The effects of Air Pollution on Health Status in Great Britain

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Abstract

This study explores the effects of air pollution on self-reported health status. Moreover, this study explores the willingness to pay for improving the air quality in UK. The estimates are based on data from the British Household Panel Survey (BHPS). The effects of air pollution on individuals' health status are estimated and their monetary value is calculated. In particular, two main air pollutants are examined; ground-level ozone (O_3) and carbon monoxide (CO). Moreover, various approaches are followed. The first approach refers to panel Fixed Effects regressions and specifically the Probit adapted Ordinary Least Squares (POLS) and the "Blow-Up and Cluster" (BUC) estimator. The second approach is the dynamic system Generalized Methods of Moments (GMM), while the last approach is the Generalized Ordered Probit with Random Effects model. The annual monetary values for ground level O_3 range between £128-£149 for a drop of one unit, while the respective values for the CO range between £122-£141. In addition, the marginal willingness to pay (MWTP) for avoiding an inpatient day in hospital for a one unit reduction in pollution is £29. In the case where the fee of £20 per stay, proposed by a former Health minister in UK, will be implemented then the MWTP ranges between £140-£150. Based on the elective (planned) and non-elective (unplanned) inpatient stay cost per day which is £2,749 and is £2,197 respectively a 5 and 4 unit respectively decrease in air pollutants will lead to a MWTP equal to the inpatient day cost. Lastly, depending on the health status of the individual the MWTP for the number of General Practitioners (GP) ranges between £10-£60.

Keywords: Air pollution, Environmental valuation, Health Status, Life satisfaction approach

JEL Codes: I31, Q51, Q53, Q54

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1. Introduction

Air pollution leads to worst health outcomes and increased death probability (Currie and Neidell, 2005). However, policies to reduce pollution are often hardly fought on the ground of their high financial costs. It is thus crucial to have reliable estimates of the public willingness to pay for a cleaner environment and to analyze the determinants of health status. Economists have long worried about valuing the environment. The difficulty in doing so steams from the absence of markets pricing the environment/pollution.

Two main techniques of environmental valuation have been used and are classified into revealed preference and stated preference methods. In the first approach traditional examples include hedonic price analysis and the travel cost approach. On the other hand in the stated preference approach, based on contingent valuation surveys, individuals are directly asked to value the environmental good in question. Both methods have been widely used in practice (Carson *et al*. 2003), however both methods have drawbacks. Regarding hedonic price analysis \ the market of interest, which is typically the housing market, should be in equilibrium at even small geographical level (Frey et al., 2009). In stated preference analysis, the hypothetical nature of the surveys and the lack of financial implications may lead to superficial answers and strategic behaviour (Kahneman et al., 1999).

Instead this paper relies on a similar approach to life satisfaction evaluation; however instead of the life satisfaction the self-reported health status is used. One advantage of this method is that it does not rely on asking people how they value environmental conditions and it does not require that the housing market is on equilibrium. Therefore, this approach does not require awareness of causal relationships- but simply assumes that pollution leads to change in health status and these changes can be driven by observed or unobserved pollution variation. Thus this approach is closely related to hedonic pricing but relies on health status rather than house price to evaluate how individuals value their environment. Because, health status may be correlated with some unobserved amenities that also affect pollution level the estimates are relied on individual level panel data so that unobserved individual level and geographical characteristics can be accounted for. The identification then comes from variation in pollution level between interviews. For this reason this study uses detailed micro-level data.

This approach however has limitations and weaknesses. Crucially, in order to yield reliable non-market valuation estimates, self-reported health status measures must reflect stable inner states of respondents, current affects and to be comparable across groups of individuals under different circumstances. Similar to a limitation of the hedonic property pricing method, it is possible that people choose where they reside. This would bias the air pollution variable's coefficient- and therefore the monetary value- downwards as those who are risk averted to air pollution would choose to reside in areas with cleaner air. However, both non-movers and movers sample are examined as it is described below. More specifically, the population of interest is limited to non-movers in order to limit endogeneity.

The purpose of this study is to examine the effects of air pollution and other determinants of self-reported health status. The analysis relies on detailed micro-level data, using local authority districts, instead of using city, county or country level like other studies did before (Ferreira et al., 2006; Luechinger, 2010). The advantage of using local authority districts is that it is possible to map the air pollution emissions at a detailed geographical reference implying more precise and more robust estimates. In addition, this is the first study that four different panel estimates to deal with the potential endogeneity of the pollution measure are applied. More specifically, the first model is the individual level fixed effect model using Probit Adapted OLS with fixed effects (van Praag and Ferrer-i-Carbonell, 2004). The second model is the "Blow-Up and Cluster" (BUC) estimator (Baetschmann et al., 2011). The third model is a dynamic Generalized Methods of Moments (GMM) model and the fourth is a latent class ordered probit model.

There are several key advantages of using these estimates. Firstly it is possible to control for the local authority district-specific, time invariant characteristics, as well as, using dynamic models it is possible to control to a large extent for many omitted variables and unobservables. Finally, estimating a latent class ordered probit model slope heterogeneity is accounted for. Additionally, two major air pollutants are explored, ozone (O_3) and carbon monoxide (CO).

The paper is organized as follows. Section 2 presents a short literature review. Section 3 describes the theoretical and econometric framework. In section 4 the data and the research sample design are provided. In section 5 the results of estimating several versions of a health status function, with air pollution included, are reported, as well as, the effects of air pollution on health status and their monetary value are presented and discussed. In section 6 the concluding remarks are presented.

2. Literature Review

The self-reported health has been used widely in previous studies of the relationship between health and socioeconomic status using British data (Ettner 1996; Deaton and Paxson 1998; Benzeval et al. 2000; Salas 2002; Adams et al. 2003; Frijters et al.2003; Contoyannis et al.2004) and of the relationship between health and lifestyles (Kenkel 1995; Contoyannis and Jones 2004). The results are various. For example regarding educational attainment a movement from unhealthy to a completely healthy lifestyle the proportions of individuals with higher levels of education gradually increases, while those that are unemployed are more likely to have an unhealthy lifestyle. One of the first applications on MWTP of air pollution and health is by Gerking and Stanley (1986). The authors used the St. Louis survey, which was conducted over the period 1977-1980 and the individuals whose major activity was recorded as employed were used in this study. The findings show that a 30% reduction in ambient mean ozone concentrations, the annual willingness to pay estimates range from $18.45 to $24.48. Chay and Greenstone (2003a) examined the air quality improvements induced by the Clean Air Act Amendments (CAAAs) of 1970 to estimate the impact of particulates pollution on infant mortality during period 1971-1972. The authors find that one per cent decline in TSP results in 0.5 per cent decline in the infant mortality rate. Chay and Greenstone (2003b) used substantial differences in air pollution reductions across sites to estimate the impact of TSPs on infant mortality. The authors establish that most of the 1980-82 declining in TSPs was attributable to the differential impacts of the 1981-82 recession across counties and that a one percent reduction in TSPs results in a 0.35 percent decline in the infant mortality rate at the county level.

On the other hand Currie and Neidell (2005) using the California Birth Cohort files and the California Ambient Air Quality Data during period 1989-2000 propose an identification strategy using individual level data and exploiting within-zip code-month variation in pollution levels and creating measures of pollution at the zip code-week level and controlling for individual differences between mothers that may be associated with variation in birth outcomes. The authors find that living in a very high-pollution area is associated with a higher risk of fetal death, suggesting that pollution may be harmful above a certain threshold level.

Knittel et al. (2011) examined the effects of PM_{10} in California Central Valley and Southern California in the years 2002-2007. Knittel et al. (2011) used as an instrument to PM_{10} weekly shocks to traffic and its interactions with ambient weather conditions. The authors argue that deviation from the regional norm originates from accidents and road closures. These shocks to traffic, and thus pollution, are likely to be uncorrelated with the error term in a model of infant mortality as a function of pollution exposure. Knittel et al. (2011) find that PM_{10} has a large and statistically significant effect on infant mortality.

3. Methodology

3.1 Theoretical Framework

One of the first simple theoretical models examining the effects of air pollution on health has been proposed by Gerking and Stanley (1986). However, we extend the model by including also leisure. The utility function is:

$$U = U(X, L, H; \mu, \varepsilon_1) \tag{1}$$

, where μ is an error term reflecting differences in preferences, and ε_1, is an error term reflecting stochastic shocks. Health is produced by the person via the following health production function:

$$H = H(M, E; \delta, \varepsilon_2) \tag{2}$$

The inputs to health production include a vector of medical care *M* (it can also include structural attributes of the health care provider), while vector *E* includes environmental factors as air pollution. The remaining inputs are δ, which is an unobserved health endowment, and ε_2, which is an error term reflecting stochastic shocks to health. From (2) is derived that $H(H_M>0$ and $H_E<0)$, the last term is negative as air pollution has negative effects on health. The person faces the following time constraint:

$$T + L + R = 1 \tag{3}$$

, where R is the hours of market work, and the total amount of time is normalized to equal one and T denotes the time necessary to receive medical care or the time lost and which is related to the health stock according to (4).

$$T = G(H) \tag{4}$$

, where $G_H<0$. The person also faces a budget constraint:

$$WR + A = P_X X + P_M M + WT \tag{5}$$

, where W is the wage, A is the non-labour income, P_X, P_M and P_Z denote the prices for X and M respectively. By combining the two constraints into a full-budget constraint, it is obvious that the cost of health production is the monetary price of health care inputs and non-medical inputs and the opportunity cost of the time used to produce health. The consumer maximizes a utility function subject to a health production function and a full-budget constraint. The choice variables in the model are the attributes of a health medical care, the non-health care inputs to health production, time used for health production, leisure time, and the composite commodity. Exogenous variables are the price of non-medical inputs, wage, non-earned income. The Lagrangian function is as follows:

$$\begin{aligned} \max\ V &= U[H(M,Z,T,E;\delta,\varepsilon_2),X,L;\mu,\varepsilon_1] + \\ &\lambda[W(1-T-L) + A - P_X X - P_M M - WT] \end{aligned} \tag{6}$$

The first order conditions are:

$$\frac{\partial V}{\partial M} = U_{\mathrm{H}} H_M - \lambda(P_M + WG(H)H_M) = 0 \tag{7a}$$

$$\frac{\partial V}{\partial X} = U_X - \lambda P_X = 0 \tag{7b}$$

$$\frac{\partial V}{\partial L} = U_L - \lambda W = 0 \tag{7c}$$

$$\frac{\partial V}{\partial \lambda} = W(1 - T - L) + A - P_X X - P_Y Y - P_M M - WT = 0 \tag{7d}$$

