The Amenity Value of the Italian Climate

by David Maddison and Andrea Bigano[1].

Non-technical abstract

Climate possesses an 'amenity' value to households in the sense that climatic conditions affect health, heating or cooling requirements, clothing and nutritional needs, recreational expenditures and leisure opportunities. Certain climate variables such as sunshine may also induce a sense of psychological wellbeing. Combined with predicitions concerning the scale and direction of possible future climate change, a knowledge of the implicit values that households place on climate variables might form the basis for a money metric measure of the overall impact of climate change on welfare.

In fact, economic theory suggests that if individuals are freely able to select from differentiated localities then the tendency will be for the benefits associated with particular localities to become collateralised into land prices and wages. Households are attracted to cities offering preferred combinations of environmental amenities and this inward migration both increases land prices within those cities as well as depressing the wage rates in local labour markets. Thus, across different cities there must generally exist 'compensating' wage and house price differentials. In such cases the implicit money value of marginal changes in the level of climate amenities can be inferred from the regional house and wage price differentials.

This theory is tested on a data set containing regional house prices and climate variables for Italy. It is shown that Italian households do indeed display a strong

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s would like to thank Giovanna Meregalli and Barbara Sianesi for their research assistance.

preference for particular types of climate. More specifically the typical Italian household would be willing to pay 1,344 Lira per year to avoid a millimetre of rain, 137,447 Lira to avoid an extra degree Centigrade on mean annual temperature and an extra 89,520 Lira to avoid an additional percentage point of cloud coverage.

Abstract

The hedonic literature suggests that locations with more favourable characteristics should display compensating wage and residential land price differentials. Using the hedonic price technique estimates of the willingness to pay for small changes in some key characteristics of the Italian climate were undertaken. The hedonic price models were specified both in terms of annual values and in terms of monthly values. The main conclusion of the analysis is that there exists considerable empirical support to the hypothesis that amenity values for climate are embedded in residential property prices. Italians would typically prefer a dryer, sunnier climate than at present, warmer in the winter and slightly cooler during the summer. The existence of compensating wage differentials was not investigated. These results may have relevance to the task of determining the economic impact of potential future climate change.

Keywords

Climate Change, Italy, Hedonics.

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1. Introduction

Climate is an important input to many household activities. Climatic factors alter the cost of engaging in various pastimes and this suggests that households ought to be interested in climate as well as explaining why households living in climatically different regions are likely to consume different patterns of marketed commodities: it is to compensate for, or alternatively take advantage of particular sorts of climate.

But if at the same time as being free to adjust patterns of demand individuals are also freely able to select from differentiated localities then climate itself becomes a choice variable. The tendency will be for the benefits associated with particular climates (in terms of the differing costs of providing particular service flows of value to the household) to become collateralised into property prices and wages. Households are attracted to regions offering preferred combinations of environmental amenities and this inward migration both increases house prices within those cities as well as depressing the wage rates in local labour markets. Thus across different cities there must generally exist both compensating wage and house price differentials. In such cases both climate and income become choice variables and the value of marginal changes can be discerned from the hedonic house and wage price regressions (eg Palmquist, 1991). The present work is an attempt at determining whether house prices in Italy are significantly affected by climate. The work is prompted by the current concern over potential future climate change. In fact, Italy has a very diverse climate and it is this feature of Italy which makes it a particularly suitable country upon which to try out the hedonic approach to revealing willingness to pay for climate variables. The work draws heavily on Bigano (1996).

The amenity value of climate is the direct impact of climate change on household welfare. Amenity values include welfare changes arising from the impact of climate on health, changes in heating or cooling requirements, clothing and nutritional needs, recreational expenditures and leisure opportunities. Also included are benefits which arise from the 'pure' amenity value of certain types of climate (eg a sense of psychological wellbeing). It is difficult to see how the latter class of benefits could ever be determined from analysing differences in consumption patterns between households based in climatically different regions. Changes in amenity values may prove to be a considerable proportion of the overall impact of climate change on society but it is a subset which has received surprisingly little attention in the climate change literature. Attaching a money metric measure to climate may prove useful given the current concern about climate change, and estimating marginal willingness to pay is a necessary step towards an economically founded evaluation of such a change. The hedonic approach also highlights the fact that, although climate change is global issue, its effects on people's welfare are likely to be different in different locations. Some regions can be expected to be negatively affected by an increase in temperature, whereas other areas may actually benefit from it. In the view of some commentators climate change may be no bad thing particularly for northern European countries like Britain (eg Maddison 1996a and Mortimer, 1996) once suitable changes to lifestyles have occurred. Coincidentally Mortimer argued his case by pointing out that Britain was predicted to approach the type of climate which currently characterises Central Italy: a climate which is widely regarded as being in some sense 'optimal'. Of course this begs the question what will happen to the climate of Southern and Central Italy if the enhanced greenhouse effect takes a grip, as subsequent replies to Mortimer's controversial article pointed out. The analysis presented below enables us to speculate on the effects of that eventuality.

