THE AMENITY VALUE OF CLIMATE TO HOUSEHOLDS IN GERMANY

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Abstract

This study uses the hedonic approach to measure the amenity value of climate in Germany. Unlike in earlier research separate hedonic wage rate and house price regressions are estimated for relatively small geographic areas and formal tests undertaken to determine whether the coefficients describing the impact of climate variables are homogenous over these areas. The evidence suggests that households in Germany are compensated for climate amenities mainly through hedonic housing markets. Given that climate is largely unproductive to industry and few industries spend more on land than labor this is consistent with what theory would predict. Overall households regard higher January temperatures as an amenity but higher July temperatures as a disamenity.

Keywords: Climate Change; Germany; Hedonic Pricing

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Introduction

Recent years have witnessed an increasing number of studies investigating the consequences of climate change. Research work has examined changes in productivity in sectors like agriculture and forestry where climate plays an obvious and important role. Other papers have attempted to estimate the costs of protecting low lying but densely populated coastal areas. Attention has also been paid to the costs of extreme events and hurricane intensity. Researchers have considered the health impacts of changes in the frequency of heat waves and of changes in the distribution of disease vectors. The ultimate goal of this and related research is presumably to compare the costs of preventing climate change to the benefits [1-6].

One important sector that will be impacted by climate change but has not yet attracted sufficient attention is the household sector. This neglect is not due to any consensus that the direct impact of climate change on households will be negligible. Climate determines the need for heating and cooling. It affects clothing, housing and nutritional expenditures and dictates recreational possibilities. Climate affects human health and certain types of climate are also known to promote a sense of happiness. The sorts of fauna and flora supported by particular climates are also a source of pleasure to households. Considering the potential importance of the household sector, information on the overall value of climate amenities to households would in our opinion make a significant contribution to the overall assessment of climate change impacts.

One methodology that suggests itself for this purpose is the hedonic technique. Fundamental to the hedonic approach is the assumption that households are attracted to those localities offering preferred combinations of amenities. Households should expect to pay higher property prices if their house is located in a preferred area and they might also be prepared to accept lower wage rates. Information on the implicit value placed on households can therefore be obtained by examining the household's locational choice. Compared to other methodologies the strength of the hedonic approach in this context is that it compares areas where it is assumed that all cost minimizing adaptations to climatic differences have already occurred. The theoretical foundations of the technique were first outlined by Rosen [7]. Roback is another major contribution to the theoretical literature on hedonic analysis being the first to note that across different geographical locations there generally have to exist both compensating wage and house price differentials and that amenity values can be capitalized into either or both of these [8]. The critical assumptions of the hedonic approach are well known [9] and with the exception of one key assumption not further discussed here.

Although a large number of hedonic studies have included climate variables for purposes incidental to the main aims of the study only a handful of studies have deliberately set out to measure the amenity value of climate to households and these vary greatly in terms of quality of the data. Hoch and Drake [10] found evidence of the influence of climate on wages for different worker categories in the United States. Englin [11] found that households prefer less rainfall to more but that holding annual rainfall constant households prefer a greater seasonal variation. Nordhaus [12] used a hedonic wage regression corrected for differences in the cost of living to estimate the amenity value of seasonal averages for temperature and precipitation. Cragg and Kahn [13, 14] estimate the demand for climate amenities using both the hedonic technique as well as a discrete choice technique that analyses the locational choice of migrants. Outside the United States Maddison and Bigano [15] find that Italians prefer a drier climate during the winter months and lower summertime temperatures.