The optimum condition of inputs in the production of health is determined by the familiar condition that the technical rate of substitution is equal to the input price ratio as:

$$\frac{\partial V}{\partial M} / \frac{\partial V}{\partial \mathrm{T}} = \frac{U_{\mathrm{H}} H_M - \lambda(P_M + WG(H)H_M)}{U_{\mathrm{H}} H_{\mathrm{T}} - \lambda W} \Rightarrow \frac{H_M}{H_{\mathrm{T}}} = \frac{P_M + WG(H)H_M}{W} \tag{8}$$

$$\frac{\partial V}{\partial Z} / \frac{\partial V}{\partial \mathrm{T}} = \frac{U_{\mathrm{H}} H_Z - \lambda P_Z}{U_{\mathrm{H}} H_{\mathrm{T}} - \lambda W} \Rightarrow \frac{H_Z}{H_{\mathrm{T}}} = \frac{P_Z}{W} \tag{9}$$

Then the utility function and budget constraint are totally differentiated and set to zero and then substituting (7a) and (7b) into utility function it will be:

$$dU = U_X dX + U_L dL + U_H H_M dM + U_H H_E dE = 0 \tag{10}$$

Then dividing (7a) and (7b) and substituting into (10) it will be:

$$dX = -(P_M + WG(H)H_M)(dM + \frac{H_E}{H_M} dE) \tag{11}$$

Then by differentiating budget constraint, setting up to zero and substituting (11) in to it then it will be:

$$\frac{\partial A}{\partial E} = -\frac{H_E}{H_M} P_M \quad (12)$$

Equation (12) shows the individual's willingness to pay for an improvement in air quality associated with the opportunity cost of time of taking time off. However, in the case of Great Britain there is no cost for the individual for a visit to NHS. However, two scenarios are presented. In the first scenario P_M is replaced by time which is needed to visit a General Practitioner (GP), including both transportation and waiting time. For simplicity, 3 hours are examined. In the second scenario two prices are used. The first is a monthly fee of £10 for using National Health Service (NHS) and £20 for a night stay in hospital. However, the latter is used for the number of inpatient days in hospital instead of visiting a GP. This scenario is examined based on the proposal by Lord Warner a former Labour health minister (Borland, 2014). In the previous model medical care is viewed as the only way by which individuals can improve or rebuild their health. Therefore, the direct cost associated with the health status and illness is due to the time lost to the consultation of a general practitioner and/or the possible fee of using NHS. Leger (2014) argues that there are individuals with poor health status and who are ill do not consult a practitioner yet suffer financially from their illness. Thus, those individuals simply take time off to rest and rebuild their health capital. In the case examined the model is expanded to account not only the self care but also household care as the literature provides evidence that family support and size can be protective and beneficial to people with a chronic illness (Aldwin and Greenberger, 1987; Doornbos, 2001). In addition, results shown in the next sections confirm this hypothesis there the household size is positively associated with the good health status. In that case the P_M in the budget constraint (5) can be replaced by P_{HD}, where denotes the "price" of self care and/or household-family support, while P_M and H_M in relation (12) will be replaced by P_{HD} and H_{HD}. It should be noticed that these models are not additive meaning that the total willingness to pay for improvements in air quality is not necessarily the sum of individuals willingness to pay of both practitioner consultations and self/care-family support.

3.2 Econometric Framework

3.2.1 Fixed Effects

Self-reported health status can serve as an empirically valid and adequate approximation of individual welfare, in a way to evaluate directly the public goods. Additionally, by measuring the marginal disutility of a public bad or air pollution in that case, the trade-off ratio between income and the air pollution can be calculated. The following model of health status using the life air pollution effects on health status for individual *i*, in area *j* at time *t* is estimated:

$$HS_{i,j,t} = \beta_0 + \beta_1 e_{j,t} + \beta_2 \log(y_{i,t}) + \beta' z_{i,j,t} + \gamma W_{j,t} + \mu_i + l_j + \theta_t + l_j T + \varepsilon_{i,j,t} \tag{13}$$

$HS_{i,j,t}$ is the health status. The vector $e_{j,t}$ is the measured air pollution in location *j* and in time *t*, $log(y_{i,t})$ denotes the logarithm of personal or household income and z is a vector of household and demographic factors, discussed in the next section. W is a vector of meteorological variables, in location *j* and in time *t*. Another meteorological variable that could be used is the wind direction. However, because of the data unavailability wind direction is not considered. Set μ_i denotes the individual-fixed effects, l_j is a location (local authority) fixed effects, θ_t is a time-specific vector of indicators for the day and month the interview took place and the survey wave, while l_jT is a set of area-specific time trends. Finally, $\varepsilon_{i,j,t}$ expresses the error term which we assume to be *iid*. Standard errors are clustered at the local authority level. One of the desirable features of the FE design is that it allows for the unit-specific effect to be correlated with the Xs. Thus it explicitly accounts for one form of endogeneity, that resulting from time-invariant omitted variables.

For a marginal change of *e*, the marginal willingness-to-pay (MWTP) can be derived from differentiating (1) and setting dHS=0. This is the income drop that would lead to the same reduction in health status than an increase in pollution. Thus, the MWTP can be computed as:

$$MWTP = -\frac{\partial HS}{\partial e} / \frac{\partial HS}{\partial y} \tag{14}$$

Having panel data allows us to identify the model from changes in the pollution level within individuals rather than between individuals. This reduces the possible endogeneity bias in the estimates since unobservable characteristics of the neighbourhood that may be correlated with pollution and health status are eliminated in a fixed effect model. Moreover, in order to limit endogeneity issue the population of interest is limited to non-movers. Focussing on non-movers also allow us to capture unobservable characteristics of the neighbourhood that may be correlated with pollution and health status that are fixed over time.

In its current form the model cannot be estimated by ordered probit or logit using fixed effects. Thus the procedure introduced by van Praag and Ferrer-i-Carbonell (2004) is followed. More specifically Probit-OLS uses a transformation such that the new dependent variable takes the conditional mean-given the original ordinal rating- of a standardised normally-distributed continuous variable, calculated based on the frequencies of the ordinal ratings in the sample. Van Praag and Ferrer-i-Carbonell (2004; 2006) show both heuristically and in several applications that Probit OLS is virtually identical to the traditional ordered probit analysis. Generally, both OLS and Probit-OLS have been compared with the ordered models and no differences have been found among them (Ferrer-i-Carbonell and Frijters 2004; Van Praag and Ferrer-i-Carbonell 2006; Van Praag 2007; Luechinger 2009, 2010; Stevenson and Wolfers 2008; Wunder and Schwarze 2010).

Another estimator is the FCF developed by developed by Ferrer-*i*-Carbonell and Frijters (2004). However, the "Blow-Up and Cluster" (BUC) estimator (Baetschmann et al., 2011) as well as the above mentioned approaches are preferred for two reasons. Firstly, Baetschmann et al., (2011) provide reasons that, in general, FCF estimator is inconsistent as the way that by choosing the cutoff point based on the outcome, produces a form of endogeneity. Secondly, this approach uses only individuals who move across the cut-off point resulting in a large loss of data. This large loss of data will lead to measurement errors as they may well become a large source of residual variation (Ferrer-*i*-Carbonell and Frijters, 2004). This is also not appropriate for our analysis because the purpose of this study is to examine and control for various factors affecting health status. Therefore, the BUC estimator is applied in this study (see Baetschmann et al., 2011 for technical details and working example). In addition, the ordered dependent variable is collapsed in to a binary and then the conditional fixed effects logit proposed by Chamberlain (1980) is applied. This approach was followed by Jones and Schurer (2007) and lately by Schmitt (2013). More specifically, the conditional fixed effects logistic regression is used as in the case of BUC estimator, where the dependent variable has to be collapsed into binary format. The binary variable is:

$$\begin{aligned} I_{i,j,t} &= 1 \ \ if \ \ HS_{i.j.t} < \overline{HS}_{i,j} \\ I_{i,j,t} &= 0 \ \ if \ \ HS_{i.j.t} \geq \overline{HS}_{i,j} \end{aligned} \tag{15}$$

, where

$$\overline{HS}_{i,j} = \frac{1}{T}\frac{1}{J}\sum_{t=1}^{T}\sum_{j=1}^{J} HS_{ijt} \tag{16}$$

The generated dummy variable $I_{i,j,t}$ equals one if person *i* has stated a value of health status at time *t* and area (local authority district) *j* which is lower than the individual mean value over the whole period. Therefore, two things should be clarified. As the original health status is coded as excellent for lower values and very poor for high values the same order is kept in this case to be consistent with all the previous and the next econometric models which are followed. Thus, 1 means that a person stated a lower (better) value of health status than the individual mean. On the contrary, the dummy variable takes 0 if person *i* has stated a value of health status higher (worse) than the individual mean. Secondly, the average is taken on LAD level and not on national level as Schmitt (2013) applied. The purpose is that taking LAD level the characteristics (economic activity, air pollution weather) are clustered and are better comparable. In addition, in the estimating process only individuals are included, whose HS is not constant over the whole period. This means that at least one switch in the dummy variable *I* is necessary. Using this approach makes it possible to exclude all static effects of the living environment of the individuals like for example labour market conditions, economic activity, weather and air pollution among others, from the analysis of the relation between air pollution and *HS*.

3.2.2 Dynamic Panel Regressions

The second model which can be considered is system GMM with lagged dependent variable and can be defined as:

$$HS_{i,j,t} = \beta_0 + \beta_1 HS_{i,j,t-1} + \beta_2 e_{j,t} + \beta_3 \log(y_{i,t}) + \beta' z_{i,j,t} + \gamma W_{j,t} + \mu_i + l_j + \theta_t + l_j T + \varepsilon_{i,j,t} \qquad (17)$$

The dynamic models are useful because the lagged dependent variable control for a dependent variable that follows an autoregressive-AR(1) process. Furthermore, the parameter of the lagged dependent variable shows how an individual changes his or her adaptation level to living conditions represented by the stimulus level in the preceding period. However, the issue with equation (17) is that econometric problems may arise. In particular, the variables on the right hand, as the air pollution and income, are assumed to be endogenous. Because causality may run in both directions, from income to health status and vice versa – these regressors may be correlated with the error term. Furthermore, time-invariant fixed effects, like local authority districts, may be correlated with the explanatory variables. Moreover, the lagged dependent variable $HS_{,i,j,t-1}$ gives rise to autocorrelation (Nickell 1981). Function (17) presents the mentioned problems when *T*, denoting time, is short, where is the case examined. More specifically, the Blundell – Bond estimator was designed for small-*T* and large-*N* panels, where *N* denotes the region or individual effects. Therefore this study examines the Blundell-Bond (1998) system GMM.

