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How Much do We Care about Air Quality Improvements?
Evidence from Italian Households Data

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Abstract - The purpose of this study is to identify the drivers of the Willingness to Pay (WTP) for air quality improvements in Italy. A better understanding of which factors, besides income, influence the willingness to pay for air quality improvements is important to guide future air quality policy.
We estimate the WTP for air quality improvements in Italy using a novel approach (Ebert, 2007) and a unique dataset obtained by merging data on Italian households' monthly current expenditure and information on a bundle of air pollutants' concentrations. We find a WTP for air quality improvements between 2 and 10 Euros/month per household. We then consider how WTP varies by location of the household, the level of air quality and over time.
We find higher WTP values for the Northwest and the Centre of Italy where the big metropolitan areas are located. We also observe that the WTP for air quality improvements declines as the level of air quality improves. Finally, the value of improvements in air quality decreases over time, maybe signaling a change of preferences.

JEL classification: H22, H23, D63
Keywords: Willingness to Pay, Air Quality Improvements, Demand Systems

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1. INTRODUCTION

The value of improvements in air quality levels has been the subject of inquiry for many decades. How individuals, households or nations value improvements in air quality is crucial for policy planning and, in particular, for assessing the benefits of air quality improvements against their costs.
One of the most important drivers of the value of air quality improvements is income. The early environmental policy literature hypothesized a positive relationship between willingness to pay (WTP) for air quality improvements and income. This relationship is usually measured by the income elasticity of WTP for air quality improvements, a very difficult to calculate yet crucial incidence measure. For example, how the net benefits of environmental improvements will be distributed by income levels is very important when evaluating reforms that will affect other countries or generations or different groups of citizens within a country. Depending upon the distribution of costs and benefits, air quality benefits may be pro-rich or pro-poor. They are pro-rich when they rise with income and in this case they are said to be progressively distributed. They are pro-poor, when they fall with income[1] and in this case they are regressively distributed. Even though the early environmental economics literature hypothesized air quality to be a luxury good (the demand for which increases more than proportionally with respect to income) more recent studies consider air quality as a normal good, implying that its income elasticity of demand is positive but not greater than one (Martini and Tiezzi, 2010).
Income, however, is not the only driver of air quality improvements and other factors may be relevant to guide public policy. Is there a change in preferences over time towards greater environmental quality ? Are there diminishing returns to air quality improvements ? How does the demand for air quality improvements vary by household location?
A better understanding of how these factors influence the willingness to pay for air quality improvements is important to guide future air quality policy.
The purpose of this study is to explore the drivers of WTP for air quality improvements in Italy and to provide a tentative answer to the above questions. For this purpose we estimate the WTP for air quality improvements in Italy using a novel approach (Ebert, 2007) and a unique dataset.
The remainder of the paper is structured as follows. Section 2 summarises the main methods used in the literature to estimate WTP for air quality improvements and other environmental public goods. Section 3 explains the approach we adopt to estimate willingness to pay for air quality improvementsin Italy. In section 4 the demand system specification and the data used are presented. Section 5 comments on the results. Section 6 concludes.

2. LITERATURE REVIEW

This section provides a literature review on the main methods available to estimate willingness to pay for environmental quality improvements and their results. The different approaches will be briefly outlined, then the focus of a number empirical studies will be described, and the

[1] Turning to environmental costs, rather than benefits, they will be progressively (pro-poor) distributed when they rise with income and regressively (pro-rich) distributed when they fall with income.

results – focusing in particular on drivers different from income – summarised.

Since the early seventies different approaches have been adopted to estimate the demand for public goods and the WTP. The first was a collective choice approach based on the median voter theorem (Boercherding and Deacon, 1972; Bergstrom and Goodman, 1973). The assumption is that political decisions on the level of expenditure on public goods will be identical to the quantity demanded by the median voter. Champ *et al.* (2003), Freeman (2003), and Mäler and Vincent (2005) provide useful and broad overviews.
Since the seminal paper by Rosen (1974), the hedonic and location choice approaches have been widely used for measuring the value of environmental public goods, especially in the United States. The advantage of this approach is that observed behavior in the housing and labor markets is used to infer the value of non-market goods. The marginal willingness to pay for public goods is measured, in this case, by their implicit prices as reflected in housing prices and wages. Recent methodological innovations can be found in Bajari and Benkard (2005), Ekeland *et al.* (2004), and Bayer *et al.* (2009).
Another important survey based approach was introduced by Bergstrom *et al.* (1982) who fitted demand equations for local public services with data from a household survey supplied by the University of Michigan. This was followed by the flourishing of contingent valuation (CV) studies using stated preferences to estimate WTP for public goods, such as Kriström and Riera (1996), Alberini *et al.* (1997), Hokby and Söderqvist (2003), Schläpfer (2006) to cite a few.
Finally, averting behavior employs the demand for market goods as a proxy for environmental goods or services (Costa, 1997; Pereyra and Rossi, 1998; Ghalwash, 2006). Several studies used averting behavior to obtain WTP values for a reduction in exposure to air pollutants or in the symptoms that result from it. Berger *et al.* (1987), for example, derive WTP using both cost of illness and averting expenditures, including air conditioners. Differently, Dickie and Gerking (1991) adopt the household production approach to investigate the relationship between health and air quality, while Mansfield *et al.* (2006) combine stated preference and averting behavior to estimate WTP for a decrease in ozone pollution.

In general, income has emerged as a fundamental driver of WTP and it has been at the centre of many emprirical studies devoted to estimate the WTP for different typologies of public goods. As a result, the income elasticity of WTP has been a widely used parameter[2], and different approaches have produced heterogeneity in results. The most widely used approach uses data based on contingent valuation surveys (Kriström and Riera, 1997, Hökby and Söderqvist, 2003, Schläpfer, 2006). Studies based on this approach consistently find a very low income elasticity of willingness to pay in the range $0.1-0.5$. These elasticities contrast in magnitude with those calculated from collective choice-based studies for various public goods (Boercherding and Deacon, 1972; Bergstrom and Goodman, 1973) which are greater than one; and from averting behavior approaches using the demand for market goods as a proxy for environmental goods or services (Costa, 1997; Pereyra and Rossi, 1998; Ghalwash, 2006).

[2] The main problem in estimating the income elasticity of WTP is that individual demand and prices for a public good cannot be directly observed. Since the quantity of most environmental goods is rationed, the income elasticity of WTP for a fixed quantity of the public good rather than the income elasticity of demand is the relevant parameter for measuring benefit incidence.

A variety of environmental public goods has been analysed in these contributions. Clearly, the corresponding WTP can have common drivers, but differentdrivers are likely to be relevant for different goods. In particular, biodiversity – and related variables, such as environmental services – has become the focus of several studies since the nineties (Johansson, 1990; Riera, 1994; Li and Mattson, 1995) and at the same time climate change related variables, such as air quality, have begun to be investigated (Berger et al., 1987), Dickie and Gerking, 1991). The interest in these variables has grown later on (Carlsson and Johansson-Stenman, 2000; Leger, 2001; World Bank, 2002; Wang and Mullahy, 2008). The focus on renewable energy and other energy-related variables is more recent (Yoo and Kwak, 2008; Zografakis *et al*., 2010; Mozumder *et al*., 2011). Policies are more and more oriented towards the development of low emissions energy sources as part of wider climate change mitigation strategies. In this respect, the WTP for air quality improvements and for energy-related variables may have more drivers in common than the WTP for biodiversity conservation.

