HEDONIC PRICING OF CLIMATE CHANGE IMPACTS TO HOUSEHOLDS IN GREAT BRITAIN

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Abstract
This study investigates the amenity value of climate to British households. By using the hedonic price approach, the marginal willingness to pay for small changes in climate variables, specified as averages and ranges, is derived. The estimates suggest that British people would typically prefer a greater distribution of precipitation across the seasons (i.e. holding annual precipitation constant, drier summers and wetter winters are preferred). Higher temperature ranges are likely to reduce welfare. Moderate global warming with warmer winters and drier summers might thus benefit British households. In particular we find that those places with little or average range in rainfall like Nottingham and those with a huge range of annual temperature like the Boroughs of London might profit. Places already characterized by a broad range of annual precipitation like Aberdare in Mid Glamorgan on the other hand would most likely lose from climate change.

Keywords: amenity values, climate change, environmental valuation, Great Britain, hedonic pricing

JEL Classification: Q29, R29

1 Introduction

Little attention has been drawn to climate as an important input to household activities. Research work on the economic consequences of climate change has generally focused on changes in productivity in sectors where climate plays an important role, comparing the costs of preventing climate change to the benefits (IPCC, 1998; and more recently IPCC, 2001). Measurement of the value of climate not only to economic sectors but also to individuals would provide some valuable information when designing an appropriate abatement strategy. This paper uses the hedonic price approach, one of the methods to measure non-market benefits, to estimate the amenity value of climate to households in Great Britain.

Economic theory states that perfectly mobile individuals would locate where they can maximize their net benefits and living in climatically different regions means consuming different types of goods supported by the respective climate. Since people are attracted to those regions offering preferred combinations of amenities, these regions should have both compensating house price and wage differentials. If a household wishes to enjoy e.g. fewer rainy days or more hours of sunshine, it will have to buy a house in such an area and pay a premium for it. Consequently, Rosen (1974) and Roback (1982), chief proponents of the hedonic price approach argue that the value of marginal changes of amenities can then be derived from property price and wage regressions. Still, to obtain significant estimates for climate as an amenity, sufficient variation of the climate variables is essential. Varying topographical and geographical characteristics of the region under consideration are prerequisites. Since Britain's climate is heavily influenced not only by its topographical and geographical characteristics but also by the Atlantic ocean, this country can be used to analyse house price and wage differences.

In Great Britain, the sunniest parts are along the Southern coast of England. Wales and Scotland are in general cloudier because of the hilly nature of the area and the proximity to the Atlantic. Rainfall varies widely over Great Britain. The wettest parts with an average annual rainfall exceeding 2,000 mm are the Lake District, the Western Highlands of Scotland, the mountain areas of Snowdonia and the Brecon Beacons. The coastal area of Wales, the East coast of Scotland, East Anglia, much of the Midlands, Eastern and North-Eastern England as well as parts of the South-East receive less than 1,000 mm a year. In South East England rainfall is close to 500 mm per year. Over Great Britain the mean annual temperature varies from about 7°C on the Shetland Islands to 11°C near the coast of Cornwall.

Although the number of studies using the hedonic approach for environmental valuation purposes is extremely limited, one other study has investigated the amenity value of the climate of Britain (Maddison, 2001). However, our study differs in several ways. It is the first work using GIS (geographic information systems) derived measures of local amenities in a hedonic analysis of the amenity value of climate. These are mainly distance measures such as the proximity to London indicating e.g. the accessibility of certain leisure activities and cultural life.[1] Also, this study is exceptional in three more ways. First of all, attention is drawn

[1] Other studies using GIS derived measures for hedonic pricing are e.g. Lake *et al.* (2000). They derive more refined information of property characteristics (like walking distances or car travel times) for Scotland. More recently Bastian *et al.* (2002) investigated recreational and scenic amenities associated with rural land.

to problems of endogeneity when employing census tract data. Secondly, not only a wide range of climate variables and higher-order terms are included, but different specifications of climate variables are also taken into consideration. Finally, we investigate if British households might benefit from slight global warming.

Section 2 starts with a brief literature review of studies of the amenity value of climate and continues with a description of the theoretical framework of the hedonic pricing method. That section concludes with some critical remarks concerning the underlying assumptions. In Section 3 the data employed for the research are discussed. Section 4 reports on the econometric results of the analysis. In Section 5 the implicit prices of marginal changes of the climate variables on welfare, derived from the hedonic regression, are calculated. To investigate the willingness to pay to avoid climate change, the implicit prices for future climate change are evaluated for two different climate change scenarios and three time-slices in the second part of that section. Section 6 concludes.

2 Valuing Impacts of Climate Change from Market Data: The Hedonic Price Approach

2.1 Hedonic Studies

In a seminal paper, Rosen (1974) described a model of market behaviour in a market with differentiated goods. He illustrated how the willingness to pay for an environmental improvement can be derived from the relationship between property prices and their attributes: structural characteristics, location specifics and the quality of the environment. Although there are many earlier papers Rosen provided the theoretical underpinning of the hedonic approach.[2] Since then the hedonic approach has been widely applied to estimate the economic value of non-market goods.[3] However, only very few studies were set out to measure the amenity value of climate to individuals. Still, individuals are interested in certain climates as it makes it possible to consume particular goods.[4]

Hoch and Drake (1974) were one of the first who analysed the wage paid to three different categories of workers and climate. A large number of climate variables were included, where summer temperature, annual precipitation and average wind velocity had considerable explanatory power. Smith (1983) used a 'real wage' model where a regional cost of living index was added as a deflator. Among the five climate variables only hours of sunshine, measured as the mean annual percentage of possible sunshine, was statistically significant. The effects of climate on both wages and house prices was first investigated by Roback (1982). The climate variables were specified as total snowfall, heating degree days, number of cloudy and clear days. Four different regressions were then conducted to calculate the implicit

[2] Waugh (1929) was the first who provided a systematic analysis of the impact of quality on the price of a commodity. Court (1941) improved the analysis of "commodity spectra" by allowing for marginal analysis. Other important contributions were provided by Griliches (1971).

[3] An overview of the hedonic price approach is given in Palmquist (1991) and Freeman (1993).

[4] See http://www.findyourspot.com/ e.g. In an online quiz the offered program uses individual preferences like accessibility of local services, city size, geographic type and climate to find the individual best place to live in the US.

price of the amenity evaluated at average annual earnings. Her theoretical model is another major contribution to the literature on hedonic analysis. She was the first who argued, that across different towns there generally have to exist compensating wage and house price differentials. Others drawing upon the work of Roback (1982), but using more detailed data were Blomquist *et al.* (1988). They estimated separate hedonic regressions for wages and housing expenditures to calculate a quality of life index. Since then some researchers have analysed the amenity value of climate to households, like Englin (1996), who investigated the amenity value of rainfall on property prices for the period from 1970 to 1981. He found that households would prefer less rainfall and a greater seasonal variation. Other studies are Nordhaus (1996), Cragg and Kahn (1997) and Cragg and Kahn (1999). Nordhaus used hedonic wage techniques to estimate the impact of an equilibrium CO_2 doubling on climate amenities. The estimates show a disamentiy premium of about 0.17 percent of GDP. Cragg and Kahn estimated the demand for climate amenities regarding the determinants of population migration decisions. Earlier studies on migration and climate are provided by Graves (1980) and Cushing (1987). Both works are founded on urban economic theory, rather than welfare theory.

