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Can Property Values Capture Changes in Environmental Health Risks? Evidence from a Stated Preference Study in Italy and the UK

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Summary

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Keywords: Home Values, Air Pollution, Stated Preference, Vsl, Value of Statistical Life, Value of a Prevented Fatality, Health Risks, Cancer Premium

JEL Classification: I18, J17, K32, Q51, Q53

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JEL Classification: I18 (Government Policy; Regulation; Public Health); J17 (Value of Life; Forgone Income); K32 (Environmental, Health, and Safety Law); Q51 (Valuation of Environmental Effects); Q53 (Air Pollution; Water Pollution; Noise; Hazardous Waste; Solid Waste; Recycling)

Keywords: home values, air pollution, stated preference, VSL, Value of Statistical Life, Value of a Prevented Fatality, health risks, cancer premium

I. INTRODUCTION

Hedonic property value models are often used to place a value on environmental quality and the associated risks to human health. This approach assumes that the flow of housing services is affected by changes in environmental quality, and that this is capitalized into property prices. In principle, it is relatively straightforward to estimate the extent to which the real estate prices are impacted. One simply estimates regressions where home prices are a function of structural characteristics of the dwelling (e.g., square footage, number of floors), neighborhood (e.g., distance from the city center, crime), and measures of environmental quality at the time the home was sold. After controlling for everything else, the coefficient(s) on the environmental quality measure(s) is used to infer the welfare effects of an environmental change.[1]

Elegant and appealing as this approach might be, in practice it is fraught with difficulties. For starters, if the measure of environmental quality is correlated with other omitted characteristics of a home or neighborhood, the analyst may falsely attribute price impacts to shifts in environmental quality. Second, researchers typically assume, without testing, that markets respond to objective measures of environmental quality, such as the readings from air quality monitors (Chattopadhyay, 1999), or cancer risk assessments (Gayer et al., 2000, 2002). In reality people—and hence housing markets—are often either unaware of these measures, or may be responding to something else entirely.

Stated preference (SP) methods provide an opportunity to circumvent these issues. In stated preference studies, survey respondents face hypothetical scenarios with clearly specified measures of environmental quality. Furthermore, a well-constructed scenario will hold potentially confounding factors constant, thus reducing the potential for omitted variable

[1] Rosen (1974) demonstrates that at equilibrium one can infer marginal welfare effects from changes in property values. Furthermore, assuming frictionless movement of buyers and sellers, non-marginal welfare impacts of sufficiently local goods (i.e. only affects a few homes) are simply windfall gains or losses to the property owner, and therefore can be estimated solely from the hedonic price function (Palmquist, 2005).

bias in respondents' stated choices. Framing SP studies in the context of housing is a natural step towards facilitating comparisons across hedonic and SP methods. Despite this, only a few SP studies have examined the value of environmental amenities (Earnhart, 2001; 2002) and disamenities (Jenkins-Smith et al., 2002; Chattopadhyay et al., 2005; Simons and Winson-Geideman, 2005; Phaneuf et al., forthcoming) in this context.

In this paper we report the results of a SP study where we asked people to choose between homes that differ from each other in two attributes—the health risks associated with air pollution levels at a home's location and its price. The health risks are couched as reductions in the risk of dying from specified causes linked with air pollution exposures (e.g., an X in 1,000 decrease in the probability of dying). Earlier SP studies have elicited the willingness to pay for mortality risk reductions, but to our knowledge, this is the first one where the payment vehicle is a housing price differential. One advantage of this approach is that people may be more accepting of the notion of paying a premium for a home at a less polluted--and hence a lower-risk—location, than they are of other payment vehicles such as taxes or general price increases.

To our knowledge, this is the first SP study where respondents are asked to trade off attributes of a housing bundle, where the environmental attribute of interest is expressed quantitatively (i.e., reduced mortality risks from air pollution). Our survey was administered on-line to a representative sample of persons aged 40-60 in 16 cities across Italy and the United Kingdom (UK).

We ask three research questions. First, are people willing to trade off mortality risk reductions for a change in the cost of their home, and if so, what is the value of a statistical life (VSL) we can infer from their responses? Our results can be compared with the VSL figures from other studies that deployed different contexts, and with the value of a statistical cancer case estimates from hedonic pricing studies based on actual home sales (Gayer et al., 2000, 2002; Davis, 2004).

Second, does the cause of death to which the mortality risk reduction pertains affect respondents' willingness to pay? For example, do the results support the use of a "cancer premium" in benefit-cost analyses? The European Commission (2001) already recommends that a 50% premium be applied to the VSL in the context of cancer deaths. However, the empirical evidence about the existence and magnitude of such a premium is mixed (Tsuge et al., 2005; Van Houtven et al., 2008; Alberini et al., 2012). To further investigate this we randomly assign respondents to three possible causes of death to which the risk reduction pertains (cancer, cardiovascular and respiratory illnesses, and "all causes of death").

Finally, is the willingness to pay to reduce risks affected by air pollution levels where one lives? We reason that pollution levels should influence (pre-abatement) health risks, and these in turn should influence the willingness to pay per unit of risk reduction. Specifically, we would expect respondents who are faced with higher pollution levels to hold higher VSL figures. We empirically test this hypothesis using actual air pollution levels in the cities where the survey was conducted, as well as the levels of pollution subjectively perceived by the respondent.

Briefly, we find that respondents are willing to pay for homes where the risk of dying is lower. The implied VSL is about €6.4 million in Italy and €2.1 million in the UK ($8.5 and $2.8 million USD, respectively).[2] We investigate possible reasons for the difference across the two countries, and find that the respondents' perceptions of local air pollution levels explain the variation in the VSL above and beyond the actual levels of pollution in the city where each respondent lives.

[2] Converted to US dollars using 0.75464 exchange rate, which was the average for the year 2010 (http://www.oanda.com/currency/average, accessed May 31, 2011).

Persons who perceived pollution to be severe are willing to pay hefty figures to reduce risks. To illustrate, the average resident of the city of Rome holds a VSL value of €5.9 million, but if he or she believes that pollution levels in Rome are high, the VSL is as high as €10.3 million. We find that the Italians are willing to pay more for cancer mortality risk reductions, while the British respondents hold the same VSL values for all of the three causes of deaths examined in our questionnaire.

The remainder of this paper is organized as follows. We provide a review of the relevant literature in section II, and then describe the study design and housing choice questions in section III. Section IV presents the formal model. Section V describes the data. Section VI presents the estimation results, and section VII concludes.

II. BACKGROUND AND LITERATURE REVIEW

The Value of a Statistical Life (VSL) is the willingness to pay for a marginal change in one's risk of dying. In a simple static model where the state-dependent utility of income is *u(y)* when alive and *v(y)* when dead, and the chance of dying is *R*, it can be shown that the VSL is

$$\left.\frac{\partial y}{\partial R}\right|_{U-const} = \frac{u(y)-v(y)}{(1-R)u'(y)+Rv'(y)} \qquad (1)$$

The VSL is used to quantify the benefits of environmental and safety programs that reduce mortality risks.

Estimates of the VSL used in US environmental policy analyses are obtained mainly from labor market studies that measure the compensation required by workers to accept riskier jobs (controlling for all other determinants of workers' wages) (US EPA, 2010). These studies run regressions relating (log) wages to worker characteristics (e.g., experience, education, age and gender) and job characteristics, including occupation, industry, and, of course, risk of fatal and non-fatal accidents. The bulk of these studies were based on single cross sections of data and ignored the likely endogeneity of wages and risks. Viscusi and Aldy (2003) review existing studies and suggest that a plausible range of values for the VSL is $4-9 million (2000$).