In estimating the WTP for air quality improvements, income is a key driver but other variables are also important. In particular, health related variables play a relevant role (Leger, 2001; Wang and Mullahy, 2008; Wang and Zhang, 2009), and the same is true for household location (Carlsson and Johansson-Stenman, 2000).

Carlsson and Johansson-Stenman (2000) estimate the WTP for reducing the concentration of harmful air pollutants by 50% in Sweden, concentrating both on where beneficiaries live and work. Reduced health impacts are the most important driver of WTP for slightly more than half of the sample. The living place also matters, with households in big cities having a slightly larger WTP. The authors estimate a two-step model for WTP, including a selection (Probit) and a structural equation. The estimated marginal effects for income and education are positive and significant in both equations, increasing both the probability of having a positive WTP, and the amount of WTP. Interestingly, men have a lower probability of a positive WTP than women, but they have a large maximum WTP. Having a serious disease and being involved in an environmental organization have a positive effect in the selection equation. By contrast, partner income, number of children, knowledge about pollution, retired status, and house ownership are significant in the structural equation.

Léger (2001) concentrates on the relationship between WTP for reducing ozone concentration in Montreal and health expenditures. The authors adopt a household production function approach (Gerking and Stanley, 1986) and use the time saved due to the reduced consumption of medical services for estimating WTP. Such an approach seeks to measure the trade-off between health expenditures and air quality, considering actual behavior and not survey responses. Socioeconomic variables such as age, sex, presence of kids, marital status, as well as labor force participation are also included in the estimation, and they are all significant. Willingness to pay is relatively small when medical expenditures are limited to formal medical care (i.e. visits to physicians). When individuals rebuild their health stock taking time off from work, WTP increases dramatically. Still, these estimates should be considered as lower bounds since they do not account for other medical expenses such as pharmaceuticals nor they allow for individuals to value clean air *per se.*

World Bank (2002) examines the effects of reducing the concentration of different air pollutants in Mexico City, adopting different approaches, among which the benefit transfer method. The study highlights that the value of health risk avoidance depends on the type and magnitude of risk, and on income and cultural settings. Moreover, it is important to consider if the risk is experienced voluntarily or not, and the perception of its persistence. Consistently with Léger (2001), also in this case monetary estimates of health benefits are very likely to be a lower bound.

Afroz *et al.* (2005) compare the WTP values for reducing air pollution in Klang Vallery, Malaysia obtained by different question formats. They also assess the significance of the WTP values by using explanatory factors such as socioeconomic variables and health variables, such as the duration of ill health episodes or the number of symptoms. Gender, age, education, health conditions and income have a significant positive effect on WTP, education and income playing the most important role.

Wang and Mullahy (2008) develop a contingent valuation study in Chongqing, one of the largest cities in China. Based on these data and similarly to the two-step model developed by Carlsson and Johansson-Stenman (2000), they estimate the probability of finding a positive WTP, and then the WTP level. Age, gender, marital status, family size, education, income, employment, health condition, medical expenditures, household location, and pollution perception are used as explanatory variables. With respect to the determinants of the probability of positive WTP, age has a negative effect, while not surprisingly income has a positive one. As expected, people who believe that they live in a severely polluted area tend to have a higher probability of expressing a positive WTP. With respect to the determinants of WTP level, education and income show positive relationships with WTP, as well as living in more polluted areas. Unlike the results from the probability analysis, in this equation people from larger families tend to have higher WTP. Wang and Zhang (2009) use the same method to investigate WTP for air quality in the city of Ji'nan, in China. The same variables than in Wang and Mullahy (2008) are used, adding also the opinion about correlation between pollution and health. Education, income and medical expenditures are found out to be significant for the probability of having a positive WTP. Surprisingly, factors such as gender, age and household size are not significant. With respect to the factors affecting the amount of WTP, annual income, medical expenditures and number of workers positively influence WTP. Both the probability of a positive WTP and the monetary amount are larger for men than for women.

Noolan (2011) analyses the variation in the benefits associated to air quality improvements by means of a meta-analysis. To this aim, over 50 empirical analysis are collected, and the benefits estimates are converted to a common metric represented by WTP for air quality improvements. The studies analysed employ different methods and data sources, and examine different scenarios. The meta-analysis is aimed to demonstrate how the benefits vary significantly across the sample, not only due to the differences mentioned above. As expected, income affects the benefits estimates. In particular, benefits are rising in income for wealthy nations but declining in income for developing countries. The amount of pollution reduction also substantively affects benefits estimates, due to diminishing returns of air quality improvements. This last trend is surveyed adopting two main approaches. First, a fixed-effects regression is used to check whether higher or lower baseline levels affect WTP, finding no evidence of diminishing returns. The second approach estimates another fixed-effects regression to test for the constancy in WTP, using the variation in air quality to explain the variation in WTP. A significant inverse relationship is found confirming the expected decline in WTP for additional (larger) improvements.

When looking at studies of the WTP for energy-related variables, we find that drivers are partially similar to those already identified for air quality. Additional drivers become relevant in this case, such as energy prices (Mozumder *et al.,* 2011), environmental awareness and the creation of new jobs (Ek, 2006; Zografakis *et al.,* 2010). Health variables appear to be less important in determining WTP for renewable energy.

Menekaki (2008) highlights that WTP for renewable energy is generally higher among individuals with high income (Wiser, 2005; Bergmann *et al*., 2006). Individuals with lower income seem to assign a greater importance to job creation (Ek, 2006). Also Bergman *et al.* (2006) and Zografakis *et al.* (2010) find that WTP is sensitive to the creation of additional jobs. WTP is higher among younger people, those who do not rent their home, do not have children and are highly educated (Wiser, 2005; Ek, 2006). Also, attitudinal factors positively affect WTP, such as having family and friends supporting renewable energy use (Wiser, 2005) and having an interest in environmental issues (Ek, 2006).

Yoo and Kwak (2009) find out that age and education are not statistically significant when estimating the WTP for renewable energy development, in contrast with Zografakis *et al.* (2010) who find a positive effect of having a high family income and a large house size, and disposing of more environmental information. Both studies adopt a contingent valuation approach, respectively applied to Korea and Greece. Applying the same approach to New Mexico, Mozumder *et al.* (2011) show that energy prices positively influence WTP for renewable energy development. Environmental concerns also have a positive influence, as well as the share of income donated to environmental causes. Consistently with earlier findings (Kotchen and Moore, 2007; Ito *et al.,* 2010) the level of education has a negative impact on WTP, which is a contrasting result with other studies available on this topic (for example, Carlsson and Johansson-Stenman, 2000; Wang and Mullahy, 2008).