A key aspect of previous research employing the hedonic technique is that researchers have found it necessary to estimate hedonic regressions over large geographic areas to identify statistically significant effects of climate on house prices and wage rates. This is because climate variables are undeviating over relatively large distances. But at such distances one of the underlying assumptions of the hedonic technique, namely the existence of a unified market for housing and employment within which the net benefits of different locations are eliminated, becomes untenable. Researchers risk biased results by attempting to fit a single hedonic price function to what are in effect separate hedonic price schedules [16]. The fact that researchers attempting to value a range of other environmental amenities have encountered evidence of structural instability at geographical distances much less than those over which significant differences in climate can be observed [17, 18] invites the question of whether previous hedonic climate studies have in fact succeeded in measuring what they intended to measure.[1]

This study uses the hedonic approach to investigate household preferences for climate in Germany. Although it is the most populous country in the European Union we are not aware of any research attempting to determine the value of climate amenities to households in Germany. Indeed, although environmental issues and in particular climate change are taken very seriously in Germany, hedonic valuation studies of any kind are surprisingly scarce. A review by Navrud [19] of European valuation studies completed between 1992 and 1999 revealed that Germany is one of the countries having the least valuation studies of any description. Existing studies using the hedonic price method in Germany have looked mainly at noise and air pollution [20].

The data for this exercise is drawn from the German socio-economic panel. This is a survey of private households and individuals providing detailed information on housing, occupational and socio-economic characteristics of households and individuals. For the 1999 survey the panel offers additional information on neighbourhood characteristics necessary for the conduct of a hedonic analysis.

Unlike earlier research we estimate hedonic regressions for relatively small geographic areas and then formally test whether the coefficients describing the impact of climate variables on house prices and wage rates are homogenous across these regions. This is only possible because we use climate data at a far higher level of geographical resolution than that employed by earlier researchers. Several papers estimating climate variables in the context of the United States for example assume that climate is homogenous at the level of the State [13, 14]. In this paper by contrast, Germany, a country equal in size to Montana and half the size of Texas, is divided into more than four hundred climatic zones. If the null hypothesis of parameter homogeneity is rejected then steps are taken to identify smaller geographical areas over which the assumption of parameter homogeneity is not rejected. Such an approach is especially warranted in a country only recently reunited. This strategy can be compared with existing hedonic analyses of climate effectively assuming a national market for housing and labour whilst including dummy variables for administrative areas or islands [15].

Although the climate of Germany is mostly temperate and not nearly as diverse as for example that in Italy or the United States, it is nonetheless influenced by the different geographical and topographical characteristics of its regions. Due to the effect of the sea the climate of the North German plain and the Baltic coast is relatively unvarying. The combination of high levels of sunshine and high rainfall results in a green and fertile landscape. The climate in Central and Southern Germany is more varied due to topographical features of these regions. In Bavaria the climate is similar to the Austrian Alps with cold winters and frequent snowfall. In Rhineland Palatine and Saarland in South Western Germany by comparison the climate is held to be particularly pleasant.

For Germany climate models predict as a consequence of projected increased greenhouse gas emissions an increase in temperature of about 4°C by 2100 with a greater degree of warming expected in the South of the country. Very warm summers will become more frequent and very cold winters increasingly rare. Summers are expected to become drier over all of Germany whilst winter is likely to become wetter [21].

Before moving to the empirical analysis it is worthwhile remarking that the hedonic technique is not the only valuation methodology by which researchers have attempted to estimate the amenity value of climate to households. Frijters and Van Praag [22] analyze self-reported happiness in Russia and find that this is greatly influenced by the climate of the location in which the individual lives. Maddison [23] uses the household production function approach to explain differences in international patterns of consumption partially in terms of climatic differences, thereby deriving an estimate of the welfare impact of climate change. In addition, a number of studies on migration have found an important role for climate [24, 25]. Since they focus on the process by which the net benefits offered by particular locations are eliminated, such studies are clearly interesting. But because they typically lack of welfare-theoretic underpinnings they cannot be used to draw inferences regarding the amenity value of climate.

The remainder of the paper is as follows. The next section describes the data used for the analysis and presents preliminary hedonic price regressions. In section three the parameters describing the effects of climate are checked for geographic instability. Section four computes the full implicit price of the climate variables and provides predictions of future climate change. The final section concludes.

