THE AMENITY VALUE OF THE CLIMATE

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Executive summary

Researchers have employed a variety of revealed preference valuation techniques to estimate the amenity value to households of a change in climate. These techniques include the hedonic price method, the household production function technique, hypothetical equivalence scales and analyses of subjective wellbeing. The results do not however provide a comprehensive estimate of the impact of climate change since they consider only the direct impact on households (amenity values) and not the impact arising from changes in incomes, prices or changes in climate occurring elsewhere. And whilst there are many reasons why households might prefer one sort of climate to another amenity values cannot be easily attributed to particular motive.

Because the United Kingdom does not have a particularly varied climate most valuation studies are for countries other than the United Kingdom. Even ignoring the fact that these estimates provide an incomplete measure of the welfare impact of climate change the extent to which they can usefully inform climate policy remains unclear. Because they exploit spatial variation in climate as an analogue for climate change they implicitly assume perfect adaptation. Furthermore they generally consider the preferences of current rather than future households. Additional complexity arises because willingness to pay for climate change depends on baseline climate.

Two empirical studies undertaken as part of a PhD thesis can be used to estimate the change in the value of climate amenities to United Kingdom households. The first study, which is based on a hedonic analysis of Great Britain, estimates the change in climate amenity values associated with IPCC emissions scenario A1B averaged over the time period 2030-2059 at £21.2bn. The second study, which is based on a cross country analysis of expenditure patterns, also points to a benefit of £4.1bn. Results derived from a recently

completed but as yet unpublished study of the amenity value of climate based on life satisfaction point to even larger benefits of £69.2bn for the same scenario. Although large these estimates are consistent with evidence from other countries that households are willing to pay thousands of dollars to inhabit a more preferred climate.

1 Introduction

Many explanations can be offered as to why households might prefer one sort of climate to another.[1] Climate determines domestic heating and cooling needs (immediately implying both positive and negative impacts). Climate alters humans' calorific requirements. Different types of climate necessitate different types of outside clothing. Climate constrains certain outdoors leisure activities whilst promoting others. Particular types of climate are known to generate a sense of wellbeing. And certain kinds of climate are conducive to good health and a reduced risk of premature mortality.[2] More formally, otherwise identical households inhabiting different climates are likely to have different levels of utility because the climate alters the cost of producing 'service flows' of interest to households (Becker, 1965).[3]

It is possible to measure in monetary terms the impact on households of a change in climate. Doing so moreover does not require the researcher to identify all possible reasons for preferring one sort of climate over another (what is referred to by some as the 'enumerative' approach might anyway be impossible given the ubiquity of climate). Nor can the resulting estimates be easily attributed to particular motives e.g. X percent for health benefits and Y percent for energy savings.

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[1] Parker (1995) identifies 830 sociological studies, 458 psychological studies and 807 physiological studies concerning the effects of climate on human functioning.

[2] See for example Health Protection Agency (2008).

[3] More formally

$$U = U(s_1(x,z), s_2(x,z), \ldots, s_n(x,z))$$

where U is utility, s represents the level of n different service flows, x is a vector of marketed goods and z is a nonmarket good (climate). This utility function is maximised subject to the household's budget constraint.

The appropriate monetary measure depends on the direction of change. For a move to an ‘inferior’ climate the appropriate measure is the minimum compensation necessary to persuade the household to accept the change. For a move to a ‘superior’ climate the appropriate measure is the maximum amount that that household would be willing to pay to secure the change. Together, these are referred to as the ‘compensating surplus’ measures of welfare change.[4]

Although researchers have employed a wide variety of valuation techniques to estimate the compensating surplus for a change in climate none have involved asking individuals e.g. “What is the maximum amount your household is willing to pay in order to enjoy a climate similar to that of Nice?” Whilst conceptually meaningful, this type of question is regarded as too difficult to expect individuals to respond accurately. Most researchers hoping to estimate the value to households of changes in the climate have instead chosen to use revealed preference techniques.

Before describing them it is important to understand that, whereas the utility of a household in location i will depend on a vector of prices P, income Y, the level of the nonmarket good z in location i and potentially the level of the nonmarket good in other locations j, these techniques measure the compensating surplus only for changes in z at location i.[5] But climate change might alter not only z_i but also P, Y and z_j. For example, climate change might alter P because it alters agriculture productivity in other countries and therefore the price of food on world markets. Likewise spending on defences built in anticipation of sea level rise would cut household income but this is not measured by any of the techniques.