These analyses were mainly conducted for the United States.[5] Valuation studies for Europe are much less frequent, although their number is increasing.[6] Empirical work in Europe has been mainly prepared using the contingent valuation method, only very few valuation studies make use of the hedonic price method in general and hardly any analysis investigates the amenity value of climate. One reason for this imbalance is that contingent valuation techniques had improved substantially during the 1980s, while hedonic price approaches still had to be worked out (Turner *et al*., 1992). Although the theoretical basis for hedonic analysis is well defined by now, the availability of necessary data has an enormous influence on the design of a study and makes applications rare - at least in Europe.

The only empirical work for Great Britain investigating the amenity value of climate is Maddison (2001).[7] This study is using county level average wage and house price data for Great Britain to explain regional variations in property prices and wage rates. His work is based on Roback's (1982) theoretical model. The study uses county averages for 127 different counties. The wage regression allows for different categories of workers. Other variables describing local services and fiscal conditions are included, these are e.g. burglary rate, tax rate, unemployment rate, population density and number of railway stations. Climate variables are found to be significant in the house price regression, but not in the wage

[5] A database containing detailed information of about 960 environmental valuation studies, including hedonic price studies, can be found on the internet, see http://www.evri.ec.gc.ca/EVRI/. These studies are primarly from North America. Both Environment Canada and US EPA use this database to guide their policy work.

[6] Bringing the total number of European studies to at least 650 at the end of 1999. Although this is no final number of studies, it seems reasonably complete. A review of European valuation studies completed until 1992 is provided by Navrud (1992). A list containing the period 1992 to 1999 is in included in Navrud and Vagnes (2000). Among the countries that traditionally have performed many valuation studies is the UK (192) next to Norway (44) and Sweden (36). In brackets are the number of studies done between 1992 and 1999, see Navrud and Vagnes (2000).

[7] Cheshire and Sheppard (1995) were first investigating the demand for housing characteristics in general in Britain.

regression. British households regard higher temperature as an amenity and higher precipitation as a disamenity.

Many earlier studies, like Maddison (2001), are carried out using data on the level of large administrative boundaries. This is generally caused by data limitations. For Great Britain data are mostly available only as aggregated data on county level. However, there seems to be evidence that differences within a county exist which influence location choices not only between counties, but also within a county. To obtain the required location specific information this study experiments with GIS derived measures of local amenities, mainly distance measures.

2.2 The Model

In contrast to the quantity of the supplied environmental goods like climate, which is exogenously determined and fixed at least at the short run, the market responds to the demand for environmental goods. The demand is a function of the price of that good[8] and the more the good is desired the higher is its price. The market clears when the marginal price for an additional unit of the characteristic equals its price.[9] There are at least two markets where consumers can compete for environmental goods: the housing market and the labour market. Consumers might pay higher property prices if the house is located in a preferred area. Also, they might accept lower wage rates for living in such areas.[10]

Consequently two hedonic equations have to be estimated which causes a number of problems. As the functional form is not determined by theory, the regression analysis becomes fairly complex as two equations need to be specified.[11] Also, an extensive collection of location specific data is required to control all important factors on which location choices are based. These variables must be carefully chosen not only to avoid omitted variable biases but also to reduce problems of multicollinearity.

In this analysis, we follow Englin (1996) and apply a simpler model. We argue that the area under consideration, Great Britain, can be divided into smaller geographic areas – labour market areas. Within those areas the local amenities such as the different climate variables vary. Consequently, all adjustment must take place in the housing market since the labour market cannot adjust. This is another difference to Maddison (2001).

[8] As well as the price of all other goods and the income.
[9] The market is assumed to be competitive. No single consumer has influence on the market price, they are price takers.
[10] The sign of the wage and rent gradient depends on whether the amenity is productive to companies or to production costs. If a company's production costs are not affected by the amenity the wage gradient is negative and the rent gradient positive. The sign of the wage gradient is ambiguous, if the amenity is productive. Workers are then not forced to accept lower wages. See Roback (1982).
[11] However, it is possible to specify just one equation with net household income as dependent variable, see Maddison and Bigano (forthcoming). In case no individual data are available (e.g. individual household income), using this procedure means leaving out important independent variables (e.g. structural dwelling characteristics).

An aspect which carefully needs to be taken into consideration when applying census tract data is the problem of endogeneity. In studies using individual price or wage data, socio-economic variables like unemployment, population density[12], crime rates or local public services are exogenously determined. Individual house purchases do not have an impact on these variables. In studies using more aggregated data there might exist a bi-causal relationship between these variables and the dependent variable. Hence they might be endogenous. In contrast to Maddison (2001), who included these socio-economic variables as explanatory variables, our study considers these variables as being jointly determined with the house prices. None of these socio-economic variables enters as an explanatory variable into the regression. Instead, the GIS derived variables describing accessibility of different location should contain location specific information that is not being endogenously determined.

Nordhaus (1996) is one of the few studies that draws attention to problems of endogeniety. He explicitly modelled population density as an endogenous variable.[13] Earlier, Steinnes and Fisher (1974) used a structural simultaneous equation model to show that location of employment and residence (population density) are simultaneous allocations. Drawing upon Nordhaus, Maddison and Bigano (forthcoming) were the first to test for exogeneity of this variable. They found population density to be exogenous, at least in the short run. In principle, the assumption of exogeneity is a testable hypothesis. However, the required instrumental variables are in general difficult to obtain. An exception is Gayer (2000), who applied an instrumental variable estimation to a hedonic analysis. He proved the existence of a bi-causal relationship between housing prices and environmental risk.

Focusing on the case of housing, a dwelling can be characterized through a number of attributes: structural characteristics (age, number of rooms, size etc.), neighbourhood characteristics (infrastructure, public services, proximity to metropolis etc.) and environmental quality (air quality, water quality, average temperature etc.). The actual market price reflects the sum of the underlying housing characteristics which might have opposite directions. The size of a dwelling can be thought of as a positive attribute, whereas a high level of monthly precipitation might reduce the price and be a negative attribute.

A house may be described by the vector of its related characteristics *i*

(1) $x = (x_1, x_2, ..., x_i)$ where $i = 1,...,33$ [14]

The marginal willingness to pay (implicit price) for small changes of the *i*-th housing attribute is found by differentiating (1) with respect to x_i while other attributes are held constant.

[12] As a proxy for pollution levels or cultural life.

[13] He argued that military personnel (as a proxy for population density) are stationed in particular areas for reasons unaffected by net labour incomes.

[14] A list containing all dwelling related characteristics of our study is shown in table 1.

In our model with different labour markets (z_k) equation (1) changes to

(2) $x_j = (x_{j1}, x_{j2}, ..., x_{ji})$ where each x_j is an element of some z_k; $i = 1,...,33$, $j = 1,...,755$ and $k = 1,...,110$.

In the above equation i is the number of housing attributes, j the number of locations and k represents the different labour markets. The number of observations changes between labour markets. See section 3.

