NEW TECHNIQUES FOR ESTIMATING HOUSEHOLD CLIMATE PREFERENCES (AND THE BENEFITS AND COSTS OF CLIMATE CHANGE)

By

Thomas Murray

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Department of Economics
The University of Birmingham
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Abstract

In order to make an informed decision on the optimal reduction in greenhouse gas emissions it is necessary to understand fully the damage costs of climate change. However, current modelling techniques fail to provide adequate emphasis on important components of the costs and benefits of avoided climate change. This approach risks over or underestimating true damage costs. Disregard for the amenity value that climate may hold and assumptions that restrict geographic mobility and determine the rate of social discounting may all contribute to significant error. Using spatial variations as an analogue for future climate change, this thesis finds that climate is important in determining the desirability of migration destinations and holds substantial amenity value. It also concludes that more work is required to be confident in assuming an elasticity of marginal utility equal to unity. Alternative techniques, including subjective wellbeing and hypothetical equivalence scales, are utilised to avoid having to make potentially restrictive assumptions on preferences for climate. Finally, this thesis stresses the importance of accounting for measurement error in cross-sectional survey data on household income. It seeks to inform how an econometrician can seek to implement appropriate instrumental variables to overcome this error.

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Abbreviations

CCOL	Climate Cost of Living
CES	Climate Equivalence Scale
CO_2	Carbon Dioxide
CS	Compensating Surplus
CV	Compensating Variation
DICE	Dynamic Integrated Climate-Economy
DM	Deutschmark
DWP	Department for Work and Pensions
EU	European Union
EU ETS	European Union Emissions Trading Scheme
EVS	European Values Survey
GDP	Gross Domestic Product
GIS	Geographic Information System
GHG	Greenhouse Gases
GNP	Gross National Product
HDI	Human Development Index
HPF	Household Production Function
IEQ	Income Evaluation Question
IPCC	Intergovernmental Panel on Climate Change
IRM	International Retirement Migration
IV	Instrumental Variable
LIWFI	Leyden Individual Welfare Function of Income
LS	Life Satisfaction
OECD	Organisation for Economic Co-operation and Development
OLS	Ordinary Least Squares
MWTP	Marginal Willingness to Pay
NLS	Non-linear Least Squares
NO_2	Nitrogen Dioxide
NUTS	Nomenclature des Units Territoriales Statistiques
QOC	Quality of Climate
QOL	Quality of Life
RUM	Random Utility Model
SO_2	Sulphur Dioxide
SqmPP	Square metres Per Person
STPR	Social Time Preference Rate
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
WTA	Willingness to Accept
WTP	Willingness to Pay

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CHAPTER 1

INTRODUCTION

1.1 The economic impact of climate change

Significant scientific evidence concludes that human activity is contributing towards changes in the earth's climate through elevated emissions of greenhouse gases (GHGs). The perfect mixing of GHGs in the atmosphere makes climate change a global issue. In attempts to mitigate global GHG emissions, international agreements have led to the signing of the United Nations Framework Convention on Climate Change (UNFCCC) in 1992 and countries benchmarking current emissions against 1990 baselines. Subsequent negotiations have led to a group of industrialised countries agreeing to more stringent, legally binding targets under the auspices of the Kyoto Protocol. The merits and limitations of the Kyoto Protocol are well documented (e.g. see Böhringer, 2003) and it expired in 2012. More recently the Copenhagen Accord (2009) has led to various post-Kyoto agreements, including acceptance of the recommendations of the IPCC (2007) to ensure rises in global temperature remain within 2 degrees Celsius of pre-industrial levels.

The economic impact of climate change continues to be the subject of much uncertainty. Recent international meetings of the UNFCCC identify the need for deep cuts in global GHG emissions. The Bali Action Plan in 2007 aimed to kick start negotiation for post-Kyoto emissions reductions targets by 2009 (UNFCCC, 2008). However, the subsequent

Copenhagen Accord (2009) failed to agree specific targets for emissions reduction. The most recent climate change conference in Durban 2011 anticipates universal international agreement on climate change by 2014 (UNFCCC, 2012). From a policy perspective it is vital to understand the costs of mitigating global GHG emissions as well as the benefits of avoiding the damage costs associated with predicted changes in climate. This is to ensure the net benefits of reducing GHG emissions are maximised.

