents at least 80% of the population or is the customary survey methodology. In Central and Eastern Europe, as well as in the developing world, including much of Latin America, the former Soviet Union countries, nearly all of Asia, the Middle East, and Africa, an area frame design is used for face-to-face interviewing. Face-to-face interviews are approximately 1 hour, while telephone interviews are about 30 minutes. In many countries, the survey is conducted once per year, and fieldwork is generally completed in two to four weeks.

Satisfaction with air quality is measured on the basis of the following question: *"In the city or area where you live, are you satisfied or dissatisfied with the quality of air?"*; the respondent can choose between two response options: "*satisfied*" vs. "*dissatisfied*". Responses to this question are taken as a proxy for individuals' satisfaction with air quality.

[8] Exceptions include areas where the safety of interviewing staff is threatened, scarcely populated islands in some countries, and areas that interviewers can reach only by foot, animal, or small boat.

Figure 4 shows, for each country, the proportion of urban residents (i.e. those living in a large city or suburbs of a large city) who said that they were dissatisfied with air quality in the city or area where they lived. This rate varies between 10% in New Zealand and 60% in Lebanon; in most countries, less than half of urban respondents reported being dissatisfied with air quality.

Figure 4. Proportion of respondents living in urban area who report being dissatisfied with air quality in the city or area where they live (average values, 2006-2008)

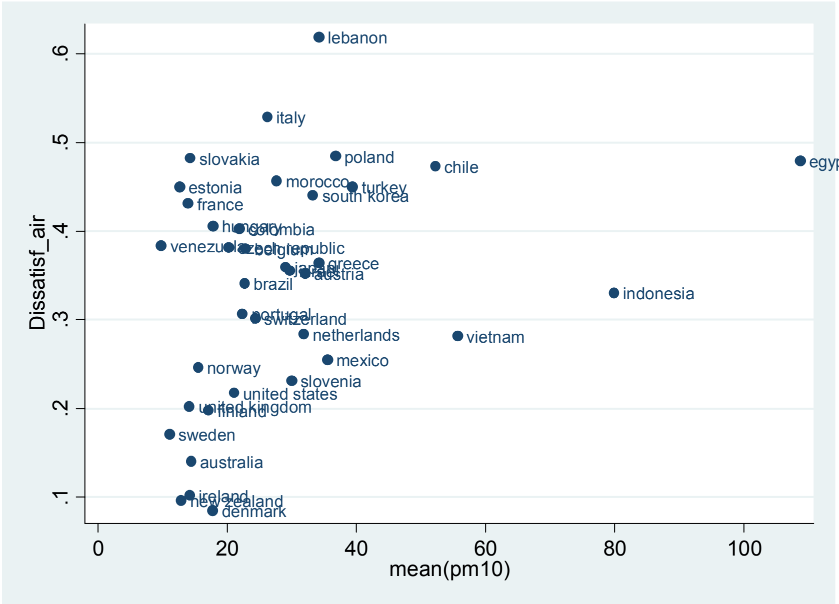


Source : the Gallup World Poll (2006-2008)

Correlation between PM_{10} concentrations and satisfaction with air quality

Using Gallup World Poll data to measure individuals' satisfaction with air quality (only for those living in a large city or in the suburbs of a large city) and GMAPS World Bank data for PM_{10} concentrations (global country average urban population weighted PM_{10} levels), we obtain a Pearson correlation coefficient of 0.32 for the strength of the association between these two measures at aggregate level, which is relatively good considering the heterogeneity of data sources. In other words, there is a clear positive relationship between PM_{10} concentrations measured in urban areas and the proportions of urban residents declaring that they are dissatisfied with air quality.

Figure 5. Country-level association between dissatisfaction with air quality and PM_{10} concentrations



(y) Proportion of respondents living in urban areas who report being dissatisfied with the quality of air in the city or area where they live (2006)
Source: the Gallup World Poll (2006)

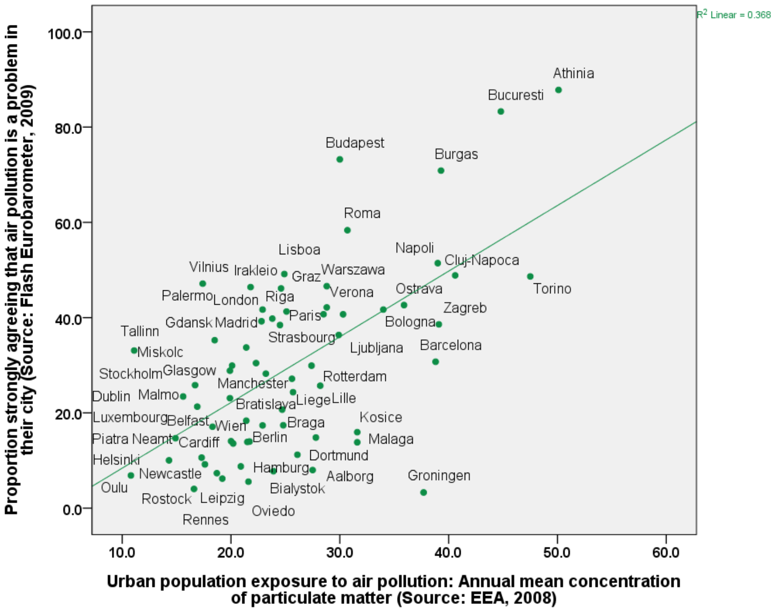
(x) global country urban population weighted PM_{10} levels (2006)
Measure: Data for countries are urban-population weighted PM_{10} levels in residential areas of cities with more than 100,000 residents; the estimates represent the average annual exposure level of the average urban resident to outdoor particulate matter.
Source: World Bank GMAPS (2006 – 2008)

The European Commission's **Urban Audit Perception survey** is another study that explored perceptions about air quality in urban areas.[9] In the Fall of 2009, Gallup conducted 37,500 interviews in 75 European cities; 500 randomly selected citizens (aged 15 and older) were interviewed in each of these 75 cities. In this study, respondents were asked whether they agreed, or disagreed with the statement that "air pollution is a problem in their city".

It is important to notice that in this case the PM_{10} concentration values provided by the European Environmental Agency (EEA) are at the level of the individual cities (i.e. population weighted annual mean concentration of PM_{10} at urban background stations)[10]. Compared to Figure 5 (presenting country-level average values), the geographic precision of the PM_{10} measure with respondents' location is greatly improved. As such, the Pearson correlation coefficients for the relationship between the perception that air quality is a serious problem and the annual PM_{10} concentrations – both measured at city-level – is 0.61; this value represents a strong correlation between the two measures.

[9] *Urban Audit Perception survey among the general population in selected cities in the 27 Member States, Croatia and Turkey*" (Flash Eurobarometer N° 277); for more details, see: http://ec.europa.eu/public_opinion/flash/fl_277_en.pdf
[10] Source: http://epp.eurostat.ec.europa.eu/tgm/table.do?tab=table&init=1&plugin=1&language=en&pcode=tsien110

Figure 6. City-level association between perceptions about air quality and PM_{10} concentrations



The results presented so far support the hypothesis that people are aware of local air quality and that their subjective appreciation of air quality (with respect to PM_{10} concentrations) is relevant. Nonetheless, we lack the empirical foundation to fully understand the nature of the relationship between actual PM_{10} concentrations and perceived satisfaction with air quality; for instance, an important question is whether this appreciation is based on direct physical perceptions, or rather on information about air pollution that is reported in various media sources and that influences awareness about air pollution. Bickerstaff and Walker (2001) concluded that "*the importance of primary experience is evident in the widespread public recognition of pollutants that could be distinguished through the physical senses*."