The advantages of taking the hedonic approach to valuing the amenity of climate is that one is essentially using current day analogues to future climate change it can be presumed that any underlying differences reflect differences once long run cost minimising adaptation to climate has occurred. Although the rate of climate change may be rapid in geological terms it is still very slow in relation to the lifespan of households. Apart from its strong theoretical underpinnings it is in this sense that the hedonic technique possesses particular advantages over rival methodologies many of which attempt to infer the likely effects of a permanent change in climate from the observed effects of day to day variations in weather. Nonetheless the hedonic approach has problems relating to the question of how reasonable the underlying assumptions of the method are and these obviously need to be discussed in depth.

The remainder of this paper is organised as follows: the next section reviews existing evidence on the amenity value of climate as indicated in the hedonic literature. In the third section the data sources for the exercise are discussed and the climate of Italy is described. The fourth section considers the special problems posed by the nature of the variables under investigation, the plausibility of the assumptions underlying the technique and the deviations of the empirical model from the model proposed in theory. The fifth section reports on the results of the hedonic analysis. The results cannot for a number of reasons be regarded as definitive but they are without doubt highly encouraging. The final section concludes.

2. Studies into the amenity value of climate.

The existing hedonic literature on the amenity value of climate has been recently examined by Leary (1994). He judged that the existing evidence strongly suggests that the effect of climate on migration decisions, wages and house prices is important, that the amount of money that people is willing to pay to live and work in a better climate conditions ranges from several hundreds to a several thousand dollars per year, that some climate characteristics can unambiguously be regarded as amenity and other as disamenities. On the other hand, all the studies considered, although focusing exclusively on United States Standard Metropolitan Statistical Areas (SMSA), differed widely in the actual specification of the hedonic model, the choice of the explanatory variables so that comparison of results is almost impossible. Moreover he noted that only for a few climate variables a consistent and robust characterisation in terms of individuals' preferences can be inferred from the literature, so that they can be reasonably classified as amenity or disamenity. In particular, the studies support the intuitively appealing propositions that households prefer sunny, mild climates. Higher summer temperatures are sometimes found to repel migrants and have negative implicit prices, suggesting that hot summers may be a disamenity. For other attributes of climate, results are mixed. Indeed, climate attributes have hardly ever been the main focus of the analyses performed, the main exception being the seminal paper of Hoch and Drake (1974) and the papers by Maddison (1996a and 1996b).

Hoch and Drake analysed three samples of worker categories using Bureau of Labour Statistic micro data for 86 SMSAs. Hoch and Drake assumed away the property side of hedonic models by hypothesising perfectly elastic land supply thus preventing amenity effects from being capitalised into land rents. Climate was specified in terms of precipitation and summer and winter temperature, the squares of the two latter terms, an interaction term for summer temperature and precipitation, wind speed, degree days, snowfall, number of very hot (>90°F) and number of very cold (<32°F) days. The analysis was performed separately for three job category subsamples. In the first one, the coefficients on climate variables were significant and had the expected sign only as long as regional dummies were excluded, whereas in the other two they performed better. It must be noted however, that the only other explanatory variables were regional dummies, racial composition and urban size. No account was given of important site specific characteristics like crime rates, pollution and other quality of life indicators.

The first attempt to estimate climate effects on both wages and house prices is to be found in Roback (1982) as an empirical illustration of her theoretical model. She used microdata for the 98 largest American urban areas. Roback performed a different pair of regressions (on wages and residential site prices) for each climate variable (snowfall, degree days, cloudy days and clear days). These variables are highly significant and their coefficient have the expected sign in the wages regression, but performed poorly in the residential site prices regressions, where only population growth, population density and unemployment rates are significant.

Smith (1983), used only real wages as dependent variables, and employed a cost of life index as a deflator. The focus of the analysis was mainly on the different effects of job-specific and site-specific characteristics on wages for different industries, job categories and ethnic composition of the workers. Climate, expressed by five variables (mean annual sunshine hours, higher and lower temperatures, annual average wind speed and precipitation) was one of the site-specific characteristics considered. Only sunshine proved to have significant (negative) effect on wages indicating that it is regarded as an amenity.