2.3 Critical remarks

The hedonic price method is based on a number of restrictive assumptions. This section explains the crucial ones in detail (a general overview of critical arguments is provided by Palmquist, 1991; and Freeman, 1993).

A starting point for all hedonic studies is the assumption of equilibrium in hedonic markets; wages and rents have adjusted such that individuals are indifferent across locations. This also includes perfect information of the attributes of all alternative sites and no transaction costs (Mäler, 1977). However, the extent of any existing disequilibrium is unlikely to be correlated with the level of particular amenities, as Palmquist (1991) pointed out. The regression results will not be biased.

Furthermore, the model supports the assumption that each household should be able to buy exactly the amount of dwelling-related characteristics it wants. If the availability of dwelling-related characteristics is restricted, households may be located at a corner solution (Mäler, 1977). The location of the household is then caused by market constraints. However, this assumption is reasonable for any study of the amenity value of climate since climate varies smoothly over a region (Maddison, 2001).

Where mobility between areas is restricted, the issue of market segmentation arises. Consequently, the hedonic price function would not be stable across different regions and the results would be biased. This was first considered by Strazheim (1974) who suggested a separate estimate for each area. However, this study explicitly models segmented markets.

3 Data Sources

The dataset contains housing data for the year 1993.[15] The housing data are provided by Halifax Building Society and contain the average prices of properties in 755 different Posttowns, Metropolitan Areas and Boroughs of London throughout Great Britain. The data are disaggregated in two ways, first by property type (terraced house, semidetached and detached house, bungalow and flat) and second by the number of bedrooms.[16] The Ordnance Survey Gazetteer of Great Britain (1992) was used to determine the grid references and coordinates of the locations. With the software MapInfo the coordinates of each location were mapped.

In a further step the cities and towns were assigned to the 127 different local authorities of Great Britain. The information about the different local authorities was taken from Focas *et al.* (1995). Due to the lack of housing observations for three regions in Scotland (Western Isles, Orkney and Shetland), these local authorities were omitted. Furthermore, those boroughs of London belonging to Inner London were taken as one authority.[17] Therefore, the dataset contains only 110 different local authorities. The average number of cities and towns per county is seven.[18]

Since no data on wage rates by city or town were available we followed the approach adopted by Englin (1996), as mentioned above. County dummies for the local authorities were added and each of these counties was assumed to represent one labour market. Also, this explores the possibility of segmented markets, not only labour markets. Consequently, no adjustments can occur on the labour market or any other market. They have to be captured by the housing market and the related explanatory variables. This also implies that climate has to vary within one county to possibly explain variation in property prices, which seems not very likely. However, our regression results (section 4) indicate the significance of some climate variables.

The data for the climate variables (hours of sunshine, wind speed, rainy days, ground frost days, precipitation, mean temperature, relative humidity and vapour pressure) and data for the altitude were available on a 10km square grid (provided by the Climate Research Unit, University of East Anglia, Norwich). The variables were measured at monthly average values within each grid cells for a period from 1961 to 1990. These climate variables were matched with the respective location. Table 1 shows the variables included in the regression. The range of values of these variables, their means and standard deviations are presented in table 2.

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[15] The housing market in 1993 is not characterized by any unusual or extreme incidents. Since the peak in late 1989 house prices fell continuously. In 1993 the prices stabilized and started falling again in early 1996. From then on the prices increased steadily and are now at record levels. See http://www.nationwide.co.uk/hpi/.

[16] The dataset contains 17 different structural housing characteristics for each location, see table1.

[17] Containing Camden, Greenwich, Hackney, Hammersmith & Fulham, Haringey, Islington, Kensington & Chelsea, Lambeth, Lewisham, Newham, Southwark, Tower Hamlets, Waltham Forest, Wandsworth and Westminster.

[18] The number of cities and towns per county ranges from one for two Boroughs of London and some Metropolitan areas to the maximum of 32 for Kent.

Table 1: Definition of variables included in the regression

Variable	Definition
HOUSING	Purchase price of property in 1993 (in Pounds)
DSEA	Distance to sea (km)
DLONDON	Distance to London (km)
DWMINE	Distance to nearest working mine (km)
DNWMINE	Distance to nearest non-working mine (km)
CAPITAL	Dummy variable which takes the value unity if the property is located in a County capital, zero otherwise
DCAPITAL	Distance to County capital (km)
DMAJOR	Distance to nearest major town (km)
ABOVESEA	Above sea level, altitude (m)
SUNAV	Average hours of sunshine on a 1961-1990 average per year
SUNRG	Range of hours of sunshine on a 1961-1990 average per year
WINDAV WINDRG	Average wind speed (m/s) on a 1961-1990 average per year Range of wind speed (m/s) on a 1961-1990 average per year
PREAV	Average precipitation (mm) on a 1961-1990 average per year
PRERG	Precipitation range (mm) on a 1961-1990 average per year
TMPAV	Average temperature (°) on a 1961-1990 average per year
TMPRG	Temperature range (°) on a 1961-1990 average per year
AVTERR1B	Dummy variable which takes the value unity if the property is a terraced house with one bedroom, zero otherwise
AVTERR2B	Dummy variable which takes the value unity if the property is a terraced house with two bedrooms, zero otherwise
AVTERR3B	Dummy variable which takes the value unity if the property is a terraced house with three bedrooms, zero otherwise
AVTERR4B	Dummy variable which takes the value unity if the property is a terraced house with four bedrooms, zero otherwise
AVSEMI2B	Dummy variable which takes the value unity if the property is a semidetached house with two bedrooms, zero otherwise
AVSEMI3B	Dummy variable which takes the value unity if the property is a semidetached house with three bedrooms, zero otherwise
AVSEMI4B	Dummy variable which takes the value unity if the property is a semidetached house with four bedrooms, zero otherwise
AVDETA2B	Dummy variable which takes the value unity if the property is a detached house with two bedrooms, zero otherwise
AVDETA3B	Dummy variable which takes the value unity if the property is a detached house with three bedrooms, zero otherwise
AVDETA4B	Dummy variable which takes the value unity if the property is a detached house with four bedrooms, zero otherwise
AVDETA5B	Dummy variable which takes the value unity if the property is a detached house with fife bedrooms, zero otherwise
AVBUNG2B	Dummy variable which takes the value unity if the property is a bungalow with two bedrooms, zero otherwise
AVBUNG3B	Dummy variable which takes the value unity if the property is a bungalow with three bedrooms, zero otherwise
AVBUNG4B	Dummy variable which takes the value unity if the property is a bungalow with four bedrooms, zero otherwise
AVFLAT1B	Dummy variable which takes the value unity if the property is a flat with one bedroom, zero otherwise
AVFLAT2B	Dummy variable which takes the value unity if the property is a flat with two bedrooms, zero otherwise
AVFLAT3B	Dummy variable which takes the value unity if the property is a flat with three bedrooms, zero otherwise
COUNTY(k) $k = 1,\ldots, 110$	Dummy variable which takes the value unity if the property is located in County k, zero otherwise

Source: Climate Research Unit, University of East Anglia; Harris et al. (1991) and (1994); Focas et al. (1995); Halifax Building Society.