1.1 The hedonic technique

[4] These are unlikely to be the same and it is likely that willingness to accept compensation exceeds willingness to pay see e.g. Bateman et al (1997).

[5] Algebraically

$$U_i = U(P, Y, z_i, z_j)$$

The hedonic technique suggests that if households are freely able to select from differentiated localities then climate becomes a choice variable. The tendency will be for the costs and benefits associated with particular climates to become capitalised into rental prices and wage rates. In such cases, the value of marginal changes in climate variables can be discerned from hedonic rental and wage price regressions (Roback, 1982).[6]

Although many hedonic studies have included climate variables as additional controls the first proper hedonic analysis of the climate is Nordhaus (1997) who uses wage data, adjusted for regional differences in the cost of living, to estimate United States households' valuation of climate, and then projects the welfare impact using climate change scenarios.

Mendelsohn (2001) presents a second hedonic analysis for the United States. Using county level data he includes 30-year averages for winter, spring, summer and fall temperatures and precipitation totals. Mendelsohn then estimates separate regressions for rents and four different kinds of employment. He combines the results with climate change predictions and discovers that a small increase in temperature of 2°C, coupled with an increase in precipitation of between 8 and 15 percent, would result in benefits to households of between $1bn and $75bn annually measured in 1987 USD (or £1bn to £88bn in 2009 GBP).

Maddison and Bigano (2003) use the hedonic technique to analyse the amenity value of the climate of Italy. Using data on Italian provinces they find that labour incomes net of housing costs are significantly higher in areas with high July temperatures and high January rainfall which they interpret as evidence of compensating differentials for these disamenities.

Mueller (2005) conducts a hedonic analysis of the climate of Brazil. Investigating two different climate change scenarios for the year 2050 she estimates the welfare cost to be between $8.5bn and $38.8bn measured in 2004 USD (or £5.2bn to £23.9bn in 2009 GBP).

Rehdanz and Maddison (2009) use the hedonic approach to measure the amenity value of climate in Germany. Their evidence suggests that households in Germany are compensated

[6] In this literature researchers refer to 'climate amenities' where the word 'amenity' means 'desirable feature of a particular location'.

for climate amenities through hedonic housing markets rather than labour markets. Houses are significantly more expensive in areas with higher January temperatures and less precipitation, as well as in areas with lower July temperatures.

Migration decisions are made on the basis of differences in wage rates, rental costs, employment possibilities etc. But do regions with more desirable climates ceteris paribus experience net inward migration? How does an individual trade off wage rates against the climate?

Adopting a discrete choice Random Utility modelling framework Cragg and Kahn (1997) examine the propensity of individuals to move between states as a function of climate variables holding constant wage rates, housing costs and employment prospects. Their results indicate that individuals are attracted by higher winter time temperatures and lower summer time temperatures.

Timmins (2007) uses an approach somewhat different to that of Cragg and Kahn to examine the relationship between migration and climate in Brazil. His analysis allows for individuals potentially to change location in response to climate change; a response shown to be empirically important. The costs associated with a moderate climate change scenario are estimated to be between $1.6bn and $8.1bn measured in 1991 USD (or £1.6bn to £7.8bn in 2009 GBP).

1.2 Household production function approach

Economists regularly analyse expenditure patterns to calculate equivalence scales for households with differing demographic composition. Such analyses are motivated by questions such as: “How much money would a family with two children need before it attains the same level of welfare as a household without any children?”

Those concerned with environmental valuation have extended this approach to answer questions, not about the relative costs of households with different numbers of children and adults, but about the relative costs of households with different quantities of nonmarket goods.

In order to determine the amenity value of climate variables using the household production function approach requires data on expenditures by households inhabiting different climates. It is assumed that these households share the same underlying tastes and that expenditure patterns differ only because households face different prices, enjoy different incomes, or are confronted by different quantities of nonmarket goods. The technique also assumes that nonmarket goods and marketed goods exhibit demand dependency (which constitutes a restriction on preferences).[7]

Maddison (2003) analyses consumption patterns for 88 countries. He uses his results to calculate changes in the cost of living imposed by a climate change scenario associated with carbon dioxide doubling. In this scenario residents of Northern Europe and Canada enjoy a significant reduction in the cost of living.