Empirical Analysis

Most of the data used in this study was provided by the German socio-economic panel survey. Since 1984 the survey has provided annual information on housing, and on the occupation, employment history and earnings of individuals. In 1990 it was extended to include former East Germany. In addition to a stable set of core questions, each year the survey focuses on a special topic and in 1999 the dataset included detailed information on neighbourhood characteristics important for the conduct of a hedonic analysis. In order to take advantage of this information the analysis in this paper relies exclusively on the 1999 survey. Currently the data is made available on the district level (specifically Kreise and kreisfreie Städte) and given their size it is plausible to assume that individuals living within these small geographic areas generally enjoy the same climate.[2] In total 418 different Kreise or kreisfreie Städte (named Kreis subsequently) are included in the following analysis.[3] Each of these districts is assigned to one of 16 different Federal States (or Bundesländer). These are illustrated in Figure 1.

Figure 1. The Federal States of Germany

Mitchell *et al*. [26] provide data on temperature and precipitation. The data, supplied on a 10' grid (about 18 km square) and measured at average elevation above sea level as monthly averages, was overlaid onto a digital map showing the boundaries of the Kreise in order to calculate the average value of climate variables. Across these politically defined districts, January mean temperatures range from -3.9˚C to 2.1˚C whilst July mean temperatures range from 13.1˚C to 18.1˚C. Precipitation in January ranges from 28mm to 77mm whilst July precipitation ranges from 51mm to 158mm.

Following Roback [8] hedonic regressions were estimated both for house prices and wage rates. For the hedonic house price regression, the logarithm of monthly rental costs per square meter was regressed on a large number of environmental characteristics and structural attributes of the properties. Note that for owners, the survey provides self-reported imputed rents whereas for tenants the survey records actual rents. Data for tenants and home owners are analyzed both together as well as separately. Hoffmann and Kurz [27] state that the rental housing market in Germany is generally less regulated when compared to many other European countries. We excluded from our analysis households living in residential homes, student halls and hostels.

Climate variables (discussed in more detail below) are included in the regression alongside unemployment rates and population density. The latter two variables vary only at the level of the Kreis and are taken from Statistisches Bundesamt Deutschland [28]. Also included are dummy variables indicating whether a particular Kreis neighbors the sea and the proportion of woodland that it contains; the proportion of recreational area; the proportion of area given over to residential use; the proportion of area taken by water; and the proportion of area covered by transport infrastructure. Also included are variables identifying those Kreise bordering other countries and separating the former FRG and GDR. Two dummy variables pick out those Kreise through which run Germany's main rivers; the Danube and the Rhine. Latitude is also included since it has a potentially important role in controlling for variations in daylight across the seasonal cycle, important in high latitude countries. Unlike earlier studies longitude is excluded. Controls are also included for the size of the town or city in which the property is located as well as variables indicating the distance to the nearest large city (if not already in one); the nearest transport link; the nearest park; the nearest bank; the nearest shop; the nearest restaurant; the nearest surgery; the nearest school; the nearest kindergarten; the nearest sport facility; the nearest club for teenagers and the nearest club for pensioners. Dummy variables indicate whether the property is in a predominantly residential area with mainly old buildings, a predominantly residential area with mainly new buildings, an industrial or a commercial area.[4] A dummy variable indicates in which of the 16 Bundesländer the household is living in order to capture any differences in fiscal structure and the provision of public goods.

In terms of structural attributes the model includes dummy variables describing a property's state of renovation, its date of construction, as well as the type of property (flat, detached house etc). The model controls for the size of the property in square meters, as well as whether the house has central heating, a garden, a balcony, if it is owner-occupied, a subsidized apartment and how many years the household has lived there.