5. Empirical analysis of satisfaction with air quality and subjective well-being

In this section, we switch to a micro-level approach (i.e. using individual-level data); we again draw upon two main sources of data. First, the Gallup World Poll, from 2006 to 2010, provides data from individual respondents on perceptions about air quality. In this study, about 50 countries from the Gallup World Poll were selected (i.e. the 34 OECD countries, the remaining G20 countries and a small number of additional countries – such as Lebanon, Bangladesh, Vietnam, Colombia and Venezuela). Second, as discussed above, the World Bank GMAPS database provides data on urban PM_{10} concentrations at country-level or city-level.

Explanatory variables

As explanatory variables, we include several socio-economic characteristics of individuals; these include age, gender, level of education, marital status and whether there are any children below 15 years-of-age in the respondent's household. In an attempt to control for unobserved heterogeneity represented by individuals' personality traits, we also include variables that measure respondents' concerns about the environment in general. More specifically, explanatory variables included in the analysis are:

- *Level of education*: countries have unique ways of classifying education levels; to make comparisons across countries by educational attainment, consistent categories needed to be created. All education descriptions can be placed within three categories:

- *Elementary*: Completed elementary education or less (up to eight years of basic education)
- *Secondary*: Completed some secondary education, up to three years tertiary education (9 to 15 years of education)
- *Tertiary*: Completed four years of education beyond "high school" and/or received a four-year college degree

- *Household Income*: annual household income in international dollars is calculated using the Individual Consumption Expenditure by Household PPP ratio from the *World Bank Global Purchasing Power Parities and Real Expenditures 2005 International Comparison Program (ICP-iceh)* report. In this analysis, two alternative measures of household income will be used: (1) annual household income in international dollars, and (2) household income per capita. The latter variable estimates income per-capita by dividing imputed household income by imputed household count.

- *Personal health*: respondents were asked whether they "*were satisfied or dissatisfied with their personal health?"* and could choose between the response options "*satisfied*" or "*dissatisfied*".

- *Presence of children in the household:* respondents were asked: *"how many children under 15 years-of-age were living in their household?"*; in the analysis, a dichotomous variable is used indicating the presence or absence of children in the household.

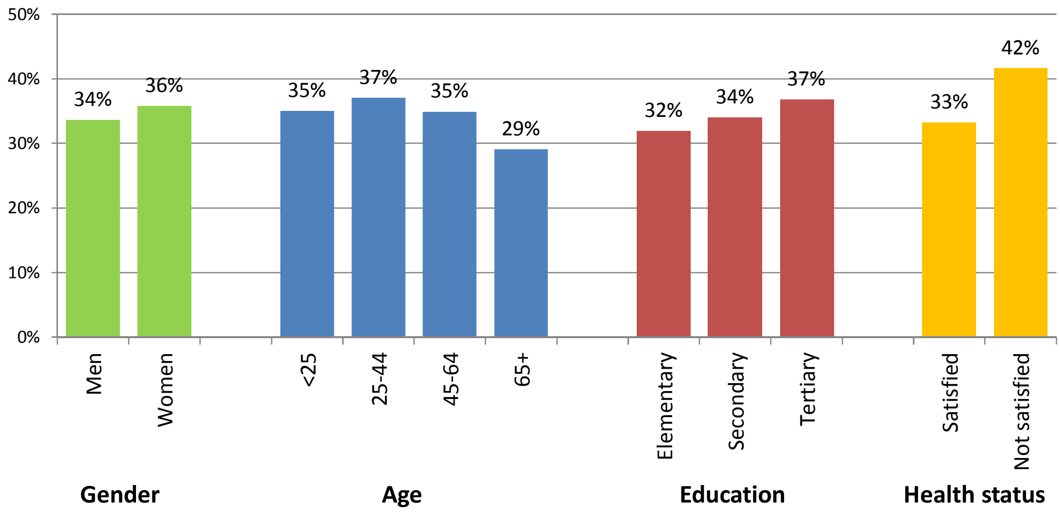
- *Place of residence:* respondent were asked whether "*they lived in a rural area or on a farm, in a small town or village, in a large city, or in the suburb of a large city"*. Only respondents who said they were living in a large city or in the suburb of a large city were included in the analysis; this population is referred to as the "urban population".

- *Perceived vulnerability to global warming*: respondents were asked "*how serious of a threat global warming was to them and their family?*" with a response options *"very serious", "somewhat serious", "not very serious" and "not at all serious"*; this variable is included to capture respondents' sensitivity to environmental problems in general.

- *City beauty:* respondents were asked whether they "*were you satisfied or dissatisfied with the beauty or physical setting in the city or area where they lived?"*; the inclusion of this variable is meant to test the more general finding that perceptions about environmental quality are affected by physical contextual factors.

Figure 7 presents the percentage of urban residents who reported being dissatisfied with air quality according to different demographic and socio-economic characteristics. This figure shows, for example, that the oldest respondents (aged 65 and above) were the least likely to be dissatisfied with air quality, while those aged between 25 and 44 were the most likely to report being dissatisfied (19% vs. 37%, respectively). Similarly, while 33% of urban residents who were satisfied with their general health status said they were dissatisfied with the quality of air in their local area, this figure increased to 42% for those being dissatisfied with their health.

Figure 7. Percentage of urban respondents who reported being dissatisfied with the quality of air in their city or local area – by socioeconomic characteristics



Source: the Gallup World Poll (2006-2008, urban population)

Annex 3 provides more detailed comparisons of satisfaction levels with air quality across different demographic groups in selected cities (i.e. Toronto, Vienna, Tokyo and Shanghai).

Multilevel modelling

As noted above, we do not have data on air pollution concentrations at the level of the individual respondent. Fortunately, this shortcoming can be overcome through the use of a multilevel modeling strategy; our data have a two-level structure with individuals at level-1, nested within groups at level-2 (i.e. countries and cities).

One particular benefit of multilevel modelling[11] is the ability to explore the effects of group-level variables while simultaneously allowing for the possibility that the dependent variable *Y* is influenced by unmeasured group factors. Variables defined at level-2 are called contextual variables, and their effect on an individual's *Y* value is called the contextual effect. In our analysis, the only contextual effect of interest is the PM_{10} concentration level, but multilevel-modelling allows us to control also for unmeasured group factors. For instance, many country-level variables may influence people's satisfaction with air quality, by influencing either actual air pollution levels (e.g. a country's pollution control) or perceptions of air quality (e.g. media coverage).

Our dependent variable – i.e. reported satisfaction with air quality – is a binary variable; as such, all models are estimated by means of a multilevel logit models. The conditional distribution of the response, given the random effects, is assumed to be Bernoulli, with the success probability determined by the logistic cumulative distribution function (c.d.f.). The estimation procedure in Stata uses the adaptive Gaussian quadrature (AGQ) method with seven quadrature points per level.