The VSL is also inferred from consumers' behaviors (Blomquist, 2004) or expenditures on equipment that reduces risks (Jenkins et al., 2001). Hedonic pricing methods have been applied in automobile markets to examine the price premium for vehicles with additional safety features (Atkison and Halvorsen, 1990; Andersson, 2005), and for homes in neighborhoods with decreased mortality or cancer risks (Portney, 1981; Gayer et al., 2000, 2002; Davis, 2004).

In practice, a number of stringent assumptions must hold for the abovementioned approaches to produce credible estimates of the VSL. For starters, market participants must be aware of the risks being studied (Portney, 1981). Second, the risks must be measured correctly in the econometric analyses, and must be uncorrelated with omitted variables influencing prices or wages (Boyle and Kiel, 2001, page 140). Finally, there must be sufficient variation in risks across individuals or locales and over time.

To circumvent or at least mitigate some of these concerns, recent compensating wage studies have relied on longitudinal data, attempted to reduce measurement error, and instrumented for workplace risks (Hintermann et al., 2010; Kniesner et al., 2010; Kniesner et al., 2012). The hedonic property value literature has increasingly turned towards deploying "quasi experiments" for statistical identification. For example, Davis (2004) exploits the exogenous shock to a housing market created by a cluster of pediatric leukemia cases, and compares the affected county with a neighboring county that serves as a control group. Chay and Greenstone (2005) devise a quasi experiment that exploits the discrete relationship between air pollution regulations and compliance and non-compliance status under the U.S.

Clean Air Act. Currie et al. (2012) examine how property values and local air quality are impacted by the opening and closing of industrial plants that fall under the U.S. EPA's Toxic Release Inventory.

Still, "stated preference" studies, which are based on what people *say* they would do under hypothetical circumstances, are an attractive alternative approach when one or more of the above conditions fail. In stated preference studies, survey respondents face hypothetical scenarios with clearly specified risks and risk reductions. Self-selection is avoided because risks and risk reductions are assigned exogenously to the respondents, and appropriate study designs create the required variation in risks.

Another advantage of stated preference methods, and especially of discrete choice experiments, is that the alternatives individuals are asked to examine are created through varying the attributes of these alternatives independently of one another. This allows the researcher to disentangle the effects and the preferences for attributes that tend to be highly correlated in real life. Furthermore, a researcher can specify a scenario that holds other confounding factors constant, and therefore minimizes omitted variable bias.[3]

Finally, stated preference methods cater to a variety of contexts and causes of death, allowing researchers to test if, for example, accidental mortality risks are valued differently from causes of death usually linked with environmental exposures. Stated preference methods have been used to elicit the willingness to pay for risk reductions in a variety of contexts, including transportation and road safety (e.g., Persson et al., 2001, Bhattacharya et al., 2007), contaminated site cleanup (Alberini et al., 2007), and risks from power generation (Itaoka et al., 2006), among others.

In this paper, we use discrete choice experiments, a popular stated preference method (see Kanninen, 2007), to estimate the VSL. We ask people to choose between two

[3]Of course these advantages stem from the hypothetical nature of stated preference exercises, which is the primary criticism of the approach (Freeman, 1993, pg. 176).

hypothetical housing bundles that are identical in all aspects except for the levels of two attributes—the risk of dying from air pollution exposures at the home's location, and the price of the home. The health risks were couched as reductions in the risk of dying from specified causes linked with air pollution exposures. To our knowledge, this is the first stated preference study in the housing context with clearly specified mortality risks.

Our approach differs from Earnhart (2001, 2002), Chattopadhyay et al. (2005) and Phaneuf et al. (forthcoming) in that i) we do not ask respondents to trade off other house characteristics (e.g., size) and neighborhood characteristics (e.g., school quality), which are held constant across alternatives, and ii) health risks are explicit, rather than implied by a qualitative description of the environmental quality at the site. To further elaborate on ii), we tell people that at home A, for example, the risk of dying from cancer is X in 1000 over 10 years. In contrast, Chattopadhyay et al. (2005), for example, describe environmental quality in terms of additional pollution, no change relative to the current situation, and partial or full cleanup.

Our approach is different from that used by Chanel and Luchini (2008), where respondents are asked to indicate which of two *cities* they would move to, the cities being identical in all aspects (size, housing, weather, public services, etc.), except for the cost of living and air pollution. These authors expressed health risks as follows: "One person out of 100 randomly chosen in the street is likely to die before 80 due to poor health related to air pollution exposure. This person will have lost around 10 years of life." Although Chanel and Luchini's wording is consistent with epidemiological evidence about air pollution (where results are typically expressed in loss of life expectancy) and introduces uncertainty by mentioning a random person, it is unclear how the respondents interpreted this statement, and it takes an extremely complicated model to infer the Value of a Statistical Life Year.

Since cost *is* an attribute in our study, and because we focus on non-accidental causes of death, our approach is also different from that deployed in Van Houtven et al. (2008), where respondents chose between two locations that are exactly the same except in terms of automobile and cancer mortality risks. Van Houtven et al. do not estimate a VSL per se; instead their interest lies in estimating how to adjust existing VSL estimates by investigating peoples' willingness to trade off different types of mortality risks.

In general, stated preference methods have found that people are willing to pay less for a home when local environmental quality problems are disclosed, whether these problems be described in a purely qualitative fashion (Jenkins-Smith et al., 2002; Simons and Winson-Geideman, 2005) or quantitatively in terms of pollutant concentrations (Guignet, 2012). We therefore expect to find that people *are* willing to pay for a home at a location with cleaner air and a lower risk of dying. We wish to find out how much exactly they are willing to pay for each unit of risk reduction, and whether their willingness to pay depends on the cause of death (cancer or otherwise).

III. QUESTIONNAIRE AND STUDY DESIGN

This paper examines the responses to housing choices under hypothetical but clearly specified conditions. These questions were placed roughly in the middle of a broader questionnaire about mortality risks (see Alberini and Ščasný, 2011).

By the time the respondents started the housing section of the questionnaire, they had received a probability tutorial, read information about one's risk of dying from various causes at any given age, and undertaken a series of discrete choice experiments about mortality risk reduction profiles. This means that they were informed about mortality risks and risk-reducing measures, and that they understood that risk reductions usually come at a cost.

We began this section of the questionnaire by asking the respondents to indicate the type of home they live in (e.g., single-family home or other), the size of the home, whether they own or rent it, how long they have lived there, and how much longer they plan to continue living there.[4] We also elicited the monthly rent for those that rent their home, and respondents who own their home were asked to estimate its value in today's housing market.[5]

Because in our choice questions respondents face tradeoffs between money and health risks due to air pollution, we next inquire about respondents' perceptions of local air pollution levels. We asked them to indicate their degree of agreement or disagreement with several statements about air pollution, such as- "The air pollution where I live could eventually have harmful effects on my health," "I am aware of my local air pollution levels," and "I am physically sensitive to air pollution."

Finally, we presented our hypothetical choice scenario:

> "Suppose you are about to buy a new home at a location that is close to where you live now, but where pollution levels are lower. You have found two homes that are almost identical for general feel of the neighbourhood, size, number of bedrooms and bathrooms, and other characteristics. The ONLY differences between these two homes are:

Risk	Risk of dying from [cause of death] attributable to air pollution, compared to that at your current home.
Price	The cost of buying the home."

Each respondent was then presented with two housing choice questions. In the first, the respondent must choose between home A (where risk and price are the same as their current home) and home B (which is in an area with better air quality, and hence lower mortality risks, but is more expensive). In the second choice question, the respondent must

[4] The purpose of the latter two questions was to determine whether the respondent is acquainted with the current housing market—as a recent buyer or a potential seller. We reason that the better the familiarity with the housing market, the more reliable the choice responses. However, our subsequent econometric analysis revealed that familiarity with the housing market had little impact on housing choice.

[5] Respondents were asked the following, "Suppose you were going to sell your home. Considering how much you paid for your home and the current housing market, how much do you think you could get for it?"

choose between two different homes. Both of these hypothetical homes are located in neighborhoods with lower levels of air pollution (and thus lower health risks) than the current neighborhood, and are more expensive than the current home.