The impacts associated with the future damages of climate change are manifold. Research into estimating these impacts have focused on sea-level rise, biodiversity and ecosystem loss, changes in the productivity of agriculture, impact on human life and health, increased probability of extreme weather events and forced migration.

Sea level rise is expected to occur as a consequence of climate change due to the melting of glacial and polar ice sheets and thermal expansion of oceanic waters. The various IPCC (2007) emissions scenarios estimate sea-levels to rise from 18cm to 59cm by the end of the 21st century[1]. A number of studies estimate these costs (e.g. Fankhauser (1995), Darwin and Tol (2001) and Bosello et al (2007).

The IPCC (2007) also estimate that a rise of 1.5-2.5^{o}C is likely to lead to:

> 'major changes in ecosystem structure and function, species' ecological interactions and shifts in species' geographical ranges, with predominantly negative consequences for biodiversity and ecosystem goods and services'.

[1] Relative to 1980-1999 levels

The extent to which ecosystems may be harmed depends on their capacity to adapt to changing climatic conditions, such as rising temperatures and changing precipitation patterns (Omann et al, 2009).

The impact of climate change on agriculture is likely to be determined principally by changes in precipitation patterns. For example, the IPCC (2007) anticipate agricultural production in many African countries to be 'severely compromised' and yields of rain fed crops to be reduced by up to 50%. Seo et al (2009) explore the effect of two climate change scenarios on net revenue of farms across multiple agro-ecological zones in Africa. One scenario predicts mild and wet conditions in the future, the other hot and dry. It is clear that the choice of scenario is crucial. Seo et al (2009) estimate that the hot and dry scenario leads to significant damages to the net revenue of African farms, whilst the mild and wet scenario will actually benefit them.

Climate change has both a direct and an indirect impact on mortality and morbidity. The IPCC (2007) outline a number of the potential risks. Higher sea-levels and increased probabilities of tropical cyclones and tsunamis present serious risks to life. Extended periods of drought cause malnutrition and an increased frequency of high temperatures leads to heat-related deaths, particularly in the poorest countries (and a reduction in cold-related deaths in higher latitude countries). Increases in extreme temperatures and rainfall are likely to alter contraction of disease and malnutrition in sub-Saharan Africa (Wang et al, 2009).

Climate change will lead to changes in the frequency of extreme weather events (Mirza, 2003). Impacts include increased heat waves, intensification of the water cycle and storminess (Stern et al, 2007). Periods of drought followed by intense rain reduces the capacity for soil water absorption and increases the potential for flooding (Rosenzweigh et al, 2001).

Forced migration may occur through a failure of humans to adapt to climate change (Black et al, 2011). Modelling work suggests moderate climate change may lead to significant increases in long-run international migration (Marchiori and Schumacher, 2011).

1.2 Climate change: a case of optimal control of emissions

The problem of the emission of GHGs, most notably that of carbon dioxide (CO_2) is best understood as the optimal control of a stock pollutant. Plourde (1972) considers the intertemporal welfare problem presented by a stock pollutant over an infinite time period. Society 'demands' CO_2 emissions in order to produce goods and services. However, emitters of CO_2 emissions such as firms, households and agents of deforestation ignore the external costs of their CO_2 emissions, treating the services of the atmosphere, which acts as a waste sink, as if they were free. This leads to divergence between the private and the social costs of CO_2 emissions. Optimality requires internalising the external costs of CO_2 emissions to the point where the marginal damages of these emissions is equal to the marginal benefits (Baumol and Oates, 1988).