3.2.3 Random Effects Latent class Ordered Probit Model

Using the conventional fixed or random effects models described in the previous sections, correct for intercept heterogeneity. One step further, is to model for slope heterogeneity. The model endogenously divides the observations-in a probabilistic sense- into separate classes, which differ by the parameters-slope and intercept- of the relation between income and happiness (Clark et al. 2005). This model assumes that an agent *i* evaluates her health status at time *t*. Let β_{it} denotes her answer, which belonging to ordered set of labels $J = \{j_1, j_2 ... j_J\}$, where *J* denotes the labels for $j=1,2...J$. The ordered probit (OP) model is usually justified on the basis of an underlying latent variable, *HS*, in our case, which is a linear in unknown parameters, function of a vector of observed characteristics *z*, and its relationship to certain boundary parameters, μ. We can therefore write for simplicity the model:

$$HS_{i,t}{}^{*} = a_{i,t} + \beta_{i,t}\log(y_{i,t}) + \varepsilon_{i,t} \tag{18}$$

So model (17) is related to the observed outcome *HS* a

$$HS = \begin{Bmatrix} 0 \quad if\ HS^{*} \leq 1 \\ j \quad if \quad \mu_{j-1} < HS^{*} \leq \mu_{j},\ for\ 1 < j < J \\ J\ if \quad \mu_{J-1} \leq HS^{*} \end{Bmatrix} a_{i,t} + \beta\log(y_{i,t}) + \varepsilon_{i,t} \tag{19}$$

Formally, a latent variable c^{*} is defined, which determines latent class membership. This is assumed to be a function of a vector of observed characteristics *x*; with unknown weights *β* and a random disturbance term ε as:

$$c^{*} = x'\beta + \varepsilon \tag{20}$$

The overall probability of an outcome *j=1,2…J* is simply the sum of those respective classes and have the form:

$$\Pr(HS = j \mid x,z) = \Pr(c = 1 \mid x)\Pr(HS = j \mid z,c = 1) + \ldots.. + \Pr(c = J \mid x)\Pr(HS = j \mid z,c = J) \tag{21}$$

In this context the estimated parameters of relation (18) are individual and potentially time-varying parameters. Therefore, in this general model heterogeneity is twofold; firstly because the “marginal utility” of income and the baseline-intercept- level of health status are individual-specific, and secondly because individuals may use different labels to express the same level of health status.

3.2.4 Number of Days Inpatient in Hospital

In the next model the effects of health status and other personal and socio-economic characteristics on the number of days being in-patient in a hospital are estimated.

$$Hd_{i,j,t} = \beta_0 + \beta_1 HS_{i,j,t} + \beta_2 \log(y_{i,t}) + \beta' z_{i,j,t} + \gamma W_{j,t} + \mu_i + l_j + \theta_t + l_j T + \varepsilon_{i,j,t} \quad (22)$$

,where $Hd_{i,j,t}$ denotes the number of days the individual was inpatient in hospital. The remained variables are defined as in the previous models. A Fixed Effects Model is implemented in this case. However, having a poor health caused for example by air pollution or smoking are not the only factors leading to hospital inpatient situation, as number of days in-patient in hospital refer to all the cases, including ie. car or industry accidents. For this reason a regression model examining the number of visits to a General Practitioner (GP) is described in the next section.

3.2.5 Multinomial Logit Random Effects

The next model examined is the following Multinomial Logit Random Effects:

$$VGP_{i,j,t} = \beta_0 + \beta_1 HS_{i,j,t} + \beta_2 \log(y_{i,t}) + \beta' z_{i,j,t} + \gamma W_{j,t} + \mu_i + l_j + \theta_t + l_j T + \varepsilon_{i,j,t} \quad (23)$$

,where $VGP_{i,j,t}$ denotes the number of days the individual has visited a GP. More specifically, the dependent variable is a categorical variable with the following 5 classes: *No visit*, *One or Two Visits*, *Three to Five Visits, Six to Ten Visits*, *More than Ten Visits*. The remained variables are defined as in the models discussed previously. Given normally distributed random errors in the multinomial logit model, exponentiation of those random errors yields a set of log-normally distributed disturbances, with means and variances well defined. Let for example Y_{it} denote the value of an ordinal or a nominal categorical variable with (K + 1) levels, which in the case examined is the number of visits to GP, associated with person i at area j and time t. Conventionally, adding scalar between-persons random effects to the fixed-effects multinomial logit model, the probability that $Y_{it} = k$ ($k = 1, \ldots, K$) for person i at time t is given by:

$$P_{itk} = \Pr(Y_{it} = k \mid x_{it}) = \left[1 + \sum_{h=1}^{K} \exp(x'_{it}\beta_h + v_{ih}\right]^{-1} \exp(x'_{it}\beta_k + v_{ik}) = \left[1 + \sum_{h=1}^{K} \exp(x'_{it}\beta_h + v_{ih}\right]^{-1} \exp(x'_{it}\beta_k)\exp(v_{ik}) \tag{24}$$

, where x_{it} is the $(M+1)\times 1$ covariate vector including intercept. Likewise, β_k is the $(M+1)\times 1$ vector of unknown regression parameters to be estimated, and v_{ik} is the between-persons random effect assumed to be distributed as $(0,\sigma^2_{vk})$. The probability $P_{ij}(K+1)$ is viewed as the reference or residual probability given the constraint that a set of choice probabilities must sum up to unity.

4. Data

We use the British Household Panel Survey (BHPS) an annual survey of each adult member of a nationally representative sample of more than 5,000 households which started in 1991. Individuals moving out or into the original household are also followed (Taylor et al. 2010). The data period used in the current study covers the waves 1-18 during the period years 1991-2009.

Based on the literature discussed on the previous section, the demographic and household variables of interest are household income[1], gender, age, age squared, family size or household size, labour force status, house tenure, marital status, education level and local authority districts. The income is measured in thousands of pounds and has been converted to 2009 British pounds using the CPI. The principal health outcome is self-assessed health (SAH) defined by a response to the question “Please think back over the last 12 months about how your health has been; excellent/good/fair/poor/very poor?”.

Furthermore, in order to reduce the variation, to increase the robustness of the estimations and in an effort to capture the missing values of air pollutants, the monthly average preceding the interview is computed. The average monthly values are more appropriate especially because the effects of air pollution cannot be always instant in the general health status. However, the day prior to interview is estimated. The latter is taken into consideration because the time of the interview is unknown, therefore the air pollution on the same day might have little or insignificant effect on health status, especially when the interview is conducted during the early morning hours. In addition, the household income of the last month is considered. There are 124 monitoring stations for O_3 and 105 for CO.

Two major air pollutants are examined: Ground-level ozone (O_3) and Carbon Monoxide (CO). The air pollutants are based on daily frequency and measured in $\mu g/m^3$. In order to match the air pollution emissions with the individuals the following steps are applied. Firstly, the exact location of air monitoring stations is known given in grid points –easting and northing- which can be found on DEFRA website. Secondly, we have special access on individuals’ local authority district (LAD) level expressed on grid references provided by the Institute for Social and Economic Research (ISER) at the University of Essex.

[1] The analysis was also conducted using individual level income; however this is affected by labour force participation which we do not explicitly model here.

In order to convert the point data from the monitoring stations into data up to LAD Level we used the inverse distance weighting (IDW) a GIS-based interpolation methods. In IDW, the weight of a sampled data point is inversely proportional to its distance from the estimated value. The final level of regional aggregation in the analysis is based on local authority district level 1. More specifically, firstly the centroid of each post code is calculated. Then the distance between the air pollution monitor and the centre of the LAD is measured using the Euclidean distance[2]. Then the pollution in LAD level 1 is calculated as:

$$F(x,y) = \sum_{i=1}^{n} w_i f_i \qquad (25)$$

, where n is the number of scatter points in the set, f_i are the prescribed function values at the scatter points, which are the centroids of the local authority districts in our case, and w_i are the weight functions assigned to each scatter point. The classical form of the weight function is:

$$w_i = \frac{d_i^{-p}}{\sum_{j-1}^{n} d_j^{-p}} \qquad (26)$$

, where p is an arbitrary positive real number called the power parameter, typically p=2 is used. Nevertheless, p=3 is used similar to the study by Luechinger (2009), to map the cubic grids and d_i is the distance from the scatter point to the interpolation point calculated using

[2] This is simply a matter of applying Pythagoras' theorem and using Euclidean distance. The required distance is the hypotenuse of a triangle. The other two sides of that triangle are, respectively, ($e_2 - e_1$) and (n2 - n1), where e1 and e2 are the eastings of the two points, and n_1 and n_2 are their northings. The distance can be calculated by means of the following formula $dist = \sqrt{(eas_2 - eas_1)^2 + (nor_2 - nor_1)^2}$.

the Haversine formula.[3] However for presentations convenience the simple Euclidean distance is:

$$d_i = \sqrt{(x-x_i)^2 - (y-y_i)^2} \qquad (27)$$

, where (x,y) are the coordinates of the interpolation point and (x_i, y_i) are the coordinates of each scatter point. The weight function varies from a value of unity at the scatter point to a value approaching zero as the distance from the scatter point increases. The weight functions are normalized so that the weights sum to unity. Although the weight function shown above is the classical form of the weight function in inverse distance weighted interpolation, the following equation is used:

$$w_i = \frac{\left(\frac{R-d_i}{Rd_i}\right)^{-3}}{\sum_{j-1}^{n}\left(\frac{R-d_i}{Rd_i}\right)^{-3}} \qquad (25)$$

, where d_i is the distance from the interpolation point to scatter point i and R is the distance from the interpolation point to the most distant scatter point, and n is the total number of scatter points. This equation has been found to give superior results to the classical equation (Franke and Nielson, 1980). In this study weight function (25) is used, while in other studies the initial weight function (26) has been used (Currie and Neidell, 2005; Ferreira, 2013). Various researches used as distance threshold 20 kilometres. However, a major issue in measuring pollution in this way that the choice of 20 kilometres as the cutoff is arbitrary. To test the sensitivity of this assumption, pollution levels using distance cutoffs of 5 and 15

[3] Vincenty formula gives very similar results.

kilometres are also assigned and estimated as robustness tests similarly with the study by Currie and Neidell (2005).

The unique feature of these restricted Census data is that they provide information about the location of individual people's residence down to a disaggregated level which allows us to identify far more accurately than using other geographical references such as cities, counties or countries. In robustness checks we estimate separate regressions for weekly averages and one day lag of air pollution, quadratic term specification on income and air pollutants, urban and rural areas, age groups and sex. In table 1 the summary statistics of air pollutants, income and meteorological data are reported.

5. Empirical results and discussions

5.1 Air Pollution and Health Status

Equation (13) is estimated separately for each pollutant in order to disentangle their effects. In table 2 the estimates of health status with monthly averages are reported[4]. The air pollutants and income present the expected positive and negative signs respectively. Therefore a rise in air pollution increases the probability of health deterioration occurrence.

It should be noted that a positive sign implies a higher probability of worse health status as the self-reported health status is coded in BHPS from 1-excellent- to 5 very poor health. Similarly, a negative sign implies an improvement on health. In addition, it should be noticed that the sum of non-movers and movers within Britain is not equal to total sample. The reason is that additional classes of moving status are included, as moving from abroad or unknown

[4] Based on Hausman test fixed effects are preferred to random effects.

status, which classes are not useful for the analysis, because the main interest is the respondents who move across Britain.