The dependent variable for the hedonic wage rate regression is the logarithm of the hourly wage rate net of tax. Apart from the many variables indicating geographical and socio-economic differences outlined above, the wage rate regression also controls for a large number of worker and employer characteristics. These include gender; age and its squared value; the number of years with the current employer; possession of a degree; years of education; marital status; disability-status; whether the worker is a trainee or part-time employee. Dummy variables identify the occupational grade of the worker (manager, professional, labourer etc) the industry in which they were working (agriculture, service sector, manufacturing etc) and the size of the employer. Although generally included in hedonic wage regressions, data on union membership is unfortunately not provided by the survey. Dummies once more indicate in which of the 16 Bundesländer the worker is living and to which of the following four groups the worker belongs: residents in the former FRG, foreigners in the former FRG, German residents in the former GDR and immigrants.

A limitation of the data used in the hedonic wage regressions is that the location of the employer is not recorded, only the location of the worker's place of residence to which all the geographical and socio-economic data are matched. Consequently we report separate hedonic wage regressions for those workers who reside within 10 km and 30 km of their work place as well as for all workers.

Results

After experimenting with different ways of describing the climate was it determined that the single best description of climate in both the hedonic wage and house price regression was afforded by the use of January and July averages.[5] In the context of the United States Cushing [25] investigated the determinants of population migration decisions using different specifications of temperature and found that the warmest and coldest and wettest and driest months provided the best description of climate whereas annual averages were the least preferred. We also tried including higher order terms for the climate variables but discovered that even in regressions including all Bundesländer they provided no significant increase in explanatory power. Note also that three different transformations of the dependent variable were considered: the linear, semi-logarithmic and inverse models. For both the wage and house price regression the semi-logarithmic model provided the most consistent results judging by tests for functional form.

In order to account for any correlation of residuals when observations are taken from the same Kreis, the standard errors of the hedonic house price and wage rate regressions were adjusted for clustering on the level of the Kreise. The effect is to increase slightly the standard errors of the parameter coefficients. This procedure also leads to robust variance estimates in the face of heteroscedasticity. In total 5,366 observations are included in the house price regression whilst 6,862 observations are included in the wage regression.

Table 1 presents the hedonic house price regression for all Germany including dummy variables for the different Bundesländer. To save space the estimates for coefficients other than those relating to climate are omitted but these can be obtained from the authors on request. Separate regressions are also presented for the former FRG and the former GDR as well as for owner occupied properties and those that are rented.

Table 1. Climate Coefficients of the House Price Regressions

Dependent Variable = Log Price

Method = Panel Corrected Least Squares

Variable	All Germany	Former FRG	Former GDR	Owner Occupied	Rented
JANTEMP	6.75E-02 ***	8.83E-02 ***	5.74E-02 *	1.12E-01 ***	4.94E-02 ***
JULTEMP	-5.11E-02 ***	-6.87E-02 ***	-7.80E-03	-5.88E-02 **	-5.18E-02 ***
JANPREC	-6.12E-03 ***	-7.45E-03 ***	3.50E-03	-7.73E-03 ***	-5.08E-03 ***
JULPREC	1.16E-03	1.88E-03 **	-4.17E-03 **	2.38E-03 *	6.17E-04
No. Obs.	5,355	3,886	1,469	1,964	3,391
R-Squared	0.358	0.401	0.340	0.412	0.367
RESET (P>|t|)	0.476	0.685	0.321	0.298	0.116

*Note: Significance at the ten-percent level is indicated by *, significance at the five-percent level is indicated by ** and significance at the one-percent level is indicated by ***. These have been adjusted for heteroscedasticity and clustering on the level of the Kreise. Numerous other variables were included in the regression but are not displayed (see text for details).*

The results from the hedonic house price regressions suggest that there is a strong effect of climate variables over Germany as a whole. In particular it appears that higher January temperatures increase house prices whereas higher July temperatures have the opposite effect. Precipitation in January has a negative affect on house prices whereas precipitation in July does not appear to have any effect at all. Dividing the data into the former FRG and GDR suggests that the climate signal is strongest in the FRG. This is not surprising since the area defined by the former FRG is much larger and has a more diverse climate. There is however little evidence that the parameter estimates vary significantly between the two regions. Dividing the data into owner occupied and rented accommodation suggests that the climate signal is present in both with a pattern very similar to that for all Germany.