Table 2: Characteristics of the 110 Boroughs and metropolitan areas

Variable	Mean	Std. Deviation	Minimum	Maximum
HOUSING	64460.59	34735.44	22255	316245
DSEA	32.41	28.34	0	108
DLONDON	202.26	156.61	0	717
DWMINE	81.56	71.78	1	277
DNWMINE	84.29	69.38	1	252
DCAPITAL	24.08	17.23	0	103
DMAJOR	54.10	44.90	0	258
ABOVESEA	92.12	69.97	31	541
SUNAV	119.63	10.487	80.64	148.2
SUNRG	146.40	11.097	124	177.5
WINDAV	4.77	0.48	4.05	6.62
WINDRG	1.38	0.457	0.80	3.2
PREAV	67.00	20.517	44.79	178.96
PRERG	36.37	20.077	13.2	142.1
RDAV	14.70	1.63	12.63	22.46
RDRG	6.10	0.95	4	9.8
TMPAV	9.23	0.75	4.81	10.7
TMPRG	12.18	0.77	9.5	13.2
FDAV	8.54	1.38	3.22	14.12
FDRG	17.57	2.09	8.3	26
VAPAV	10.14	0.49	7.83	11.46
VAPRG	7.42	0.42	5.9	8.20
REHAV	84.51	1.66	79.98	90.19
REHRG	12.27	2.57	4.30	16.5

Source: Own calculation.

Except the dwelling specific characteristics and the climate variables a number of other variables are likely to effect the quality of life. These include the quality of health care services, school quality, transport links or population density. In contrast to earlier works we argue that the quality of these local services is jointly determined along with house prices. Hence they are endogenous (discussed in section 2.2).

Data on unemployment as an explanatory variable has been generally included in earlier hedonic studies. A high rate of unemployment is regarded as a disamenity in the way that compensation is necessary for households living in such areas.[19] However, as we are using average property price data, the level of unemployment might then be partly determined by wages. This in turn affects property prices. The study by Steinnes and Fisher (1974) confirms the two-sided relationship between employment and residence.

One focus of the domestic policy in Britain in the early nineties was the privatisation of state-owned companies. This was followed by a huge amount of closures in the coal mining sector between 1991 and 1993. The rate of unemployment rose significantly in the affected areas. In contrast to the underlying assumption of a fixed supply of jobs and a functioning labour

[19] See e.g. Graves (1980), Smith (1983) or more recently Maddison (2001).

market such a shortage of jobs implies that individuals cannot satisfy their demand for environmental characteristics while no suitable jobs are available in areas with higher environmental quality.To capture these effects of disequilibria it was necessary to include information on mining sites in our analysis. This was taken from the Directory of Mines and Quarries (Harris *et al*., 1991 and 1994). By comparing the 1994 working coal mines to the 1991 working mines we found those which had been working prior to 1991 but had shut down by 1993 and those still working in 1994. Also, the directory contained the grid references of the selected mines. These grid references were converted into coordinates of latitude and longitude for each mine. By using the software MapInfo, the geocodes of the 266 working and the 154 non-working coal mines were used for mapping them. Assuming, that the distance to a mine can capture this effects of disequilibria on the labour market, we measured the distances between the cities and towns and the nearest working and non-working mine. This information was then added to the dataset. The more distance is between a mine and a city or town, the less influence a closure should have on property prices.

Apart from the distances between cities or towns and mining sites further distance measures were carried out to obtain information about the relative importance of a city or town by measuring the accessibility of certain non-residential locations. In some earlier studies latitude and longitude were included to capture the proximity to a certain location as an amenity (e.g. Maddison and Bigano, forthcoming). However, both variables are correlated with several climate variables and including them might thus effect the results.[20] In contrast, not including any kind of distance measures might also have biased the results of earlier studies.

First of all, the distance between a town and Inner London was measured. London is by far the most important city in the UK, not only in economic terms. London provides services no other city or town is able to provide. The proximity to London determines the ability to make use of these services. A shorter distance suggests increased property prices. Although London is unique, other cities exist which also offer location specific services within one region. Glasgow might be viewed as an example of a metropolitan area in the North West of Great Britain. Edinburgh would be the counterpart located in the North East. To find out about their importance the distance between a city or town and the nearest major city was measured.[21] Finally, to capture the importance of the capital of a county the information on the distance from a city or town to the specific capital city of that county was added as well as a dummy for all capitals.[22] As mentioned above, a short distance to a major town or the county capital should have an increasing effect on property prices.

[20] In our analysis latitude is mainly correlated with the variables measuring hours of sunshine (minimum and maximum, average sunshine, range of sunshine and sunshine in July), temperature (temperature maximum, average temperature and July temperature) and vapour pressure (minimum and maximum vapour pressure, average vapour pressure, vapour pressure range and vapour pressure in January and July). Longitude is correlated with rain days (maximum rain days, average rain days and rain days in January), temperature range and range of vapour pressure. Variables named are all characterized by correlations above +/- 0.7.

[21] These are cities where the population is above 250,000 (London, Birmingham, Glasgow, Liverpool, Sheffield, Leeds, Bristol, Manchester, Edinburgh, Leicester, Hull, Coventry, Bradford, Cardiff, Nottingham, Stoke-on-Trent and Wolverhampton). The information was taken from the World Gazetteer, see http://www.world-gazetteer.com/. Interestingly, these 17 major towns are spread throughout Britain with an accumulation in the center.

[22] The capital city of a county has been defined as that city with the highest population. For Greater London Inner London was taken as the capital. With respect to the Metropolitan Areas, for each area one capital was chosen.

Finally, the proximity to the sea (distance between a city or town and the coast) was measured.[23] In general, being close to the sea is expected to be an amenity. However, as all industries related to the proximity to the sea, such as fishing or shipbuilding industries have been in decline over the last decades, a greater distance to the coast might then imply a lower likelihood of becoming unemployed, which might be an amenity. Hence, this variable might be correlated with a disequilibrium on the labour market and thereby absorbing nuisance variation in the data. Therefore, the sign of the variable is not predetermined.

4 Empirical Analysis

Having many different climate observations available is generally beneficial for the fit of a regression analysis. However, the great variety of variables also leads to a problem of multicollinearity and complexity. Therefore the available information needs to be consolidated. First, all climate variables were converted into three different concepts to allow for different descriptions of the monthly climate data. These concepts are represented by the minimum and maximums values of a twelve month period, January and July averages and annual averages and ranges. The range of a variable is the difference between the month with the maximum value to the month with the minimum value.

The variables describing the climate are entered as both linear and squared terms. Including squared terms[24] enables us to test if households prefer a mild climate rather than one characterizes by extremes (Maddison 2001).[25] Climate affects housing prices nonlinearly – from a certain level of sunshine, the effect of an additional hour of sunshine on the housing price declines. This implies that the sign of the coefficients of the quadratic terms should be opposite to their linear counterparts. For the variable describing hours of sunshine the coefficient of the square is expected to be negative.

To guard against further problems of multicollinearity, the number of climate variables included was restricted. Assuming that the number of rain days and precipitation or ground frost days and temperature contain to some extent similar information, a regression with four rather than six different climate variables was considered.[26] The correlation between both temperature and ground frost days as well as rain days and precipitation is above 60 and 80 per cent respectively.

[23] All distance measures were carried out by using the software program MapInfo.