Age has a negative impact on health status as it was expected. This implies that a higher probability of health problems in old age means that health status becomes more important with age. People generally encounter deterioration in health with old age; however this does not imply that the decline in health with age is experienced at the same rate by individuals neither implies that it is homogenous for all people. Moreover, not all the people are willing to pay the same amount for an improvement on health status. Nevertheless, the results regarding slope heterogeneity are reported in a later part of this section.

Regarding household size its impact on health status is positive. The literature provides evidence that family support and size can be protective and beneficial to people with a chronic illness (Aldwin and Greenberger, 1987; Doornbos, 2001). Moreover, it should be noticed that the health status in this study examined is general and includes many cases (ie. Mental health, respiratory and cardiovascular diseases among others). Therefore, household size and support can be a proxy for home health care indicating that home health care substitutes for medical care obtained on the market and improves people's health leaving on families with big size than people who do not.

A strong relationship between socio-economic status (SES) and health status has been found in previous researches, which is important to health not only for those people in poverty, but at all levels of SES. On average, the more advantaged individuals are, the better their health, especially for the well educated people belonging in higher income classes. Based on the results of table 2 the respondents who are employed, unemployed and retired present a lower level of health than the self-employed individuals. This can be explained by various facts as the unemployed are more depressed if they are unable to find a job, and especially the long-run unemployed, while the employed might be more stressed and have less freedom than self employed. Also this can be explained by the fact that employed can have lower income, without this to be strictly necessary. However, this is not examined as it is out of the scope of this study. Finally, retired people might have more health problems, reflecting their old age which implies additional health problems. The results in table 2 show that living as a couple and being divorced has not difference on the health status with the respondents who are married. However, being widowed has significant negative effects on health status. People who own the house with mortgage have significant lower health status levels than the people who own out-rightly the house. Moreover, the health deteriorates for the people who rent the house from employer or they privately rented unfurnished house. The education level it seems it is a important factor as the respondents with A level education have lower health level than the people who earned a higher than first undergraduate university degree. However, the results show that the health status is not statistically different between respondents who earned a higher degree, the individuals with a first undergraduate degree and individuals with teaching qualifications. The results are consistent with other studies (Benzeval et al. 2000; Prus 2001; Robert and Li 2001; Beckett and Elliott 2002; Bostean 2010). Finally, the non-smokers present a better health status.

The effects of wind speed, precipitation, minimum and maximum temperature on health status are negative, while average temperature has positive impact on health. This can be explained that even wind speed and precipitation clean the air pollutants; wind speed implies lower temperature which leads to additional health problems. In addition, precipitation has negative impact on health status which might come from the fact that rainfall and acid rain included chemical compounds and air pollutants including CO and O_3. High frequencies of acid rain might have a negative effect on health condition of human.

Similarly, the effects of maximum temperature on health status are negative and significant, as higher temperature is associated with higher air pollution concentration levels.

However, the average temperature contributes positively on health status, which implies better environmental and weather conditions for individuals, including sun days, especially those with health problems. However, the temperature does not have monotonic effects on health status as it is shown by the maximum temperature.

The next step is to compute the marginal willingness-to-pay (MWTP). This is the level of household income that makes individuals indifferent to a drop of a unit in a pollutant. The average MWTP for CO is 0.066, 0.0716 and 0.0092 per cent for the total, non-movers and movers sample respectively. Regarding O_3 the MWTP is higher and equal at 0.0798, 0.0832 and 0.0158 per cent for the total, non-movers and movers sample respectively.

The average marginal willingness-to-pay (MWTP) in monetary values for a reduction in CO of a one unit is £19, £21 and £3 per year for total, non-movers and movers sample respectively as it is shown in table 2. The respective figures are £23, £25 and £5 for O_3. However, the MWTP for the movers sample in the case of CO is insignificant as the coefficient of air pollutant is insignificant too.

In table 3 the results from BUC and GMM are reported. Regarding the BUC estimates the estimates are consistent with those found in table 2 and the signs are the same. However, the main difference is that the coefficient for individuals who are divorced becomes significant. Moreover, the magnitude of the coefficients is larger than in adapted Probit-OLS as BUC is based on conditional logit binary regression. However, the main interest is the MWTP. In that case is very similar and it is £20 and £24 for CO and O_3 respectively. Regarding GMM estimates, in the case of both air pollutants the coefficient of health status with one lag has a negative sign and it is significant. Similarly, the coefficient of air pollutants is positive and significant. The results of table 3 are useful to explore the adaptation level, when the air pollution is taken into consideration. The parameter of the dependent variable with one lag indicates the extent to which an individual changes his or her adaptation level and adapts to living conditions represented by the stimulus level in the preceding period. More, specifically, the coefficient of the one lagged health status in table 3 ranges between 0.4808-0.4812. Therefore, the adaptation level at present is a weighted average where living conditions in the previous period are weighted at approximately 48 per cent, while the previous adaptation level is weighted at 52 per cent. Therefore, the individual's expectations about health status at the present level are shaped significantly by the living conditions both in the current and the previous period. The MWTP for a unit drop in CO and O_3 is respectively £22 and £27.

In table 4 the Chamberlain binary conditional fixed effects Logit and ordered Logit panel regressions are reported to compare the results with those derived from the previous approaches. The first approach gives very similar results and MWTP are very close with those derived by adapted Probit OLS in table 2. More specifically, MWTP monetary value is £21 and £23 for CO and O_3 respectively. Regarding ordered Logit the main difference is that all the coefficients are significant indicating that all determinants are important for the health status of individuals. However, it should be noticed that a drawback of ordered Logit regression is that is based on random effects. The commonly used ordered probit and logit models to identify equation (12), might lead to biased results in the coefficients of the health status determinants, which is caused by ignoring time-invariant individual factors. However, the MWTP is very similar with GMM estimates and it is £22 and £26 for CO and O_3 respectively.

In table 5 the latent class ordered probit regressions for the CO and O_3 respectively are presented. Using conventional fixed or random effects corrects for intercept heterogeneity. However, latent class models allow the parameters of the unobserved (latent) individual utility function to differ across individuals i.e. slope heterogeneity (Tinbergen 1991; Clark et al. 2005). Based on the results of table 5 it becomes clear that both air pollutants have significant effects in all classes. Additionally, the effects become stronger, as well, as the

MWTP is increased in class 4 (poor health status) followed by class 3 (fair health status), while the lowest values of MWTP are observed in classes 1 (excellent health status) and 2 (good health status). The latent class models allow for slope heterogeneity; therefore it is possible to examine for differences of air pollution and income effects on health. Thus different MWTP are assigned in each class. The results indicate that the respondents with poorer health status are willing to pay more-for a drop in a unit of air pollution-than the respondents with good self-assessed health status. It should be noticed that the MWTP in each case is calculated based on income in every class. Additionally, the membership of class 1 is 22.87 per cent while the memberships for classes 2-4 are 45.61, 21.28 and 7.9 per cent respectively. Age is not homogenous in health status groups as it becomes more important factor for those with poor self reported health status. Similarly smoking becomes more important as long as the respondents' health status is declined. Regarding the weather variables the effects remain the same as the findings shown before. Household size has positive effects on health status in all classes; however it seems that the effects are more important in class 1 when the O_3 is examined. The job status remains a very important factor for the health status in all classes. Nevertheless, being unemployed, employed and retired the health status is less than individuals who are self-employed and the effects are increased with the individuals' self-reported health status. Marital status is another important determinant of health status. More specifically, based on the results of table 5 widowed and divorced respondents are more likely to report a lower health status than the married people, but it is only significant for the classes 2 and 3. Similarly, living as a couple implies a lower level in health status than people who are married and it is only significant for classes 2 and 3. Regarding tenure, individuals who responded that they own the house with mortgage or rent by employer or rented privately unfurnished, have a lower health status than the respondents who out-rightly own the house. Finally, the health status between respondents with higher degree, first undergraduate degree or with a teaching qualification is not statistically different. Nevertheless, the health status for individuals with A level education is lower than the respondents who earned or are in a possession of a higher degree. Overall, the results show that O_3 and CO present negative effects on health status and the MWTP for both pollutants is very similar across various and different econometric techniques.

In table 6 the regression results for robustness checks are reported. Regarding the weekly averages in Panel A the air pollutants present significant effects, while the effects become insignificant when the daily air pollution levels one day prior to interview are taken into consideration. This is expected, as the health status is an accumulative process rather than an instantaneous, with the exception of people who suffer from specific cardiovascular diseases and only during high polluted days, which is rather rare in UK. More over the results using weekly averages of air pollution are almost identical with those derived using monthly averages. Panel B presents the results for the respondents who are located within 15 and 5 kilometres from the air monitoring stations based on the IDW method. The results for 15 kilometres are almost identical with those in table 2, while as it was expected the effects of air pollutants on health status becomes stronger and the MWTP is increased to £23 and £26 for O_3 and CO respectively. Panel C summarises the estimates for urban and rural areas. It becomes clear that stronger effects are reported in urban areas as it was expected, based on the MWTP, because especially O_3 is the prime ingredient of smog which is observed mainly in the urban areas. In Panel D other specifications of the air pollutants and income are examined, as quadratic, instead of linear terms, but the coefficients of the air pollution are found to be insignificant. On the contrary, when the quadratic term of the income is introduced into the regressions it becomes significant. This shows that the relationship between health status and income is rather quadratic than monotonic. More specifically the linear term of income is positive indicating negative effects on health status. This implies that in the low income is not enough to improve health status, which the latter depends on additional expenses on medical care including therapies, medicine and visits on general and special practitioners among others. More specifically, the turning points for O_3 and CO are respectively £12,770 and £12,517, implying that the income has a positive effect on health status after these turning points. In panel E the estimates for male and female separately are reported. The results show that income is more important factor for men, while the air pollutants are more important factors for women. In addition, the MWTP for CO and men is £16 while for women is increased at £27. Similarly the MWTP for O_3 is less for men and it is equal at £22, while for women is £28. Finally, in panels F1-F2 the estimates for various age groups are reported. The findings support that the individuals in the age groups 25-44 and 45-64 are willing to pay more than the other groups followed by the older aged people and the young. However, it should be noticed that the monetary values of MWTP are not as important as MWTP are. More specifically, based on table 8 the MWTP for example age group 65 and older and O_3 is 0.0931, while the MWTP for age groups 45-64 and 25-44 are 0.0907 and 0.0825 per cent respectively. However, in order to estimate the average MWTP monetary values the average household income is considered. Thus the household income per month ranges between £2,600-£2,700 for the age groups 45-64 and 25-44, while the average household income for people 5 years old and older is roughly £1,800.