1.3 Hypothetical equivalence scales

In the hypothetical equivalence scales approach a sample of individuals are asked whether they would describe a particular income as ‘good’, ‘bad’ or ‘neither good nor bad’ for someone in their particular circumstances. The results are analysed using regression analysis to identify those factors respondents appear to believe mean that their household requires more or less income to reach an arbitrarily defined level of welfare. The underlying assumption of this technique is of course, that individuals share a common understanding of what constitutes a ‘good’ and ‘bad’ standard of living.

In Van Praag (1988) a survey of European respondents drawn from different localities were asked to evaluate their own household’s income in terms of being ‘very bad’, ‘bad’, ‘neither good nor bad’, ‘good’ or ‘very good’. This enabled Van Praag to identify the monetary value

[7] There is a class of commonly used utility functions from which the full impact of changes in the level of environmental amenities cannot be recovered. These are utility functions in which the environmental amenities form a strongly separable subset. Whether or not demand dependency holds is itself not a testable hypothesis (see Bradford and Hildebrandt, 1977).

to respondents of a range of climate variables including temperature, precipitation and humidity.

1.4 Subjective wellbeing

Psychologists have long used so-called ‘Cantril scales’ inviting individuals to state how happy they feel on a numerical scale. Recently, economists too have started to use such studies to explore important economic questions such as whether economic growth makes people happier and what are the welfare costs of inflation.

Frijters and Van Praag (1998) use this approach to explore the amenity value of the climate of Russia. They analyse the responses of individuals asked to rate their happiness on a 1-10 scale to construct climate equivalence scales for six Russian cities. These equivalence scales are normalised to Moscow and provide a sense of the extent to which the extreme climates encountered in Russia affect the cost of living. The cost of living in Dudinka (located on the edge of the Arctic Circle) is almost two and a half times greater than the cost of living in Moscow.

Rehdanz and Maddison (2005) analyse cross-country data on happiness. Despite simultaneously including a large number of variables (including absolute latitude) only GDP per capita and climate variables are statistically significant. It appears that lower temperatures in the coolest month, and higher temperatures in the warmest month, serve to reduce happiness.

2 Evidence on climate amenity values in the United Kingdom

All the valuation methodologies described above hinge on the validity of assumptions that cannot be tested. For example, the hedonic technique assumes that changes in house prices and wage rates households caused by internal migration have eliminated the net benefits of different locations. The hypothetical equivalence scales approach assumes that individuals have a shared understanding of what constitutes a ‘good’ and ‘bad’ standard of living. The household production function technique assumes that climate and marketed commodities exhibit demand dependency in order to guarantee that parameters of interest can be retrieved from econometric analysis of expenditure patterns.

Some studies employ international data whereas others use data from a single country. If data from a single country is used the climate must be sufficiently diverse to identify households' preferences for particular types of climate. Frequently data on household expenditures or happiness is aggregated over large, climatically diverse regions or even entire countries. Better results would be obtained using data from smaller climatically homogenous areas. Many studies include only temperature and precipitation and ignore variables like hours of sunshine and relative humidity. Studies seem to characterise climate variables in a different way e.g. annually averaged temperatures versus January and July averages or degree-days. Along with the likely dependency of marginal willingness to pay estimates on baseline climate this is likely to frustrate any attempt to compare results obtained by different studies.

But despite differences in geographical location, the quality of the data and the plausibility of the underlying assumptions all the studies indicate that climate is an important determinant of household welfare. Households are it seems in many instances willing to pay thousands of dollars to enjoy more preferred types of climate. Using this evidence to value the impact of climate change on amenity values in the United Kingdom is nevertheless difficult. Because the United Kingdom does not have a particularly diverse climate, researchers have tended to focus on other countries e.g. the United States. It would be unsafe to use overseas studies to estimate the value to households of a change in climate in the United Kingdom because (a) the value of a change in climate depends on the baseline climate upon which such changes are superimposed and (b) no study can successfully control for every aspect of a country's climate.

Only two studies provide estimates of the value to United Kingdom households of a change in the climate.