The risk reductions were expressed as X in 1000 over 10 years. Respondents were assigned at random to one of three different causes of death: (i) all causes, (ii) cancer, or (iii) cardiovascular and respiratory illnesses. This experimental treatment allows us to examine whether people hold systematically higher values for different types of mortality risk reductions. Costs were presented as an increase in price relative to one's current home (e.g., X euro more than your current home). We also presented the annual equivalent of this premium, for each of 10 years.

To create our experimental design, we began with specifying a vector of four possible risk reductions: 2, 3, 4 and 5 in 1000 over 10 years (equivalent to 2, 3, 4, and 5 in 10,000 for one year). Five possible "price differentials" were also specified (250, 500, 1000, 1800 and 3000 euro per year, for a total of 10 years).[6]

In the first housing choice questions, home A was the same as the respondent's current home, and so the risk reduction and price differential with respect to it were zero. Home B was selected at random from the 20 possible combinations of risk reductions and price differentials mentioned above. For the second housing choice questions, we created a total of 120 pairs. One of the homes in these pairs was selected from the 20 possible combinations listed above. The other home for each pair was selected from the remaining non-dominated combinations. Respondents were then assigned at random to one of these 120 pairs. The responses to these questions are used to estimate the model outlined in the next section.

[6] For the UK respondents the costs were converted to, and presented as, British Pounds.

IV. THE MODEL

A. Theoretical Motivation

Suppose an individual is considering moving to a new house (home *j*) that consists of the bundle of attributes $(\boldsymbol{z}_j, R_j)$, where the vector $\boldsymbol{z}_j$ denotes all characteristics of the home (e.g., number of bathrooms, interior square footage, lot size) and neighborhood (e.g., public parks, school quality, crime), and R_j is an individual's risk of dying. Mortality risk is part of the housing bundle because environmental factors at the location of home *j*, such as air quality, may affect one's health and in turn their risk of dying. The expected indirect utility of home *j* to individual *i* is:

$$V_j = V(\boldsymbol{z}_j, R_j, y - C_j) = (1 - R_j) \cdot u(\boldsymbol{z}_j, y - C_j) + R_j \cdot v(\boldsymbol{z}_j, y - C_j) \qquad (2)$$

where C_j is the cost of home *j*, y denotes an exogenous level of income, $u(\cdot)$ is the level of utility experienced if the individual does not die and $v(\cdot)$ is the utility level realized if an individual does die. The housing attributes and cost of home *j* can be expressed in terms of the difference relative to one's current home $(\boldsymbol{z}_0, R_o)$, and, assuming $u(\cdot)$ and $v(\cdot)$ are linear, we can re-write equation (2) as:

$$V_j = \gamma \cdot (\boldsymbol{z}_0 + \Delta\boldsymbol{z}_j) + \alpha \cdot (R_0 + \Delta R_j) + \beta \cdot (C_0 + \Delta C_j) \qquad (3)$$

where C_0 denotes the cost of the current home, and $\Delta\boldsymbol{z}_j$, ΔR_j, and ΔC_j are the differences of the home and neighborhood characteristics, mortality risk, and costs, respectively, between home *j* and the current home. Parameters γ, α, and β are unknown coefficients.

B. Empirical Model

We posit that the responses to the choice questions in this survey are driven by an underlying random utility model (RUM). Therefore individual *i* will choose home alternative *k* at choice occasion *t* if

$$V_{ikt} + \varepsilon_{ikt} \geq V_{ijt} + \varepsilon_{ijt}\ , \ \ \forall\, j = 1, \dots, J \qquad (4)$$

where J is the number of alternative homes in the choice set (including home k). The error term ε_{ijt} captures aspects of the utility that are known to the respondent but not to the researcher. This random component is assumed to be an i.i.d. draw from a type I standard extreme value distribution.

Plugging in the deterministic aspect of utility from equation (2), and cancelling out common terms, the inequality in (4) can be rewritten as

$$\alpha\Delta R_{ikt} + \beta\Delta C_{ikt} + \varepsilon_{ikt} \geq \alpha\Delta R_{ijt} + \beta\Delta C_{ijt} + \varepsilon_{ijt}\ , \ \ \forall\, j = 1, \dots, J \qquad (5)$$

In this study we do not vary the characteristics of the home and neighborhood across alternatives, therefore $\Delta \boldsymbol{z}_{ikt}$=0 and is excluded from equation (5). The scalar ΔR_{ikt} is the mortality risk reduction made possible by living in home k relative to one's current home, and ΔC_{ikt} is the price premium that must be paid relative to the value of the current home. The coefficients to be estimated are the marginal utility of a unit risk reduction (α) and the marginal utility of income (-β).

We present respondents with two different choice questions (t=1, 2). Each choice question contains two alternative homes (J=2). In the first choice question home A is the same as the respondent's current home, so ΔR and ΔC are both zero for home A, and are different from zero for home B. In the second choice question, ΔR and ΔC are different from zero for both home A and home B.

Since we assume that the random component of utility follows a type I standard extreme value distribution, the probability of choosing home k is:

$$\pi_{ikt} = exp(\alpha\Delta R_{ikt} + \beta\Delta C_{ikt}) / \textstyle\sum_{j=1}^{2} exp\big(\alpha\Delta R_{ijt} + \beta\Delta C_{ijt}\big). \qquad (6)$$

Assuming that the error terms are independent across respondents, the log likelihood of the sample is:

$$\log L = \textstyle\sum_{i=1}^{n} \sum_{t=1}^{2} \sum_{k=1}^{2} \pi_{ikt} \qquad (7)$$

where *n* denotes the total number of respondents.

Coefficients α and β are estimated by the method of maximum likelihood. We expect the marginal utility of a reduction in mortality risk (α) and the marginal utility of income ($-\beta$) to be positive. The Value of a Statistical Life (VSL) is estimated as $(\hat{\alpha}/\hat{\beta}) \times (-1000)$. Multiplication by 1000 is necessary because risk reductions are expressed as X (per 1000) rather than 0.00X.

We estimate this model separately for respondents in Italy versus the UK. Equations (3)-(6) assume that the marginal utilities are constant across all individuals. We subsequently relax this assumption by including interactions between the risk reduction and price premium with individual characteristics of the respondent, such as gender, age and income. We also enter interactions with the perceived seriousness of the air pollution problem where the respondent lives, actual pollution levels, and the (randomly assigned) cause of death to which the mortality risk reduction pertains.

V. THE DATA

The questionnaire was administered over the internet to persons aged 40-60 in Italy and the UK in August and September 2010.[7] We collected a total of 2,426 completed questionnaires in the UK and 2,369 in Italy. The samples were comprised of an even number of men and women, and were nationally representative for education and income of the Italy and UK populations in that age group. The survey sample included both homeowners and renters, but in this paper we focus on the 1,591 and 1,477 respondents in Italy and the UK, respectively, who own their home.[8]

[7] These persons belonged to a panel of consumers assembled and maintained by IPSOS, a large survey firm with headquarters in Paris. We used the IPSOS Office in Prague, Czech Republic.

[8] The original sample included 1,868 and 1,674 homeowners from Italy and the UK, respectively, but about 13% of respondents were disregarded because they did not seem to correctly understand probabilities based on earlier visual representations and screening questions.

In both countries the respondents were drawn from the residents of cities selected to ensure geographical and air quality representativeness. The number of respondents from each city is shown in table 1. Based on our sampling scheme the majority of UK respondents were from London (39.1%) and Manchester (23.4%). Most of the Italian sample consisted of individuals from Milan (28.9%) and Rome (22.4%).