Hoen et al. (1987) and Blomquist et al. (1988) utilise the same empirical analysis as empirical illustration of two slightly different theoretical models. Micro data for 285 SMSAs were used. They estimated two hedonic regressions one for wages and one for housing expenditures. A Box-Cox grid search procedure was implemented, showing that neither the linear nor the semilog spcification where the one performing better. They controlled for structural characteristics of houses and individual characteristics of workers. The same amenity variables were used in both equations and included coast proximity, crime rates, teacher-pupil ratios, total suspended particulates, visibility and six (other) climate variables (sunshine, precipitation, humidity, wind speed, heating and cooling degree days). Amenity variables were found highly significant in both equations. Among the climate variables, only sunshine was found unambiguously to be an amenity, i.e. its coefficient displayed the same sign in both equations, whereas the other climate variables net effect depended on the relative magnitude of their coefficients. In Blomquist et al. the same set of result was used to derive quality of life rankings for the metropolitan areas considered.

To the best of the authors' knowledge, outside of the United States there is an almost complete lack of published climate amenity value studies. Possibly the reason for this is that climate variables are generally undeviating even over large distances at which point the underlying asssumptions of the hedonic technique become difficult to defend because of language, political boundaries and cultural differences. The only work is Maddison (1996b and 1996c) who considers the case of Great Britain along the lines of Roback's (1982) general framework. Maddison estimates the property price and the wages equation in turn using pooled data for 127 English Counties, Scottish and Welsh Regions, Metropolitan Areas and London Boroughs. Climate is described in terms of annual averages for precipitation, sunshine, wind speed, temperature and relative humidity. Plausible implicit prices emerge for each of these climate variables. The main conclusion is that British people would strongly prefer a warmer climate and that property prices rather than wage rates account for most of the compensation for differences in climate between British counties.

3. Data sources

The primary data source for this investigation into the amenity value of the Italian climate is *Il Sole -24 Ore del Lunedì* which is a leading financial newspaper based in Milan. The paper publishes an annual report on the quality of life in different Italian provinces. Six sets of indicators were used: general economic indicators, job and business activity indicators, public services and environmental quality indicators, crime rates, demographic characteristics and leisure quality indicators. Apart from reporting the data the paper also computes an overall quality of life index by ranking regions according to the best performing province on each account and then summing across the different performance indicators to provide the final ranking. Such a procedure is of course entirely arbitrary. The property price data contained in the survey relates to average house prices in the semi-central zone of the provincial capital measured in thousand of lira per square metre. Data is available for five years from 1991 to 1995 at the provincial level and there are data records for 95 provinces in Italy[2]. Additional data relating to annual inflation rates is taken from the Istituto Nazionale di Statistica in Rome. A significant closure on the model arises in that provinicial wage rates are not available. Hence only the hedonic house price function can be estimated. The variables contained in the data set are contained in table 1.

The climate data is taken from Cramer and Leemans (1991). This database merges records drawn from a variety of published sources and after various checks for quality and reliability a terrestrial grid is created at the 0.5° level of resolution. Only mean temperature, precipitation and cloudiness are included in the data set and these are reported as monthly averages. The data refer to the typical climate recorded over the period 1941 to 1961. Temperature data recorded in the original sources often incorporated adiabatic lapse rates. The presence of such factors implies that temperature values were corrected as if the station were located at sea level. Fortunately Cramer and Leemans report temperatures corrected to reflect the modal altitude of the grid cell above sea level which is the more appropriate concept for our purposes. Each province was allocated a set of climate variables using the grid cell in the data set closest to the provincial capital. For some provinces (Ancona Brindisi, Lecce, Bari, Chieti Pescara, Palermo, Siracusa Trapani and Macerata) the grid square in the Cramer and Leemans data set was not complete because the cells were less than 60% land. In these cases adjacent grid cells were used.

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new provinces have recently been created but the database remained with the original set for the sake of comparison.