[11] Multilevel (hierarchical) modeling is a generalization of linear and generalized linear modeling in which regression coefficients are themselves formalised, with parameters estimated from the data. In a multilevel model, residual variance is split into two components, corresponding to the two levels in the data structure; the group-level residuals are called "group random effects". Residuals at both levels are assumed to follow normal distributions centred on zero. The total variance is partitioned into *between group variance*, based on departures of group means from the overall mean, and *within-group between-individual variance*, based on individual departures from group means.

In Models 1 and 2, we make use of micro-level data from the Gallup World Poll, collected in 41 countries between 2006 and 2008.[12] As noted above, our analysis is limited to respondents who reported living in a large city or in the suburbs of a large city.

In order to maximise the number of observations used in each regression model, we first run a baseline model (Model 1) that only includes variables that are available for all three waves (2006, 2007 and 2008). In Model 2, three additional variables are included that are not available in the 2006 wave, and the original income variable is replaced by a per capita version of the variable; this reduces our analysis from a sample of 22,529 individuals to 16,044 individuals. More details about the exact sample sizes for all countries included in our analyses can be found in Annex 1.

In a subsequent stage (Models 3 and 4), we make use of city-level data using a sub-sample of 4,272 individuals living in 58 cities across the world; the micro-level data for this sub-sample refers to 2010. For these respondents, in addition to their country of residence, information is also available about their exact location – i.e. the city they live in (see Annex 2 for more details on the city-level samples).

Table 1. Models used in analysis of satisfaction with air quality

Model	Table	Type of estimation	Dependent variable	Explanatory Variables	Years	Sample Size
Model 1	Table 4	ML Logit	Satisfaction with air quality	Base model (8 variables)	2006-2008	22,529 respondents in 57 level-2 groups (country x wave)
Model 2	Table 5	ML Logit	Satisfaction with air quality	Base model + 3 additional variables	2007-2008	16,044 respondents in 40 level-2 groups (country x wave)
Model 3 & 4	Table 6	ML Logit	Satisfaction with air quality	Base model	2010	4,272 respondents in 58 cities (level-2)

Results – country-level PM_{10} concentrations

In the tables with results of the regression models, in order to provide a more straightforward interpretation of effects, odds-ratios are presented instead of estimated regressions coefficients. In Models 1 and 2, unobserved heterogeneity in satisfaction with air quality is captured by country/wave dummies; these dummies indicate significant differences between countries, despite the introduction of individual characteristics and country-level PM_{10} concentration levels in urban areas.

In general, results of Model 1 and Model 2 are very similar; the most important differences relate to the effects of income and the presence of children in the household. The effect of income on satisfaction with air quality proves to be significant in Model 2, while it is insignificant in Model 1. The opposite is observed for the effect of "children in the household" which is significant in Model 1, but proves to be insignificant in Model 2. These differences are explained below.

[12] Note: Since no recent information for PM_{10} concentrations is available, observations of the 2009 and 2010 waves of the Gallup World Poll cannot be used in our analysis. The original set of countries consisted of 47 countries; however, six countries were dropped from analyses due to missing values of covariates.

Table 2. Multilevel logit model of satisfaction with air quality – Model 1

Probability modeled : Dissatisfied with air quality				
Mixed-effects logistic regression		Number of obs	=	22259
Group variable: wave_country		Number of groups	=	57
Observations per group		Min	=	79
		Avg	=	390.5
		Max	=	1685
	Odds-Ratio	P > z	[95% Conf.	Interval]
Gender (ref. men)				
Women	1.14	0.000	1.07	1.20
Health (ref. satisfied)				
Dissatisfied	1.51	0.000	1.40	1.62
Education (ref .secondary)				
Elementary	0.72	0.000	0.66	0.79
Tertiary	1.14	0.000	1.06	1.23
Age in classes (ref. 26-40 year-olds)				
15-20 year-olds	0.91	0.096	0.8	1.02
21-25 year-olds	0.95	0.403	0.86	1.06
41-50 year-olds	0.92	0.063	0.85	1.00
51-60 year-olds	0.83	0.000	0.75	0.91
Over 60 year-olds	0.65	0.000	0.59	0.72
Children under 15 (ref. no children)				
Children in household	0.93	0.014	0.86	0.98
Income				
Ln (household income)	1.00	0.733	0.97	1.05
Place of residence (ref. large city)				
Suburbs	0.63	0.000	0.59	0.69
Air pollution (country-level average)				
Ln PM_{10}	1.45	0.001	1.16	1.81
Random effect parameters	Estimate	Standard Error	[95%Conf.	Interval]
wave_country: Identity				
sd(_cons)	0.49	0.051	0.40	0.60
likelihood-ratio test comparing the mixed model to ordinary regression : chibar2(01) = 651.80 Prob>=chibar2 = 0.0000				

Table 3. Multilevel logit model of satisfactions with air quality – Model 2

Probability modeled : Dissatisfied with air quality				
Mixed-effects logistic regression		Number of obs	=	16044
Group variable: wave_country		Number of groups	=	40
Observations per group		min	=	129
		avg	=	401.1
		max	=	743
	Odds-Ratio	P > z	[95% Conf.	Interval]
Gender (ref. men)				
Women	1.13	0.000	1.05	1.22
Health (ref. satisfied)				
Dissatisfied	1.39	0.000	1.27	1.52
Education (ref. secondary)				
Elementary	0.77	0.000	0.68	0.87
Tertiary	1.11	0.020	1.01	1.20
Age in classes (ref. 26-40 year-olds)				
15-20 year-olds	0.74	0.000	0.63	0.86
21-25 year-olds	0.77	0.001	0.67	0.9
41-50 year-olds	0.87	0.016	0.78	0.98
51-60 year-olds	0.86	0.013	0.76	0.97
Over 60 year-olds	0.74	0.000	0.65	0.83
Marital status (ref. single)				
Married / living with partner	0.90	0.038	0.81	0.99
Separated /widowed	1.00	0.977	0.87	1.15
Children under 15 (ref. no children)				
Children in households	0.95	0.268	0.87	1.04
Income				
Ln (household income per UC)	1.05	0.039	1.00	1.10
Place of residence (ref. large city)				
Suburbs	0.63	0.000	0.57	0.69
Global Warming (ref. not very/ not at all serious)				
Very Serious / somewhat Serious	1.54	0.000	1.40	1.70
City beauty (ref. dissatisfied)				
Satisfied	0.25	0.000	0.23	0.27
Air pollution (country-level average)				
Ln PM_{10}	1.40	0.022	1.05	1.86
Random effect parameters	Estimate	Standard Error	[95% Conf.	Interval]
wave_country: identity matrix				
sd(_cons)	0.47	0.0546	0.37	0.59
likelihood-ratio test comparing the mixed model to ordinary regression : chibar2(01) = 449.83 Prob>=chibar2 = 0.0000				

Being a woman increases the probability of being dissatisfied with air quality. However, an analysis distinguishing between OECD and non-OECD countries (for more details, see Annex 4) reveals that the effect of gender is only significant in the sub-sample of OECD countries. Further analysis is needed to identify why this is the case.