Descriptive statistics of the samples are reported in table 2 and 3. As per our sampling plan, the two samples are similar in terms of gender and age. They are also remarkably similar in terms of perceived health status, and percent with a college degree (28.8% in Italy and 26.9% in the UK). However, mean annual household income is higher in the UK (€45,551 euro) than in Italy (€34,601).[9] Regarding marital and family status, about 78% of the Italian respondents are married versus 73% of the UK respondents. Seventy-five percent of the Italian respondents and 67% of the British respondents have children.

In figure 1 we compare the perceptions of air pollution and associated health risks across the two countries. Clearly, the Italy respondents report the air quality in their city or neighborhood to be worse than their UK counterparts. The Italians are also more likely to agree with statements that air pollution levels where they live can be harmful to their health, they are more aware of their local air quality, and report being more physically sensitive to air pollution.

The fact that the Italian respondents perceive pollution in their city to be more of an issue than their UK counterparts is consistent with actual pollution levels. In figure 2, for each city we plot the mean response to inquiries about respondents' perceptions of air pollution where they live against an objective measure of air pollution (mean concentrations of particulate matter, PM_{10}, in 2009). The figure shows that air pollution levels are relatively lower among the UK cities in this study, and that in general, risk perceptions are positively

[9] All income figures are in 2010 PPP euro.

correlated with objective measures of air pollution. In other words, residents in cities with relatively high levels of air pollution perceive it to be more of an issue. We examine this relationship and its impact on willingness to pay more formally in the econometric models discussed in the next sections.

VI. RESULTS

A. Can Individuals Assess the Value of Their Home?

Our first order of business is to examine if respondents are willing and capable of assessing the value of their homes. If this is the case, we argue that they should be capable of trading off home prices and risks in the discrete choice questions of the questionnaire.

To see how well the respondents do with assessing the value of their current housing bundle, we regress the log of the respondent-reported market price of the home on a vector of structural characteristics of the home (e.g., type of home, number of bedrooms, presence of air conditioning) plus dummies indicating the city where the respondent lives.

Columns A and B in table 4 show the regression results for Italian homeowners, and columns C and D for homeowners in the UK. The reported R-squares are reasonably high, for a micro cross-sectional dataset like this one, ranging from 0.129 to 0.311. The signs and magnitude of the implicit price estimates seem plausible, even when they are not statistically significant. For example, an additional room increases the value of a home by 12 to 16%, all else constant. Models B and D include indicator variables denoting the city where a home is located, which were jointly (and often individually) statistically significant. Taken together, these results suggest that respondents are willing and capable of assessing home prices, and bode well for their ability to engage in meaningful home price-risk tradeoffs.

B. Discrete Housing Choice Results

We present our base housing choice model results (equations 5 through 7) in table 5.[10] Columns A and B refer to homeowners in Italy, and C and D to homeowners in the UK. In both countries, the marginal utility of a risk reduction (i.e., the coefficient on *drisk*, the size of the risk reduction for a given housing alternative) is positive and statistically significant. The coefficients on *dcost* (the price of the home) are always negative and statistically significant. These results in themselves are consistent with economic theory. They also imply that the larger the risk reduction, the more people are willing to pay for it. The responses to these valuation questions therefore pass the "scope" test.

Model A shows that homeowners in Italy trade off risks for income at a rate consistent with a VSL of €6.437 million euro. In model C, the corresponding figure for UK homeowners' is only about €2.143 million (PPP euro).[11] Our descriptive statistics show that the UK sample is certainly no less wealthy than the Italy sample, so we suspect that such differences in the valuation of a risk reduction might be due to differences in perceived and actual pollution levels where one lives, and the related health impacts (see section VI.D).[12]

It is of interest to see if the cause of death matters, a topic that was explored previously by Alberini and Ščasný (2011), Bosworth et al. (2009), Adamowicz et al. (2011), and Van Houtven et al. (2008), among others. The results from this earlier literature are mixed and do not point to one cause of death being valued consistently more than others.

In columns B and D of table 5 we allow the marginal utility for a risk reduction to vary depending on the randomly assigned "cause of death" to which the mortality risk

[10] Standard errors are clustered at the respondent level in all discrete choice models.
[11] Re-estimating these models with only responses from the first choice question, where a 'status quo' option was provided, yield similar VSL estimates (€8.060 and €2.492 million in Italy and the UK, respectively).
[12] As a validity check, models A and C were re-estimated with alternative specific intercepts. For both models these intercept estimates were not statistically different from zero, confirming that respondents were not systematically choosing an alternative irrespective of the attributes defining that alternative.

reduction pertains. To accomplish this, we include in the model interactions between the risk reduction and dummies for the cause of death the respondent was to consider.

Column B shows that the Italian homeowners place a greater value on reducing cancer risks (VSL= €9.266 million) than on cardiovascular and respiratory risks (VSL= €5.013 million) or when the cause of death is not specified (VSL= €5.353 million). In contrast, column D suggests that the British homeowners value reductions in the risk of dying from cardiovascular disease and from "all causes" about equally. Cancer risk reductions are valued only about half as much, but this difference is only marginally significant.

C. The Effect of Respondent Characteristics

Preference heterogeneity is often a concern when estimating discrete choice models based on a random utility framework. In other words, the marginal utilities may vary across individuals. One way of checking for this possibility is to enter in the model interactions between the attributes and individual characteristics of the respondents.

Table 6 displays results from models where we include interactions between the risk reduction and cost with individual demographics and socioeconomic characteristics of the respondent (e.g, age 55 and older, having a college degree, gender, having a child aged 5 or younger, household income expressed in units of 10,000 euro). Essentially we are looking for evidence of heterogeneity in the marginal utility of a risk reduction and/or in the marginal utility of income.

In general, the coefficients on most of the interaction terms have the expected signs, but are statistically insignificant. One exception is that, at least in Italy, respondents who have a college degree hold a higher marginal utility for a risk reduction. It is also reassuring that the interaction term between *dcost* and household income is positive, suggesting that wealthier persons hold a lower marginal utility of income, even though the coefficient on this interaction is not statistically significant at the conventional levels.[13]

In runs not reported here, we also estimated several models that include interaction terms between *drisk* and *dcost* with characteristics of a respondent's home, such as the number of rooms and type of home (multi-family condominium, row or townhome, or single-family). Our concern here was that the type of housing one lives in may be a proxy for household characteristics, and so the coefficients on these interaction terms could reflect heterogeneous tastes for risk reductions and income. Alternatively, one may reason that single-family and multi-family dwellings are separate segments of the housing market, and this might influence the housing price differential that respondents associate with different health risk levels. In any case, the coefficients on these interactions were statistically insignificant.

We also estimated variants of these models that included *drisk* interacted with the number of children in a household under 18 years of age, a dummy variable denoting whether the respondent had any children, and the total number of individuals in the household. The corresponding coefficients on these variables were positive, but not statistically different from zero.

Columns B and D in table 6 include interaction terms between *drisk* and dummy variables denoting the city where a respondent lives. A Wald test of the null that the coefficients on these interactions are jointly equal to zero fails to reject the null with the Italy data (column (B), wald statistic = 8.46, p=0.2940), but rejects it with the UK data (column (D), wald statistic = 12.49, p= 0.0518).

Given the mixed results in terms of heterogeneity based on observable respondent characteristics, we also examined the possibility for unobserved heterogeneity among

[13] Similar results were found in other specifications not reported here, where income was represented using a quadratic relationship or by including a dummy variable denoting whether household income was above the median income among respondents in that country.

respondents. The results from several mixed logit models revealed that the marginal utility for a risk reduction (α) does vary across respondents, even after controlling for observed home and household characteristics.

Assuming α is normally distributed, the mean VSL point estimates were very similar to our previous models, and so these results are omitted from the paper. However, we believe that it is more plausible for α to follow a distribution that is restricted to the non-negative semi-axis. We experimented with a log-normal distribution for α, but the estimation routine did not attain convergence. Other researchers have reported similar problems (e.g., Sillano and Ortúzar, 2005; Cherchi, 2009; Adamowicz et al., 2011).