5.2 Air Pollution, Health Status and Visits to GP

In table 7 the results of Fixed Effects Model (23) are reported. The sign of the coefficients is similar with those presented in the previous tables. More specifically, a higher household income and size implies a reduction of in-patient days in NHS hospital. Individuals with poor health status stay on average 8 days more in hospital than individuals with good health status.

The number of days is increased at 9 for the movers sample. The average temperature has positive effects on health as it has been shown previously, leading to a decrease of in-patient days in hospital, while minimum and maxim temperature, wind speed and precipitation result to an increase to hospitalisation days. Therefore, controlling for meteorological variables is important as these are significant determinants of health status. Being smoker increases the number of hospitalisation days as well as being unemployed and retired. Living as a couple or being divorced has no difference in the hospitalisation days relatively with the married couples. However, widowed individuals are hospital in-patients by 1 and 2 days more for the non-movers and movers sample respectively than the married couple. Without be a rule, widowed people are usually old age people, as retired individuals are, reflecting the importance of age in determining the health status. More specifically, the 89 per cent of the total sample being widowed is 60 years old and older, while only 11 per cent is less than 60 years old. Regarding house tenure individuals owing the house with mortgage present a higher number of in-patient days in hospital than people who own out rightly the house. Lastly, there is no difference in the number of days among individuals with different education level, with the exception of people with *A* level education for the total and the movers sample.

In table 8 the multinomial Logit model for the number of visits in GP are reported. More specifically, classes are the following: class 2 (one or two visits), class 3 (three to five visits), class 4 (six to ten visits) and class 5 (more than ten visits). The reference outcome is class 1 (no visit). As it was expected, individuals with poor health status (classes 4 and 5) are visiting GP by 7 and 11 times more than people with excellent health status (class 1). Additionally, the results show that age is an important determinant of visit GP as the coefficient are significantly higher in classes 4 and 5 and different than the rest of the classes. Therefore, old aged people face higher health problems. Similarly, the weather factors play a more important role in health status and number of visits in GP for people with poor health status. More specifically, the coefficients for average, minimum and maximum temperature and wind speed are significantly higher in classes 4 and 5. More over, the average temperature has no different effects in classes 2-3 relatively to the reference class 1. In addition, there is no difference on precipitation effects between classes 2-4 and the reference class 1, while the precipitation coefficient becomes significant in class 5. Thus, higher levels of precipitation, which include air pollutants, imply that precipitation is an important determinant for people with poor health status leading to additional visits to GP increasing the costs for NHS. Household size in all cases leads to a reduction of GP visits and its effects become significantly stronger for poor health individuals belonging in classes 4 and 5. This is consistent with the previous literature that that family support and size can be protective and beneficial to people with a chronic illness and poor health (Aldwin and Greenberger, 1987; Doornbos, 2001). Regarding the SES and specifically, the job status employed, unemployed and retired present a higher frequency of GP visits than self-employed. The effects are significantly higher for retired people. Concerning the marital status there is no difference between classes 1 and 2 of living as a couple or being widowed or divorced. However, being widowed becomes significant for classes 3-5 and being divorced becomes significant in classes 3-4. Finally, living as a couple, in class 5, is more likely to visit more frequently GP than in reference class 1. House tenure and specifically, renting the house from employer or privately increases the probability of GP visits in classes 4-5. Lastly, education level show no difference in GP visits among classes, with the exception of class 5 where individuals with A level education are more likely to visit GP than more educated people.

In table 9 the MWTP and its monetary value for number of in-patient days in hospital GP are presented. The relation (12) based on the results of tables 2 and 7 is used. Based on NHS (2010) the national average cost of an elective (planned) inpatient stay excluding excess bed days is £2,749, while the cost for non-elective (unplanned) is £527 for short stays and £2,197 for long stays. In the case examined only 1 inpatient day is taken into consideration as it is unknown from the data how many consecutively days the individual was inpatient. Therefore, as it was mentioned before, a person with poor health status stays on average 8 days more than a person with good health status. In the case of table 9 the possible fee of £20 per stay proposed by Lord Warner a former Labour health minister Borland (2014) is implemented.

Using the information provided by UK Government the minimum wage in 2010 was 5.5 (https://www.gov.uk/national-minimum-wage-rates). This is a very simplified example and minimum wage is used as the opportunity cost for being in hospital instead of working. Moreover the fee of £20 is equivalent with almost 2.5 working hours paid in minimum hourly wage plus the three hours scenario which might be necessary for transportation, waiting and consultation time. Then the MWTP monetary value for a one-unit drop in CO per year is £137, £145 and £33 for total, non-movers and movers sample respectively, while the MWTP values for O_3 are £150, £159 and £60. Even if P_M is zero then the MWTP for the total sample becomes £95 and £98 for CO and O_3 respectively for a one unit decrease in air pollutants. Based the results of table 9 a reduction of roughly 5 units in air pollutants examined will be equal at the elective inpatient stay costs of £2,749 and 4 units for a non elective long stay. However, this is not precise, because the number of inpatient hospital days used in the regressions include both planned and unplanned stays and cover all the kinds of health episodes, as car and industrial accidents among others which are not caused from air pollution. Therefore, the estimates overestimate the effects of air pollution or in other words the reduction of air pollution is not realistic. However, this study suggests the examination of air pollution effects using detailed hospitalisation data. Therefore, examining the determinants of health status and especially the air pollution can be a very useful tool for policy makers on health care system. As the majority of the studies examine the effects of SES on health status and the age as the most important factors, air pollution effects on health status and health care system costs are neglected.

In table 10 the MWTP and its monetary value for number of visits in GP are presented. The relation (12) based on the results of tables 2 and 8 is used under two scenarios. The first is the case where P_M is equal at 3 hours, including transportation and waiting time. However, this is not definitely precise as the transportation time is varied between individuals and location. Also the transportation time cost is varied depending whether the individuals use car or public transit. Nevertheless, for simplicity 3 hours is used in the analysis.

From table 10 and panel A the MWTP expressed in monetary value for CO is £12, £26, £65 and £74 respectively for classes 2 (one or two visits), 3 (three to five visits), 4 (six to ten visits) and 5 (more than ten visits) per year. Similarly, the respective MWTP values for a one-unit drop in O_3 are £15, £29, £71 and £80. In panel B the results for the second scenario using a monthly fee of £10 proposed by Lord Warner as a possible candidate for using the NHS GP services are reported. In that case the monthly fee of £10 is equivalent to 1.8 working hours plus the three hours scenario taken as opportunity cost. For class 2 the MWTP for CO and O_3 are £22 and £27 respectively, while for class 3 are £53 and £58. Similarly, as in panel A, the individuals in classes 4 and 5 with poor self-reported health status are willing to pay higher amounts equal at £96 and £105 for CO and O_3 respectively for class 4 and £123 and £132 per year for CO and O_3 respectively for class 5. However, individuals with excellent, good and fair health status are willing to pay less for a one-unit decrease in air pollution as also they do not visit GP more than five times per year. Nevertheless, MWTP reported in table 10 are based on a one unit decrease. Thus, reducing air pollution by additional units people are willing to pay more. The conclusion is that policy makers can take measures to improve air quality resulting on inpatient days decrease and GP visits and reducing the cost of hospital in-patient days. Leger (2001) examined the relationship between O_3 and health status in Montreal of Canada during the period 1992-1993 found that for a 50 per cent reduction of ozone the MWTP is $1.50 per year, while when physical limitations and time off are included, this average willingness to pay for a 50 per cent reduction of ozone is almost $29.00 annually. In this study the MWTP for an inpatient day in hospital for a one unit reduction in pollution is £29, while for visits in GP ranges between £12-£265. The results are different for various reasons. Firstly, the findings have been inflated in 2009 the last year of the BHPS in order to have comparable estimates with the present values. Secondly, BHPS is a long panel capturing 18 years and Great Britain, instead of only one city as Montreal. Thirdly, the sample includes people from various socio-economic status and income. Fourthly, different classes of visits to GP are examined. Lastly, this study explores also the inpatient days cost in hospital as well as it accounts for the candidate fees for using GP and hospital stays.

This study examined only the general health status, therefore the results are not so precise, as it would be in the case where specific diseases are examined too, such as bronchitis, asthma, stroke, cancer, and other respiratory diseases, as well as, infant mortality. Therefore this study suggests the examination of specific illnesses. In addition, the MWTP for an inpatient day considers only one day stay in hospital, without considering additional days stay in. More precisely, additional days imply additional costs, but the precise data providing this information are not available.

6. Conclusions

This study has used a set of panel micro-data on self-reported health status from the British Household Survey. The results showed that the MWTP for a one unit drop in CO per year ranges between £122-£141, while the MWTP for O_3 ranges between £128-£149. In addition, various econometric techniques and different cases have been employed in order to account for issues on endogeneity and self reported answers. Moreover, various cases have been examined in order to calculate the MWTP, as the urban versus rural areas, gender and age groups showing differences in MWTP depending on the period and the characteristics of the area.

The approach followed in this study has been used to assess how willingness to pay varies over time and by region, age, income, education and level of pollution among others. Additionally, one very strong and useful point of this approach is that the estimated coefficients can be used to calculate the marginal rate of substitution between income and air quality directly, and thus it does not suffer from the contingent valuation problem of large gaps between stated willingness to pay and willingness to accept. Moreover, this approach can be very helpful in environmental and economic policy planning and decisions. Generally, the results show this approach contains very useful information on individuals' preferences and at the same time expands the economic tools in the area of non-market evaluation. Lastly, considering that the inpatient stay cost per day is £2,749, a 5 unit decrease in air pollutants will lead to a MWTP equivalent to the inpatient cost.