[24] As Rasmussen and Zuehlke (1990) state squared terms might reduce the sum of squared residuals. In contrast, Ridker and Henning (1967) pointed out, a problem a multicollinearity might appear as correlations between a variable and its square are generally high. However, to avoid these problems, the mean of that particular variable can be subtracted before squaring it.

[25] It also allows the implicit price to have a varying sign depending on the level of the variable.

[26] Furthermore, changes in both variables relative humidity and vapour pressure depend mainly on changes in temperature. They are related non-linearly, see any standard textbook on general meteorology. To prevent any problems of misinterpretation, different models were tested where the temperature variable was replaced either by relative humidity or vapour pressure. The fits were always lower then the equation containing hours of sunshine, wind speed, precipitation and mean temperature.

Caused by the extensive number of housing characteristics, the dataset contains 17 different types of housing per city or town (see table 1). Clusters were formed to account for the correlation of residuals when observations are derived from the same town. This leads to robust variance estimates.

The theory of the hedonic approach does not provide much guidance concerning the functional form. Three different transformations of the dependent variable were examined: the linear, semilog and inverse models. To gain the most suitable model all three functional forms were tested for the three different concepts (minimum and maximums values of a twelve month period, January and July averages and annual averages and ranges). However, each of these different concepts contains eight different combinations of climate variables. One possible combination is e.g. hours of sunshine, wind speed, precipitation and temperature. One alternative would be hours of sunshine, wind speed, precipitation and frost days, etc.

In total, 72 different regressions were performed. The semilog model was found to be most appropriate. Within the possible semilog models the concept of averages and ranges containing hours of sunshine, wind speed, precipitation and mean temperature was found to be most suitable. All other specifications explain less variation in the data. An F-Test to test for omitted climate variables revealed that no additional climate variables such as ground frost days or rain days need to be included in the analysis.[27] A Ramsey RESET test, testing for functional form, was not rejected.[28] The estimated coefficients of the model and the results of the tests are shown in table 3. The regression analysis is able to explain 92 per cent of the variation in the data.

[27] Both variables relative humidity and vapour pressure were not considered for an F-Test as they are highly non-linearly correlated with the variable temperature.
[28] Ho: Model has no omitted variables. $F(3,2916) = 2.17$, $Prob > F = 0.0891$. With respect to all other possible specifications, only the semilog models were found to pass the RESET test. All estimates for linear or inverse models were found to be misspecified.

Table 3: The results of the regression

Dependent variable = lnHOUSING

Parameter	Coefficient
CONSTANT	1.398553 (-0.76)
DSEA	0.0066811 (5.24)
$DSEA^2$	-0.0000424 (-3.78)
DLONDON	-0.0020224 (-2.20)
$DLONDON^2$	0.00000233 (1.30)
DWMINE	0.003385 (2.61)
$DWMINE^2$	-0.0000106 (-1.67)
DNWMINE	0.0033654 (2.34)
$DNWMINE^2$	-0.0000109 (-1.28)
CAPITAL	0.0053556 (0.21)
DCAPITAL	0.0003362 (0.21)
$DCAPITAL^2$	-0.0000147 (-0.65)
DMAJOR	-0.0032819 (-3.36)
$DMAJOR^2$	0.0000148 (2.87)
ABOVESEA	0.0002605 (0.48)
$ABOVESEA^2$	0.000000415 (0.47)
SUNAV	0.104419 (2.62)
$SUNAV^2$	-0.0003995 (-2.49)
SUNRG	0.0080961 (0.22)
$SUNRG^2$	-0.0000279 (-0.23)
WINDAV	-0.1680324 (-0.28)
$WINDAV^2$	0.0115575 (0.19)
WINDRG	0.0472365 (0.34)
$WINDRG^2$	-0.0349883 (-0.86)
PREAV	-0.0031978 (-0.68)
$PREAV^2$	0.0000251 (1.09)
PRERG	0.0131709 (4.28)
$PRERG^2$	-0.0001064 (-4.09)

TMPAV	-0.4600428 (-1.47)
$TMPAV^2$	0.0265692 (1.62)
TMPRG	0.9215534 (1.39)
$TMPRG^2$	-0.0431353 (-1.54)
AVTERR1B	-0.6619733 (-13.95)
AVTERR2B	-0.5066817 (-10.77)
AVTERR3B	-0.3916794 (-8.28)
AVTERR4B	-0.0177375 (-0.28)
AVSEMI2B	-0.3714274 (-8.14)
AVSEMI3B	-0.1902057 (-4.03)
AVSEMI4B	0.2270238 (4.41)
AVDETA2B	dropped
AVDETA3B	0.1431882 (3.05)
AVDETA4B	0.4742146 (10.02)
AVDETA5B	0.9394878 (18.69)
AVBUNG2B	-0.1445352 (-3.17)
AVBUNG3B	0.1296411 (2.62)
AVBUNG4B	0.5190249 (5.79)
AVFLAT1B	-0.7873051 (-16.28)
AVFLAT2B	-0.5783115 (-11.84)
AVFLAT3B	-0.3028043 (-3.07)
R-Squared	0.9167
Number of observations	3,076
Number of clusters	667
Ramsey RESET test[29]	2.17
Root MSE	0.13108

Source: Own calculation. T-statistics are in parentheses. Method used is panel corrected least squares.

[29] Ho: Model has no omitted variables. F(3,2916) = 2.17, Prob > F = 0.0891.

As shown in table 3, four of the climate variables are individually significant. Also, some distance variables are found to be statistically significant. Both the distance to a non-working mine and to a working mine have a positive sign. This is consistent with our assumption that a greater distance to a coal mine, regardless if working or non-working, might decrease the probability of being unemployed and might increase property prices. Furthermore, the distance to London as well as the distance to the nearest major town are significant whereas the distance to a county capital and the capital dummy are statistically not significant. This suggests, that households are more attracted by a metropolitan area rather than the main city of their county. Finally, the distance to the sea is highly significant, indicating proximity to the sea as a disamenity. This result is consistent with our above argument of the declining shipping and fishing industry. Besides, when you are expecting closeness to the sea to be an amenity, e.g. as a chance for leisure activities, these results seem surprising. However, the distances are measured in kilometres rather than meters. Only very few cities or towns are really close to the sea.

Table 4 contains the results of the F-Tests for joint significance of variables entering as both linear and squared terms. Compared to table 3, the numbers change slightly. The variables measuring the distance to London and the distance to the non-working mine are jointly significant at least at the 10 per cent level. In contrast to the results presented in table 3, the variable measuring the annual range in temperature becomes significant at the 5 per cent level.

Table 4: F-Test on joint significance of variables

Variable	**F(2/666)**	**Prob > F**
DSEA and DSEA2	14.72	0.0000
DLONDON and DLONDON2	2.98	0.0513
DWMINE and DWMINE2	3.43	0.0331
DNWMINE and DNWMINE2	2.87	0.0573
DCAPITAL and DCAPITAL2	1.12	0.3272
DMAJOR and DMAJOR2	5.73	0.0034
ABOVESEA and ABOVESEA2	0.40	0.6708
SUNAV and SUNAV2	3.69	0.0255
SUNRG and SUNRG2	0.03	0.9706
WINDAV and WINDAV2	0.31	0.7347
WINDRG andWINDRG2	0.81	0.4474
PREAV and PREAV2	1.20	0.3006
PRERG and PRERG2	9.41	0.0001
TMPAV and TMPAV2	1.50	0.2230
TMPRG and TMPRG2	3.05	0.0481

Source: Own calculation.