D. Influence of Air Pollution Levels and Risk Perceptions

We have noted earlier that respondents' perceptions of air quality problems in their cities are in good agreement with actual air pollution levels. Since the housing price-risk tradeoffs were couched in an air quality setting, we wish to examine whether respondents are willing to pay more for mortality risk reductions at locales where the air quality is worse. This would provide support for the notion that the VSL is higher when the baseline risk is higher (Pratt and Zeckhauser, 1996).

We have two measures of air quality—actual pollution levels in the city where the respondent lives, and the respondent's subjective perceptions, which may reflect his or her familiarity with and attention to local air quality, as well as actual variation in local pollution levels within a city. In what follows we report results based on entering in the model interactions between each of these measures and *drisk*.

In the models of table 7, we add an interaction term between *drisk* and average PM_{10} pollution levels in the city where a respondent lives.[14] To account for other city-specific differences in the housing market, cost of living and attitudes, we also included interactions between *dcost* and city dummies .

Column A suggests that in Italy the actual pollution level where one lives has little impact on the marginal utility for a risk reduction. The interactions between *dcost* and the city indicators are generally individually significant, but a Wald test suggests that they are not significantly different from each other ($\chi^2(7) = 4.75$, p=0.690). In contrast, in the UK (column C) respondents who live in more polluted cities hold a higher marginal utility for a risk reduction. The marginal utility of income is also different across UK cities ($\chi^2(6) = 17.45$, p=0.008).

We used the results of columns A and C in table 7 to compute city-specific VSL figures, and plotted them against average air pollution levels in Figure 3. This figure summarizes the regression results, and shows that (i) the VSLs are higher for the Italy sample, which is also faced with higher pollution levels, (ii) within the Italy sample, the VSL is relatively insensitive to actual air pollution levels, whereas (iii) for the UK sample, the VSL (while generally lower than that of the Italians) increases sharply with air pollution.[15]

On the argument that people's perceptions of (or actual experience with) air pollution may be different than mean pollution levels in one's city of residence, in columns (B) and (D) of table 7 we further add interactions between *drisk* and a dummy denoting that respondents believe air pollution in their city is "high" or "very high." In both countries the coefficient on this interaction is positive and statistically significant: Perceptions or personal experience do

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[14] To proxy pollution levels where one lives we use 2009 average concentrations of particulate matter (PM_{10}). The European Environment Agency has developed a dataset consisting of 10 km^2 interpollated cells covering all of Europe (http://www.eea.europa.eu/data-and-maps/data/interpolated-air-quality-data-1, accessed April 10, 2013). Theses data are derived primarily from air quality monitoring data, and are also supplemented with model calculations, and altitude, meteorological, and climatological data (Horálek et al., 2007).

[15] Figure 3 excludes Ediburgh and Glasgow, which did not lend themselves to this model because of the very low air pollution levels in these cities.

explain the VSL above and beyond actual city-wide average pollution levels. We obtained similar results when this measure of respondent-perceived pollution severity was replaced with the other measures collected through our questionnaire.

As an illustration of the importance of perceptions, consider the average respondent. Using the results from model B, if this respondent lives in Rome he or she holds a VSL of €5.9 million, and if he perceives the pollution levels in Rome as high, he holds a VSL of €10.3 million. Using model D, this same average respondent in London would hold a VSL of about €2.8 million, but if air pollution levels in London are perceived as high, then the VSL would be closer to €5.2 million. In sum, in both countries, respondents who perceive the air pollution where they live as high hold a VSL that is almost twice as large. This confirms that personal experience and perceptions of air pollution, which in turn should influence a respondent's calculation of baseline risks, do play a crucial role in the valuation of risk reductions.

VII. CONCLUSION

We conducted a stated preference (SP) study asking Italian and British respondents to engage in tradeoffs between mortality risk reductions associated with improved air quality and the cost of housing. There have been several SP studies that estimate the value of reductions in health risks (e.g., Krupnick et al., 2004; Alberini et al., 2007; Alberini and Ščasný, 2011a; Tsuge et al., 2005), but to our knowledge we are the first to do so in the context of housing and using a housing price differential as the payment vehicle. Other SP studies have asked respondents to trade off housing bundle attributes, one of which is environmental quality, but we are the first to express environmental quality in terms of a quantitative environmental health risk--a reduction of X in 1,000 in mortality risks.

Our results show that people are willing and capable of making tradeoffs between mortality risks associated with air pollution and the cost of their home. Their responses are consistent with the economic paradigm: The marginal utilities of a risk reduction and income are positive and significant. In other words, the larger the risk reduction, the more people are willing to pay for it.

The VSL figures we obtain for Italy (about €6 million) are consistent with those estimated in other studies on that country, which range from €0.3 to €6.2 million (2010 euro) (Alberini and Chiabai, 2007; Alberini et al., 2007; Alberini and Scasny, 2011; Alberini et al., 2012).[16] We did notice large differences in the Value of a Statistical Life (VSL) between homeowners in Italy and the UK. We attribute this difference to the fact that our British sample is less concerned about air pollution and its effect on their health, a rationale that is seemingly based on objective mortality risks. For example, anthropogenic emissions of particulate matter ($PM_{2.5}$) resulted in a 6.9 month decline in statistical life expectancy in the UK in 2000, whereas the corresponding loss in Italy was 2.1 months greater (Amann et al., 2005, pg. 60). Mean annual concentrations of PM_{10} in 2005 and 2009 were much lower among the UK cities featured in our study, compared to the corresponding cities in Italy. In general, respondents in more polluted cities do perceive the air pollution levels where they live as relatively high, and hold a higher value for a reduction in the associated mortality risks.

In both countries, perceived pollution and/or personal experience with pollution seem to play a large role in determining respondents' value for a risk reduction. Even after controlling for actual pollution levels we find that respondents who perceive the air pollution levels where they live as relatively high hold a VSL that is twice as large, all else constant.

[16] All figures were converted to 2010 Euro using the consumer price index reported by ISTAT (http://www.istat.it/en/, accessed June 13, 2013).

Similar to the past literature, we find mixed support for the use of a cancer premium in benefit-cost analyses. Among Italian homeowners we find that the VSL associated with air pollution is much higher for cancer deaths, versus those from cardiovascular and respiratory disease or when the cause of death is not specified. However, among the UK respondents there are no statistically significant differences in the VSL estimates across different causes of death.

In summary, both hedonic property value and SP methods have their strengths and weaknesses. A potential direction for future research would be to repeat a similar valuation questionnaire in conjunction with a supplemental hedonic study.[17] Building on the combined hedonic and SP work of Earnhart (2001, 2002), Chattopadhyay et al. (2005), and Phaneuf et al. (forthcoming) will help us better compare the two approaches, and more systematically identify in what contexts the results agree and disagree. This will allow economists to more accurately identify how environmental quality affects home values, and in turn, yield better estimates of welfare impacts.

[17] See Whitehead et al. (2008) for a review of studies that combine both revealed and stated preference techniques, the advantages and disadvantages of each method, and how combining these methods can reduce these disadvantages.

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Figure 1. **Perceptions of Air Pollution.**

Figure 1a. Air pollution level in my city.