Respondents' age has been implemented as a six-class variable in our models; this allows us to identify a non-linear nature of the link between age and satisfaction with air quality. Indeed, in Model 2, age is found to have a U-shape effect on satisfaction with air quality; both the youngest and the oldest respondents are more likely to be satisfied with air quality in their city or local area than respondents between 26 and 40 years-of-age.

As noted above, the role of education is assessed by using a three-class variable making a distinction in terms of the length of someone's studies. Our results show a clear gradient in the effect of education; the more educated respondents are, the more likely they are to be dissatisfied with the quality of air in their local area. This result raises the question about people's awareness of air pollution and the impact this can have on their perceptions about air quality. In line with this finding, people declaring that they considered "*global warming to be a very serious or somewhat serious threat*" are more likely to be dissatisfied with the quality of air in their local area (see Model 2).

Bickerstaff and Walker (2001) emphasised that awareness of, and concern about air pollution are very much influenced by the local setting and lived experience, and that for many individuals low general environment quality factored in their negative evaluation of air quality. To test this hypothesis, we introduced the variable "city beauty" (as defined above) in our analysis. The results in Model 2 indicate that respondents who are satisfied with the "*beauty or physical setting*" of the city or area where they live, are less likely to be dissatisfied with air quality. This result tends to confirm the correspondence between physical beauty of one's local area and satisfaction with the quality of air.

In Model 1, the effect of the household income on reported satisfaction with air quality is not significant. A non-linear effect of income is also tested by creating a 3-class variable (comparing the first and last income quartiles with the third and fourth quartiles combined); the effects were all insignificant (results not shown). Since 2007, Gallup also provides imputed income per-capita estimates; this variable replaces the original income variable in Model 2. In Model 2, the effect of this income measure proves to be small, but significant. The effect of having children living in the household becomes insignificant in Model 2 when "household income" is replaced by "imputed household income per capita".

One of the main determinants of the probability of being dissatisfied with air quality is the respondents' place of residence. Although we do not have precise information about respondents' place of residence, we find a negative coefficient associated with living "in the suburbs of a large city" rather than living "in a big city"; this result underlines the very local character of air pollution problems. However, the heterogeneity of all urban situations labelled as "living in the suburbs of a large city" may also explain the finding; for example, this category groups together industrial suburbs polluted by dense traffic axes and more residential areas connected to the city. Note also that this effect of living in the suburbs is significant in OECD countries, while it is insignificant in non-OECD countries (see Annex 4). This finding might reflect the different natures of suburban areas in the set of countries included in our analysis and requires further analysis.

The information on PM_{10} concentrations is introduced in the model as country-year annual averages for urban respondents. After controlling for the effects of individual socio-economic characteristics, PM_{10} concentrations are still one of the main drivers of air quality satisfaction. PM_{10} concentrations in countries range from 10 $\mu g/m^3$ to 120 $\mu g/m^3$ (i.e. from approximately one to two on a logarithm scale). An increase of 100 $\mu g/m^3$ in a country's average PM_{10} concentration in urban areas a significant increase in urban residents' probability to be dissatisfied with air quality.

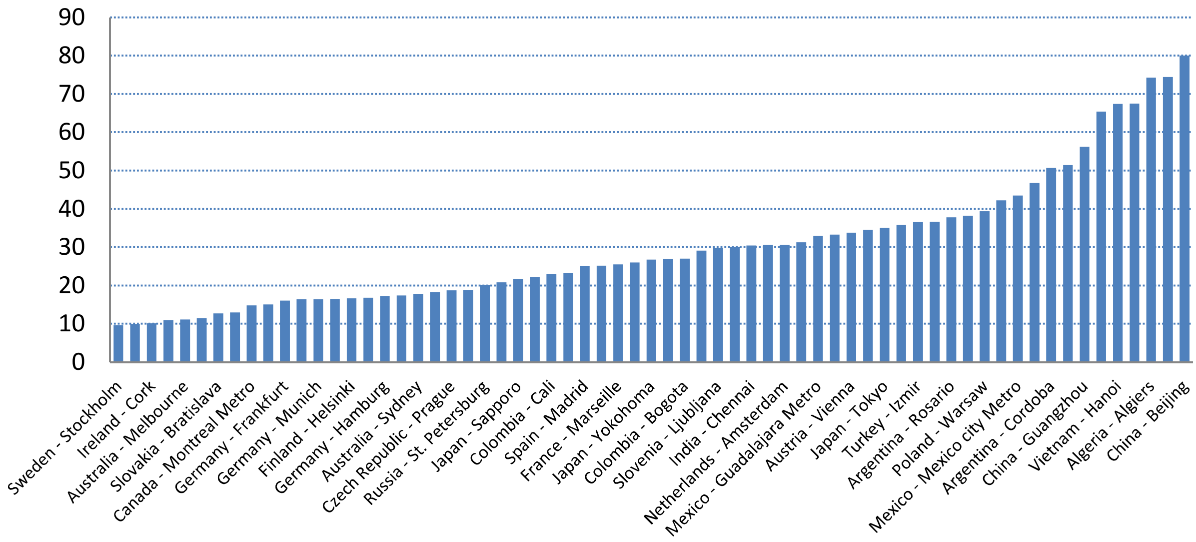
Results – city-level PM$_{10}$ concentrations

Using country-level observations for PM$_{10}$ concentrations in urban areas is not satisfactory. As noted above, for a sub-sample of the 2010 Gallup World Poll wave, information is also available about their exact location – i.e. the city they live in. This information is linked to World Bank GMAPS data on PM$_{10}$ concentrations in those exact same cities.

Figure 8 gives the PM$_{10}$ concentrations for the 58 cities included in this party of the analysis[13]. It is interesting to note that 25% of respondents in cities with PM$_{10}$ concentrations of less than 20 µg/m^3 reported that they were dissatisfied with air quality in their city; the figure for those living in cities with PM$_{10}$ concentrations of between 20 µg/m^3 and 60 µg/m^3 increased to 50%, while the corresponding figure for those living in cities with PM$_{10}$ concentrations above 60 µg/m^3 was lower – at 30%.

One possible reason for this is that changes in PM$_{10}$ concentrations through time have a distinct impact on reported satisfaction – i.e. residents in a city with a high, but decreasing PM$_{10}$ concentration are more likely to report satisfaction than residents in a city with a low, but increasing PM$_{10}$ concentration. There might, therefore, be a reference effect, a finding common in the behavioural economics literature. This finding is also consistent with the more general discussion on "endowment effects" (unrelated to income) in the valuation literature (see, for instance, Gowdy 2004).

Figure 8. Average annual PM$_{10}$ concentrations in selected cities (2008)



Source: World Bank GMAPS (2006 – 2008)

At the city-level, the estimation by multilevel modelling is based on 4,272 individuals living in 58 cities. Models 3 and 4 are exclusively based on 2010 Gallup World Poll micro-data, associated with the 2008 World Bank GMAPS PM$_{10}$ concentration values at city-level. Similar to the approach used in earlier models, Model 3 uses ln PM$_{10}$ concentrations to model the effect of actual air pollution on perceptions about air quality. In Model 4, on the other hand, the effect of PM$_{10}$ concentrations is implemented by thresholds: (1) cities with PM$_{10}$ concentrations below the WHO guideline of 20 µg/m^3, (2) cities with PM$_{10}$

[13] The figure also contains values for a number of additional cities; these were dropped from the analysis dues to missing values of covariates.

concentrations between 20 μg/m^3 and an arbitrary chosen upper limit of 60 μg/m^3, and (3) cities with PM_{10} concentrations above 60 μg/m^3. The odds ratios are presented again to allow for a straightforward interpretation of the results.