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Table 1. Summary statistics of income and air pollutants

Variables	*Mean*	*Standard Deviation*	*Minimum*	*Maximum*
Personal income	1,122.863	1,166.68	0.0	72,176.51
Household income	2,465.564	1,965.826	0.0	86,703.29
Ozone (O_3)	35.314	17.357	0.0	124
Carbon Monoxide (CO)	0.418	0.375	0.0	6.7
Average temperature	50.368	7.342	13	81.4
Wind speed	8.374	4.037	0.0	35.2
Precipitation	3.531	1.587	0.69	6.800
Minimum Temperature	44.593	4.022	31.385	53.206
Maximum Temperature	55.725	3.947	41.806	63.667

* The air pollutants are measured in micrograms per cubic meter (µg/m^3)

Table 2. Health Status Regressions for Monthly Averages

Model	(1)	(2)	(3)	(4)	(5)	(6)
		CO			O_3	
Household Income	-0.0150	-0.0126	-0.0338	-0.0149	-0.0128	-0.0337
	(0.0067)**	(0.0061)**	(0.0157)**	(0.0060)**	(0.0054)**	(0.0162)**
Air Pollutant	0.0098	0.0103	0.0023	0.0108	0.0114	0.0040
	(0.0043)**	(0.0049)**	(0.0022)	(0.0048)**	(0.0052)**	(0.0021)*
Age	0.0113	0.0098	0.0126	0.0109	0.0093	0.0117
	(0.0052)**	(0.0046)**	(0.0054)**	(0.0049)**	(0.0043)**	(0.0057)**
Average Temperature	-0.0055	-0.0067	0.0070	-0.0067	-0.0072	-0.0088
	(0.0027)**	(0.0031)**	(0.032)**	(0.0038)*	(0.0033)**	(0.0149)
Minimum Temperature	0.0088	0.0101	0.0019	0.0094	0.0114	0.0015
	(0.0042)**	(0.0052)*	(0.0184)	(0.0044)**	(0.0061)*	(0.0189)
Maximum Temperature	0.0118	0.0148	0.0096	0.0117	0.0152	0.0100
	(0.0065)*	(0.0064)**	(0.0309)	(0.0051)**	(0.0072)**	(0.0325)
Wind Speed	0.0209	0.0400	0.0673	0.0212	0.0365	0.0742
	(0.0092)**	(0.0125)***	(0.0369)*	(0.0100)**	(0.0134)***	(0.0496)*
Precipitation	0.0100	0.0112	0.0187	0.0092	0.0106	0.0175
	(0.0118)	(0.0157)	(0.0428)	(0.0131)	(0.0163)	(0.0470)
Smoker (No)	-0.0162	-0.0124	-0.0208	-0.0159	-0.0174	-0.0317
	(0.0074)**	(0.0057)**	(0.0102)**	(0.0074)**	(0.0079)**	(0.0145)**
Household size	-0.0041	-0.0037	-0.0304	-0.0043	-0.0032	-0.0311
	(0.0020)**	(0.0018)**	(0.0176)*	(0.0020)**	(0.0014)**	(0.0178)*
Job Status (ref=self-employed)						
Job Status (Unemployed)	0.108	0.118	0.0104	0.106	0.112	0.0296
	(0.0195)**	(0.0207)***	(0.1101)	(0.0207)***	(0.0221)***	(0.1121)
Job Status (Employed)	0.0283	0.0348	-0.0425	0.0325	0.0410	-0.0474
	(0.0139)**	(0.0149)**	(0.0884)	(0.0148)**	(0.0157)**	(0.0872)
Job Status (Retired)	0.158	0.154	0.342	0.163	0.162	0.301
	(0.0202)***	(0.0212)***	(0.186)*	(0.0213)***	(0.0212)***	(0.166)*
Marital Status (ref=married)						
Marital Status (Living as couple)	-0.0451	-0.0595	0.0676	-0.0497	-0.0668	0.0789
	(0.0451)	(0.0553)	(0.4455)	(0.0430)	(0.0585)	(0.4556)
Marital Status (Widowed)	0.0298	0.0185	0.1063	0.0233	0.0174	0.1132
	(0.0139)**	(0.0087)**	(0.4410)	(0.0112)**	(0.0082)**	(0.4493)
Marital Status (Divorced)	0.0422	0.0321	0.0861	0.0420	0.0373	0.0808
	(0.0517)	(0.0425)	(0.5211)	(0.0540)	(0.0486)	(0.0639)
Tenure (ref=owned outright)						
Tenure house	0.0163	0.0221	0.1406	0.0161	0.0202	0.1472
(Owned with mortgage)	(0.093)*	(0.0110)**	(0.0663)**	(0.092)*	(0.0117)*	(0.0675)**
Tenure house	0.0558	0.0421	-0.179	0.0584	0.0564	-0.155
(Rented from Employer)	(0.0330)*	(0.0243)*	(0.0092)*	(0.0350)*	(0.0329)*	(0.0842)*
Tenure house	0.0561	0.0558	0.1110	0.0549	0.0518	0.1094
(Rented Private Unfurnished)	(0.0204)***	(0.0287)*	(0.0675)	(0.0212)**	(0.0315)*	(0.0684)
Education (ref=Higher degree)						
Education Level (First Degree)	-0.0668	-0.0643	-0.0362	-0.0558	-0.0491	-0.0421
	(0.0427)	(0.0392)	(0.1649)	(0.0463)	(0.0523)	(0.1607)
Education Level	0.0773	0.0882	0.0883	0.0569	0.0645	0.0991
(Teaching, HNC)	(0.0499)	(0.0552)	(0.2064)	(0.0544)	(0.0590)	(0.2034)
Education Level (A Level)	0.0132	0.0154	0.0367	0.0169	0.0216	0.0314
	(0.0072)*	(0.0081)*	(0.0151)**	(0.0437)	(0.0608)	(0.0137)**
No obs.	149,626	131,114	12,110	138,471	121,044	11,322
R square	0.5374	0.5423	0.4953	0.5375	0.5423	0.4938
MWTP	0.0660	0.0716	0.0092	0.0798	0.0832	0.0158
MWTP for a drop of one unit per year	£19	£21	£3	£23	£25	£5

Standard errors between brackets, clustered standard errors on local authority districts
(1) and (4) refer to total sample, (2) and (5) refer to non-movers, (3) and (6) refer to movers within GB
***, ** and * indicate significance at 1%, 5% and 10% level

Table 3. BUC and GMM System Health Status Regressions for Non-Movers

Variables	CO	O_3	CO	O_3
	BUC		*GMM System*	
Health Status t-1			-0.4812	-0.4808
			(0.0101)***	(0.0101)***
Household Income	-0.0138	-0.0137	-0.0159	-0.0161
	(0.0064)**	(0.0062)**	(0.0065)***	(0.0062)***
Air Pollutant	0.0101	0.0111	0.0127	0.0132
	(0.0061)**	(0.0046)**	(0.0061)**	(0.0054)**
Age	0.0092	0.0089	0.0083	0.0083
	(0.0045)**	(0.0041)**	(0.0006)***	(0.0006)***
Average Temperature	-0.0071	-0.0091	-0.0105	-0.0105
	(0.0033)**	(0.0038)**	(0.0029)***	(0.0029)***
Minimum Temperature	0.0118	0.0154	0.0112	0.0121
	(0.0062)*	(0.0081)*	(0.0052)**	(0.0054)**
Maximum Temperature	0.0155	0.0165	0.0104	0.0101
	(0.0077)**	(0.0081)**	(0.0044)**	(0.0045)**
Wind Speed	0.0426	0.0418	0.1154	0.1211
	(0.0161)***	(0.0159)***	(0.0122)***	(0.0124)***
Precipitation	0.0192	0.0190	0.0236	0.0234
	(0.0109)*	(0.0105)*	(0.0047)***	(0.0047)***
Smoker (No)	-0.0187	-0.0194	-0.0175	-0.0179
	(0.0091)*	(0.0092)**	(0.0047)***	(0.0048)***
Household size	-0.0043	-0.0041	-0.0046	-0.0048
	(0.0019)**	(0.0018)**	(0.0019)**	(0.0020)**
Job Status (ref=self-employed)				
Job Status (Unemployed)	0.1355	0.1548	0.1891	0.1861
	(0.0215)***	(0.0226)***	(0.0224)***	(0.0214)***
Job Status (Employed)	0.0418	0.0431	0.0385	0.0374
	(0.0198)**	(0.0205)**	(0.0162)**	(0.0157)**
Job Status (Retired)	0.164	0.168	0.293	0.226
	(0.0206)***	(0.0202)***	(0.0314)***	(0.0319)***
Marital Status (ref=married)				
Marital Status (Living as couple)	-0.0492	-0.0678	-0.0514	-0.0507
	(0.0384)	(0.0435)	(0.0441)	(0.0433)
Marital Status (Widowed)	0.0164	0.0155	0.0231	0.0226
	(0.0092)*	(0.0075)**	(0.0123)*	(0.0105)**
Marital Status (Divorced)	0.0612	0.0655	0.0619	0.0626
	(0.0498)	(0.0421)	(0.0423)	(0.0425)
Tenure (ref=owned outright)				
Tenure house (Owned with mortgage)	0.0262	0.0326	0.0317	0.0314
	(0.0121)**	(0.0146)**	(0.0146)**	(0.0145)**
Tenure house (Rented from Employer)	0.0438	0.0454	0.0408	0.0409
	(0.0223)*	(0.0142)***	(0.0128)***	(0.0128)***
Tenure house (Rented Private Unfurnished)	0.0539	0.0583	0.0672	0.0689
	(0.0225)**	(0.0275)**	(0.0332)**	(0.0337)**
Education (ref=Higher degree)				
Education Level (First Degree)	-0.0633	-0.0619	-0.0762	-0.0750
	(0.0421)	(0.0515)	(0.0479)	(0.0479)
Education Level (Teaching, HNC)	0.0758	0.0733	0.0820	0.0793
	(0.0482)	(0.0450)	(0.0384)**	(0.0385)**
Education Level (A Level)	0.0225	0.0227	0.0265	0.0266
	(0.0115)*	(0.0116)*	(0.0106)**	(0.0112)**
No obs.	133,031	123,310	112,326	102,797
Pseudo R Square	0.1329	0.1328		
Wald Statistic			8,251.96	8,224.21
			[0.000]	[0.000]
P-value for Sargan Statistic endogeneity			0.076	0.078
P-value for weak instrument test			0.442	0.421
P-value for Arellano-Bond test for AR(2)			0.257	0.253
MWTP	0.0701	0.0826	0.0733	0.0847
MWTP for a drop of one unit per year	£20	£24	£22	£27

Standard errors between brackets, p-values between square brackets,
***, ** and * indicate significance at 1%, 5% and 10% level

Table 4. Chamberlain Conditional Logit Fixed Effects and Ordered Logit Health Status Regressions for Non-Movers