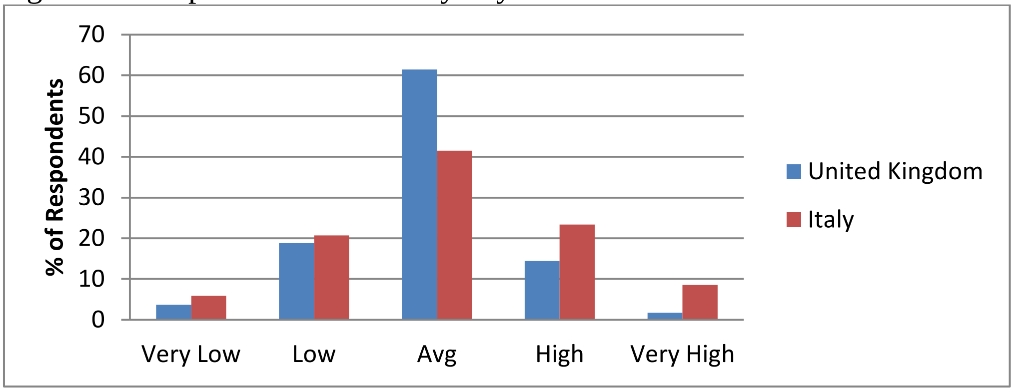


Figure 1b. Air pollution where I live could harm my health.

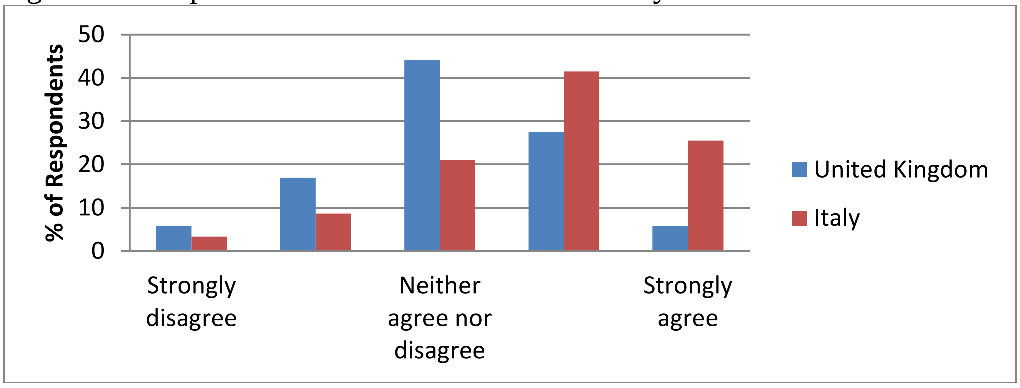


Figure 1c. I am aware of my local air pollution levels.

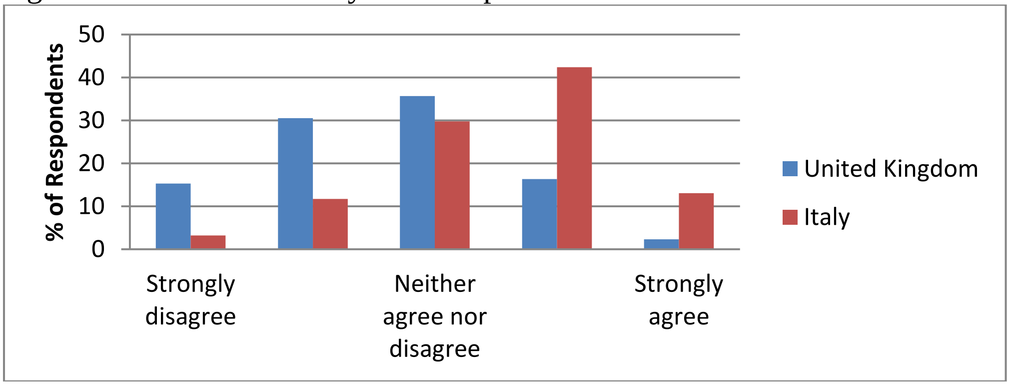


Figure 1d. I am physically sensitive to air pollution.

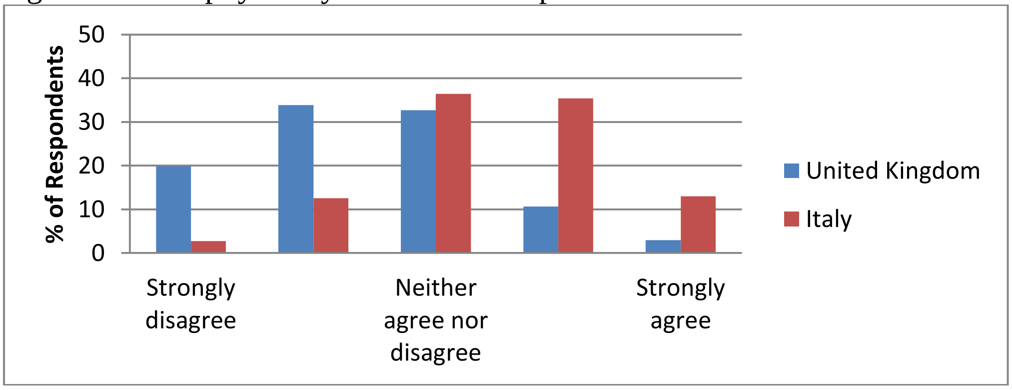


Figure 2. Mean Perceptions versus Actual Air Pollution by City.