The WTP for energy efficiency is a very seldom investigated variable. Gallaraga *et al.* (2011) propose a combined approach for estimating WTP for improving energy efficiency of home appliances in Spain, using the results of the hedonic approach together with the Quantity Based Demand System model. Own and cross price elasticities for substitute goods are provided, in particular having low and high energy efficiency. Introducing demographic-related variables such as household composition or location – as in, for example, Galwash (2008) – could provide useful insights into the determinants of the demand for energy efficient appliances.

Studies estimating the WTP for other environmental public goods confirm the importance of location as a driver of WTP (Basili *et al.* 2006), and this driver becomes even more relevant due to the smaller connection with a global environmental problem such as climate change.

Galwash (2008) investigates the demand for environmental services by means of demand system estimation. In the model, translating intercepts are included for household size and composition and also for the place of residence, enabling the author to obtain demand elasticities for different regions.

Bromberg (2010) estimates the WTP for biodiversity, in particular concentrating on the predator policy (i.e. policies aimed to protect wolves) in Sweden. He finds out that the place of residence plays a relevant role, living inside or near wolf territories having a negative effect on the WTP for predator policy. The likelihood of supporting the policy increases with income but this effect is not significant. The author considers the number of household members a budget related factor having both a direct effect on preferences for environmental quality and an indirect one through the budget constraint.

Travisi *et al.* (2004) perform a meta-analysis to analyze the variation in the estimated WTP associated with the impacts of pesticide risk. They find that WTP is influenced by the perception of risk and the information available, by socio-demographic characteristics, and by geographic location. These findings highlight that differences in WTP might be caused by non-income differences, for example in terms of whether the household lives in a rural or urban location (Lindhjem et al. 2007).

In general, although income is often considered a relevant covariate in WTP estimation, recent meta-analyses have focused on the determinants of income effects (Schläpfer 2006; Jacobsen and Hanley 2009). Schläpfer (2006) finds that income effects tend to be much smaller when developing a CV approach than in collective choice models. If the cost distribution is well defined and existing institutions are envisaged to provide the public good, the author finds that the probability of a significant income effect is lower. Other variables are relevant in such a case, for example demographic-related or location variables.

Jacobsen and Hanley (2009) investigate a sample of 145 WTP estimates, where only 56 reported a significant income effect, 39 reported an insignificant income effect and 50 did not report any information. The likelihood of observing a significant income effect decreases with the income level and is lower for preserving existing biodiversity than for increasing biodiversity.

To summarize, although income plays a central role in many studies, other variables are relevant WTP drivers. Household composition, both in terms of age and employment status of its members, and household geographical location are examples. In the following empirical analysis we emphasize the role played by these additional drivers.

3. HOUSEHOLD PRODUCTION AND DEMAND ANALYSIS

To estimate the WTP for improvements in air quality in Italy we use a new methodological approach, proposed by Ebert (2007)[3]. This is based on the following assumptions: i) a complete (conditional) demand system for market goods, which may depend on environmental goods, can be observed; ii) a household production function, combining market and environmental goods according to a given technology, is known; iii) the environmental goods considered do not enter the utility function directly. Using these assumptions Ebert shows that one can derive the marginal willingness to pay functions for the non market goods which augment the conditional demand system. Then one has to investigate the integrability of the mixed demand system consisting of the demand functions for market goods and the inverse demand functions for the non market goods. If the integrability conditions are satisfied a unique preference ordering can be recovered and the WTP can be obtained as well as relevant derived

[3] This section is based on Martini and Tiezzi, 2010.

parameters, like the income elasticity of willingness to pay.

To implement this approach we consider household production of the internal level of air quality chosen by the household and assume that households combine a market good, air conditioning, with a non market good, the level of external air quality, in order to produce the desired level of internal air quality according to a given technology. Since the household production function implicitly describes the marginal rate of substitution between air quality and air conditioning, we can compute the marginal willingness to pay for marginal improvements in air quality. Most of the pollutants considered in our air quality index are known to have strong temperature related effects. For this reason it can be assumed that a high concentration of these pollutants is associated with higher temperatures. Consequently bad air quality conditions are very likely to be correlated with expenditure on air conditioners. In fact, conditioners reduce indoor temperatures and in this sense they are an input in producing the level of air quality preferred by the household.

The data set we use is obtained by merging data on Italian households monthly current expenditure and unique information on a bundle of air pollutants concentrations. We show that the resulting (mixed) demand system is integrable and we compute the marginal willingness to pay for a marginal increase in the index of air quality.

4. SPECIFICATION AND ESTIMATION OF A CONDITIONAL DEMAND SYSTEM WITH HOUSEHOLD PRODUCTION

4.1 A Conditional Censored Almost Ideal Demand (CCAID) System

Conditional demand functions can be used to deal with non market goods, such as environmental goods or bads. The level of, for example, air quality provided without charge to the user may affect the individual's consumption of goods available in the market. Since consumption of air quality is fixed, it is the conditional demand functions which are appropriate for the analysis of an individual demand for goods and services in the short run (Pollak, 1969). The functional form chosen to specify our model is the Almost Ideal Demand System (AIDS, Deaton and Muellbauer, 1980b). To obtain the system of conditional uncompensated shares equations we use a logarithmic *conditional* cost function, for household h, which implies PIGLOG preferences (Pollack and Wales, 1992):

$$ln\, C(u, p, d^h, q) = ln\, a(p, d^h, q) + u\, b(p) \qquad (1)$$

where $a(p, d^h, q)$ and $b(p)$ are functions of the market price vector p, ln indicates the natural logarithm, d^h are demographic variables and q is the fixed quantity of the non market good, air quality in this case. $a(p, d^h, q)$ is increasing and homogenous of degree one in p and $b(p)$ is increasing and homogenous of degree zero in p. $C(u, p, d^h, q)$ is the *conditional cost function*, i.e. the minimum cost necessary to achieve utility level u, given the price vector p, given demographics d^h and when the quantity q of the non market good is given. The corresponding system of conditional Marshallian demand functions for household h and goods *i=1,…,n* expressed as expenditure shares is given by:

$$w_i^h = \alpha_i + \sum_j c_{ij} \ ln \ p_j + b_i \ ln\left[\frac{y^h}{P^h}\right] + \sum_i (\alpha_i + \alpha_{ik} d_k^h + g_i q) \ ln \ p_i \quad (2)$$

where y^h is total expenditure of household h; the parameters c_{ij} are defined as c_{ij} = $\frac{1}{2}(c_{ij}^* + c_{ji}^*)$ = c_{ji}; α_{ik} are the coefficients of the translating intercepts $d^h = d_1^h ... d_k^h$ which in this model include households' types, households' location and an annual time trend and P^h is a Translog price index specified as:

$$P^h = \alpha_0 + \sum_i (\alpha_i + g_i q + \alpha_{ik} d_k^h) \ ln \ p_i + \frac{1}{2} \sum_i \sum_j c_{ij}^* \ ln \ p_i \ ln \ p_j \quad (3)$$

Demand functions (3) satisfy integrability, i.e. are consistent with utility maximization, when the following parametric restrictions hold: $\sum_i \alpha_i = 1, \sum_i b_i = \sum_j c_{ij}^* = 0$, $\sum_i \alpha_{ik} = 0 \quad \forall k$ (Adding-up); $\sum_j c_{ij} = 0$ (Homogeneity); $c_{ij} = c_{ji}$ for all i, j (Symmetry).