Theory suggests the use of market based instruments, such as Pigovian taxes and trading of permits for the purposes of cutting GHG emissions at least economic cost. However, the precise outcome of such measures in terms of marginal abatement costs and emissions reductions, are uncertain because of uncertainty about the marginal abatement cost schedule (Stavins, 1997).

Carbon permit trading has been the principle method by which Annex B signatories of the Kyoto protocol have attempted to curb emissions. The European Union's Emissions Trading Scheme (EU ETS) is the principle carbon permit trading scheme of the Kyoto Protocol. It covers approximately 11,000 emitters of carbon intensive firms, mainly in the power sector and manufacturing (EC, 2009). From 2012 civil aviation is also required to trade carbon permits (EC, 2009). By controlling the number of tradable permits the EU can in principle control the overall quantity of emissions.

Further methods are also available to Annex B countries to offset CO_2 emissions under the Kyoto Protocol.[2] Principally these are joint implementation and the Clean Development Mechanism. Joint implementation enables two Annex B countries to pool their emissions reductions obligations, dividing their responsibilities as they see fit. The Clean Development Mechanism allows Annex B countries to implement an emissions reduction project in a developing country to earn certified emissions reductions credits. The Clean Development Mechanism requires that the claimed emissions reductions are additional to what would have otherwise have been achieved.

[2] An Annex B country is a country with a legally binding carbon dioxide emissions reduction target under the Kyoto Protocol.

1.2.1 Quantifying the impacts of climate change

Economists have followed a number of alternative approaches to quantifying the effects of climate change. The enumerative approach requires identifying the physical impacts of climate change based on scientific evidence (such as changes in agricultural productivity, sea-level rise and morbidity and mortality), monetising them and summing. Fankhauser (1995) monetises a wide variety of climate change impacts and estimate that a doubling of GHG concentrations relative to 1990 levels (leading to a 2.5^{o}C rise in global average temperature) will cost 1.4% of global GDP. Tol (2002a, 2002b) follows a similar approach and finds climate change has an overall average benefit to OECD countries across the time frame considered whilst the impact on Africa is unequivocally negative.

There exist drawbacks to following this methodology. Significantly, assuming the costs and benefits of individual impacts are additively separable is unrealistic. There is likely to be clear instances of interdependence between impacts which will be ignored (Tol, 2009).

Integrated Assessment Models (IAMS) attempt to determine optimal policy response to the impact of climate change. The purpose of IAMS is to combine current understanding of geophysical data on climate change projections into an intergenerational model of economic activity. They attempt to monetise the aggregate benefits and costs of climate change following various climate policies. Current economic activity is dependent on the emission of GHGs, primarily CO_2.[3] Increasing atmospheric concentrations of GHGs leads to changes in climate (more specifically temperature change) and damages to economic activity in the future. IAMS estimate a dynamic price path for CO_2, identifying the necessary emissions

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[3] GHGs other than CO_2 are often converted into a CO_2 equivalent to maintain consistency.

reductions over time for an efficient climate strategy (in terms of the burden of abatement and acceptable damages), whilst maximising intergenerational utility.

The seminal work is that of Nordhaus (1993) who develops a Dynamic Integrated Climate-Economy ('DICE') model incorporating a Ramsey economic growth framework. Climate change acts as an externality to economic growth leading to an underinvestment in climate capital. This model therefore integrates a climate change impacts-function linking the damage costs associated with specific increases in temperature and a function linking GHG emissions to economic activity and expenditures on abatement (Nordhaus 1993; 1993a).[4] GHG emissions accumulate in the atmosphere according to the carbon cycle and, after a lag, generate global temperature increases leading to economic damages. In his model a modest degree of emissions reductions appear to provide a net benefit to society, starting with low targets and a carbon tax which gradually increases through time.

In such models the earth is assumed to be a single agent zone with damages a function of global average temperature increases. Subsequent models, such as the Regional Integrated Model of Climate and the Economy (RICE) (Nordhaus and Yang, 1996), regionalise climate change policy to the country level and investigate international cooperative and non-cooperative climate policies. More recently, adaptation as an additional policy response to climate change has been incorporated as a decision variable into the IAMS framework ('AD-DICE') in addition to mitigation in the DICE (e.g. de Bruin et al, 2009).