Variables	CO	O_3	CO	O_3
	Chamberlain		*Ordered Logit*	
Household Income	-0.0152	-0.0148	-0.0198	-0.0201
	(0.0073)**	(0.0071)**	(0.0064)***	(0.0062)***
Air Pollutant	0.0122	0.0128	0.0141	0.0147
	(0.0059)**	(0.0057)**	(0.0077)*	(0.0065)**
Age	0.0099	0.0103	0.0101	0.0097
	(0.0044)**	(0.0045)**	(0.0006)***	(0.0006)***
Average Temperature	-0.0117	-0.0124	-0.0115	-0.0140
	(0.0052)**	(0.0054)**	(0.0049)***	(0.0049)***
Minimum Temperature	0.0216	0.0219	0.0224	0.0233
	(0.0052)**	(0.0059)**	(0.0074)**	(0.0073)***
Maximum Temperature	0.0164	0.0160	0.0256	0.0253
	(0.0073)**	(0.0072)**	(0.0076)***	(0.0073)***
Wind Speed	0.0760	0.0658	0.1016	0.1159
	(0.0353)**	(0.0336)*	(0.0266)***	(0.0262)***
Precipitation	0.00156	0.0152	0.0495	0.0480
	(0.0081)*	(0.0082)*	(0.0142)***	(0.0136)***
Smoker (No)	-0.0102	-0.0101	-0.0370	-0.0358
	(0.0055)*	(0.0055)*	(0.0029)***	(0.0032)***
Household size	-0.0104	-0.0110	-0.0125	-0.0154
	(0.0049)**	(0.0053)**	(0.0021)***	(0.0032)***
Job Status (ref=self-employed)				
Job Status (Unemployed)	0.2830	0.2831	0.5125	0.5004
	(0.0640)***	(0.0666)***	(0.0358)***	(0.0372)***
Job Status (Employed)	0.1015	0.1092	0.1131	0.1077
	(0.0470)*	(0.0490)**	(0.0215)***	(0.0233)***
Job Status (Retired)	0.2717	0.2831	0.6085	0.6140
	(0.0550)***	(0.0562)***	(0.0266)***	(0.0278)***
Marital Status (ref=married)				
Marital Status (Living as couple)	-0.1392	-0.1721	0.3804	0.3485
	(0.2041)	(0.2083)	(0.1078)***	(0.1117)***
Marital Status (Widowed)	0.0120	0.0125	0.4170	0.3830
	(0.0053)**	(0.0054)**	(0.1086)***	(0.1124)***
Marital Status (Divorced)	0.0223	0.0255	0.4197	0.4003
	(0.0205)	(0.0218)	(0.1099)***	(0.1139)***
Tenure (ref=owned outright)				
Tenure house (Owned with mortgage)	0.0427	0.0482	0.1180	0.0973
	(0.0230)*	(0.0253)*	(0.0150)***	(0.0155)***
Tenure house (Rented from Employer)	0.1281	0.1544	0.1804	0.1884
	(0.0673)*	(0.0782)**	(0.0665)***	(0.0689)***
Tenure house (Rented Private Unfurnished)	0.0621	0.0617	0.2683	0.2413
	(0.0318)*	(0.0305)**	(0.0440)***	(0.0450)***
Education (ref=Higher degree)				
Education Level (First Degree)	-0.0745	-0.0898	-0.1165	-0.1206
	(0.1580)	(0.1661)	(0.0712)	(0.0820)
Education Level (Teaching, HNC)	0.0532	0.0619	0.0863	0.0720
	(0.1873)	(0.1970)	(0.0475)*	(0.0435)*
Education Level (A Level)	0.0208	0.0202	0.1243	0.1321
	(0.0092)**	(0.0096)**	(0.0597)**	(0.0655)**
No obs.	100,195	92,167	112,326	121,046
LR chi-square	1,599.80	1,438.25	8,251.96	8,768.76
	[0.000]	[0.000]	[0.000]	[0.000]
MWTP	0.0708	0.0812	0.0736	0.0852
MWTP for a drop of one unit per year	£21	£23	£22	£26

Standard errors between brackets, p-values between square brackets,
***, ** and * indicate significance at 1%, 5% and 10% level

Table 5. Latent Class Generalized Ordered Probit Health Status Regressions for Non-Movers

	CO				O_3			
	Class 1	Class 2	Class 3	Class 4	Class 1	Class 2	Class 3	Class 4
Household Income	-0.0123 (0.0032)***	-0.0108 (0.0043)**	-0.0134 (0.0039)***	-0.0139 (0.0056)**	-0.0118 (0.0046)**	-0.0127 (0.0065)**	-0.0129 (0.0051)**	-0.0143 (0.0065)**
Air Pollutant	0.0068 (0.0018)***	0.0079 (0.0012)***	0.0113 (0.0054)**	0.0130 (0.0032)***	0.0074 (0.0034)**	0.0083 (0.0039)**	0.0119 (0.0066)***	0.0133 (0.0009)***
Age	0.0096 (0.0022)***	0.0101 (0.0008)***	0.0144 (0.0066)***	0.0168 (0.0069)***	0.0087 (0.0013)***	0.0098 (0.0008)***	0.0171 (0.0006)***	0.0208 (0.0007)***
Average Temperature	-0.0065 (0.0028)***	-0.0069 (0.0031)**	-0.0058 (0.0026)**	-0.0060 (0.0031)*	-0.0119 (0.0023)***	-0.0099 (0.0024)***	-0.0071 (0.0029)**	-0.0067 (0.0032)**
Minimum Temperature	0.0242 (0.0050)***	0.0097 (0.0049)***	0.0178 (0.0063)*	0.0111 (0.0032)***	0.0108 (0.0044)**	0.0071 (0.0033)**	0.0099 (0.0048)**	0.0140 (0.0008)***
Maximum Temperature	0.0134 (0.0022)***	0.0109 (0.0051)**	0.0152 (0.0066)***	0.0171 (0.0062)***	0.0110 (0.0051)**	0.0093 (0.0045)**	0.0098 (0.0046)**	0.0081 (0.0037)**
Wind Speed	0.0250 (0.0080)***	0.0376 (0.0079)***	0.0165 (0.0099)*	0.0159 (0.0080)*	0.0508 (0.0242)**	0.0501 (0.0241)**	0.0349 (0.0160)**	0.0235 (0.0113)**
Precipitation	0.0345 (0.0108)***	0.0268 (0.0106)***	0.0207 (0.0130)	0.0103 (0.0051)*	0.0059 (0.0042)	0.0152 (0.0058)***	0.0182 (0.0068)***	0.0096 (0.0117)
Smoker (No)	-0.0255 (0.0123)**	-0.0281 (0.0139)**	-0.0297 (0.0148)**	-0.0286 (0.0141)**	-0.0255 (0.0122)**	-0.0296 (0.0147)**	-0.0314 (0.0151)**	-0.0307 (0.0152)**
Household size	-0.0052 (0.0012)***	-0.0050 (0.0023)**	-0.0040 (0.0021)*	-0.0041 (0.0019)**	-0.0116 (0.0024)***	-0.0091 (0.0043)**	-0.0074 (0.0035)**	-0.0033 (0.0014)**
Job Status (Unemployed)	0.2081 (0.0383)***	0.3423 (0.0302)***	0.3519 (0.0422)***	0.2390 (0.0821)***	0.2141 (0.0341)***	0.3589 (0.0323)***	0.3998 (0.0454)***	0.3592 (0.0309)***
Job Status (Employed)	0.1316 (0.0210)***	0.0782 (0.0216)***	0.0749 (0.0317)**	0.1092 (0.0629)*	0.1129 (0.0226)***	0.0704 (0.0236)***	0.0845 (0.0349)**	0.1945 (0.0716)***
Job Status (Retired)	0.2768 (0.0274)***	0.3423 (0.0302)***	0.3519 (0.0422)***	0.4633 (0.0679)***	0.3150 (0.0299)***	0.4071 (0.0290)***	0.3998 (0.0456)***	0.5585 (0.0770)***
Marital Status (Living as couple)	-0.0840 (0.0899)	0.1792 (0.1045)*	0.5443 (0.0202)***	0.2212 (0.3846)	- 0.1475 (0.957)	0.1724 (0.1027)*	0.5777 (0.2065)***	0.2101 (0.3922)
Marital Status (Widowed)	0.0349 (0.0898)	0.2858 (0.1045)***	0.6440 (0.200)***	0.3532 (0.3856)	0.0071 (0.0077)	0.2960 (0.1097)***	0.6792 (0.2067)***	0.3604 (0.3930)
Marital Status (Divorced)	0.0017 (0.0931)	0.3115 (0.1074)***	0.7571 (0.2022)***	0.4844 (0.3869)	0.1107 (0.0551)**	0.2817 (0.1131)**	0.7670 (0.2098)***	0.4498 (0.3947)
Tenure house (Owned with mortgage)	0.0345 (0.0156)**	0.0581 (0.0151)***	0.0830 (0.0200)***	0.1152 (0.0328)***	0.0309 (0.0149)**	0.0681 (0.0164)***	0.1057 (0.0217)***	0.1231 (0.0353)***
Tenure house (Rented from Employer)	0.0296 (0.0553)	0.1627 (0.0561)***	0.1210 (0.0824)	0.1240 (0.1567)	0.0598 (0.0295)**	0.1804 (0.0609)***	0.2960 (0.0274)***	0.1712 (0.1645)
Tenure house (Rented Private Unfurnished)	0.1005 (0.0298)***	0.2172 (0.0294)***	0.1179 (0.0411)***	0.1494 (0.0708)**	0.1059 (0.0318)***	0.2280 (0.0315)***	0.3267 (0.0362)***	0.1307 (0.0757)*
Education Level (First Degree)	-0.0792 (0.0496)	-0.0738 (0.0536)	-0.0215 (0.0723)	-0.0684 (0.1147)	-0.0153 (0.0516)	0.0076 (0.0557)	0.1148 (0.0777)	0.1311 (0.1286)
Education Level (Teaching, HNC)	0.0105 (0.0530)	0.0049 (0.0566)	0.0926 (0.0748)	0.0392 (0.1179)	0.0290 (0.0560)	0.0194 (0.0602)	0.1428 (0.0818)*	0.0758 (0.1321)
Education Level (A Level)	0.0902 (0.0489)*	0.0974 (0.0527)*	0.1545 (0.0701)**	0.0237 (0.1093)	0.1527 (0.0510)***	0.1856 (0.0549)***	0.3072 (0.0757)***	0.2516 (0.1225)**
No obs.	133,031				121,044			
LR chi-square	4,560.80 [0.000]				4,469.52 [0.000]			
MWTP	0.0495	0.0607	0.0834	0.0872	0.0493	0.0605	0.0868	0.0886
MWTP for a drop of one unit per year	£15	£18	£24	£26	£15	£18	£26	£27

Standard errors between brackets, p-values between square brackets, ***, ** and * indicate significance at 1%, 5% and 10% level