The presence of zeros in the dependent variables is quite important for our specific sample. To deal with this problem we use the two-step estimator proposed by Shonkwiler and Yen (1999) which involves probit estimation in the first step and a selectivity-augmented equation system in the second step[4]. The system of equations (3) is thus estimated in the following form:

$$s_i = \Phi(z_i^{'} \tau_i) w_i(p, y; \theta) + \delta_i \phi(z_i^{'} \tau_i) + \xi_i \quad (4)$$

where s_i is the observed expenditure share for good i; z_i is a vector of exogenous variables; τ_i is a parameter vector; θ is a vector containing all parameters (α_i, α_{ik}, b_i, g_i and c_{ij}) in the demand system, $\xi_i = s_i - E(s_i)$ and where $\phi(\cdot)$ and $\Phi(\cdot)$ are the standard normal probability density (pdf) and distribution (cdf) functions, respectively. The system of equations (4) is estimated in two-steps: (i) we obtain Maximum Likelihood (ML) probit estimates $\hat{\tau}_i$ of τ_i using the binary outcome $s_i = 0$ and $s_i > 0$; (ii) we calculate $\Phi(z_i^{'}, \hat{\tau}_i)$, $\phi(z_i^{'} \hat{\tau}_i)$ for all i and estimate $\theta, \delta_1, \delta_2, ..., \delta_n$ in the augmented system (4) by ML. Such two-step estimator is consistent, but the error terms are heteroscedastic, thus the estimated elements of the second-step conventional covariance matrix are inefficient. For simplicity, we empirically calculate the standard errors of WTP and elasticities using bootstrapping and running 500 replications. This ensures that the standard errors of these derived parameters are correct.

Differentiation of equation (4) gives demand elasticities for the first $n-1$ goods. Elasticities for the n[th] good are obtained exploiting the Cournot and Engel restrictions (Deaton and Muellbauer, 1980a, p. 16). Denoting the Marshallian, Hicksian and expenditure elasticities for good i as σ_{ij}^h , σ_{ij}^{*h} and σ_i^h, respectively, then σ_{nj}^h , σ_{nj}^{*h} and σ_n^h can be calculated using the Cournot restriction $\sum_{i=1}^n w_i^h \sigma_{ij}^h + w_j^h = 0$ and the Engel restriction $\sum_{j=1}^n \sigma_{ij}^h + \sigma_i^h = 0$.

Exogenous variables used in the first-step probit estimates are: total expenditure, dummies indicating household location, whether the household resides in a big town, seasonality and the annual time trend in logarithms. The dependent variable in the first-step probit estimates is the

[4] Shonkwiler and Yen (1999); Yen, Lin and Smallwood (2003) and Yen and Lin (2006) provide useful literature review on estimation procedures for censored demand systems.

binary outcome defined by the expenditure in each good. The proportion of consuming households for Food, Housing and Communication all exceed 95%, which prevents reliable probit estimates. Thus, probit is estimated only for the remaining commodities, for which the predicted pdf and cdf are included in the second step of the procedure (see Yen, Lin and Smallwood, 2003, p. 464). In all the estimates we impose homogeneity and symmetry. Economic theory also requires the matrix of the substitution effects to be negative semi-definite. Such a requirement is satisfied by adopting a Cholesky decomposition procedure of the price coefficients. Finally, we drop the "other goods and services" equation to accommodate adding up.

4.2 Household Production and WTP for Air Quality Improvements

To specify the WTP function for improvements in air quality we choose the class of household production functions:

$$Z = F_{\varepsilon}(Y, q) = (Y^{1/2} + 1)q^{\varepsilon} \tag{5}$$

for $\varepsilon \in (0,1/2]$ proposed by Ebert (2007, p. 285). Y is the quantity of air conditioners used as an input into the household production of Z, the internal level of air quality chosen by the household, and q is our index of air quality. In this household production function Y is a nonessential good[5]. This class of household production functions implies the cost functions:

$$C_{\epsilon}(p_{Y,}q, Z)=\begin{cases} 0\ for\ Z \leq q^{\epsilon} \\ p_Y\left(\frac{Z}{q^{\epsilon}} - 1\right)^2 for\ Z > q^{\epsilon} \end{cases} \tag{6}$$

The corresponding WTP function is:

$$w_q(p, q, y) = 2\varepsilon p_Y (Y^{1/2} + 1)Y^{1/2}/q \tag{7}$$

We consider three values of ε: $\varepsilon = 0.1$, $\varepsilon = 0.35$ and $\varepsilon = 0.5$ and we test whether the WTP function (7) is integrable by checking whether the integrability conditions are satisfied. Ebert (2007, p. 283) sets out the necessary and sufficient conditions for integrability of this conditional demand system supplemented by a WTP function. The first three conditions are symmetry conditions of the Slutsky matrix for the augmented demand system:

$$s_{xY} = \frac{\delta x}{\delta p_Y} + Y\frac{\delta x}{\delta y} = \frac{\delta Y}{\delta p_x} + X\frac{\delta Y}{\delta y} = s_{Yx} \tag{8}$$

$$s_{xq} = \frac{\delta x}{\delta q} - w_q\frac{\delta x}{\delta y} = -\left(\frac{\delta w_q}{\delta p_x} + x\frac{\delta w_q}{\delta y}\right) = -s_{qx} \tag{9}$$

$$s_{Yq} = \frac{\delta Y}{\delta q} - w_q\frac{\delta Y}{\delta y} = -\left(\frac{\delta w_q}{\delta p_Y} + Y\frac{\delta w_q}{\delta y}\right) = -s_{qY} \tag{10}$$

where s_{xY} are the conventional Slutzky substitution effects for market goods x and Y, i.e. they measure the change in the quantity demanded of each element in vector x following a change in the price of good Y, whereas s_{xq} is the change in the quantity demanded of each element in x following a change in the price (WTP) of q. Condition (8) is satisfied by assumption, because x

[5] That is to say Y is not necessarily required to produce Z given q. See Ebert, 2007, footnote 11, for an interpretation of this property.

and Y form a conditional demand system, but conditions (9) and (10) have to be checked. In addition the Slutsky matrix of substitution effects for the market goods x and Y must be negative semidefinite. Finally, the change in the quantity demanded of good q following a change in its price (WTP) must be negative:

$$s_{qq} = \frac{\delta w_q}{\delta q} - w_q \frac{\delta w_q}{\delta y} < 0 \qquad (11)$$

When conditions (8) - (11) are satisfied the mixed demand system with household production defined by (4), (5) and (7) is integrable. This approach does not require further assumptions and it provides a useful and operational basis for recovering preferences. Its starting points are the "observed" demand functions for market goods and the household production functions. Conditions like weak complementarity or the essentiality of inputs are not required, nor is required the imposition of the Willig condition to derive exact welfare measures (see Ebert, 2007, p. 278 for a discussion of this point).