The results of the city-level models (Models 3 and 4 – see Table 5) are broadly consistent with those presented above. Compared to Models 1 and 2, however, the odds ratio for the effect of PM_{10} concentrations is more important in the current models. Model 4 (in which threshold values for PM_{10} concentrations are applied) indicates that respondents living in cities with PM_{10} concentrations in excess of the WHO guideline of 20 μg/m^3 are more likely to report being dissatisfied with air quality; however, only the parameter for the middle category (>20 μg/m^3, but <=60 μg/m^3) is significant. There is no obvious interpretation for this finding, other than presented above – i.e. that there is a correlation with high and falling PM_{10} concentrations.

Furthermore, the effect of respondents' level of education is no longer significant. Although the presence of children in the household remains significant in the city-level models, it now has an odds ratio of less than one; this may be a direct consequence of using city-level data. Since there can be a great deal of heterogeneity in pollution concentrations within a city, there is likely to be some bias in the estimated coefficients. For instance, households with children may choose to live in less polluted areas. Similarly, wealthier, smaller households are likely to live in less polluted parts of a city, introducing a problem of endogeneity. Further work will attempt to address this issue.

Table 4. Multilevel logit model of satisfaction with air quality with city-level data – Models 3 & 4

Probability modeled : Dissatisfied of air quality				
	Model 3		Model 4	
Number of observations		4272		4272
Groups (cities)		58		58
Log likelihood		-2560.29		-2556.35
	Odds Ratio	P>z	Odds Ratio	P>z
Gender				
Women vs. men	1.21	0.006	1.21	0.006
Age				
Age	1.02	0.117	1.02	0.111
Age^2	0.99	0.020	0.99	0.019
Health Status				
Dissatisfied with health	1.37	0.001	1.36	0.001
Education: Ref. Secondary				
Elementary level	0.83	0.087	0.82	0.068
Tertiary level	1.10	0.095	1.11	0.234
Children < 15 in household	0.84	0.066	0.84	0.031
Household income (ln)	0.97	0.667	0.98	0.651
Air pollution				
- PM_{10} (ln)	1.82	0.006		
- PM_{10} (Ref. <=20 µg/m^3)				
>20 µg/m^3 , but <=60 µg/m^3			2.67	0.000
>60 µg/m^3			1.93	0.098
_cons	0.093	0.016	0.33	0.066
sd(_cons)	0.811		0.741	

6. Environmental quality and subjective well-being

In the second stage, we estimate the role that actual and perceived environmental factors play in determining people's sense of subjective well-being. In the Gallup World Poll, subjective well-being is measured using the Cantril Self-Anchoring Striving Scale (Cantril, 1965); this scale consists of the following:

> *Please imagine a ladder with steps numbered from zero at the bottom to ten at the top. The top of the ladder represents the best possible life for you and the bottom of the ladder represents the worst possible life for you. On which step of the ladder would you say you personally feel you stand at this time?*

Three environmental variables were selected from the Gallup World Poll. The two main variables are reported satisfaction with air quality (as defined above) and satisfaction with water quality (i.e. respondents were asked if they were *satisfied or dissatisfied with quality of water in their city or area*). In this analysis, we will also use reported satisfaction with the beauty or physical setting of respondents' place of residence as a proxy of the overall physical environment of life satisfaction (i.e. respondents were asked if they were *satisfied or dissatisfied with the beauty or physical setting of their city or area*).

In this section, we use a sample of the 2010 wave of the Gallup World Poll; the analyses are constrained to the data from 4,880 individuals living in 66 cities. For these 66 cities, PM_{10} concentration values are available; this is important because in some of the models, we will replace information on reported satisfaction with air quality with data on city-level PM_{10} concentrations.

In all models, the dependent variable is the individual's satisfaction with life (based on the Cantril ladder; note: higher values represent higher levels of satisfaction). Three models are estimated:

- Model 5: Multilevel Linear Regression Model (level-2=city), including satisfaction levels with the three environmental variables
- Model 6: Multilevel Linear Regression Model (level-2=city), including satisfaction levels with two of the environmental variables (water and "city beauty"), and city-level PM_{10} concentrations (instead of reported satisfaction with air quality)
- Model 7: Multilevel Linear Regression Model (level-2=city), including city-level PM_{10} concentrations and a synthetic indicator of satisfaction with the three environmental variables

Using the 2010 wave of the Gallup World Poll allows us to add some additional variables in the models, such as the number of adults (aged 15 and over) in the household and respondents' marital status (married or living with partner vs. not married – i.e. single, divorced, separated or widowed).

The synthetic indicator of satisfaction with environmental conditions is constructed as a 4-point scale; a score of 0 is given to respondents who reported being satisfied with air quality, water quality and "city beauty", a score of 1 is given to respondents who report being dissatisfied with at least one of these three environmental conditions etc.

Table 5. Multilevel logit model of life satisfaction with city-level data – Models 5-7

	Model 5		Model 6		Model 7	
	ML Regression		ML Regression		ML Regression	
Number of observations		4880		4933		4880
Number of groups (cities)		66		66		66
Wald chi2 (d.f.)	(16)	727.67	(16)	745.53	(16)	759.37
Prob > chi2		0		0		0
	Coef.	P>z	Coef.	P>z	Coef.	P>z
Women vs. men	0.26	0.000	0.23	0.000	0.24	0.000
Age	-0.05	0.000	-0.05	0.000	-0.06	0.000
Age^2	0.00	0.000	0.00	0.000	0.00	0.000
Number of adults in household : Ref. 1						
2 adults	-0.15	0.110	-0.14	0.101	-0.14	0.019
3+ adults	-0.06	0.517	-0.06	0.527	-0.04	0.031
Married vs. not married	0.27	0.002	0.28	0.001	0.28	0.001
Children under 15 in household	-0.05	0.391	-0.05	0.404	-0.05	0.743
Dissatisfied with personal health	-0.98	0.000	-0.98	0.000	-0.95	0.000
Educational level : Ref. Secondary						
Elementary level	-0.39	0.000	-0.51	0.000	-0.52	0.000
Tertiary level	0.17	0.007	0.28	0.000	0.29	0.006
Ln (income)	0.29	0.000	0.28	0.000	0.28	0.000
Employment : Ref. employed						
Unemployed	-0.47	0.001	-0.56	0.000	-0.55	0.001
Out of workforce	0.03	0.689	0.00	0.944	0.00	0.714
Dissatisfied with air quality	-0.17	0.006				
ln(PM10 city concentration)			-0.42	0.036	-0.42	0.037
Dissatisfied with water quality	-0.18	0.018	-0.23	0.001		
Dissatisfied with city beauty	-0.26	0.000	-0.26	0.000		
Environmental quality indicator: Ref. = 0						
1					-0.14	0.041
2					-0.50	0.000
3					-0.49	0.000
Constant	4.91	0.000	6.45	0.000	6.48	0.000
sd(_cons)	0.61		0.55		0.57	
sd(Residual)	1.76		1.77		1.76	

The results in Table 5 are consistent with what is known about the socio-demographic correlates of life satisfaction: for example, women have a higher life satisfaction than men, and there is a “U-shaped” relationship between life satisfaction and age. Similarly, respondents with higher levels of education, those satisfied with their health, employed respondents and those with higher levels of income are more likely to be satisfied with their lives.