Unlike many other European countries climate in Italy varies markedly across the regions and provinces (see table 2). Its topographic characteristics and the influences of the seas that surround the peninsula lead to a noticeable variety in climatic regions. Cantu (1969-1981) indicates eight climatically quite different regions: the Alps, the Po Valley, the Northern Adriatic, the Central and Southern Adriatic, Liguria and Northern Tuscany, the Thyrrenian versants, Calbria and Sicily, and Sardinia. In Alpine Italy, climate is similar to that of Switzerland or Austria although with heavier precipitation. Winter is bitterly cold and generally the driest season. Daily thermal excursion is high. A climate similar to the one prevailing in Central Europe can be found in the Po valley, although this area is colder than Paris or London in midwinter. Summers are generally hot and quite humid. The Northern Adriatic region is characterised by the influence of the Bora, a very cold and gusty wind blowing mostly in wintertime from north-east, which can be quite strong and sudden in appearence. Its effects, however, are generally limited to the small area around Trieste and its influence is hardly ever noticed below Pescara. The southern reaches of the Alps and the Appenini Ridge form a natural shield from the Northern influences, and temperatures in Liguria and Northern Tuscany, and in the Thyrrenian versants are generally higher than those prevailing at the same latitudes to the east of the Appennini. Here, a typical Mediterranean climate prevails, with mild winter and hot and dry summers. The Appennini, however, are generally wet for the most part of the year and quite snowy in winter. On the Adriatic side, below the 39th parallel the climate is similar to the Western Side in spring and summer, but subject to different influences. In particular, anticyclonic weather in the warm seasons is due to the influence of the Balkans, whereas in winter depressions can reach the area through the Po valley. Finally in Calabria, Sicily and Sardinia the weather is generally characterised by the contrast between a very long and stable sunny summer and a high degree of instability in winter.

Table 1: Definition of variables included in the data set

PRICE	Property prices in the provincial capital (1000 Lira per m^2).
CULTURE	Number of cultural and artistic societies per 100,000 inhabitants.
BOOKS	Number of bookshops per 100,000 inhabitants.
GYM	Number of gymnasiums per 100,000 inhabitants.

MURDER	Number of murders per 100,000 inhabitants.
CARTHEFT	Number of cars reported stolen per 100,000 inhabitants.
BURGLARY	Number of burglaries per 100,000 inhabitants.
BANKROB	Number of bank robberies per 100,000 inhabitants.
FRAUD	Number of frauds per 100,000 inhabitants.
BAGS	Number of bags snatched per 100,000 inhabitants.
PENSION	Average waiting days for payment of a new pension.
LETTER	Average waiting days for the delivery of a letter.
PHONE	Average waiting days for the installation of a telephone.
STUDENT	Average number of students per class in high school.
VEHICLES	Number of motor vehicles per kilometre.
POPDEN	Population density (persons per km^2).
NOTOCCUP	Unoccupied houses as a percentage of all houses (%).
UNEMP	Unemployed persons as a percentage of the labour force (%).
PRECIP	Precipitation (mm).
JANPRECIP	January's precipitation (mm).
JULPRECIP	July's precipitation (mm).
TEMP	Mean temperature (°C).
JANTEMP	January's temperature (°C).

JULTEMP	July's temperature (°C).
CLOUD	Fraction of cloudy days.
JANCLOUD	Fraction of cloudy days during January.
JULCLOUD	Fraction of cloudy days during July.

Source:Leemans and Cramer (1991), Il Sole - 24 Ore del Lunedì (1991, 1992, 1993, 1994 and 1995) and Istituto Nazionale di Statistica (1995).

Table 2: Climatic characteristics of the 95 Italian provinces

	Mean	Std Dev	Minimum	Maximum
TEMP	12.49791	3.54117	1.10833	18.14170
PRECIP	1012.33830	353.02262	530.00000	1889.00000
CLOUD	0.49000	0.054127	0.39833	0.61417
JANPRECIP	84.97660	36.12755	32.00000	243.00000
JULPRECIP	45.05106	39.53409	2.00000	164.00000
JANTEMP	3.16000	4.05075	-7.10000	10.90000
JULTEMP	22.08894	3.60361	9.50000	26.20000
JANCLOUD	0.37423	0.051221	0.27000	0.48000
JULCLOUD	0.64787	0.080485	0.44000	0.79000

Source: Cramer and Leemans (1991).