4.3 Data

We use monthly cross-sections, from January 2002 to December 2006, of individual Italian households' current expenditures collected by the National Institute of Statistics (ISTAT) through a specific and routinely repeated survey[6] called "*Indagine sui Consumi delle Famiglie*". In this survey, current expenditures are classified in about two hundred elementary goods and services, with the exact number changing from year to year due to minor adjustments in the items' list[7]. Also included is detailed information on the household structure, such as location on a regional basis, number of household members, ownership of air conditioners. All annual samples are independently drawn according to a two-stage design[8].

A sub-sample of 10,671 observations has been selected considering households owning air conditioners[9] and living in eight regions of Italy: Friuli-Venezia Giulia, Trentino Alto Adige, Liguria, Lombardia, Toscana, Lazio, Sardegna and Sicilia representing four macro-regions: North East (NE), North West (NW), Centre (CE), South and the Islands (SI). We estimate a ten commodities demand system: (1) Food and beverages; (2) Housing excluding rent; (3) Air Conditioners; (4) Clothing; (5) Health Care; (6) Transports; (7) Communication; (8) Recreation; (9) Alcohol and Tobacco; (10) Other goods and services[10]. Each commodity has been obtained as an aggregate of detailed current expenditures on more than two hundred elementary goods and services[11]. The list of commodities has been chosen according to availability of monthly and regional consumption price indices also supplied by ISTAT, which are included in the data set. These prices have been extracted from the Consumer Price Index (1998=100), also published by

[6] A different sample of households is interviewed during each month; the item list includes also non-current expenditures, with a total number of about 280 goods and services.

[7] We implicitly assume strong separability in consumers' preferences between current and other expenditures.

[8] Details on the sampling procedure used to collect these data can be found in ISTAT, *Indagine sui Consumi delle Famiglie. File standard. Manuale d'uso. Anni 1997-2006*.

[9] This choice is explained by the fact that air conditioners are an input in the household production function to produce the household level of air quality (see section 4.2 for a description of the household production function).

[10] The rationale for choosing to include home related expenditures (aggregate (3)) is that a substitution relationship is likely to exist between air conditioning and other goods and services purchased by the household (by way of example, the need of air conditioning is likely to diminish in better insulated houses).

[11] Aggregation is possible assuming, as it is usually done, that goods within each group are consistent with the Hicks and Leontief Composite Commodity Theorem (Deaton and Muellbauer, 1980a, pp.120-121).

ISTAT. Specifically we use the Consumer Price Index for the whole nation (NIC) which monitors sales prices every month in all Italian provinces. NIC is divided into 12 expenditure categories entering the national index with a specific weight reflecting the relative importance of the concerned good on total consumption. Many of these categories coincide with the commodities in our demand system. Some of them have been aggregated to correspond to the remaining goods in our demand system. In addition, we consider expenditures on air conditioning and the corresponding elementary price index also supplied by ISTAT. To summarize, the sample used in our estimations consists of 10,671 household observations collected for 8 regions over 12 months for 5 years. Using *r* to indicate the region, *m* the month and *y* the year, the data have been organized by lining up monthly data ($m = 1-12$) on each macro-region ($r = 1-4$) for each year ($y = 1-5$) in a vector of 10,671 observations. A set of dummy variables is included to account for the macro-area in which the household lives (NW, NE, CE, SI) and for the likely seasonality in air conditioning expenditure (SEASON) equal to 1 for the warmest months of the year: June, July, August and September. We also add a categoric variable (LOC) for whether the household lives in a town with more than 50,000 inhabitants (1), less than 50,000 inhabitants (2) or in a small village (3) and a logarithmic annual time trend.

We combine these data with information on air concentrations of three pollutants: Ozone (O_3), Particulate (PM_{10}) and Nitrogen Dioxide (NO_2). These have been used to compute a categorically continuous index of air quality (IQA), a standardized indicator of air quality in a given location. Following the definition given by the National Agency for the Protection of the Environment (APAT) according to European guidelines, the index is constructed as a weighted average of data on hourly concentrations of three air pollutants supplied by APAT[12]. The weights were provided by each of the regional agencies in charge of calculating air quality indices on a regional basis.

Data on hourly concentrations of Ozone (O_3), Particulate (PM_{10}) and Nitrogen Dioxide (NO_2) were available from January first 2002 to December 31st 2006. For each Italian region hourly pollutants concentrations have been collected from a very large number of stations located in a Traffic, Industrial or Background area. We consider concentrations from Traffic and Background stations only in order to merge them with consumption expenditures of households in Urban or Background areas. Due to missing data over the investigation period, only eight Italian regions have been considered: Lombardia, Liguria, Friuli Venezia Giulia, Trentino Alto Adige, Lazio, Toscana, Sicilia and Sardegna.

Starting from a total of 1,596,938 hourly observations, a daily regional IQA_d has been obtained as: $IQA_d = \frac{I_1 + I_2}{2}$ where the subscript d indicates the day; $I_1 = \left(\frac{PM_{10}}{\overline{\overline{PM}}_{10}} \right) \times 100$ is a sub-index where PM_{10} is the mean daily particulate concentration and $\overline{PM}_{10}$ is the threshold value for particulate concentrations admitted by the Italian law[13] ($50 \mu g/m^3$). The second sub-index, I_2, is

[12] Data on air pollutants concentrations are freely downloadable at www.apat.it. The same data are available from the European Air Quality Database of the European Environmental Agency.

[13] D.M. 60/02

simply the highest between Nitrogen Dioxide and Ozone concentrations: $I_2 = max(NO_2, O_3)$. Threshold values for NO_2 and O_3 concentrations are, respectively, $200\mu g/m^3$ and $120\mu g/m^3$.

Daily IQAs have been averaged over each month to obtain monthly indices. As a result, our regional IQA is given by a sample of 960 observations (12 months × 5 years × 16 areas). These monthly indices have then been used to construct a categoric variable (LQ) varying between 1 (low air quality) and 7 (high air quality) used in estimation.

Summary statistics of the data are shown in Table 1. Figures 1 and 2 show the pattern over time of the national and regional monthly IQA.