Turning now to the remaining variables living in a property which is close to the river Rhine or has lower latitude significantly increases rent. A property that was recently built, has a balcony or has central heating also commands a significantly higher rent. Being far from the nearest big city or the nearest green space, and living in a flat which needs complete renovation reduces the rent, as does living in a less populated city with a high rate of unemployment. The rent per square meter varies with the number of square meters occupied suggesting that significant transactions costs prevent owners from dividing larger dwellings into separate apartments. We find evidence that rents are typically higher for tenants with more recent contracts whereas living in subsidized apartments is likely to reduce rents. This is consistent with the findings of Hoffmann and Kurz (2002) who argue that although the law allows landlords to increase rents by up to 30 per cent in any three-year period, the most substantial increases always take place when tenants move. A significant dummy variable for those dwellings occupied by their owners suggests that there might be a tendency for owners to overstate their potential rent. An alternative interpretation however, is that owners are more likely to improve the conditions of their houses than tenants and that this variable therefore reflects unrecorded characteristics of the dwelling.

Hedonic wage rate regressions are presented in Table 2 for all Germany as well as for the former FRG and former GDR. For reasons explained above separate regressions are also run for those individuals who reside within 10 kilometres and 30 kilometres of their place of work. The estimates for all Germany suggest that the effect of climate on wage rates is somewhat limited. This is perhaps unsurprising given the dominance of national wage bargaining in Germany. The only significant climate variable is July temperatures where it appears that higher temperatures are a disamenity i.e. they raise wage rates. The results from former FRG and GDR are not very different. Restricting the number of individuals to those who live within 10 kilometers of their workplace and those who live within 30 kilometers of their workplace does not result in any major differences in the parameter estimates of the climate variables. Higher levels of July precipitation are a disamenity in the regression including only those who live within 10 kilometers of their workplace but in this one instance the RESET test for functional form points to a possible misspecification. Note that only 3,816 individuals (out of 6,862) gave information on the distance to their workplace and out of these 2,563 lived within 30 kilometers of their workplace whilst 929 lived within 10 kilometers.

Table 2. Climate Coefficients of the Wage Rate Regressions

Dependent Variable = Log Wage

Method = Panel Corrected Least Squares

Variable	All Germany	Former FRG	Former GDR	Lives within 10 km	Lives within 30 km
JANTEMP	-2.00E-02	-5.42E-02	-1.93E-02	-1.98E-02	1.67E-02
JULTEMP	6.85E-02 **	8.22E-02 *	7.80E-02	9.26E-02	2.79E-02
JANPREC	5.39E-04	2.67E-03	-6.96E-04	-5.33E-03	-4.30E-03
JULPREC	-5.26E-04	-1.83E-03	1.31E-03	8.33E-03 **	2.33E-03
No. Obs.	6,862	4,907	1,955	929	2,563
R-Squared	0.200	0.185	0.199	0.232	0.235
RESET (P>|t|)	0.513	0.176	0.346	0.022**	0.460

*Note: Significance at the ten-percent level is indicated by *, significance at the five-percent level is indicated by ** and significance at the one-percent level is indicated by ***. These have been adjusted for heteroscedasticity and clustering on the level of the Kreise. Numerous other variables were included in the regression but are not displayed (see text for details).*

Turning to the remaining explanatory variables – once more not displayed – the greater the number of years spent with the current employer, the greater is the wage. The possession of a university degree, being self-employed or having spent more years on education all increase wages, while being in training, living close to the river Rhine or working in a small town reduces the wage. The age of a worker as well as its square is highly significant indicating that wages increase with age but decline as one approaches retirement. The coefficient for marital status is not significant, but being male or working full-time markedly increases the wage rate. Belonging to the West German sample also increases wages. Somewhat curiously the local rate of unemployment within the Kreis has no significant effect on wages which might also be indicative of the pervasiveness of national wage bargaining.