Table 5 also shows that all of the environmental variables are significant, and of the expected sign. The effect of the variable "city beauty" – which is of a more global nature – is larger than the effects of the other environmental variables. When the synthetic indicator of satisfaction with environment conditions is included, its effect on life satisfaction is non-linear with respect to the number of attributes for which dissatisfaction is expressed.

For purposes of comparison, in Model 7, the elasticities of the effects of household income and PM_{10} concentrations at city-level have been calculated with values of 0.04 and -0.09, respectively, at means of income and PM_{10} concentration values. The effect of PM_{10} concentrations as well as reported satisfaction with air quality relative to income are implausibly large. In other words, the logarithmic relationship between household income and life satisfaction, and between PM_{10} concentrations at city-level and life satisfaction can be put into question. Introducing different specifications for these relations changes the magnitude of the elasticities significantly and these changes should be explored in future work.

However, the effects of perceived and actual environmental conditions are plausible relative to other effects. For example, reporting dissatisfaction with personal health decreases someone's life satisfaction score by 0.95 – or, in other words, respondents dissatisfied with their health are roughly one step lower on the Cantril Scale than those satisfied with their health. By comparison, reporting dissatisfaction with two or three of the measures of environmental quality in our index decreases someone's life satisfaction by 0.48 – i.e. roughly half a step lower on the Cantril Scale (when compared to someone with an environmental quality score of zero). In summary, the effect of environmental quality on life satisfaction is much lower than the corresponding effect of health status.

7. Conclusions

There is good empirical evidence that environmental factors affect people's sense of subjective well-being. Nonetheless, one of the lessons emerging from this literature is that there is no one-to-one relationship between actual pollution levels and reported satisfaction with environmental quality. In addition, the relationship between reported satisfaction with environmental quality and life satisfaction varies. It is, therefore, necessary to assess both: (a) the factors (including environmental conditions) which affect one's level of satisfaction with environmental quality, and (b) the impact that this has on subjective well-being (and how this relationship differs across socio-demographic groups).

In this preliminary empirical work, we focused primarily on the first relationship, using individual-level data from the Gallup World Poll on respondent's satisfaction with air quality combined with more aggregated data on PM_{10} concentrations in urban areas. Given data availability constraints, multilevel modelling is applied, with country-level and city-level pollution concentrations applied at the upper level.

Preliminary results indicate, for instance, that higher PM_{10} concentrations do have a significant effect on reported dissatisfaction with air quality; the size of the odds ratios in our models indicate that this effect is pronounced. However, the relationship between these two factors is non-linear, with the relationship being less robust at high levels of pollution. Reported dissatisfaction with health status, being a woman, having a higher income level, higher level of education and being between 26 and 40 years-of-age also increase one's likelihood of being dissatisfied with air quality.

An additional analysis was undertaken to study the effect of environmental conditions on subjective well-being. This work indicates that actual observations and perceptions about environmental conditions also affect self-reported subjective well-being, although it must be emphasised that this work is very preliminary. In particular, the effects of both actual and perceived environmental quality on reported life satisfaction relative to changes in household income is implausibly large, although relative to reported health satisfaction, the effect of environmental factors is consistent with previous work.

While the field is still young, and requires further research to answer many open questions, it is clear that an analysis of determinants of subjective well-being can be a useful complement to more traditional welfare economics, based on utility maximisation arising out of revealed choices. One area in which this type of analysis is most likely to become important is in the field of environmental economics.

While it is far too early to say whether analysing determinants of subjective well-being has the potential to serve as a partial substitute for more orthodox valuation techniques (through the income compensation method), it can certainly inform the establishment of policy priorities in a more informal manner. Nonetheless, there may be a great variation in the reliability of the SWB approach across different environmental questions.

On the one hand, areas in which the SWB approach is likely to be most informative, are those in which the environmental impact relates to "use" values which are perceptible and tangible, and for which there is variation across respondents but not across short time-frames. Possible areas for study include the relationship between air pollution and perceived health impacts; other examples include limited access to recreation opportunities due to water pollution and access to green space (e.g. parks and public gardens).

On the other hand, should SWB analyses find that there is little apparent relationship, although it is known from other evidence (e.g. epidemiological studies) that there is a relationship between the environmental factor (e.g. PM concentrations) and important outcomes (e.g. personal health), such studies indicate the need for governments to educate the public in order to allow them to make informed decisions in relevant markets.

ANNEX 1. SAMPLE USED IN MODEL 1 AND MODEL 2

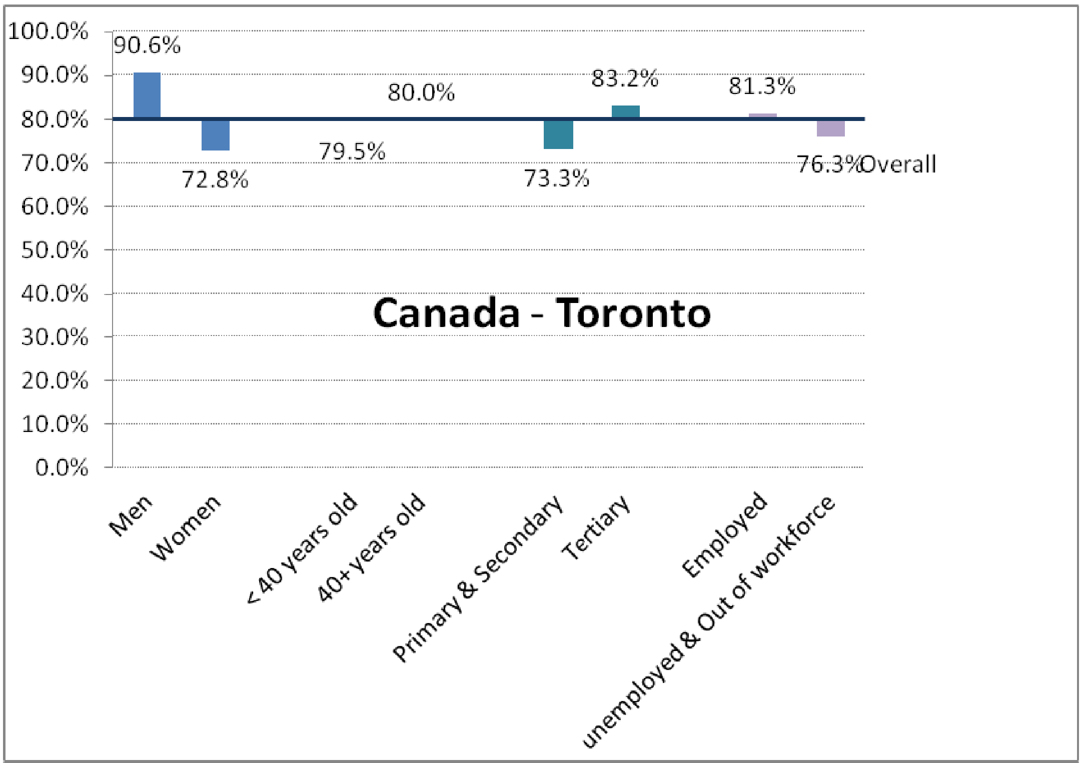
	MODEL 1			MODEL 2	
Year	2006	2007	2008	2007	2008
United States		582		684	
Lebanon			556		435
Turkey			504		458
Indonesia	631	398		203	
Bangladesh		297			
United Kingdom		435	270		346
France			280		345
Germany			234		331
Netherlands			284		314
Belgium		82	138	246	237
Spain			241	0	365
Italy			146	0	258
Poland		196	205	288	260
Hungary	355	208	352	0	407
Czech Republic		267		330	
Sweden			304	0	345
Greece		272		517	
Denmark		309		416	
Japan		480	1147	655	407
China			1702		
India			533		362
Venezuela		500	591		505
Israel		462	611	629	
Canada			481		587
Australia	601	481	485		637
New Zealand		190	253		
South Korea			706		743
Argentina			572		618
Austria			234		349
Chile		587	606	531	511
Colombia		378	492	321	420
Estonia	316	316	187		254
Finland			338		399
Iceland			219		259
Ireland			241		337
Luxembourg			99		129
Norway			248		273
Portugal	198		229		333
Slovakia					
Slovenia	258				
Switzerland	242				
Totals	2601	6440	13488	4820	11224
			22529		16044