Table 1: The Data

No. of households: 10,671				
Current Expenditures (Euro/month)	mean	std dev	min	max
Total Expenditure	1,784.705	1,063.757	250.019	6,958.370
Food From Stores	485.747	283.304	0.000	2,374.739
Alcohol and Tobacco	44.466	58.495	0.000	551.480
Clothing	190.509	285.023	0.000	4,387.530
Household Operation	210.760	154.237	0.000	3,501.580
Air Conditioners	12.315	82.999	0.000	1028.930
Health	112.068	278.392	0.000	5,228.750
Transports	162.021	129.441	0.000	1,042.620
Communication	64.838	50.950	0.000	652.949
Recreation	52.934	85.197	0.000	1,597.560
Other Goods and Services	458.282	530.354	0.000	5,228.920
Price indices (1998=1)				
Food from Stores	1.135	0.034	0.826	1.337
Alcohol and Tobacco	1.247	0.115	0.826	1.436
Clothing	1.127	0.040	0.824	1.364
Housing	1.145	0.053	0.821	1.365
Air Conditioners	0.964	0.040	0.869	1.074
Health	1.095	0.034	0.816	1.365
Transports	1.190	0.068	0.815	1.392
Communication	0.842	0.083	0.701	1.393
Recreation	1.101	0.030	0.813	1.393
Other Goods and Services	1.185	0.052	0.809	1.393
Other exogenous variables				
IQA	5.630	1.232	1.000	7.000
NW	0.279	0.448	0.000	1.000
NE	0.108	0.311	0.000	1.000
CE	0.219	0.414	0.000	1.000
SI	0.393	0.488	0.000	1.000
LOC	1.158	0.446	1.000	3.000
SEASON	0.346	0.476	0.000	1.000
Annual time trend	3.183	1.378	1.000	5.000

Figure 1: Index of Air Quality 2002-2006

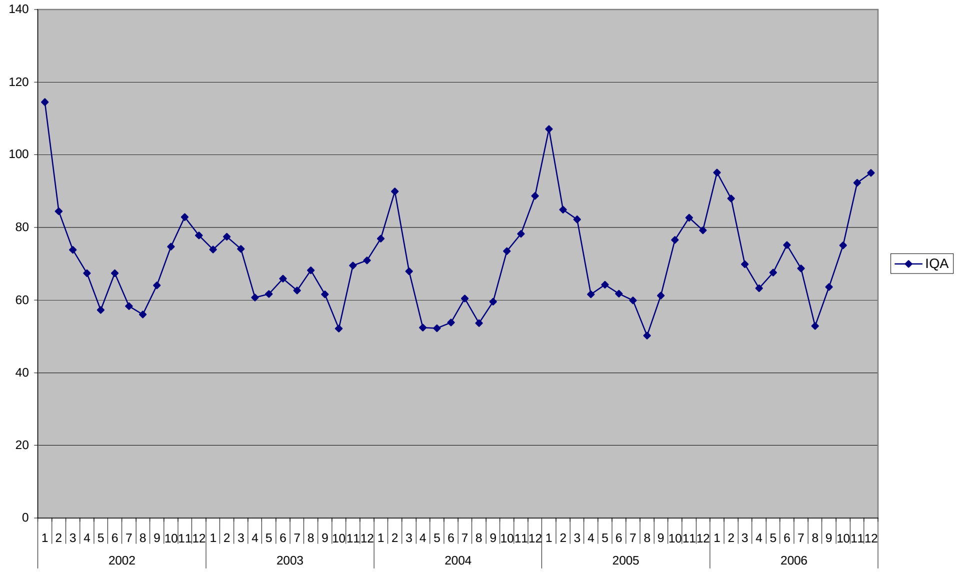
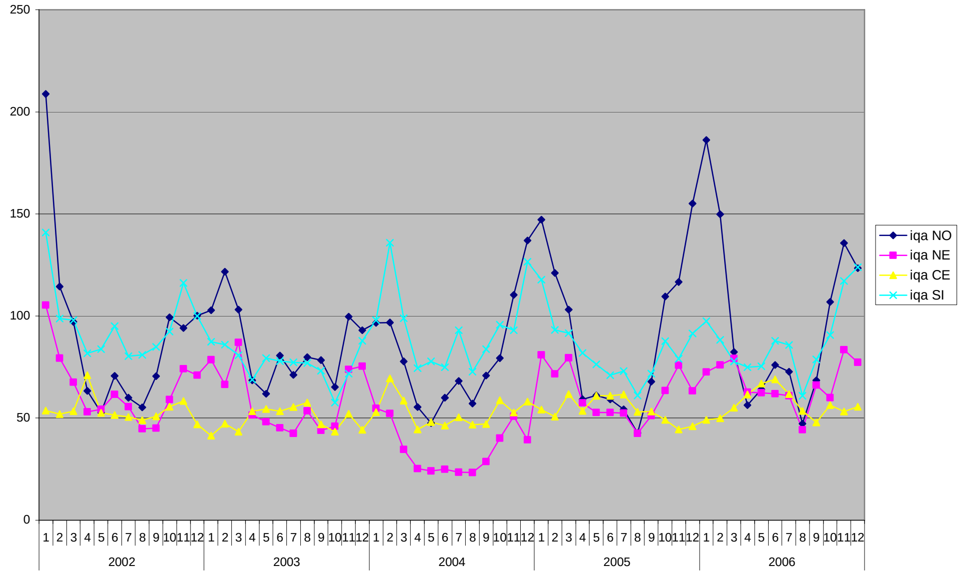


Figure 2: Index of Air Quality by Region 2002-2006



5. RESULTS

Table 2 shows first-step probit estimates along with their asymptotic standard errors. Many of the variables included are significant at the 5% level in each expenditure share equation. Income plays a positive role in explaining the budget share of all goods. Seasonality and the annual time trend also play a significant role in the probability of consuming many of the commodities. The index of air quality (*LQ* variable) is also significant in explaining the decision to purchase air conditioners and has the expected negative sign[14]. Going from a big to a small town (LOC variable) has a negative role in determining air conditioners' purchase, probably because big cities are more polluted. Going from a big to a small town also plays a positive and significant role in explaining Transports and Alcohol/Tobacco choices, but has a negative and significant role, as expected, in explaining recreation choices. Hicksian (compensated) elasticities, based on parameters of the second-step[15], are computed at the sample mean as: $\sigma_{ij}^{*h} = \sigma_{ij}^{h} + \sigma_i^h w_j^h$ where σ_{ij}^{h} is the uncompensated price elasticity of good i with respect to price j and σ_i^h is the expenditure elasticity of good i.