Figure 2a. Air pollution levels in my city. †

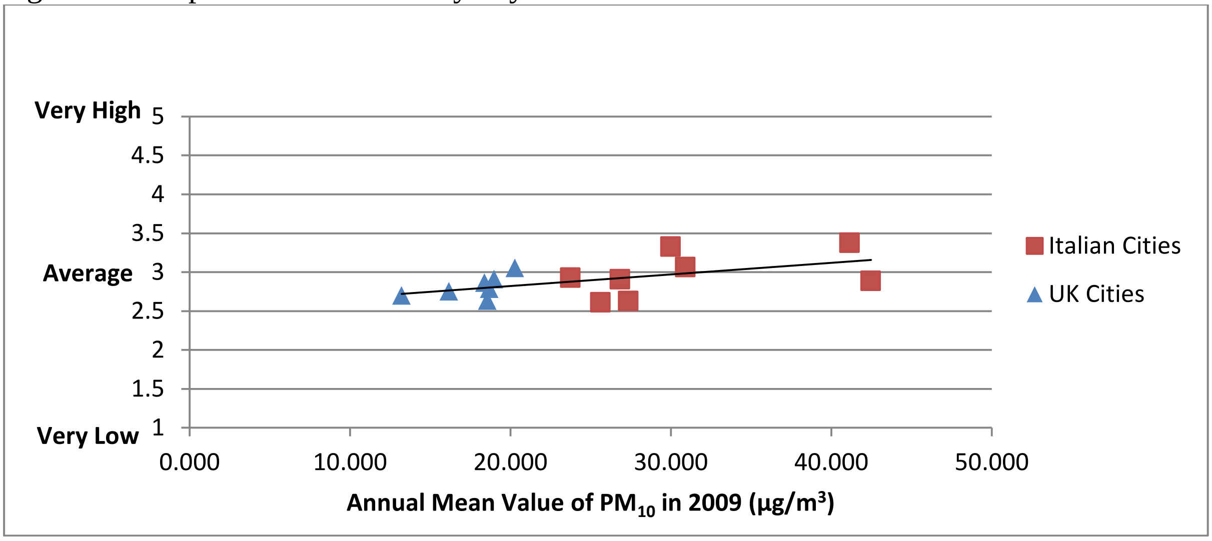
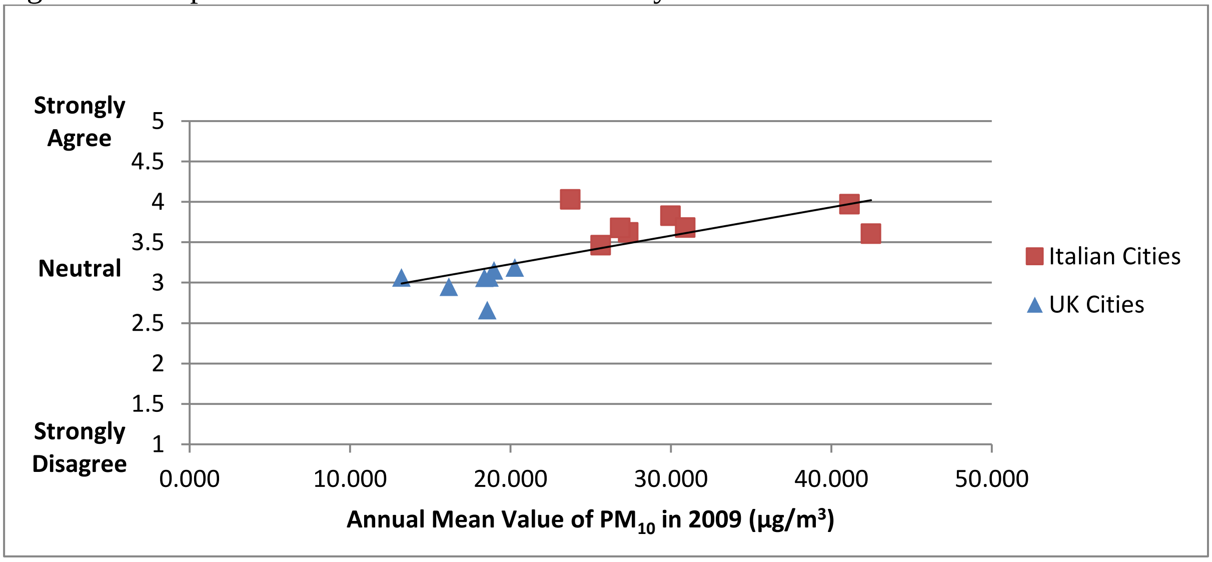
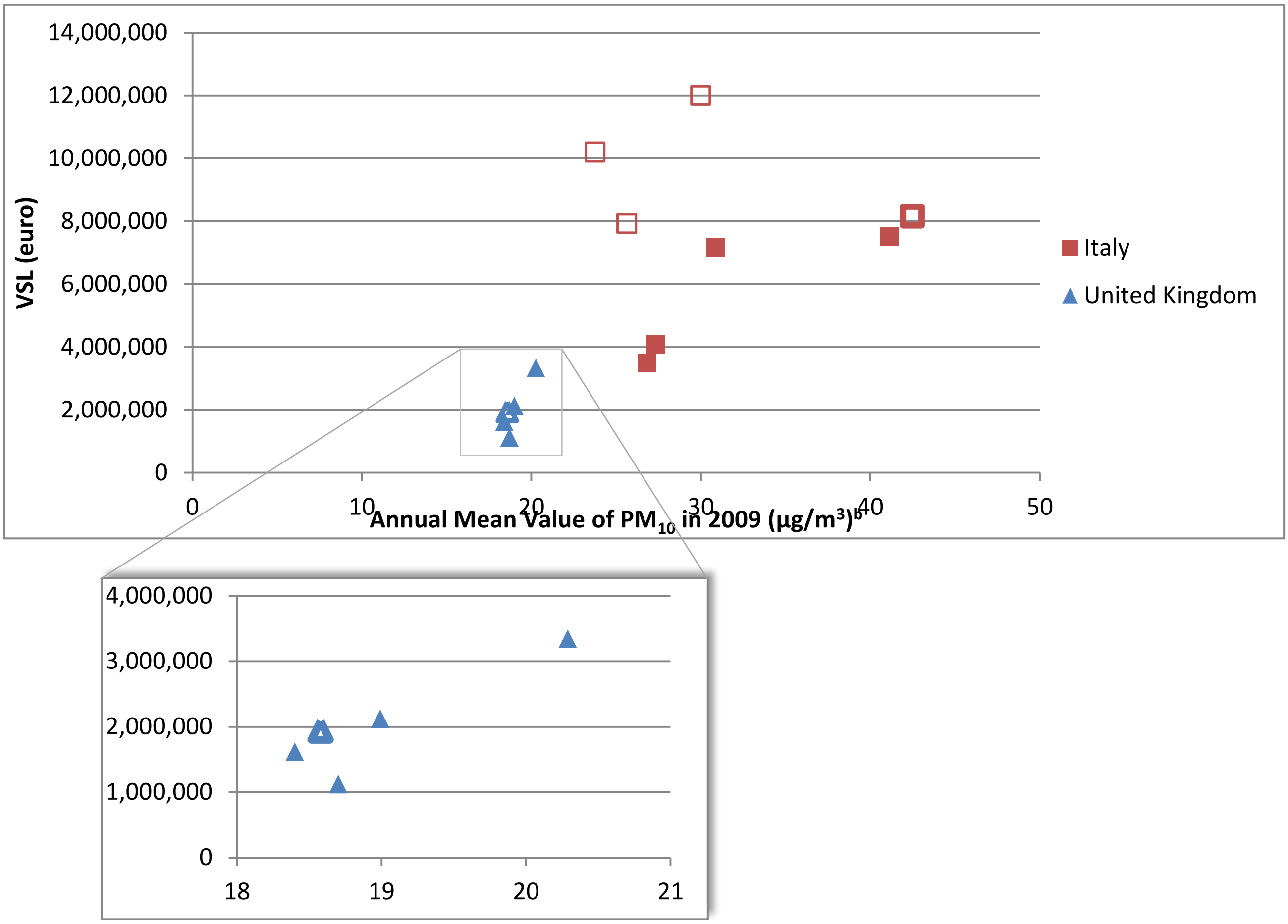


Figure 2b. Air pollution where I live could harm my health.†



† City specific pollution levels extracted from http://www.eea.europa.eu/data-and-maps/data/interpolated-air-quality-data-1, accessed April 10, 2013.

Figure 3. City Specific VSLs and Air Pollution Levels (from models A and C in table 7).[a]



a – A completely filled-in marker denotes statistical significance at least at the 5% level, and a partially filled-in marker at the 10% level. A marker that is note filled-in denotes estimates that are not statistically distinguishable from zero.

b – City specific pollution levels extracted from http://www.eea.europa.eu/data-and-maps/data/interpolated-air-quality-data-1, accessed April 10, 2013.

Table 1. Number of Respondents by City.[a]

Italy		United Kingdom	
Bari	170	Birmingham	239
Bologna	87	Bristol	93
Florence	67	Cardiff	38
Milan	457	Edinburgh	63
Naples	174	Glasgow	120
Palermo	69	London	576
Rome	355	Manchester	345
Turin	205		

a – Seven respondents in Italy and 3 in the UK did not indicate their city.

Table 2. Sample Descriptive Statistics of Italy Homeowners.

Variable	Obs	Mean	Std. Dev.	Min	Max
Age (years)	1584	49.004	6.074	40	60
Perceived health status (1 to 5, 1=poor and 5= excellent)	1583	3.190	0.852	1	5
College degree (dummy)	1591	0.288	0.453	0	1
Male (dummy)	1584	0.502	0.500	0	1
Married (dummy)	1591	0.777	0.416	0	1
Single (dummy)	1591	0.223	0.416	0	1
Hhsize (# of people in household)	1591	3.120	1.162	1	8
Income (Household income, 10,000 euro)	1591	3.460	1.715	0	7.000
Children (dummy)	1591	0.757	0.429	0	1
Children0_18 (# of children 18 years old or younger)	1205	1.032	1.712	0	18
Child0_5 (has child between 0 and 5 yrs old, dummy)	1205	0.144	0.352	0	1

Table 3. Sample Descriptive Statistics of United Kingdom Homeowners.