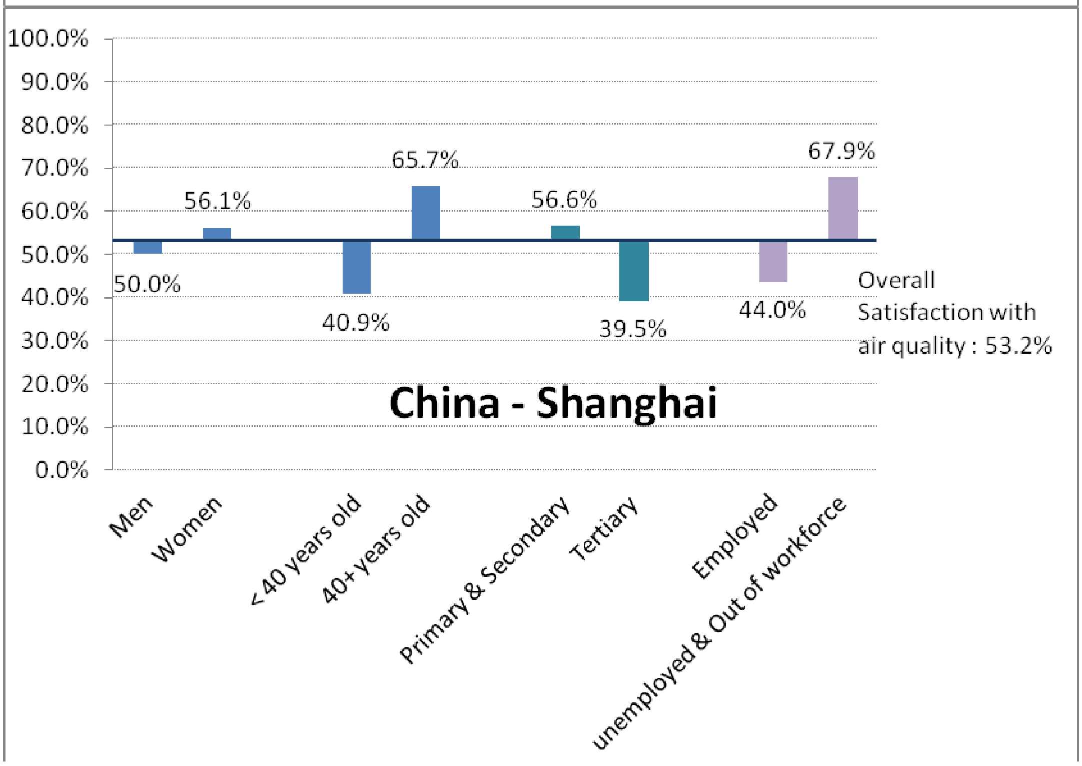
ANNEX 2. SAMPLE AT CITY LEVEL (MODELS 3 THROUGH 7)

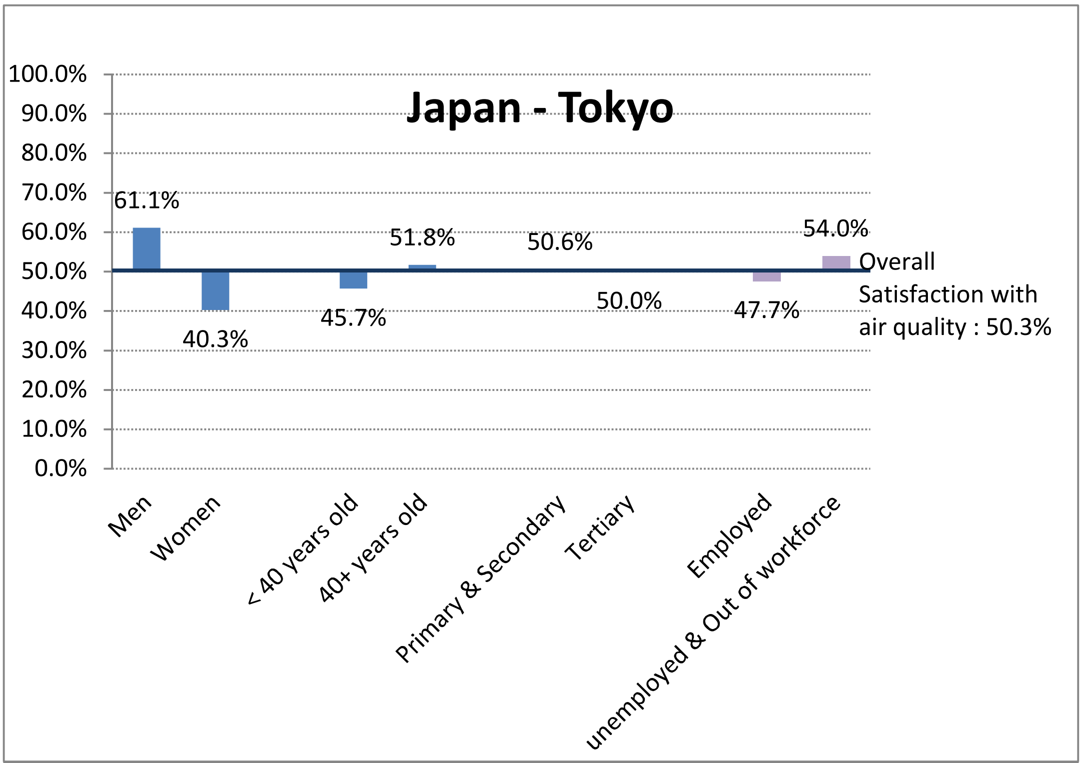
Year	**2010**
Lebanon - Beirut	376
China - Shanghai	380
China - Beijing	354
Algeria - Algiers	226
China - Guangzhou	303
UAE - Abu Dhabi	303
Japan - Tokyo	160
New Zealand - Auckland	217
Australia - Melbourne	240
Australia - Sydney	198
Greece - Athens	296
Vietnam - Ho chi Minh	100
South Korea - Seoul	220
Vietnam - Hanoi	100
Russia - Moscow	209
Austria - Vienna	194
Slovenia - Ljubljana	185
Turkey - Istanbul	176
Canada – Toronto	172
Colombia - Bogota	168
China - Chong Qing	114
Hungary - Budapest	160
India – Mumbai	144
Indonesia - Jakarta	135
Czech Republic - Prague	125
India – Kolkata	120
Canada - Montreal Metro	109
Japan - Yokohoma	21
Japan – Osaka	19
India – Chennai	96
Russia - St. Petersburg	95
Belgium - Brussels	92
India – Bangalore	90
Slovakia - Bratislava	84
Finland – Helsinki	83
Japan – Nagoya	14
Belgium – Antwerp	79
Portugal – Lisbon	75
Ireland – Dublin	74
France – Paris	73
Greece - Thessaloniki	72
Mexico - Mexico City	70
Sweden – Stockholm	68
Japan – Sapporo	17