Table 2: First-step probit estimates

n. obs. = 10,671	i=3 Air Conditioning	i=4 Clothing	i=5 Housing	i=6 Transport	i=8 Recreation	i=9 Alc./Tab.
Constant	**-2.31089**	**-2.223189**	**-0.273782**	**0.305451**	**-0.10744**	0.036938
	0.052149	*0.030557*	*0.026787*	*0.034357*	*0.030894*	*0.026971*
Income	**0.35108**	**0.985871**	**0.624047**	**0.949924**	**0.897164**	**0.524992**
	0.035823	*0.032160*	*0.024951*	*0.038235*	*0.032454*	*0.025117*
NE	-0.136346	0.01096	0.011092	-0.013062	**-0.167920**	**-0.201669**
	0.095070	*0.054493*	*0.049739*	*0.059706*	*0.055830*	*0.050095*
NW	-0.046520	0.03251	**0.159532**	**-0.137643**	-0.042201	0.022482
	0.067357	*0.040594*	*0.036888*	*0.046737*	*0.042147*	*0.037690*
SI	**-0.279650**	0.005593	-0.056621	**0.294275**	**-0.29642**	0.056652
	0.073988	*0.041384*	*0.037855*	*0.049493*	*0.042240*	*0.039231*
LOC	-0.017661	-0.01439	-0.027704	**0.279807**	**-0.129643**	**0.130386**
	0.091733	*0.052728*	*0.048059*	*0.066572*	*0.052518*	*0.050459*
SEASON	**0.404687**	**-0.100387**	-0.128067	-0.02515	**-0.139139**	**0.064412**
	0.050421	*0.029482*	*0.027122*	*0.034511*	*0.029847*	*0.028129*
LTrend	-0.069255	**-0.074566**	0.013046	**-0.06303**	**-0.122640**	**-0.004166**
	0.046642	*0.025875*	*0.023626*	*0.030016*	*0.026298*	*0.024221*
LQ	**-0.215504**	-0.009866	-0.066255	0.063225	**-0.153797**	**-0.078265**
	0.066753	*0.038757*	*0.035390*	*0.043823*	*0.039883*	*0.036113*
mean of dep. Var.	0.032	0.746	0.627	0.862	0.763	0.703
Log Likelihood	-1401.06	-5418.99	-6630.24	-3822.81	-5260.13	-6216.29
Scaled R-Squared	0.182	0.117	0.077	0.085	0.109	0.051
Predicted Power	0.968	0.756	0.666	0.862	0.770	0.705

Note: Standard Errors in Italics below coefficients. Bold entries correspond to rejection of $H_0 : e = 0$ at the 5% significance level for a two tailed test.

[14] We expect a negative sign since the IQA is computed in such a way that higher values are associated with better air quality conditions.
[15] Second-step parameters are not reported to save space, but are available from the authors upon request.

These elasticities are shown in Table 3 along with expenditure elasticities for all goods and the estimated budget shares. All expenditure elasticities are significantly different from zero. Air conditioning appears to be a luxury good, with an income elasticity equal to 1.30[16]. As to the budget shares, Food, Housing, Transports and Clothing are the consumption categories on which the largest part of the monthly expenditure is allocated. This is in line with similar works on Italian household consumption (Moschini and Rizzi, 1997; Balli and Tiezzi, 2010). All the compensated own price elasticities, calculated at the sample means of variables, have the correct sign and are statistically significant. Air conditioning displays a very high and significant compensated own price elasticity (1.80), but none of the cross-price elasticities are significant. Some of the other compensated own price elasticities are greater than one: Food, Clothing, Health, Transport and Communication.

Table 3: Mean household Budget Shares, w_j, expenditure elasticities, e_j and Hicksian elasticities e^*_{ij}

	j=1 Food	j=2 Housing	j=3 Air Conditioning	j=4 Clothing	j=5 Health	j=6 Transport	j=7 Recreation	j=8 Communication	j=9 Alc./Tab.	j=10 Other Goods
w_j	0.300	0.137	0.006	0.093	0.054	0.095	0.042	0.027	0.026	0.219
e_j	**0.731**	**0.495**	**1.334**	**1.860**	**0.575**	**1.438**	**0.534**	**1.619**	**1.004**	**1.235**
	0.006	*0.010*	*0.256*	*0.065*	*0.134*	*0.056*	*0.012*	*0.085*	*0.107*	*0.036*
e^*_{1j}	**-1.439**	-0.137	0.064	**0.362**	**0.543**	0.003	**-0.172**	**0.479**	0.037	0.260
	0.252	*0.115*	*0.056*	*0.190*	*0.155*	*0.139*	*0.042*	*0.099*	*0.077*	*0.243*
e^*_{2j}	-0.301	**-0.675**	-0.0461	0.078	0.783	**0.341**	**0.139**	**0.335**	-0.011	**-0.645**
	0.254	*0.189*	*0.048*	*0.172*	*0.178*	*0.138*	*0.053*	*0.115*	*0.072*	*0.209*
e^*_{3j}	2.569	-0.649	**-1.796**	-0.377	0.511	0.840	0.663	-0.226	-0.050	-1.486
	2.018	*0.839*	*0.604*	*0.676*	*1.065*	*0.638*	*0.455*	*0.255*	*0.376*	*1.460*
e^*_{4j}	**0.982**	0.186	-0.016	**-1.050**	-0.255	**0.230**	**0.141**	-0.137	0.025	-0.167
	0.435	*0.181*	*0.041*	*0.225*	*0.247*	*0.128*	*0.078*	*0.145*	*0.050*	*0.229*
e^*_{5j}	**2.093**	**1.341**	0.053	-0.318	**-1.612**	-0.312	-0.125	-1.215	-0.001	0.097
	0.606	*0.341*	*0.115*	*0.441*	*0.712*	*0.313*	*0.136*	*0.218*	*0.189*	*0.618*
e^*_{6j}	0.193	**0.468**	0.052	0.200	-0.188	**-1.442**	-0.062	-0.001	0.055	0.725
	0.306	*0.146*	*0.038*	*0.117*	*0.177*	*0.173*	*0.059*	*0.120*	*0.046*	*0.244*
e^*_{7j}	**-1.222**	**0.456**	0.120	0.347	-0.195	-0.317	**-0.392**	0.199	0.057	**0.946**
	0.299	*0.181*	*0.088*	*0.256*	*0.251*	*0.201*	*0.106*	*0.153*	*0.104*	*0.299*
e^*_{8j}	**3.871**	**1.293**	-0.043	-0.496	**-2.442**	0.045	0.247	**-2.477**	**0.001**	0.000
	0.777	*0.400*	*0.137*	*0.528*	*0.449*	*0.396*	*0.176*	*0.475*	*0.209*	*0.622*
e^*_{9j}	0.421	0.026	-0.012	0.047	0.010	0.179	0.084	-0.008	**-0.641**	-0.109
	0.614	*0.264*	*0.053*	*0.178*	*0.386*	*0.163*	*0.116*	*0.214*	*0.175*	*0.382*
e^*_{10j}	**0.779**	-0.235	-0.057	-0.109	-0.320	**0.375**	**0.162**	-0.233	-0.012	-0.350
	0.269	*0.124*	*0.055*	*0.153*	*0.178*	*0.143*	*0.051*	*0.111*	*0.073*	*0.324*

[16] It is worth mentioning that the income elasticity associated to air conditioning, as well as the price elasticities, are all short term elasticities. Since the stock of air conditioners is built up over time, and such a process is likely to be incomplete in some regions the income elasticity of WTP is also to be interpreted as valid in the short term.

Note: Standard Errors in Italics below coefficients. Bold entries correspond to rejection of $H_0 : e = 0$ at the 5% significance level for a two tailed test.

The conditional demand system (4) and the WTP function (7) are integrable if and only if the integrability conditions are satisfied. These integrability conditions, calculated at the sample mean for $\varepsilon = 0.5$ are all satisfied, therefore the mixed demand system with household production is integrable.