[4] Many other IAMS exist to estimate the impacts of climate change. See Kelly and Kolstad (1999) for an overview and extensive list of IAMS. Some notable models include Policy Analysis for the Greenhouse Effect or PAGE (Hope, 2006) which was implemented by Stern et al (2007) and the Climate Framework for Uncertainty, Negotiation and Distribution (FUND) implemented by Tol et al (1995).

1.2.2 Drawbacks of the approach to modelling the impacts of climate change

The nature of IAMS is that assumptions are made about the expected damages costs of predicted temperature rise. IAMS require an underlying assumption about the precise shape of the damage function. A damage exponent makes a pre-determined assumption about the convexity of the damages caused by temperature rises. Often this exponent is assumed to be quadratic and based on subjective judgements (Ackerman et al, 2009). Stern et al (2007) apply a range of values between 1 (linear) and 3 (strongly convex), finding a modal value of 1.3. Nordhaus (2007) admits the damage function to be a 'major source of modelling uncertainty in the DICE model'.

It is crucial to understand fully the damage costs of climate change to make an informed decision on the optimal reduction of GHG emissions. However, IAMS currently fail to provide adequate emphasis on important determinants of the costs and benefits of avoided climate change, which may alter damage estimates substantially. This thesis draws attention on three specific areas of limitation in quantifying the impacts of climate change.

Firstly damage costs in IAMS ignore the possibility that the human population is geographically mobile. Migration is the most fundamental way of adapting to a changing climate. A well-documented consequence of climate change is forced migration through the failure of human adaptation (e.g. McLeman and Smit, 2006; Black et al, 2011). Climate change may lead to income differentials which will affect economic incentives for international migration (Bie Lilleør & Van den Broeck, 2011). It is also necessary to consider the potential for households to relocate if there are utility gains of doing so. If climate is an important determinant in the utility maximisation problem then it can influence a household's decision to relocate (e.g. see Graves, 1980).

Second is the focus of models on the loss of marketed goods caused by climate change. Damage costs estimate the extent to which climate change leads to loss in global output (e.g. see Nordhaus 1993) and is measured in terms of GDP. A household maximises utility, for example, given its income (y) and a vector of prices (p) giving the following indirect utility function:

$$u=v(y,p) \tag{1.1}$$

Damage cost functions of IAMS infer that climate change has an impact on household utility because climate (z) is a function of both y and p.

$$u=v(y(z),p(z)) \tag{1.2}$$

Changes in z therefore have only an 'indirect' impact on the utility maximisation problem. Increasing damage costs determines y and p and results in a change in utility for the household.

This ignores, however, the existence of a 'direct' impact on utility that households may experience for z. Amenity values are often used to describe the non-monetary benefits and costs of environmental goods such as climate.

$$u=v(y(z),p(z),z) \quad \textbf{(1.3)}$$

This allows for utility to be a function of the non-market effect of *z*. This includes preferences for particular kinds of climate. In some instances it is necessary to measure in monetary terms the amenity value of environmental goods so the value of changes in the abundance of environmental goods can be incorporated into cost benefit analysis (Atkinson and Mourato, 2008). The amenity value of climate is no exception to this.

Thirdly, there exists sensitivity in selection of the rate at which future impacts of climate change should be discounted in IAMS. Ackerman (2009) outlines the generic IAMS framework as the following maximisation problem of the intergenerational social welfare function

$$W=\int_0^\infty e^{-\delta t}U[c(t)]dt \quad \textbf{(1.4)}$$

Where W is social welfare and dependent on consumption at time t (*c(t)*), U is the utility function specifying the utility from consumption and δ is the pure time preference rate. The value of δ is commonly assumed to be greater than zero.