A sensitivity analysis of the labour market specifications revealed that the results are extremely sensitive to whether or not county dummies are included. In fact, the regression without county dummies must be rejected if tested for functional form. Even a model containing the twelve different regions of Great Britain must be rejected when tested for functional form. However, a model with 63 county dummies rather than 110 (the dummies for the Boroughs of London and the different parts of metropolitan areas were replace by one dummy for London and one for each metropolitan area) passed the test for functional form. The variable measuring range of precipitation becomes insignificant, whereas average temperature becomes significant.

The results are slightly sensitive depending on whether or not the highly insignificant variables capital and the highly jointly insignificant variables altitude, range of hours of sunshine and average wind speed are omitted at once when tested for joint significance. The variables measuring the amount of annual range in wind speed then become significant. Also, the T-statistics change slightly. However, the R^2 decreases by only 0.01 per cent. The reason for using the full model containing specifically range of hours of sunshine and average wind speed instead is to allow for a comprehensive appraisal when investigating the welfare impact of climate change. See section 5.2.

The results of different model specifications, especially labour market specifications are shown in table 9 in the appendix. In general, the results are relatively robust across the reduced models.

5 The Implicit Prices

5.1 The Implicit Price of Climate

The implicit prices of the climate variables were calculated by differentiating the hedonic price function with respect to each climate variable for three different types of location.[30] First for a location offering an average climate among all locations, then for locations characterized by the minimum values of that particular climate variable and third for locations with the maximum values.[31] Table 5 shows the implicit prices of the climate variables. A negative sign indicates a disamenity. At least three climate variables are statistically significant and all results seem plausible.

[30] The implicit price for a semi-logarithmic specification is calculated by $\frac{\partial p}{\partial x_i} = p * b_i$ where b_i is the estimated coefficient for variable x_i and p the average house price. In our model with squared terms included the equation changes to $\frac{\partial p}{\partial x_i} = (b_{1i} + 2b_{2i} * x_i)p$. This price is then annuitised at 5% to provide annual benefits.

[31] The locations offering the minimum value of average precipitation differ from the locations offering the minimum amount of temperature. Therefore, these implicit prices for the 'minimum' and 'maximum' locations can not be added up to calculate a full implicit price.

Table 5: Implicit prices for climate variables (in £/household/year)

	Averages	Minimums	Maximums
Sunav (hours)	28.48 (1.55)	128.88 (2.72)	-45.10 (-1.43)
Sunrg (hours)	-0.24 (0.00)	3.79 (0.17)	-5.83 (-0.24)
Windav (mph)	-186.08 (-0.76)	-239.85 (-0.63)	-48.63 (0.00)
Windrg (mph)	-159.02 (-0.77)	-28.18 (-0.10)	-569.48 (1.17)
Preav (mm)	0.53 (0.10)	-3.06 (-0.33)	18.64 (1.41)
Prerg (mm)	17.51 (3.23)	33.40 (4.16)	-55.01 (-3.47)
Tmp av (°C)	97.46 (0.52)	-659.23 (-1.28)	349.82 (1.49)
Tmprg (°C)	-415.37 (-2.40)	328.70 (0.75)	-700.11 (-2.32)

Source: Own calculations. T-statistics are in parentheses.

It turns out that households located in a place offering on average only 80 hours of sunshine per month, such as Inverness, are willing to pay a significant amount for additional hours. Households in other locations would rather not do so. Precipitation range is an amenity at the average and the minimum level (e.g. Nottingham with a range of 13 mm per year), whereas at a location with a maximum range of about 142 mm per year like Aberdare in Mid Glamorgan, it is a disamenity. This indicates that households would prefer a greater distribution of precipitation across the seasons (i.e. holding annual precipitation constant, drier summers and wetter winters are preferred). However, there is a limit, an optimum range exists. In contrast, as the negative sign of implicit prices for temperature range indicates, higher ranges are likely to reduce welfare. There are several places with a maximum range of 13°C per year, the majority of them are located within Greater London.

Differences in data, regression specification and also study areas make comparisons to other studies difficult and might explain to some extent the different estimates. Although the findings of impacts of seasonality of precipitation are in line with Englin (1996), the extend of the impact is very different. People living in the Olympic Peninsula in Washington State are on average willing to pay $ 1.40 for a one mm increase in seasonality of precipitation compared to £ 17.71 for people living in Great Britain.[32] Unlike both Englin (1996) and Maddison (2001), the amount of average precipitation is not found to be significant. Englin (1996) estimated an implicit price of $ 0.05 for a one mm reduction in annual rainfall, whereas Maddison (2001) estimated £ 0.51 for Great Britain. Both applied a semi-log model. In addition, Maddison (2001) found average temperture and average hours of sunshine significant in his hedonic house price regression.

[32] Englin (1996) evaluated the implicit price for a one inch increase calculated at the average property value. However, to make the results comparable Englin's results were annuitised by 5% and converted to millimetres.

Although all studies find a significant role for climate variables in explaining variations in house prices, the differences between the findings are difficult to interpret. Englin (1996) e.g. constrained the number of climate variables to two (average precipitation and range of precipitation) and no squared terms were added to the regression. Maddison (2001) specified the climate variables precipitation, temperature and hours of sunshine as averages and estimated two separate equations for house prices and wage rates. In general, the limited number of European studies decreases the reasonability of comparisons. More research is required.

5.2 Implicit Prices of Climate Change

All the above welfare measures were calculated for marginal changes of the environmental attribute. As people are concerned about the future changes of climate they are interested in the total impact of climate change pointing at non-marginal changes rather than marginal ones.[33]

To investigate the willingness to pay to avoid climate change, information about the extent of changes is required. For the UK, climate models predict an increase in temperature of about 3°C by 2100 with greater warming in the South and East than in the North and West. Very warm summers will become more frequent and very cold winters will become increasingly rare. Geographical differences in rainfall are likely to become more pronounced, with Scotland becoming wetter and the South East of England becoming drier. Also, rainfall is expected to become more seasonal with drier summers and wetter winters. Snowfall will decrease throughout the UK (Hulme *et al*., 2002).

To calculate the welfare impacts of future climate change the UKCIP02 scenario data was used, provided by the Department for Environment, Food and Rural Affairs (DEFRA). These data contain changes of UK monthly climate for four climate change scenarios and three points in time (2020, 2050 and 2080) on a 50km grid. Each of the climate change scenarios assumes a different greenhouse gas emissions scenario ranging from low emissions to high emissions scenarios. The range of emissions scenarios chosen is closely related to the range of emissions published by the IPCC Third Assessment Report (Hulme *et al.*, 2002). The dataset contains monthly data for three of our four climate variables (wind speed, temperature and precipitation). These monthly data were converted into annual averages and ranges. Table 6 summarizes the characteristics of the climate variables for two of the four scenarios: the low emissions and the high emissions scenario. All values for the climate variables are expected to increase on average, except one. Annual average precipitation is likely to become smaller.