Earlier we argued that existing hedonic analyses of climate are not wholly convincing because the assumptions of the technique employed are not altogether plausible over such great distances. Any statistically significant correlations observed for the climate variables might reflect only a failure to control for unobserved differences in the geography and infrastructure. To explore further this issue we now run separate regressions for four different regions: Schleswig-Holstein, Hamburg, Lower Saxony and Bremen; North Rhine-Westphalia, Hesse, Rhineland-Palatine and Saarland; Baden-Württemberg and Bavaria; and Berlin, Brandenburg, Mecklenburg Western- Pomerania, Saxony-Anhalt and Thuringia. Estimates of the impact of climate on house prices and wage rates obtained from each region are then tested for parameter homogeneity in Tables 3 and 4.

Table 3. Parameter Homogeneity among the Coefficients from the Regional House Price Regressions

	January Temperature	**July Temperature**	**January Precipitation**	**July Precipitation**
Schleswig-Holstein, Hamburg, Lower Saxony and Bremen	-5.33E-02	4.33E-02	-2.20E-03	-9.81E-04
North Rhine-Westphalia, Hesse, Rhineland-Palatine and Saarland	6.78E-02***	-3.46E-02	-3.07E-03	1.45E-03
Baden-Wuerttemberg and Bavaria	1.38E-01***	-1.36E-01***	-9.74E-03	1.20E-04
Berlin, Brandenburg, Mecklenburg Western-Pomerania, Saxony-Anhalt and Thuringia	5.74E-02	-7.80E-03*	3.50E-03	-4.17E-03*
Parameter Homogeneity Test	$\chi^2(3) = 4.35$	$\chi^2(3) = 5.78$	$\chi^2(3) = 4.65$	$\chi^2(3) = 5.83$
Variance Weighted Estimate	6.80E-02***	-3.70E-02**	-2.00E-03	0.00E-00

*Note: Significance at the ten-percent level is indicated by *, significance at the five-percent level is indicated by ** and significance at the one-percent level is indicated by ***.*

Table 4. Parameter Homogeneity among the Coefficients from the Regional Wage Rate Regressions

	January Temperature	July Temperature	January Precipitation	July Precipitation
Schleswig-Holstein, Hamburg, Lower Saxony and Bremen	-3.88E-01**	4.96E-01**	3.47E-02**	-3.29E-02*
North Rhine-Westphalia, Hesse, Rhineland-Palatine and Saarland	5.04E-03	3.82E-02	-1.63E-03	1.82E-03
Baden-Wuerttemberg and Bavaria	-5.11E-02	4.31E-02	8.96E-03	1.56E-03
Berlin, Brandenburg, Mecklenburg Western-Pomerania, Saxony-Anhalt and Thuringia	-1.93E-02	7.80E-02	-6.96E-04	1.31E-03
Parameter Homogeneity Test	χ^2 (3) = 5.87	χ^2(3) = 3.34	χ^2(3) = 6.45	χ^2(3) = 4.05
Variance Weighted Estimate	-2.70E-02	6.60E-02*	1.00E-03	1.00E-03

*Note: Significance at the ten-percent level is indicated by *, significance at the five-percent level is indicated by ** and significance at the one-percent level is indicated by ****

The tests results indicate that the hypothesis of parameter homogeneity for the effects of climate on house prices and wage rates over these four regions cannot be rejected. These tests involve the use of the chi-squared statistic described in Hedges and Olkin [29]. Despite the limited variation in climate, for both the hedonic house price and wage rate regressions there are multiple examples of individual regions within which climate variables have a statistically significant effect. Moreover the variance-weighted estimates indicate that in the housing market there is a significant effect for January and July temperatures and likewise a statistically significant effect for July temperatures in the hedonic wage regression. Overall the pooled parameter estimates do not differ substantially from those obtained from the all Germany regressions reported in Tables 1 and 2. There is no evidence here to suggest that the results obtained with respect to the climate variables are a consequence of unacknowledged market segmentation.