Critics of this approach (e.g. see Ackerman, 2009) question the defensibility of assuming a value of $\delta>0$ in the context of climate change. It infers that present utility is more important than future utility and therefore weighted more heavily. It ignores the uncertainty in estimating the damage costs of climate change and how it might impact on future growth (Ackerman, 2009).

The DICE model incorporates the Ramsey (1928) social time preference rate (STPR) framework for discounting which has also been implemented by Stern et al (2007) to estimate the present value of the costs and benefits of climate change.[5] The STPR is given by the rate of time preference for consumption in the present (δ) plus the expected rate of consumption growth over time (g) multiplied by the elasticity of marginal utility with respect to consumption (ρ).

$$STPR = \delta + \rho g \quad \textbf{(1.5)}$$

The two key variables here are δ and ρ. There is little consensus in the literature on the appropriate value that δ should take. Pearce and Ulph (1995) explain that this is partially due to the rate of time preference being dependent on both pure time preference and the rate of growth of life chances.[6] The value of ρ is often assumed to be equal to unity based on early research contributions (e.g. Blundell et al, 1994 and Pearce and Ulph, 1995). Increasing income causes utility to diminish at a constant rate.

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[5] Optimal response to climate change is a contentious issue, particularly following the findings of Stern et al (2007). Critics argue the social discount rate for the welfare of future generation compared to other climate change research is too low (e.g. Nordhaus, 2007; Weitzman; 2007).

[6] Pure time preference is the requirement of discounting future utility purely because it occurs later. Rate of growth of life chances captures the changing risk of death over time (Pearce and Ulph, 1995).

A number of different approaches exist to estimate ρ. These include life-cycle behaviour models (e.g. Blundell et al, 1994), consumer demand for preference independent goods (e.g. Evans and Sezer, 2002), equal absolute sacrifice models (e.g. Cowell and Gardner, 1999) and the subjective well-being approach (Layard et al, 2008). However, these techniques provide a wide variation in the estimation of ρ and ultimately question whether a value of unity is too conservative (Evans, 2005). If true this risks overestimating the costs and benefits of future climate change.

1.3 Aims and methods

The limitations identified in the previous section risk undermining existing estimates of the costs and benefits of climate change. Migration patterns and amenity values both play important roles in our understanding of human interactions with climate. Choosing an appropriate social discount rate ensures an efficient and equitable GHG emissions reduction path is implemented. The scope of this thesis is to follow a statistical approach to examine the significance of these current limitations in climate change modelling.

A failure to consider these factors compounds uncertainty surrounding the true costs and benefits of climate change. It is important to remember that *projected* climate change figures provided by international institutions like the IPCC are constrained by their very nature of being projections.

An alternative to reliance on climate change scenarios is to focus instead on climate data which we know to be accurate. Current and past climate data is readily available. Furthermore, climate varies significantly across the earth. Spatial variation in current climate can be used as an analogue for future climate change. Using this approach it is possible to observe the importance of climate in the decision to migrate across climatically diverse locations. It is also possible to reveal the preferences households exhibit for climate as a direct function of utility.

This concept can also be applied to factors other than the consumption of climate. Household income is determined by many economic factors. It is a key component of utility and is often assumed to exhibit a diminishing relationship. This has often assumed to be logarithmic (e.g. HM Treasury, 2003; Stern et al, 2007). It is possible to test this relationship by observing the direct effect of income on the utility function and to estimate the value of ρ in the STPR. This requires one to assume that utility is directly observable.

The remainder of the introduction explains how the subsequent chapters of this thesis seek to examine the current limitations in monetising the impacts of climate change and provide a brief overview of the analysis.

1.3.1 International retirement migration and climate

Chapter 2 investigates the importance of climate in the decision to migrate. If migrants exhibit preferences for the climate of where they choose to migrate to then it is invalid to assume geographic immobility in the face of a changing climate. Instead, it is possible that the impacts of climate change will partially be offset by relocation to countries exhibiting a desirable climate. If this is the case then the costs of climate change may be overestimated by ignoring the adaptive capacity of households through migration.[7]

The first step of the analysis is to consider the spatial distribution of migrants. Climate is important in the migration decision if, ceteris paribus, the stock of migrants is highest in countries with the most desirable climates. This is dependent on what is observed to be a 'desirable' climate. Climate is not a single observed value but a multitude of interdependent (and often highly correlated) variables. For example, a migrant might have a preference for higher summer temperatures but at the same time dislike overly humid conditions. These complex relationships need to be considered carefully when interpreting results.