4. Empirical implementation

As Leary (1994) and Maddison(1995a) both note, choosing the best way of representing a fluctuating amenity such as noise pollution, air pollution or climate is one of the major problems in hedonic models. Climate for example has numerous aspects (temperature, wind speed, sunshine, precipitation, snowfall etc) all of which can be specified according to a wide array of forms: we can use monthly or annual averages, extreme values or synthetic indices like degree-days. Leary's (1994) survey of the existing work in the area shows how disparate the choices have been. Leary notes that, although in many cases the climate variables included in these studies was significant, the persistent lack of explanatory power displayed by some other variables could be due to insufficient attention paid to the specification of the climate variables when they were added as an additional control in models not explicitly concerned with climate issues. Moreover he notes that climate, although it may well be a determining factor of wages and house prices differences, has small effects on wages and housing prices relative to other determining factors, some of which are not always adequately controlled for in empirical work. Two parallel analyses have been performed; the first considering just the annual averages and the second the values of the climate variables in January and July. This permits us to investigate whether, as might be expected, the amenity value of a marginal increase in the level of particular climate amenities depends upon into which season they fall.

Apart from suggesting that wages and house prices differentials can be explained, among the other factors also by site specific variables like climate and environmental characteristics, the hedonic framework does not shed any light on the question of which and how many variables should be included. Indeed, these are more likely to be determined by the availability of data than through anything else. In defence of the specification chosen below it is based upon an expert assessment of what were considered to be the important factors, insofar as it was published for the purpose of determining where to live in Italy. Of course there may be variables which although held to be important determinants of the quality of life are simply not monitored. Noise-nuisance and poor air quality may be cases in point with the current data set. Rather than omit what many other studies have shown to be empirically important variables altogether they are proxied by means of population density.

There are some standard objections to the use of the hedonic technique for these purposes. Mainly these criticisms are directed at the strong assumptions underlying the technique. It has for example been suggested that the hedonic technique could not be applied to the task of measuring the amenity value of climate because of the existence of significant moving costs in relation to the benefits of particular types of climates. But this observation overlooks the fact that society has had a considerable length of time to respond to differences in climate; far longer in fact than the lifetime of any household. It has also been argued that since the climate variables are generally undeviating over relatively large distances at which point the assumptions of costless mobility become questionable because of political boundaries and language and cultural differences. In other words, there is insufficient variation in climate to identify a hedonic price gradient for climate variables. Whilst this is true for many countries it does not hold for a country with such a diverse climate as has Italy. Finally it has been asserted that the existence of disequilibrium in both the markets for housing and labour means that any relationship between house prices, wage rates and climate variables would be biased or at best obscured. But there is no reason to suppose that the extent of disequibrium in any market should be correlated with the level of climate amenities and in any case disequilibrium in these markets can be dealt with by including such variables to indicate the possible extent of the disequilibrium such as the local unemployment rate and the level of housing occupancy. Unemployment has been frequently included in hedonic price analyses. The majority of migration studies suggest that a Harris-Todaro (Todaro, 1969) migration function containing both unemployment and wage rates is appropriate. More specifically; it appears that higher wages are required to compensate for higher unemployment rates and the reduced probability of finding work. In this sense unemployment is like a 'disamenity' and would be expected to be associated with a a negative coefficient in the hedonic house price equation. Similarly a large number of unoccupied houses also depresses local property prices.

Once the dependent variables have been selected one is left with the task of finding the appropriate functional form of the hedonic function, on which the theoretical literature is silent as well. The most rigorous procedure is to apply a Box-Cox transformation to each of the dependent and independent variables as suggested by Halvorsen and Pollakowski (1981). These transformations are flexible enough to accommodate various functional forms and can be implemented using maximum likelihood estimation procedures. For our purposes they are computationally prohibitive. The only concession made to the functional form of the hedonic house price regression was to attempt the transformation of the dependent and independent variables by considering four special cases of the Box-Cox transformation: the linear model, the log-log model, the semi-log model and the lin-log model. In the log-log, semi-log and lin-log model the marginal value of any one characteristic depends upon the value of all other characteristics. Only in the linear model is the marginal value of a change in any one of the characteristics independent of the level of any other characteristic. Thus the equations to be estimated are:

$$\frac{PRICE_{it}^{\lambda}-1}{\lambda} = \alpha + \beta_1\frac{CULTURE_{it}^{\theta}-1}{\theta} + \beta_2\frac{BOOKS_{it}^{\theta}-1}{\theta} + \beta_3\frac{GYM_{it}^{\theta}-1}{\theta} +$$
$$\beta_4\frac{MURDER_{it}^{\theta}-1}{\theta} + \beta_5\frac{CARTHEFT_{it}^{\theta}-1}{\theta} + \beta_6\frac{BURGLARY_{it}^{\theta}-1}{\theta} +$$
$$\beta_7\frac{BANKROB_{it}^{\theta}-1}{\theta} + \beta_8\frac{FRAUD_{it}^{\theta}-1}{\theta} + \beta_9\frac{BAGS_{it}^{\theta}-1}{\theta} +$$
$$\beta_{10}\frac{PENSION_{it}^{\theta}-1}{\theta} + \beta_{11}\frac{LETTER_{it}^{\theta}-1}{\theta} + \beta_{12}\frac{PHONE_{it}^{\theta}-1}{\theta} + \quad (1)$$
$$\beta_{13}\frac{STUDENT_{it}^{\theta}-1}{\theta} + \beta_{14}\frac{VEHICLES_{it}^{\theta}-1}{\theta} + \beta_{15}\frac{POPDEN_{it}^{\theta}-1}{\theta} +$$
$$\beta_{16}\frac{NOTOCCUP_{it}^{\theta}-1}{\theta} + \beta_{17}\frac{UNEMP_{it}^{\theta}-1}{\theta} + \beta_{18}\frac{PRECIP_{it}^{\theta}-1}{\theta} +$$
$$\beta_{19}\frac{TEMP_{it}^{\theta}-1}{\theta} + \beta_{20}\frac{CLOUD_{it}^{\theta}-1}{\theta} + e_{it}$$

$$\frac{PRICE_{it}^{\lambda}-1}{\lambda} = \alpha + \beta_1\frac{CULTURE_{it}^{\theta}-1}{\theta} + \beta_2\frac{BOOKS_{it}^{\theta}-1}{\theta} + \beta_3\frac{GYM_{it}^{\theta}-1}{\theta} +$$
$$\beta_4\frac{MURDER_{it}^{\theta}-1}{\theta} + \beta_5\frac{CARTHEFT_{it}^{\theta}-1}{\theta} + \beta_6\frac{BURGLARY_{it}^{\theta}-1}{\theta} +$$
$$\beta_7\frac{BANKROB_{it}^{\theta}-1}{\theta} + \beta_8\frac{FRAUD_{it}^{\theta}-1}{\theta} + \beta_9\frac{BAGS_{it}^{\theta}-1}{\theta} +$$
$$\beta_{10}\frac{PENSION_{it}^{\theta}-1}{\theta} + \beta_{11}\frac{LETTER_{it}^{\theta}-1}{\theta} + \beta_{12}\frac{PHONE_{it}^{\theta}-1}{\theta} +$$
$$\beta_{13}\frac{STUDENT_{it}^{\theta}-1}{\theta} + \beta_{14}\frac{VEHICLES_{it}^{\theta}-1}{\theta} + \beta_{15}\frac{POPDEN_{it}^{\theta}-1}{\theta} + \quad (2)$$
$$\beta_{16}\frac{NOTOCCUP_{it}^{\theta}-1}{\theta} + \beta_{17}\frac{UNEMP_{it}^{\theta}-1}{\theta} + \beta_{18}\frac{JANPRECIP_{it}^{\theta}-1}{\theta} +$$
$$\beta_{19}\frac{JULPRECIP_{it}^{\theta}-1}{\theta} + \beta_{20}\frac{JANTEMP_{it}^{\theta}-1}{\theta} + \beta_{21}\frac{JULTEMP_{it}^{\theta}-1}{\theta} +$$
$$\beta_{22}\frac{JANCLOUD_{it}^{\theta}-1}{\theta} + \beta_{23}\frac{JULCLOUD_{it}^{\theta}-1}{\theta} + e_{it}$$

with the four special cases corresponding to $\lambda = 1$ and $\theta = 1$; $\lambda \to 0$ and $\theta \to 0$; $\lambda \to 0$ and $\theta = 1$; $\lambda = 1$ and $\theta \to 0$ respectively. The subscript i refers to the province and the subscript t refers to the year.

Turning now to the method of estimation these equations could be estimated separately for each year using OLS. However; a more efficient estimation technique is the Seemingly Unrelated Regression Estimation (SURE) technique proposed by Zellner (1962). This estimation procedure takes advantage of the fact that the residuals between the same provinces are likely to be correlated across time due to common omitted factors.