Maddison (2001a) presents hedonic house price and wage rate regressions for 127 counties, metropolitan areas and unitary authorities in Great Britain using data from 1994. These include separate regressions for house prices, and for wages paid to blue collar and white collar workers. Critically he assumes that both the labour market and the housing market are in equilibrium. Alongside a number of controls e.g. population density and indicators of the level of public services, the regressions include annual average temperature, hours of sunshine and annual precipitation in an attempt to explain the variation in county wage rates and house prices. Maddison finds that climate variables are statistically significant only in the hedonic house price regression. Households prefer higher annual average temperatures and lower annual precipitation. Sunshine has no statistically significant impact. There is presumed to be no difference in the marginal willingness to pay for annual average temperature and annual precipitation, even in areas where temperatures are lower than the Great Britain average and precipitation totals are higher.[8]

In a household production function analysis Maddison (2001b) invokes procedures identical to those customarily used to incorporate demographic variables into systems of demand equations. Using aggregate consumption data provided by the 1980 International Comparisons Project, Maddison discovers that including climate variables greatly enhances his ability to explain inter-country variations in observed consumption expenditures. Maddison then uses his results to estimate the compensating surplus for a 1°C increase in mean annual temperature and a 1mm increase in precipitation for each of 60 countries. United Kingdom residents appear to benefit from a warmer, drier climate.

Below these studies are used to value a specific climate change scenario for households in the United Kingdom. But before doing so it is necessary to draw attention to a number of issues.

By using spatial variation in climate as an analogue for future climate the following exercise assumes perfect adaptation. The phrase ‘perfect adaptation’ means that households have made all cost effective adjustments. The question is whether it is reasonable to assume that

[8] In a country where temperatures vary more than in the United Kingdom it might be possible to observe a curvilinear relationship between house prices and temperature whereby increasing temperatures first increase and then decrease property prices pointing to the existence of a ‘climatic optimum’.

households are able to adapt perfectly over the period in question. If not any benefits will be overestimated and any costs underestimated.

Households might enjoy particular climates because they enjoy the types of plants and animals inhabiting those climates. A potential overlap therefore exists between the studies reviewed here and any study attempting to value separately the impact of climate change on the landscape. Thus a hedonic analysis may reveal that households prefer higher levels precipitation when in fact what households value is not precipitation itself but verdant vegetation.

Hedonic analyses employing house price and wage rate data for the year 1994 reveal only what households in 1994 were willing to pay for climate. But the scenario of interest described below concerns what households in 2040 would be willing to pay. To the extent that willingness to pay for climate depends on household incomes this is a potentially large source of error. Likewise the value of changes in climate depends on prices P. For example, if the price of electricity increases then the value of temperature could change e.g. it becomes more costly to heat the interior of one's house so better to live in a warmer part of the country. But without considerable elaboration the hedonic technique cannot reveal any relationship between marginal willingness to pay for climate variables and the price of marketed commodities.[9]

Because it is based on the use of spatial analogues the hedonic technique cannot be used to value climates different from those already encountered anywhere else. But the future climate of southern regions will be warmer than the current climate anywhere in the United Kingdom.[10] Marginal willingness to pay for further increases in temperature may decrease as the climate of southern England approaches what some commentators might regard as the 'climatic optimum' of southern France. This is obviously less of an issue for studies like Maddison (2001b) using international data which includes observations for France and other warmer countries.

[9] In fact there is an even more fundamental issue here: most hedonic studies estimate only implicit prices and do not estimate Hicksian demand curves. For an example of a hedonic study that does attempt to estimate Hicksian demand curves see Day et al (2007).

[10] The same issue affects models used to value the impact of climate change on agricultural production.

Lastly these valuation studies use only a handful of variables to represent the climate e.g. annual average temperature and total annual precipitation. Other climate variables may change and these changes may be important e.g. the variance of July precipitation any increase in which might result in occasional but severe flooding. On the other hand, adding more climate variables often fails to improve the fit of hedonic house and wage rate regressions.

3 The climate change scenario

The future climate change scenario evaluated here is associated with the IPCC emissions scenario A1B, and averaged over the time period 2030-2059. Possible outturns for each climate variable are averaged over the "Administrative Regions" of the United Kingdom and are represented by a cumulative density function (see Table 1). The "Administrative Regions" of the Channel Islands and the Isle of Man are ignored. The "Administrative Regions" of Eastern, Northern and Western Scotland are combined to form a single region.[11] These outturns are described in terms of an absolute change in temperature and as a percentage change in precipitation. The baseline climate upon which these changes are superimposed is taken from the UKMO website: http://www.metoffice.gov.uk/climatechange/science/monitoring/ukcp09/download/reg_value_format.html.