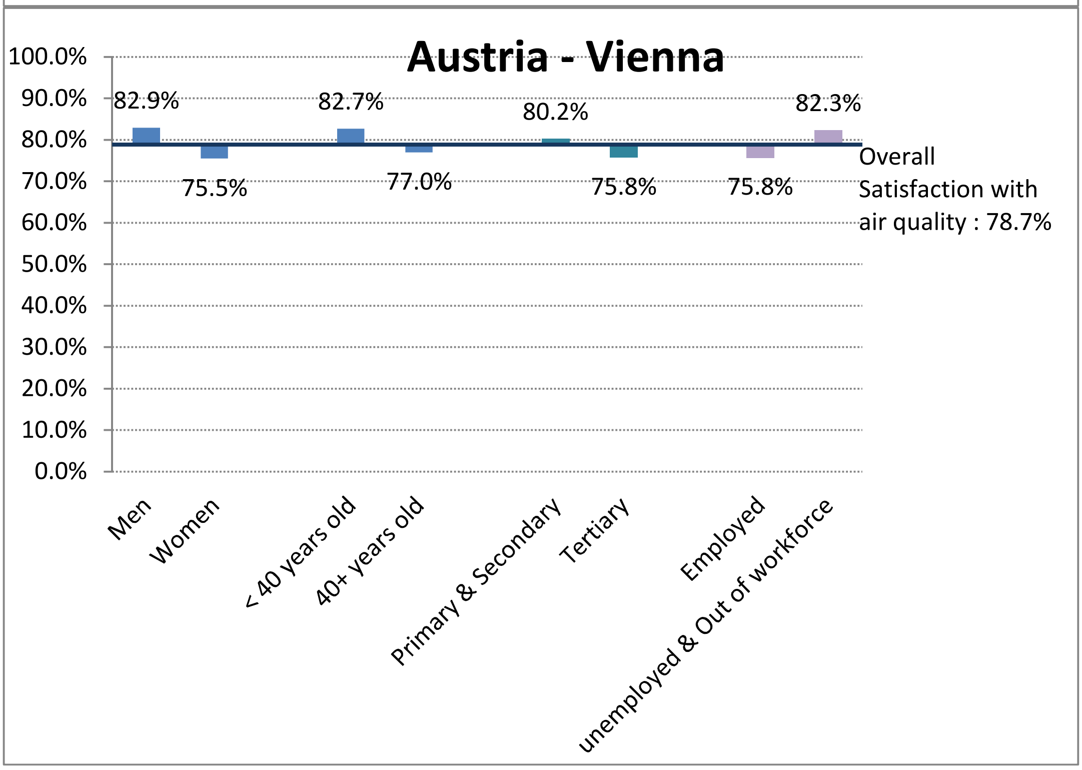
Denmark - Copenhagen	66
Spain – Madrid	61
Colombia – Cali	56
Turkey – Ankara	56
Colombia – Medellin	48
Turkey – Izmir	48
Italy – Rome	44
Netherlands - Amsterdam	43
Argentina – Cordoba	41
Mexico – Guadalajara	40
Mexico – Monterrey	40
Poland – Warsaw	40
Italy – Milan	38
Argentina – Rosario	35
Germany – Berlin	35
France - Marseille	31
Ireland - Cork	29
Germany - Hamburg	19
Germany - Munich	16
Germany - Frankfurt	16
UK - London	10
UK - Birmingham	6
Spain - Barcelona	4

ANNEX 3. SATISFACTION WITH AIR QUALITY ACROSS DEMOGRAPHIC GROUPS IN SELECTED CITIES






Japan - Tokyo
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
61.1%
40.3%
45.7%
51.8%
50.6%
50.0%
47.7%
54.0%
Overall Satisfaction with air quality : 50.3%
Men
Women
< 40 years old
40+ years old
Primary & Secondary
Tertiary
Employed
unemployed & Out of workforce


Austria - Vienna
100.0%
90.0%
80.0%
70.0%
60.0%
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
82.9%
75.5%
82.7%
77.0%
80.2%
75.8%
75.8%
82.3%
Overall Satisfaction with air quality : 78.7%
Men
Women
< 40 years old
40+ years old
Primary & Secondary
Tertiary
Employed
unemployed & Out of workforce

ANNEX 4. MULTILEVEL LOGIT MODEL OF SATISFACTION WITH AIR QUALITY – MODELS1A AND 1B

Probability modeled : Dissatisfied of air quality				
		OECD Countries		*NON OECD Countries*
Number of obs	=	25252		11240
Number of groups	=	54		15
Min	=	138		304
Avg	=	467.6		749.3
Max	=	1537		1961
	Odds-Ratio	P > z	Odds-Ratio	P > z
Gender (ref. men)				
Women	1.18	0	1.03	0.398
Health (ref. satisfied)				
Dissatisfied	1.49	0	1.6	0
Education (ref. secondary)				
Elementary	0.75	0	0.77	0
Tertiary	1.13	0	1.25	0
Age in classes (ref. 26-40 year-olds)				
15-20 year-olds	0.78	0	0.93	0.308
21-25 year-olds	0.91	0.091	1.06	0.329
41-50 year-olds	0.87	0.001	0.95	0.426
51-60 year-olds	0.81	0	0.82	0.007
Over 60 year -olds	0.62	0	0.64	0
Children under 15 (ref. no children)				
Children in household	0.91	0.087	0.93	0.115
Place of residence (ref. large city)				
Suburbs	0.57	0	0.86	0.047
Air Pollution (country-level average)				
Ln PM_{10}	2.07	0	0.99	0.97
Random effect parameters	Estimate	Std. Error	Estimate	Std. Error
wave_country: Identity				
sd(_cons)	0.44	0.046	0.39	0.0745

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