Because the residential property markets for each of these five years are separate they could, at least in principle, identify the demand curve for climate. In theory one would evaluate Marginal Willingness To Pay (MWTP) from each regression and then use these estimates as the dependent variables in a regression on a variable describing average income per capita and a constant term (see for example Harrison and Rubinfeld, 1978). From this regression the income elasticity of the uncompensated demand curve for climate might be determined and tested for its significance revealing any tendency of MWTP for climate amenitites to rise or fall with income. The second stage regression might simply be specified as:

$$MWTP_{tk} = \alpha_0 + \beta_1 GNP/CAPITA_{tk} + e_{tk} \qquad (2)$$

and would be most efficiently estimated using Weighted Least Squares (WLS) to reflect the differing degree of precision with which the MWTP is estimated in the separate markets. But with only five years of data results there is little expectation that there will be sufficient variation in income to reliably determine how the demand curve for climate shifts with income. This suggests that treating the estimates of implicit prices from each year as estimates from a single distribution would be equally acceptable and that is the procedure followed here.

5. Results

Using the method described by Maddala (1977) it was found that a semi-logarithmic model (corresponding to the case where $\lambda \rightarrow 0$ and $\theta = 1$) was the model more likely to have generated the observed data for either specification and these parameter values were adopted for the remainder of the study. The regression analyses typically manage to explain between 63% and 85% of the variation in the residential property prices when climate is specified in terms of annual means. When climate is specified as monthly means the fit for the regression equations ranges between 74% and 87% of total variance to be explained[3]. In either case the good fit reflects the use of census tract data rather than data relating to individual properties. Next, each hedonic price function is differentiated with respect to each of the variables and the derivative is evaluated at the sample means. This results in a set of implicit prices which reflect the perceived Net Present Value (NPV) of a marginal change in the level of amenities per square metre of ground in current prices. These implicit prices are annuitised using a 5% discount rate, transformed into constant prices by means of a cost of living price deflator for Italy and then multiplied by the size of an average dwelling which is assumed to be 80 square metres.

As outlined earlier, the next stage might typically involve regressing MWTP on a constant term and real per capita income levels and then computing the income elasticity of demand for the climate amenities. But the data exhibits insufficient variation in income to obtain meaningful results. Instead, a test for parameter homgeneity is employed on the separate estimates of MWTP. The test for parameter homogeneity is:

$$\chi^2 \sim \sum_{i=1}^{i=n} var(\mu_i)(\mu_i - \mu)^2 \qquad \textbf{(4)}$$

which is distributed as a chi-squared variate with n-1 degrees of freedom and n being the number of estimates. In no case is this statistic able to reject the null hypothesis of parameter homogeneity for the climate amenities (see table 3). This result is encouraging in the sense that it would be difficult to explain why the implicit prices of climate variables from analysing closely linked markets should wildly differ. On the other hand these

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omplete results of both sets of regression analyses are available from the authors upon request.

results suggest that it is rather difficult to determine the income elasticity of demand for climate amenities from the currently available data.

Given the results of the parameter homogeneity tests these implicit prices are then treated as independent samples from a single distribution whose mean is computed using the formula:

$$\mu_{est} = \sum_{i=0}^{i=n} \frac{\mu_i}{var(\mu_i)} \bigg/ \sum_{i=0}^{i=n} \frac{1}{var(\mu_i)} \qquad \textbf{(5)}$$

where μ_i is the mean from sample i. The results of this re-analysis are presented in table 4 below along with
t statistics for each of the climate variables.

Considering first the specifications involving the annual means as descriptions of the climate, all the climate variables are highly significant. It appears that higher rainfall, higher temperatures and increased cloudiness are all viewed as a disamenity. The typical Italian household would, during the period 1991-1995 have been willing to pay around 1,344 Lira to avoid a millimetre of precipitation, around 137,447 Lira to avoid an increase in average temperatures of 1°C, and around 89,520 Lira to avoid a percentage point increase in average cloud cover.

The implicit prices from the specification using January and July averages are much more revealing and illustrate how the amenity value of marginal increases in climate variables depends on into which season these increases fall. Precipitation is viewed as a disamenity in both winter and summer with an implicit price of 12,403 Lira per millimetre in January and 47,039 Lira per millimetre in July. Interestingly temperature is viewed as an amenity in wintertime with an implicit price of 320,071 Lira per °C but during the summertime is viewed as a disamenity with an implicit price of 277,470 Lira per additional °C. Given the hot summers which are possible in many parts of Italy this is a highly plausible result and not an unimportant one given that wintertime temperatures are predicted to increase more than summertime temperatures following climate change. Cloudiness is viewed as unimportant during the winter months but during the summer months is strongly disliked with an implicit price of 326,767 Lira per percentage point of cloud cover. Once more all the climate variables, bar that describing cloud cover in the winter months, are highly significant.