Table 1. Climate change scenario for 2030-2059 corresponding to IPCC emissions scenario A1B (50th percentile)

Regions	Δ Annual Temperature (°C)	Δ Annual Precipitation (%)
East Midlands	2.0	0.2
East of England	2.0	0.2
London	2.1	0.1

[11] In Tables 2 and 3 the number of households in Northern, Western and Eastern Scotland are set to missing because it is unclear how these regions have been defined.

North East England	1.9	-0.2
Northern Ireland	1.7	-0.8
North West England	1.9	-0.4
Eastern Scotland	1.7	-0.3
Northern Scotland	1.6	-1.7
Western Scotland	1.8	-1.8
Scotland	1.7	-1.3
South East England	2.1	0.2
South West England	2.0	0.2
Wales	1.9	-0.3
West Midlands	2.0	0.2
Yorkshire and Humber	1.9	-0.2

Source: Extracted from http://ukclimateprojections-ui.defra.gov.uk/ui/start/start.php. Note that the scenario for Scotland is a simple average of the scenarios for Eastern, Northern and Western Scotland.

Table 2 displays the value to households of these changes in climate derived from the work of Maddison (2001a). These changes are quite simple to calculate since, according to him, insufficient variation in climate exists across Great Britain to identify any relationship between marginal willingness to pay and baseline climate (no curvilinear relationship can be identified). Household values therefore differ only to the extent that climate change impacts more heavily on some regions than others. And since the regional differences described in Table 1 are small in terms of accuracy there is nothing to be gained from further geographical disaggregation.

Table 2. The change in climate amenity values based on Maddison (2001a)

Region	Number of Households (m)	Change in Value / Household (£)	Total (£m)
East Midlands	1.74	856	1489
East of England	2.26	871	1970
London	3.17	903	2863

North East England	1.07	833	891
Northern Ireland	0.65	758	492
North West England	2.82	831	2344
Eastern Scotland		759	
Northern Scotland		716	
Western Scotland		820	
Scotland	2.19	764	1674
South East England	3.35	902	3025
South West England	2.1	882	1853
Wales	1.19	844	1004
West Midlands	2.16	873	1886
Yorkshire and Humber	2.09	833	1741
Annual Benefit			21238

Source: Own calculations and Maddison (2001a). All figures are in 2008 prices.

Table 3 presents estimates of the change in the amenity value of climate based on the household production function approach of Maddison (2001b). Once again marginal willingness to pay for climate variables is – this time for lack of detail in the underlying source – assumed to be independent of baseline, and household values differ only to the extent that climate change impacts more heavily on some regions than others. Note that in Table 3 these estimates have been presented on a per household basis rather than on the per capita basis of the original source.

Table 3. The change in climate amenity values based on Maddison (2001b)

Region	Number of Households (m)	Change in Value / Household (£)	Total (£m)
East Midlands	1.74	159	277
East of England	2.26	162	367
London	3.17	168	534
North East England	1.07	159	170

Northern Ireland	0.65	154	100
North West England	2.82	163	461
Eastern Scotland		147	
Northern Scotland		167	
Western Scotland		190	
Scotland	2.19	166	364
South East England	3.35	167	561
South West England	2.1	162	342
Wales	1.19	165	196
West Midlands	2.16	162	350
Yorkshire and Humber	2.09	159	332
Total			4059

Source: Own calculations and Maddison (2001b). Calculations assume 2.47 persons per household. All figures are in 2008 prices.

Tables 2 and 3 point to annual benefits associated with the climate change scenario described in Table 1 ranging from £4.1bn to £21.2bn. But without access to the original data it is impossible to provide estimates of the uncertainty surrounding these point estimates. Neither do these estimates account for any uncertainty in the climate predictions themselves. Finally these benefits refer to the change in amenity values and not to the overall impact of climate change.

It is unsurprising that the estimates based on the household production function study of Maddison (2001b) are lower than the estimate based on the hedonic technique. The reason is probably that (a) given the assumption of demand dependency the household production function technique measures only a subset of the possible benefits of particular climates and (b) the study is based on data from 1980 and does not take account of income effects whereas the hedonic study dates from 1994. Neither of the studies used to generate these estimates can be considered a 'state of the art' application of the underlying technique. Both of these estimates are drawn from an ageing PhD thesis.