[33] As generally known, the willingness to pay will mainly be underestimated, if non-marginal changes are calculated, see e.g. Bartik (1988). More recently discussed by Day (2001).

Table 6: Characteristics of climate variables for different climate change scenarios

Scenario	Climate variable	Mean changes	Std.Deviation	Minimum changes	Maximum changes
Low 2020	Windav (mph)	0.01	0.01	-0.03	0.05
	Windrg (mph)	0.11	0.04	0.04	0.23
	Preav (mm)	-0.71	0.70	-2.14	1.68
	Prerg (mm)	10.81	4.32	3.07	23.70
	Tmpav (°C)	0.75	0.09	0.52	0.90
	Tmprg (°C)	0.45	0.12	0.19	0.66
Low 2050	Windav (mph)	0.02	0.02	-0.06	0.08
	Windrg (mph)	0.21	0.07	0.08	0.40
	Preav (mm)	-1.26	1.25	-3.81	2.99
	Prerg (mm)	19.30	7.70	5.47	42.26
	Tmpav (°C)	1.33	0.17	0.93	1.61
	Tmprg (°C)	0.80	0.21	0.34	1.19
Low 2080	Windav (mph)	0.03	0.03	-0.08	0.12
	Windrg (mph)	0.29	0.10	0.11	0.56
	Preav (mm)	-1.78	1.78	-5.40	4.25
	Prerg (mm)	27.37	10.92	7.76	59.97
	Tmpav (°C)	1.89	0.23	1.32	2.28
	Tmp rg (°C)	1.13	0.30	0.48	1.68
High 2020	Windav (mph)	0.01	0.01	-0.04	0.06
	Windrg (mph)	0.14	0.05	0.05	0.26
	Preav (mm)	-0.84	0.84	-2.54	2.00
	Prerg (mm)	12.86	5.13	3.65	28.17
	Tmpav (°C)	0.89	0.11	0.62	1.07
	Tmprg (°C)	0.53	0.14	0.22	0.79
High 2050	Windav (mph)	0.03	0.04	-0.09	0.13
	Windrg (mph)	0.33	0.11	0.12	0.63
	Preav (mm)	-2.00	1.99	-6.05	4.75
	Prerg (mm)	30.65	12.23	8.69	67.15
	Tmpav (°C)	2.12	0.26	1.48	2.55
	Tmprg (°C)	1.26	0.33	0.54	1.88
High 2080	Windav (mph)	0.06	0.06	-0.15	0.23
	Windrg (mph)	0.57	0.20	0.22	1.09
	Preav (mm)	-3.46	3.45	-10.48	8.22
	Prerg (mm)	53.09	21.18	15.05	116.31
	Tmpav (°C)	3.67	0.45	2.56	4.42
	Tmprg (°C)	2.19	0.57	0.93	3.26

Source: Own calculations.

The partial impacts in both scenarios and in different types of location can be easily calculated by multiplying the implicit prices shown in table 5 with the expected average change of that particular variable.[34] These partial welfare impacts describe the change in amenity values if only one of the climate variables changes. However, we are more interested in the full impact of climate change. In order to calculate these impacts, the house prices for an average house in the current climate state was compared to the house price with a changed climate. These estimates were carried out for different locations followed the above differentiation; an average location, one characterized by a minimum annual range of precipitation (Nottingham), the counterpart with a huge amount (Aberdare) and one location with a maximum range of annual temperature (Harrow). The values of different climate variables for these locations are summarized in table 7.[35] Table 8 presents the full prices.

[34] The implicit prices were calculated for a location with an average climate facing climate change on an average level, followed by the locations characterized by the minimum or maximum values of that particular climate variable, also facing climate to change on an average level. In both scenarios and for all points in time the range of precipitation was found to be highly significant at a 5 per cent level of confidence. A higher range of precipitation is always an amenity indicated by the positive sign except for a location that is already facing a huge range in precipitation. People living in such areas would rather prefer less variety. Higher ranges in temperature are significant at the 10 per cent level at least for two types of location – average and minimum. The predicted higher ranges are regarded as a disamenity.

[35] Unfortunately, the scenario baseline data (50 km grid) is different from our above employed climate data (10 km grid). As the different climate change scenarios are calculated on the basis of the scenario baseline, the estimated changes can not be linked to our above climate normals. To overcome this problem, the scenario climate normals were used to calculate the full prices of climate change.

Table 7: The values of different climate variables for different locations for “low” and “high” emissions scenarios

			Low			High		
		Current climate	2020	2050	2080	2020	2050	2080
Average	Windav (mph)	5.19	5.20	5.21	5.22	5.20	5.22	5.25
	Windrg (mph)	1.85	1.97	2.06	2.14	1.99	2.18	2.42
	Preav mm)	86.99	86.29	85.73	85.21	86.15	84.9	83.53
	Prerg (mm)	48.53	59.34	67.82	75.90	61.39	79.18	101.62
	Tmpav (°C)	8.67	9.42	10.00	10.56	9.56	10.79	12.34
	Tmprg (°C)	10.46	10.91	11.26	11.59	10.99	11.72	12.65
Nottingham	Windav (mph)	5.28	5.30	5.30	5.33	5.30	5.33	5.37
	Windrg (mph)	1.74	1.82	1.92	1.95	1.84	1.98	2.18
	Preav mm)	61.04	59.89	58.98	58.12	59.67	57.77	55.37
	Prerg (mm)	17.8	22.65	28.78	34.62	24.13	37.00	53.24
	Tmpav (°C)	9.18	9.98	10.61	11.21	10.14	11.45	13.12
	Tmprg (°C)	11.04	11.42	11.71	11.99	11.49	12.11	13.09
Aberdare	Windav (mph)	4.68	4.70	4.71	4.73	4.70	4.73	4.77
	Windrg (mph)	1.19	1.24	1.30	1.34	1.25	1.37	1.56
	Preav mm)	167.51	166.33	165.40	164.52	166.10	164.16	161.71
	Prerg (mm)	134.72	156.71	173.95	190.36	160.88	197.05	243.03
	Tmpav (°C)	8.91	9.67	10.27	10.84	9.82	11.07	12.66
	Tmprg (°C)	9.61	10.01	10.33	10.71	10.08	10.86	11.91
Harrow	Windav (mph)	5.21	5.23	5.24	5.26	5.23	5.26	5.30
	Windrg (mph)	1.48	1.57	1.67	1.70	1.58	1.72	1.95
	Preav mm)	52.89	51.87	51.06	50.30	51.67	49.99	47.87
	Prerg (mm)	19.52	26.62	32.20	37.51	27.97	39.66	54.40
	Tmpav (°C)	9.99	10.85	11.53	12.18	11.01	12.44	14.23
	Tmprg (°C)	11.74	12.20	12.59	13.00	12.28	13.16	14.31

Source: UKCIP02 Climate Scenario data.

Table 8: The total welfare impact of climate change for different locations for “low” and “high” emissions scenarios (in £/household/year)

		Welfare impact (£s) for “low”			Welfare impact (£s) for “high”		
	Average current house price (£s)	2020	2050	2080	2020	2050	2080
Average	64,461	+72	+97	+100	+82	+95	-59
Nottingham	53,263	+157	+367	+611	+208	+712	+1,448
Aberdare	37,218	-544[b]	-915[b]	-1,204[b]	-639[b]	-1,304[b]	-1,719[b]
Harrow	78,921	+339	+631	+932	+417	+1,064	+1,991

Source: Own calculation.