Taken together these results are highly encouraging and strongly supportive of the use of the hedonic methodology for the purposes of determining the amenity value of climate. The empirical estimates which emerge are plausibly signed and reasonable in terms of magnitude. They are also measured with a surprising degree of precision and are stable across consecutive years. It is important to remember however that preferences for particular types of climate can be embedded in wage rates as well as residential land price differentials and this should prevent one from placing undue faith in these results. Nevertheless, the experience from the only other study on the amenity value of climate for a European country suggested that the amenity value of climate was not collateralised into wage rates to any great extent (Maddison, 1996c). The possibility of compensating differentials being found in the price of non-tradeable goods and services also deserves to be investigated (Robak, 1982). We are not aware of any attempts to investigate the possible effect of such differences on the measured implicit price of amenities. Finally, there are other climate variables such as windspeed and humidity whose absence from the data set might have biased the coefficients on the included climate variables.

Future work might concentrate on the task of identifying the demand curve for climate amenities. This is likely to involve combining studies undertaken in different countries with different climates and different levels of income. This might shed light on the income elasticity of demand for climate amenities, the role of price of fuel, the existence of an 'optimal' climate all of which are of relevance to the debate on the economic impacts of climate change. The ability to undertake such an analysis in which the results from many different studies are combined however depends upon researchers employing similar specifications and measurement concepts for the climate variables.

Table 3: The results of the parameter homogeneity tests for the implicit prices

Annual	
Precipitation	1.7
Temperature	0.7
Cloudiness	0.4
Seasonal	

Precipitation (Jan)	1.1
Precipitation (Jul)	1.3
Temperature (Jan)	1.2
Temperature (Jul)	1.1
Cloudiness (Jan)	0.7
Cloudiness (Jul)	1.8

Source:See text.

Note: The 95% critical value of the chi-squared variate with 4 degrees of freedom is 9.5. None of the parameter homogeneity tests are failed.

Table 4: The implicit price of climate variables per household evaluated at sample means (t-statistics)

Annual	
Precipitation	-1,344 Lira / mm / household / year (3.7)
Temperature	-137,447 Lira / °C / household / year (2.6)
Cloudiness	-89,520 Lira / percentage point of cloud cover / household / year (2.5)
Seasonal	
Precipitation (Jan)	-12,403 Lira / mm / household / year (4.2)

Precipitation (Jul)	-47,039 Lira / mm / household / year (5.7)
Temperature (Jan)	+320,071 Lira / °C / household / year (3.3)
Temperature (Jul)	-277,470 Lira / °C / household / year (3.7)
Cloudiness (Jan)	+14,901 Lira / percentage point of cloud cover / household / year (0.4)
Cloudiness (Jul)	-326,767 Lira / percentage point of cloud cover / household / year (5.7)

Source:See text.

Note: These prices are evaluated at 1995 price levels assuming a typical property of 80 m^2 and a rate of discount of 5% per annum. They refer to the prices prevailing over the period 1991-1995.

6. Conclusions

The main conclusion of the analysis is that there is considerable empirical support for the hypothesis that information on the amenity value of climate is contained in Italian residential property prices. This is the case whether the hedonic price equations are specified in terms of annual values or in terms of monthly values. It also appears that the marginal willingness to pay for additional climate amenities depends upon which season they fall into. More specifically, whereas rainfall is viewed as a disamenity throughout the year, temperature is viewed as an amenity in the wintertime and a disamenity during the summer.

One of the basic assumptions of hedonic models is equilibrium in the relevant markets. This assumption was accommodated by introducing a measure of market disequilibrium, namely the number of unoccupied houses as a percentage of all houses fit for habitation, as well as provinical unemployment rates. Both of these variables are seen to be significant and are signed as expected in the relevant tables.

Despite the encouraging nature of the results the following qualifications are in order. First, the climate database did not include some relevant variables like wind speed and humidity. Second, the choice of explanatory variables is, as always, arbitrary reflecting what was available rather than any other consideration. In particular one should have accounted for environmental quality indicators as air pollutants but the mapping of environmental quality in Italy is still at a rudimentary stage and the available data are at best scattered. Finally, a second and third set of hedonic schedules for labour and non-traded goods prices should be estimated in order to attain a complete measure of the implicit prices of amenity variables. Unfortunately this has not been possible because of the lack of suitable data. Should the data series continue to be published it may, at some point in the future, be possible to identify the household demand curve for climate variables. As a next step the authors plan to combine the results of this analysis with various climate change scenarios for Italy in order to determine the resulting change in amenity values.

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