Household marginal WTP for improvements in air quality in Euro/month for five income groups are shown in Table 4 for three values of ε. All standard errors have been obtained using bootstrapping and 500 replications. WTP is smaller than 10 euros for most households, in particular a value around 3 euros has a very high frequency. Very few households have a WTP greater than 20. Changing the value of ε from 0.5 to 0.1 implies a very small impact on the WTP distribution. The WTP is positively correlated to household income revealing that rich households value air quality improvements more highly than poor ones. Nevertheless when expressed as a fraction of household income WTP increases only slightly with income for any value of ε. For higher income levels WTP as a fraction of income decreases from 0.25% for $y \leq 6000$ to 0.13% for $y > 6000$. The fact that households in lower income groups have a relatively higher WTP for air quality improvements is consistent with findings by Kriström and Riera (1996) and Hökby and Söderqvist (2003). This may be because higher income households live on average in areas with relatively low levels of air pollution and they therefore experience a less relevant physical improvement (e.g. air quality changes from good to very good) in air quality in comparison with low income households. A lower WTP for richer households may also be explained by a larger set of substitution possibilities.

Table 4: WTP for Air Quality Improvements (Euro/month)

Income level	**ε = 0.15**	**ε = 0.35**	**ε = 0.5**
Overall sample mean	**0.687**	**1.602**	**2.290**
(10,671)	*0.025*	*0.062*	*0.087*
$y \leq 800$	**0.141**	**0.329**	**0.470**
(1,016)	*0.018*	*0.044*	*0.062*
$y \leq 2000$	**0.475**	**1.108**	**1.582**
(4,993)	*0.022*	*0.049*	*0.070*
$y \leq 4000$	**1.476**	**3.444**	**4.920**
(2,808)	*0.059*	*0.140*	*0.194*
$y \leq 6000$	**2.260**	**6.207**	**8.867**
(401)	*0.253*	*0.587*	*0.870*
$y > 6000$	**2.296**	**5.357**	**7.652**
(72)	*0.484*	*1.071*	*1.568*

Note: Standard Errors in Italics below coefficients. Bold entries correspond to rejection of $H_0 : e = 0$ at the 5% significance level for a two tailed test. y = household disposable income proxied by total current expenditure.

5.1 WTP by Household Location

Table 5 shows how WTP varies across four geographical areas of Italy. Intuition suggests that certain areas, where big metropolitan areas are located, may be more likely to exhibit larger values due to their longer experience with air quality problems. This pattern is confirmed by the results of our empirical analysis, showing higher WTP values for the Northwest and the Centre, the macro-regions where the big metropolitan areas are located.

Noonan (2011) also tests the hypothesis according to which the WTP is lower for higher starting levels of air quality. In our study, the value of WTP is highest for the Northwest, the macro-region having the worst air quality, as shown in Figure 2. The South and the Islands are the next macro-region in terms of IQA value, which on average is particularly high, although not the worst one. This pattern is not mirrored by the WTP value, which in this case is the lowest. By contrast, the WTP for a marginal improvement in air quality is high for the Centre, which has the best IQA performance. The fact that the Centre has a higher WTP than Northeast shows that the hypothesis described in Noonan (2011) is not sustained in our analysis, which is consistent with the first approach in the meta-analysis developed by the author. This issue will be further investigated in the next paragraph, in particular with respect to the second approach adopted by Noonan (2011) to test the hypothesis of decreasing returns.

Table 5 clearly indicates the presence of other relevant drivers of WTP, different from the baseline level of air quality. Income plays a key role, with the Northwest being the richest macro-region, followed by the Centre. As described in the literature review, other drivers are very likely to influence WTP, such as the perception of pollution and its effects, and the education level. Moreover, the production specialization of the macro-region examined, i.e. the prevailing sector among energy-intensive industries, agriculture or services, could turn out to be relevant.

Table 5: WTP by Household Location (Euro/month)

Location	**WTP (mean)**
Northwest	**4.047**
(2,483)	*0.349*
Northeast	**2.620**
(1,017)	*0.357*
Centre	**3.009**
(1,462)	*0.131*
South and Islands	**1.755**
(3,763)	*0.209*

Note: Standard Errors in Italics below coefficients. Bold entries correspond to rejection of $H_0 : e = 0$ at the 5% significance level for a two tailed test. Number of observations in parentheses below location. Number of observations does not match the full sample due to the missing values in estimated WTP.

5.2 WTP is declining as the level of air quality improves and over time

Does the willingness to pay for additional improvements in air quality decline with increasing air quality levels? The possibility that benefits of further improvements fade away as our air gets cleaner and that the benefits are rising over time is crucial for designing efficient air policies. The existing literature shows that WTP for air quality improvements is declining as the level of air quality improves (Noonan, 2011).

Our study confirms this result. In table 6 we report the rate of change of WTP with respect to our index of air quality (Q_WTP), i.e. rate of change of WTP expressed in relative (percentage terms), i.e. expressed as a ratio to the value of WTP itself. This result is in contrast with the pattern described in Section 5.1 according to which WTP is related only partially to the baseline levels of air quality. Such a finding is nevertheless consistent with the general results of other literature studies, showing an important role played by other drivers, such as income, education, household composition, and labor status.

Whether the value of air quality improvements increases or decreases over time is another important issue. Even though air quality standards should be set and implemented irrespective of the costs of doing so, the level of public support for those standards is certainly important to decide the level of environmental protection. If there is a time trend in environmental values reflecting a change in individual preferences towards environmental public goods, then the sum of benefits may change over time affecting cost benefit analysis. In table 6 we also compute the rate of change of WTP with respect to our time trend (T_WTP). This rate of growth turns out to be negative and around - 1% per year, but it is not statistically significant. Studies introducing a time trend as an explanatory variable in regressions investigating factors affecting WTP for improvements in air quality also find a negative time trend (Noonan, 2011).

Table 6: Rate of change of WTP over time and with respect to the index of air quality

	Rate of change
Q_WTP	**-1.188**
	(0.206)
T_WTP	***-0.001***
	(0.151)

Standard errors in parentheses.

6. FINAL REMARKS

This paper makes three distinct contributions to the literature. First, it operationalizes the approach developed by Ebert (2007) for recovering the underlying preference ordering from observed behavior when nonmarket goods are employed in household production. Second, it uses a unique dataset, where household consumption data are combined with an index of air quality, to estimate the marginal willingness to pay for air quality improvements in Italy. Third, it provides estimates of the willingness to pay for air quality improvements. The results are consistent with other studies investigating WTP for marginal improvements in air quality, and in particular with the meta-analysis developed by Noolan (2011).
According to our results, WTP appears to be:

- Very sensitive to the geographical location of the household;
- Not related to the baseline level of air quality but displaying decreasing returns;
- Decreasing over time (although the coefficient is not statistically significant).

Household production combined with demand analysis has a number of advantages over other approaches. First, it is not exposed to the biases of stated preferences methods because only choice-based data are used. Second, it is operational and could be used, at a low cost, in any country where micro-data on household consumption are available. In addition, the availability of demographic characteristics would allow to account for households heterogeneity in WTP such as location, number of household members and gender. Third, it allows flexibility both in the specification of the demand system and in the specification of the household production function. Different classes of household production functions coud and should be explored. Different environmental goods could be considered and included in the demand system.

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