[a] significant at 1% level, [b] significant at 5% level, [c] significant at 10% level.

The welfare impacts are varying enormously over time and space. For an average location the prices for both scenarios are increasing over time with one exception. The climate change scenario with the highest greenhouse gas emissions indicates a loss in welfare by 2080. The same development is expected for a location such as Nottingham. Although, for such locations the effect on the house prices is more marked. However, locations with a maximum range of annual temperature (Harrow) are likely to gain in all scenarios and time-slices. In contrast, a location such as Aberdare loses enormously from climate change.[36] Especially places that are already characterized by a huge range in precipitation are expected to receive more than the average increase in precipitation.

The findings suggest that there are some locations in Britain which might benefit from climate change, especially places with little or average range in rainfall and those with a huge range of annual temperature. Although measures like this are always carried out with some extent of uncertainty and the welfare impacts are calculated only for changes in three different climate variables, the increasing prices for an average location seem to confirm the optimistic interpretation of mild global warming. However, the results of a high greenhouse gas emissions scenario, like the negative sign for an average location in 2080, confirm the pessimistic expectations of an enhanced greenhouse gas effect.

6 Conclusion

This study has demonstrated how British households' preferences for climate amenities can be derived from the hedonic price regression. British people are concerned with temperature, precipitation and the amount of sunshine at their location. The estimates suggest that British people would typically prefer a greater distribution of precipitation across the seasons (i.e. holding annual precipitation constant, drier summers and wetter winters are preferred). Higher temperature ranges are by contrast likely to reduce welfare. Modest global warming with warmer winters and drier summers might thus benefit British households. An enhanced greenhouse effect with high greenhouse gas emissions would reduce welfare.

It is remarkable that these variables were found to be significant although the number of climate variables is rather large and 110 county dummies were implemented. However, empirical results are never unimpeachable. The choice of independent variables is not predetermined and always arbitrary. Also, the selection depends to a certain extend on data availability. Therefore, this analysis might be lacking because county dummies were used whereas individual wage data would have been required. By using census tract data the possibility of including information about the quality of local public services was limited due to problems of endogeneity. Individual housing and wage data would have been required but were not available for Great Britian. For future research on impacts on climate change time-series analysis might be more desirable to control the changes in income and to test the stability of the estimated results. Finally, a 'practical' solution to derive welfare impacts of non-marginal changes needs to be available.

[36] When tested for joint significance of a particular climate change scenario, these are significant at the 5 per cent level of confidence for all scenarios. The numbers for all other locations vary between 23 and 66 per cent.

In general, the limited number of European studies makes comparisons to other research work quite difficult. The results can not be confirmed or rejected. More research for locations in Europe is required. Unfortunately, the direct valuation techniques especially the contingent valuation approach has dominated the research work in Europe in recent years and there is some evidence that this trend is likely to continue.

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Appendix

Table 9: The results of the regression for alternative models

Dependent variable = lnHOUSING

Parameter	Full model (110 county dummies)	Without county dummies	With 12 regional dummies	With 63 county dummies[d]	Reduced model
CONSTANT	1.398553	5.520181	8.449162	-0.5199158	2.627796
DSEA	0.0066811[a]	0.005683[a]	0.005102[a]	0.0076012[a]	0.0067118[a]
DSEA^2	-0.0000424[a]	-0.0000472[a]	-0.0000322[a]	-0.0000518[a]	-0.0000426[a]
DLONDON	-0.0020224[c]	-0.0015947[b]	-0.0006251	-0.0018855[b]	-0.0022743[a]
DLONDON^2	0.00000233[c]	0.00000257[b]	0.00000123	0.00000182[b]	0.00000237
DWMINE	0.003385[b]	0.003198[a]	0.0012685[c]	0.0033999[b]	0.0034253[a]
DWMINE^2	-0.0000106[b]	-0.00000452[a]	0.000000741[c]	-0.0000115[b]	-0.0000109[c]
DNWMINE	0.0033654[c]	0.0016343	0.003817[b]	0.0032873[b]	0.00333[b]
DNWMINE^2	-0.0000109[c]	-0.00000989	-0.0000161[b]	-0.00000958[b]	-0.0000112
CAPITAL	0.0053556	-0.0387197[b]	-0.0177946	0.0062275	
DCAPITAL	0.0003362	-0.0015663[b]	-0.001045	-0.0005064	0.0001199
DCAPITAL^2	-0.0000147	0.00000312	0.00000534	0.00000155	-0.0000134
DMAJOR	-0.0032819[a]	-0.002446[a]	-0.0032604[a]	-0.0032405[a]	-0.0033641[a]
DMAJOR^2	0.0000148[a]	0.00000726[a]	0.0000096[a]	0.0000176[a]	0.0000161[a]
ABOVESEA	0.0002605	0.0001848	-0.0001903	0.0002584	
ABOVESEA^2	0.000000415	-0.000000732	0.000000693	0.0000000198	
SUNAV	0.104419[b]	0.0810028[a]	0.0765919[a]	0.1242108[a]	0.095396[a]
SUNAV^2	-0.0003995[b]	-0.0003553[a]	-0.0003044[a]	-0.0004788[a]	-0.0003656[a]
SUNRG	0.0080961	-0.040887	-0.0194831	0.0258538	
SUNRG^2	-0.0000279	0.0001391	0.0000626	-0.0000799	
WINDAV	-0.1680324	-0.0100898[c]	0.1905256	0.0081344	
WINDAV^2	0.0115575	-0.0125156[c]	-0.0306129	-0.0148957	
WINDRG	0.0472365	-0.1177517	-0.1392924	0.0099791	-0.0117773
WINDRG^2	-0.0349883	0.053812	0.0383195	-0.0070133	-0.0238782
PREAV	-0.0031978	-0.0053856	-0.0003755	0.0029705	-0.002506
PREAV^2	0.0000251	0.0000315	0.000000679	-0.00000698	0.0000236
PRERG	0.0131709[a]	0.0138339[a]	0.0077933[c]	0.0062637	0.0130301[a]
PRERG^2	-0.0001064[a]	-0.0001246[a]	-0.0000648[c]	-0.0000562	-0.0001049[a]
TMPAV	-0.4600428	-0.1854236	-0.2314248	-0.8732773[a]	-0.5605536[b]
TMPAV^2	0.0265692	0.0129034	0.0128403	0.0494486[a]	0.0300064[b]
TMPRG	0.9215534[b]	0.9236759[b]	0.0790753	1.018966[a]	0.9316966
TMPRG^2	-0.0431353[b]	-0.0424027[b]	-0.0054261	-0.0477317[a]	-0.0432432[c]
R^2	0.9167	0.8719	0.8857	0.9058	0.9166
RESET test (Prob > F)	0.0891	0.0000	0.0029	0.1173	0.0872

Source: Own calculation.

[a] (jointly) significant at 1%; [b] significant at 5%; [c] significant at 10%; [d] The dummies for the Boroughs of London and the different parts of metropolitan areas were replace by one dummy for London and one for each metropolitan area.