Table 6. Robustness Checks Health Status Regressions

Model	Ground-level ozone O_3	Carbon Monoxide CO	Ground-level ozone O_3	Carbon Monoxide CO
Panel A	*Weekly Averages*		*One day prior to interview*	
Household Income	-0.0127	-0.0126	-0.0145	-0.0139
	(0.0058)**	(0.0056)**	(0.0063)**	(0.0062)**
Air Pollutant	0.0101	0.0112	0.0023	0.0039
	(0.0048)**	(0.0054)**	(0.0042)	(0.0055)
MWTP	0.0714	0.0829	0.0197	0.0237
MWTP for a unit drop	£21	£25	£6	£7
Panel B	*Within 5 kilometres*		*Within 15 kilometres*	
Household Income	-0.0139	-0.0131	-0.0128	-0.0131
	(0.0065)**	(0.0059)**	(0.0058)**	(0.0059)**
Air Pollutant	0.0109	0.0123	0.0099	0.0115
	(0.0048)**	(0.0057)**	(0.0046)**	(0.0053)**
MWTP	0.0778	0.0878	0.0707	0.0825
MWTP for a unit drop	£23	£26	£21	£24
Panel C	*Urban Areas*		*Rural Areas*	
Household Income	-0.0136	-0.0132	-0.0119	-0.0122
	(0.074)**	(0.0079)**	(0.0059)**	(0.060)**
Air Pollutant	0.0127	0.0134	0.0028	0.0036
	(0.0056)**	(0.0592)**	(0.0015)*	(0.0020)*
MWTP	0.0907	0.0957	0.0273	0.0300
MWTP for a unit drop	£27	£28	£8	£10
Panel D	*Quadratic on Air Pollution*		*Quadratic on Income*	
Air pollutant	0.0075	0.0103	0.0082	0.0111
	(0.0036)**	(0.0054)*	(0.0039)**	(0.0053)**
Air pollutant square	0.0008	0.0026		
	(0.0021)	(0.0021)		
Household Income	-0.0125	-0.0141	0.0474	-0.0431
	(0.0072)**	(0.0073)**	(0.0233)**	(0.0191)**
Household Income square			-0.0034	0.0031
			(0.0016)**	(0.0016)*
Panel E	*Male*		*Female*	
Household Income	-0.0153	-0.0132	-0.0115	-0.0119
	(0.0072)**	(0.0057)**	(0.0051)**	(0.0053)**
Air Pollutant	0.0091	0.0106	0.0112	0.0118
	(0.0042)**	(0.0048)**	(0.0037)**	(0.0046)**
MWTP	0.0533	0.0794	0.0952	0.0950
MWTP for a unit drop	£16	£22	£27	£28
Panel F1	*Age 16-25*		*Age 25-44*	
Household Income	-0.0141	-0.0145	-0.0121	-0.0133
	(0.0062)**	(0.0063)**	(0.0054)**	(0.0062)**
Air Pollutant	0.0074	0.0105	0.0101	0.0114
	(0.0025)**	(0.0029)***	(0.0035)***	(0.0058)*
MWTP	0.0462	0.0700	0.0721	0.0825
MWTP for a unit drop	£14	£21	£21	£24
Panel F2	*Age 45-64*		*Age 65 and Older*	
Household Income	-0.0118	-0.0135	-0.0157	-0.0151
	(0.0051)**	(0.0062)**	(0.0069)**	(0.0062)**
Air Pollutant	0.0108	0.0118	0.0140	0.0149
	(0.0046)**	(0.0037)***	(0.0061)**	(0.0072)**
MWTP	0.0894	0.0907	0.0823	0.0931
MWTP for a unit drop	£26	£27	£18	£20

Standard errors between brackets, clustered standard errors on local authority districts
***, ** and * indicate significance at 1%, 5% and 10% level

Table 7. Number of Days In-patient in Hospital Regressions

Model	(1)	(2)	(3)
Household Income	-0.0260	-0.0269	-0.0518
	(0.0124)**	(0.0126)**	(0.0244)**
Health Status (Poor)	8.608	8.272	9.503
	(1.975)***	(2.068)***	(4.554)**
Age	0.0082	0.0091	0.0131
	(0.0038)**	(0.0042)**	(0.0072)*
Average Temperature	-0.2421	-0.2725	-0.8458
	(0.1022)**	(0.1162)**	(0.5343)
Minimum Temperature	0.4464	0.4111	0.7613
	(0.2131)**	(0.0052)*	(0.5622)
Maximum Temperature	0.3893	0.4964	1.324
	(0.2595)	(0.3951)	(1.574)
Wind Speed	0.8970	0.7798	0.8739
	(0.4912)*	(0.5108)	(0.5932)
Precipitation	0.0425	0.0112	0.0828
	(0.0189)**	(0.0157)	(0.0431)*
Smoker (No)	-0.1110	-0.1375	0.0853
	(0.0479)**	(0.0599)**	(0.0476)*
Household size	-0.0531	-0.0655	-0.4858
	(0.0239)**	(0.0382)*	(0.2245)**
Job Status (ref=self-employed)			
Job Status (Unemployed)	3.306	4.140	5.004
	(2.124)	(2.283)*	(1.638)***
Job Status (Employed)	1.640	1.187	2.381
	(1.333)	(1.134)	(0.784)***
Job Status (Retired)	3.257	4.542	6.302
	(1.588)**	(2.365)*	(1.352)***
Marital Status (ref=married)			
Marital Status (Living as couple)	-1.949	-1.901	-5.4622
	(2.863)	(3.875)	(7.831)
Marital Status (Widowed)	1.489	1.081	1.961
	(0.6724)**	(0.4635)**	(0.537)***
Marital Status (Divorced)	0.4731	0.7337	0.3332
	(0.3812)	(0.6652)	(0.3006)
Tenure (ref=owned outright)			
Tenure house (Owned with mortgage)	0.6202	0.5746	1.537
	(0.5899)	(0.5321)**	(1.110)
Tenure house (Rented from Employer)	2.422	2.026	2.9268
	(1.852)	(1.539)	(2.514)
Tenure house (Rented Private Unfurnished)	3.932	2.211	4.549
	(2.582)	(2.473)	(4.129)
Education (ref=Higher degree)			
Education Level (First Degree)	1.004	2.394	1.008
	(2.762)	(2.096)	(1.159)
Education Level (Teaching, HNC)	2.636	3.212	1.273
	(3.088)	(2.987)	(0.946)
Education Level (A Level)	2.401	1.548	2.450
	(1.306)*	(1,261)	(0.876)***
No obs.	34,257	27,251	2,144
R square	0.5869	0.5935	0.7163

Standard errors between brackets, clustered standard errors on local authority districts
(1) refers to total sample, (2) refers to non-movers and refers to movers within GB
***, ** and * indicate significance at 1%, 5% and 10% level

Table 8. Multinomial Logit Random Effects Regressions for Visits to GP and Non-Movers Sample

	Class 2	**Class 3**	**Class 4**	**Class 5**
Household Income	-0.0162	-0.0145	-0.0179	-0.0485
	(0.0075)**	(0.0070)**	(0.0082)**	(0.0209)**
Health Status (Poor)	1.275	3.476	7.681	11.024
	(0.3226)***	(0.3184)***	(0.3432)***	(0.5159)***
Age	0.0015	0.0038	0.0102	0.0125
	(0.0007)**	(0.0009)***	(0.0021)**	(0.0013)***
Average Temperature	-0.0049	-0.0031	-0.0063	-0.0087
	(0.0031)	(0.0037)	(0.0028)**	(0.0041)**
Minimum Temperature	0.0070	0.0130	0.0208	0.0187
	(0.0038)*	(0.0065)**	(0.0084)**	(0.0082)**
Maximum Temperature	0.0075	0.0166	0.0251	0.0215
	(0.0038)*	(0.0067)**	(0.0087)***	(0.0097)**
Wind Speed	0.0065	0.0054	0.0137	0.0258
	(0.0057)	(0.0104)***	(0.0066)**	(0.0095)***
Precipitation	0.0139	0.0072	0.0230	0.0150
	(0.0115)	(0.0136)	(0.0175)	(0.0076)**
Smoker (No)	0.0014	0.0081	0.0279	0.0247
	(0.0006)**	(0.0038)**	(0.0026)***	(0.0022)***
Household size	-0.0196	-0.0225	- 0.0687	-0.0551
	(0.0017)***	(0.0023)**	(0.0109)***	(0.0118)***
Job Status (Unemployed)	0.1676	0.5047	0.6759	1.004
	(0.0467)***	(0.0568)***	(0.0762)***	(0.0903)***
Job Status (Employed)	0.2304	0.4335	0.4871	0.6477
	(0.0268)***	(0.0354)***	(0.0515)***	(0.0689)***
Job Status (Retired)	0.5148	1.012	1.260	1.776
	(0.0367)***	(0.0446)***	(0.0608)***	(0.0772)***
Marital Status (Living as couple)	0.0975	0.1088	0.4015	0.5081
	(0.1454)	(0.1786)	(0.2857)	(0.2468)**
Marital Status (Widowed)	0.1328	0.1609	0.4899	0.5178
	(0.1461)	(0.0795)**	(0.2866)*	(0.1379)***
Marital Status (Divorced)	0.0949	0.1600	0.3847	0.5176
	(0.1501)	(0.1828)	(0.1749)**	(0.2179)**
Tenure house (Owned with mortgage)	-0.0044	0.0502	0.0726	0.0382
	(0.0414)	(0.0349)	(0.0325)**	(0.0372)
Tenure house (Rented from Employer)	0.0263	0.1506	0.1854	0.3882
	(0.0232)	(0.0972)	(0.1302)	(0.1500)**
Tenure house (Rented Private Unfurnished)	0.0356	0.0600	0.0740	0.2871
	(0.0460)	(0.0482)	(0.0376)*	(0.0671)***
Education Level (First Degree)	-0.0380	0.1642	0.2392	0.1369
	(0.0538)	(0.1251)	(0.2012)	(0.1188)
Education Level (Teaching, HNC)	0.0631	0.0927	0.0508	0.0450
	(0.0567)	(0.0626)	(0.0867)	(0.0913)
Education Level (A Level)	0.0532	0.1099	0.1761	0.2414
	(0.0521)	(0.0673)	(0.0935)*	(0.1182)**
No obs.	129,883			
LR chi-square	4,735.56			
	[0.000]			

Standard errors between brackets, p-values between square brackets
***, ** and * indicate significance at 1%, 5% and 10% level

Table 9. MWTP for In-Patient Days in Hospital and Non-Movers Sample

	Total Sample	**Non-Movers Sample**	**Movers Sample**
Panel A: Number of In-Patient Days in Hospital (Table 7)			
		CO	
MWTP	0.464	0.468	0.115
MWTP for a unit drop	£137	£145	£33
		O_3	
MWTP	0.511	0.518	0.209
MWTP for unit drop	£150	£159	£60

Table 10. MWTP for Visits in GP and Non-Movers Sample

Panel A: Number of Visits in GP (Table 8) Scenario 1				
			CO	
	Class 2	Class 3	Class 4	Class 5
MWTP	0.0393	0.1074	0.2373	0.3484
MWTP for a unit drop	£12	£26	£65	£74
			O_3	
	Class 2	Class 3	Class 4	Class 5
MWTP	0.0492	0.1178	0.2603	0.3737
MWTP for a unit drop	£15	£29	£71	£80
Panel B: Number of Visits in GP (Table 8) Scenario 2				
			CO	
	Class 2	Class 3	Class 4	Class 5
MWTP	0.0628	0.1718	0.3796	0.5572
MWTP for a unit drop	£22	£53	£96	£123
			O_3	
	Class 2	Class 3	Class 4	Class 5
MWTP	0.0787	0.1884	0.4164	0.5976
MWTP for a unit drop	£27	£58	£105	£132