Discussion

Given the fact that compensation for climate amenities appears to occur mainly through the hedonic housing market it is useful to recollect the results of Roback's theoretical model [8]. According to her model the sign of the wage and rent gradient with respect to the level of an amenity depends on whether the amenity is productive to companies or attractive only to households. If a company's production costs are not affected by the level of the environmental amenity and firms are mainly labor using rather than land using, then the hedonic house price gradient is positive with respect to the level of the amenity whilst wages are not affected by the level of the amenity. Insofar as it is, with the exception of agriculture, difficult to think of many productive activities in Germany that are dependent upon climate (as opposed to weather which clearly does impact on productivity) or are intensive in the use of land, the empirical results uncovered in this paper appear consistent with what theory would predict.

The final step is to calculate the full implicit price for climate variables i.e. the implicit price of climate variables accounting for the fact that households might be compensated through both housing and labor markets. Implicit prices are calculated for the four biggest cities in Germany: Hamburg, Frankfurt-on-the-Main, Munich and Berlin. The parameter estimates obtained in Tables 1 and 2 are used to determine what fraction of annual household housing expenditures and what fraction of annual household labor income represents compensation for climate amenities. Note that annual household labor income is calculated by multiplying the average number of workers per household by the fraction of those workers in employment and then multiplying by the average net wage per hour and the number of hours worked per employed person per year. Annual housing expenditures are calculated by multiplying the average monthly rent by 12 and then by the average number of square meters occupied. These calculations are performed at the level of the Kreise and kreisfreien Städte except for the number of workers per household, which is calculated at the level of the Bundesländer [28]. The results are presented in Table 5.

Table 5. The Marginal Welfare Impact of Changes in Climate Variables per Household per Annum

	Berlin	**Hamburg**	**Frankfurt**	**Munich**
January Temperature (DM / ºC)	1,144	1,351	1,510	1,820
July Temperature (DM / ºC)	-2,128	-2,502	-2,860	-3,406
January Precipitation (DM / mm)	-74	-87	-96	-116
July Temperature (DM / mm)	24	28	32	38

Note: One Deutsche Mark is worth 1.95583 Euros.

Households are willing to pay an amount ranging from DM 1,144 to DM 1,820 for a one degree centigrade increase in January temperature. By contrast, estimates of the marginal willingness to pay for July temperatures range from DM 2,128 to DM 3,406 to avoid a one degree centigrade increase. Households are willing to pay between DM 74 and DM 116 to avoid a one millimeter increase in rainfall in January and between DM 24 and DM 38 to enjoy a one millimeter increase in July.

To investigate willingness to pay to avoid the kind of climate that climate change threatens to bring, information about the extent of climate change is required. For Germany climate models predict an increase in temperature of about 3°C by 2100 with more rapid warming in the South than in the North. Very warm summers will become more frequent and very cold winters will become increasingly rare. The models also show a slight increase in annual precipitation throughout Germany. Rainfall is also expected to become more seasonal with drier summers and wetter winters. Snowfall will decrease throughout Germany [26].