How plausible are these estimates? Although we have argued against an approach based on separately enumerating the impacts of climate change health impacts tend to dominate climate change damage cost estimates. And in its report on the health impacts of climate change the Department of Health reports that under a medium high scenario climate change might, by 2050, reduce the number of cold related deaths by 20,000 whilst increasing the number of heat related deaths by 2,000.[12] Multiplying 18,000 avoided deaths by £1.7m (representing the value of statistical life in 2008 prices) results in a benefit estimate of £30.6bn. Changed amenity values derived from the hedonic and household production function analyses are not vastly different.

4 A new approach

In view of the serious shortcomings of studies currently available to estimate the value to United Kingdom households of a change in climate this report now presents new WTP estimates based on the preliminary findings of an unpublished study (Maddison and Rehdanz, 2010).

Using data from the World Values Survey (WVS) drawn from 87 countries Maddison and Rehdanz analyse the cross country variation in life satisfaction measured on a 1-10 scale. More specifically, question V22 included in the WVS is

All things considered, how satisfied are you with your life as a whole these days? Using this card on which 1 means you are "completely dissatisfied" and 10 means you are "completely satisfied" where would you put your satisfaction with your life as a whole? (Code one number)

[12] http://www.ukcip.org.uk/images/stories/Pub_pdfs/Health%20effects.pdf. The same report mentions a range of other mortality and morbidity impacts that have not been quantified.

Maddison and Rehdanz include as explanatory variables in their cross country regressions GDP per capita, inflation, unemployment, a freedom index and the percentage of the population who are under 14 years, and over 65 years of age. Also included are controls for population density, absolute latitude, coastline, elevation, and a set of dummy variables representing different regions of the World.

To represent climate the authors employ the concept of heating degree-months (HDMs) and cooling degree-months (CDMs) as measures of the climate. These are defined as follows

$$CDM = POS(TJAN - 18.3) + POS(TFEB - 18.3) + ... + POS(TDEC - 18.3)$$

$$HDM = POS(18.3 - TJAN) + POS(18.3 - TFEB) + ... + POS(18.3 - TDEC)$$

Where TJAN represents mean January temperatures, TFEB represents mean February temperatures etc and the function POS returns either a positive value or the value zero.[13]

The authors find that DMs (the sum of HDMs and CDMs) are negatively signed and statistically significant even at the 0.1 percent level of confidence. The implication is that deviations from 65°F (18.3°C) significantly reduce life satisfaction.[14] For households inhabiting climates currently characterised by a large number of HDMs, the results indicate that warmer temperatures might improve life satisfaction. But for households inhabiting climates currently characterised by a large number of CDMs warmer temperatures might bring reduced life satisfaction.[15]

Using the same approach taken by Maddison and Rehdanz it is possible to calculate the change in GDP per capita necessary to hold life satisfaction constant when confronted by

[13] In order to check whether 65°F is the most appropriate base temperature DMs were calculated using different base temperatures. The base temperature providing the greatest explanatory power is exactly 65°F (18.3°C). HDMs and CDMs are obviously very similar to the more familiar concept of heating and cooling degree days.

[14] Adding variables describing precipitation and deleting countries with a geographical area in excess of one million square kilometres does not affect the results.

[15] Once again these results do not provide a comprehensive estimate of the impact of climate change.

climate change i.e. the compensating surplus.[16] The benefit in terms of changes amenity values associated with IPCC emissions scenario A1B averaged over time period 2030-2059 is £69.2bn (equivalent to £1130 per person).[17] Although this is clearly a very large sum it is not wholly inconsistent with (a) the estimates in the preceding section and (b) evidence that households elsewhere in the world are willing to pay thousands of dollars for a more preferred climate.

5 Conclusions

Three studies incorporating very different methodological techniques and assumptions all point to substantial benefits from limited climate change, at least in terms of the direct impacts on households. Notwithstanding the difficulties associated with making comparisons such findings appear by no means out of step with studies undertaken elsewhere in the world suggesting that households in developed countries are implicitly willing to pay thousands of dollars to inhabit preferred climates. At the same time there is considerable scope to improve these estimates by refining the sometimes very inadequate data upon which they are based.

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[16] Note that the climate of the United Kingdom is represented by a population weighted average of the climate of London and the climate of Manchester. This is obviously a very crude representation of the climate but any errors are likely to be small in relation to the variation in climate observed across the 87 countries.

[17] The reader should note that the same research paper points to considerable losses in other parts of the World.

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