Variable	Obs	Mean	Std. Dev.	Min	Max
Age (years)	1472	50.007	6.137	40	60
Perceived health status (1 to 5, 1=poor and 5= excellent)	1474	3.306	1.011	1	5
College degree (dummy)	1477	0.269	0.444	0	1
Male (dummy)	1474	0.537	0.499	0	1
Married (dummy)	1477	0.726	0.446	0	1
Single (dummy)	1477	0.274	0.446	0	1
Hhsize (# of people in household)	1469	2.683	1.234	1	8
Income (Household income, 10,000 euro)	1477	4.555	2.829	0	12.897
Children (dummy)	1477	0.674	0.469	0	1
Children0_18 (# of children 18 years old or younger)	996	0.917	1.282	0	15
Child0_5 (has child between 0 and 5 yrs old, dummy)	996	0.123	0.329	0	1

Table 4. Stated Home Price Model Results (dependent variable = ln(price)).

	Italy		United Kingdom	
VARIABLES[a]	(A)	(B)	(C)	(D)
Single-family home[b]	0.0429	0.0564	0.0642	0.1370**
	(0.0388)	(0.0380)	(0.0621)	(0.0572)
Townhouse or row home[b]	-0.0545	-0.0194	-0.0394	0.0075
	(0.0547)	(0.0536)	(0.0669)	(0.0612)
Other type of home[b]	-0.1033	-0.1121	-0.1449*	-0.1121
	(0.1405)	(0.1366)	(0.0770)	(0.0701)
Number of rooms	0.1599***	0.1617***	0.1201***	0.1221***
	(0.0084)	(0.0082)	(0.0098)	(0.0087)
Number of rooms missing	1.1890***	1.2840***	1.4480***	1.3940***
	(0.3005)	(0.2924)	(0.4609)	(0.4113)
Air conditioning	0.0835***	0.0982***	0.1214	0.1864*
	(0.0278)	(0.0278)	(0.1232)	(0.1101)
City specific constants	No	Yes	No	Yes
Observations	1,832	1,832	1,596	1,596
R-squared	0.190	0.240	0.129	0.311

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
a-Binary indicator variable unless otherwise noted.
b-Omitted category is flat or apartment in a multi-family building

Table 5. Conditional Logit Model of Home Choice: Base Model and Cause of Death.

	Italy		United Kingdom	
VARIABLES	(A)	(B)	(C)	(D)
drisk	0.1122***		0.0810***	
	(0.0182)		(0.0192)	
× all causes		0.0947***		0.0886***
		(0.0253)		(0.0287)
× cancer		0.1639***		0.0506*
		(0.0280)		(0.0270)
× cv disease		0.0887***		0.1067***
		(0.0254)		(0.0274)
dcost	-2E-05***	-2E-05***	-4E-05***	-4E-05***
	(3E-06)	(3E-06)	(4E-06)	(4E-06)
VSL [a]	6,436,931***		2,143,450 ***	
	(917,147)		(382,287)	
VSL (all causes)[a]		5,353,450 ***		2,339,466 ***
		(1,281,097)		(627,638)
VSL (cancer) [a]		9,265,555 ***		1,336,871**
		(1,684,981)		(627,426)
VSL (CV disease) [a]		5,012,595***		2,817,625***
		(1,307,602)		(604,735)
Wald Tests:				
VSLs equal		p = 0.0692		p = 0.1990
VSL(all) = VSL(cancer)		p = 0.0469		p = 0.2354
VSL(cancer) = VSL(CV)		p = 0.0331		p = 0.0788
VSL(CV) = VSL(all)		p = 0.8484		p = 0.5749
Observations	6,364	6,364	5,908	5,908
ll	-2185.5639	-2182.0112	-1975.3218	-1973.6639

Clustered standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1
a- VSL estimates reported in 2010 Euro.

Table 6. Conditional Logit Model of Home Choice: Household Heterogeneity.

	Italy		United Kingdom	
VARIABLES	(A)	(B)	(C)	(D)
drisk	0.0931***	0.0992**	0.1132***	0.1111***
	(0.0264)	(0.0444)	(0.0297)	(0.0405)
× above 55 years of age	-0.0023	-0.0045	-0.0399	-0.0436
	(0.0334)	(0.0336)	(0.0317)	(0.0318)
× college degree	0.0953***	0.0945***	0.0303	0.0376
	(0.0310)	(0.0314)	(0.0330)	(0.0332)
× male	-0.0109	-0.0078	-0.0388	-0.0396
	(0.0268)	(0.0271)	(0.0286)	(0.0288)
× has child 0 to 5 years old	-0.0065	-0.0080	-0.0256	-0.0303
	(0.0290)	(0.0292)	(0.0296)	(0.0298)
dcost	-3E-05***	-3E-05***	-4E-05***	-4E-05***
	(6E-06)	(6E-06)	(6E-06)	(6E-06)
× income	2E-06	2E-06	4E-07	8E-08
	(1E-06)	(1E-06)	(1E-06)	(1E-06)
drisk × city dummies	No	Yes	No	Yes
		$\chi^2(7) = 8.46$		$\chi^2(6) = 12.49$*
Observations	6,336	6,336	5,896	5,896
ll	-2168.0991	-2163.2639	-1968.1991	-1960.3318

Clustered standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

Table 7. Conditional Logit Model of Home Choice: Pollution Levels and Risk Perceptions.

	Italy		United Kingdom	
VARIABLES	(A)	(B)	(C)	(D)
drisk	0.0781	0.0720	-0.7048***	-0.6535***
	(0.0983)	(0.0982)	(0.2248)	(0.2252)
× pm10	0.0004	-5E-05	0.0434***	0.0340***
	(0.0028)	(0.0028)	(0.0118)	(0.0119)
× local pollution is high		0.0685**		0.1030**
		(0.0293)		(0.0407)
× above 55 years of age	-0.0024	-0.0008	-0.0424	-0.0386
	(0.0335)	(0.0335)	(0.0318)	(0.0317)
× college degree	0.0943***	0.0905***	0.0338	0.0234
	(0.0312)	(0.0313)	(0.0331)	(0.0335)
× male	-0.0120	-0.0084	-0.0387	-0.0368
	(0.0269)	(0.0270)	(0.0288)	(0.0289)
× has child 0 to 5 years old	-0.0047	-0.0043	-0.0303	-0.0338
	(0.0291)	(0.0291)	(0.0297)	(0.0298)
dcost				
× income	2E-06	2E-06	3E-07	3E-07
	(1E-06)	(1E-06)	(1E-06)	(1E-06)
× Bari	-4E-05***	-3E-05***		
	(1E-05)	(1E-05)		
× Bologna	-4E-05***	-4E-05***		
	(1E-05)	(1E-05)		
× Florence	-2E-05	-2E-05		
	(1E-05)	(1E-05)		
× Milan	-2E-05***	-3E-05***		
	(8E-06)	(8E-06)		
× Naples	-2E-05**	-2E-05**		
	(9E-06)	(9E-06)		
× Palermo	-2E-05	-2E-05		
	(1E-05)	(1E-05)		
× Rome	-2E-05***	-3E-05***		
	(8E-06)	(8E-06)		
× Turin	-2E-05**	-2E-05**		
	(9E-06)	(9E-06)		
× Birmingham			-4E-05***	-4E-05***
			(8E-06)	(8E-06)
× Bristol			-7E-05***	-7E-05***
			(1E-05)	(1E-05)
× Cardiff			-4E-05*	-4E-05**
			(2E-05)	(2E-05)
× Edinburg			-2E-06	-3E-06
			(2E-05)	(2E-05)
× Glasgow			-1E-05	-1E-05
			(1E-05)	(1E-05)
× London			-4E-05***	-4E-05***
			(7E-06)	(7E-06)
× Manchester			-4E-05***	-4E-05***
			(8E-06)	(8E-06)
Ho: dcost × city equal:	$\chi^2(7) = 4.75$	$\chi^2(7) = 4.27$	$\chi^2(6) = 17.45$***	$\chi^2(6) = 16.59$***
Observations	6,336	6,336	5,896	5,896
ll	-2165.0251	-2161.9331	-1955.5453	-1951.5928

Clustered standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

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