Table 6 illustrates the climate change predictions for the four cities under the IPCC A2 Scenario. The A2 scenario is a high future emission scenario with over 830 ppm by 2100 compared to an atmospheric carbon dioxide concentration of about 370 ppm today. Note however that multiplying the welfare impacts in Table 5 with the changes described in Table 6 in order to make a prediction about the impact of climate change involves using marginal values to approximate non-marginal changes. Furthermore any such estimates would refer to the impact of climate change on current rather than future households (see note 1). In addition uncertainty regarding future emissions of greenhouse gases combined with the fact that different climate models predict different climate change scenarios dramatically increases the range of possible outcomes. Finally, given the fact that most individuals are unlikely to be aware of differences in the frequency of extreme events offered by different locations, there is also uncertainty regarding whether individuals preferences for avoiding extreme events can be identified through housing and labor market price differentials. This is of concern since climate change is expected to increase the frequency of such events. There is nevertheless the opportunity to use the hedonic approach to value for example the floods that occurred in Germany during the last few years and which many people blamed on climate change. Houses located in areas likely to be flooded should be less expensive compared to those not at risk. Whilst this might be an interesting study for the future unfortunately the data applied for our study is not adequate to test for this relationship.

Table 6. Climate Change Predictions for Major German Cities under the IPCC A2 Scenario

	Year	Berlin	Hamburg	Frankfurt	Munich
January Temperature (ºC)	2020	0.8	1.7	1.2	-0.5
	2050	0.3	2.0	1.8	-0.4
	2080	2.3	3.0	3.0	1.6
July Temperature (ºC)	2020	20.0	18.4	20.2	19.0
	2050	20.9	19.7	21.5	19.9
	2080	22.2	20.3	22.8	21.2
January Precipitation (mm)	2020	44.6	62.4	42.6	45.8
	2050	51.8	70.3	62.0	56.0
	2080	50.0	64.8	62.5	68.6
July Precipitation (mm)	2020	53.5	74.3	65.1	109.0
	2050	63.6	77.0	52.5	103.0
	2080	48.6	70.2	41.3	92.7

Source: [26].

Conclusions

This study has illustrated the extent to which German households' preferences for climate amenities are capitalized into wage rates and house prices. Estimates derived from the hedonic house price and wage rate regressions suggest that households pay a substantial premium for living in areas characterised by higher temperatures in January and lower temperatures in July. These estimates do not appear to depend critically on potentially implausible assumptions about the geographical extent of housing and labour markets. Nevertheless, uncertainty regarding future emissions of greenhouse gases combined with the fact that different climate models predict different climate change scenarios makes it difficult to calculate the impact of future climate change to households in Germany. Also, there are other consequences of climate change apart from household amenity values which are likely to have impacts on welfare. These include indirect effects like sea level rise and changes in the price of agricultural foodstuffs. We do not consider such effects and our results are certainly not intended as a complete measure of the welfare impact of climate change on Germany.

Future research might care to investigate the amenity value of changes in other climate variables such as sunshine and snowfall. It would be interesting to use the hedonic technique to investigate the effects of extreme events on property prices. Although it is unclear whether households ever consider the probability of such events before making choices relating to location, it might be that the floods in 2003 have permanently affected property prices in low-lying areas along the river Elbe. Although examining such effects would require more detailed information than is currently (publicly) available in the German socio-economic panel survey it nonetheless presents an interesting possibility for a future case study.

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[1] One limitation of existing studies which applies also to this paper is the fact that we are examining the preferences of current households whereas it is the impact on future generations that is arguably of greater relevance. But little is currently known about the amenity value of climate and it seems nihilistic to argue that the preferences of currently existing households are uninteresting and irrelevant.

[2] The average land area of a Kreis is 795 km^2. The average land area of a US state is 183,238 km^2 whilst an average US county covers 2,916 km^2. An average Italian province extends over 3,094 km^2.

[3] In fact there are 440 Kreis but some of these are not included in the dataset.

[4] Although air pollution is not included in the model it is plausible to suggest that it will be largely controlled for by city size, population density, proximity to transport links, the proportion of land in each Kreis devoted to transport infrastructure and whether the property is located in a predominantly industrial area.

[5] We examined the use of annual averages and annual averages squared, maximum and minimum values, and averages and ranges.

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