Once a set of preferred climate variables have been established, it is possible to analyse the impact of predicted climate change on migration patterns given the preferences that have been identified in the spatial analysis. The second step of the analysis is to predict how the stock of migrants may change using a variety of IPCC emissions scenarios to predict climate change.

The focus of the analysis is on migrants who are retired and are in receipt of a UK state pension. There are a number of reasons why consideration of this type of migrant is particularly interesting. Firstly, the existence of retired migrants creates disequilibrium in the hedonic market for climate amenities. Retirees are able to relocate in regions where climate is predominantly capitalised through the labour market (Graves and Waldman, 1991). Secondly, there is currently little evidence concerning the quantitative importance of climate

[7]We refer to adaptive capacity in the context of households' choice to migrate and not as a result of forced migration. See, for example, Brown (2008) for an International Organization for Migration discussion of forced migration as a consequence of climate change.

for retired migrants. Thirdly, retirees in receipt of a UK state pension but living abroad are easily traceable and provide representative way to track emigrants and the country they now inhabit.

1.3.2 The amenity value of the climate

Chapters 3 and 4 analyse the importance of the amenity value of climate as a direct source of utility. They employ two different techniques that rely on present day spatial variation in climate being analogous to future climate change. This requires one to assume households are able to adapt perfectly to climate change and that future households possess the same preferences as current ones. Their key advantage is that it allows quantification of household preferences towards climate.

Climate is undoubtedly an important input to a household's own production activities. Climate affects expenditure on heating or cooling, food and drink and the need for particular types of clothing (Maddison, 2003). This in turn means that the consumption patterns of households are partially dependent on climate and will be affected by climate change. Some households' well-being may actually be improved by a degree of climate change. A key question is how much an individual would be willing to pay, or need to be compensated, for a unit change in a particular climate variable. This is henceforth referred to as the 'amenity value' of climate.

A number of valuation methods are used to estimate the implicit value of climate in observable markets. The most common approach is the hedonic pricing method which observes how climate is capitalised through the housing and wage markets. A second approach is migration based analysis which considers the process of equilibration in the hedonic technique where migration still occurs. Migrants then have the choice between a set of substitute sites of which one feature is the climate. Thirdly, there is the household production function (HPF) approach which observes changes in household expenditure attributable to climate. A full review of these techniques, their limitations and existing empirical evidence is provided in Chapter 3.

Chapter 3 uses a subjective well-being (SWB) approach to estimate the amenity value of climate. Typically, household surveys will ask respondents to respond to a life satisfaction or happiness question such as

All things considered, how satisfied are you with your life as a whole these days?

Respondents are then invited to give a response between 1 and 10 where 1 is "entirely dissatisfied" and 10 "completely satisfied". Life satisfaction or happiness questions provide the researcher with a simple self-reported utility scale where the question asked invites individuals to account for all the economic and non-economic factors that influence their well-being.

A handful of studies have already attempted to value climate using the SWB approach (Van der Vliert et al, 2004; Rehdanz and Maddison, 2005; Brereton et al, 2008; Ferreira and Moro, 2010). We advance this literature estimating the amenity value of the climate, overcoming the limitations of existing studies that average climate variables over large geographic areas

(Rehdanz and Maddison, 2005) or which display insufficient variation in climate variables of interest (Brereton et al, 2008; Ferreira and Moro 2010).

Chapter 4 applies a technique called hypothetical equivalence scales which estimate the additional cost of different types of households relative to a reference household. The approach has most widely been implemented in estimating of the cost of additional household members (e.g. Van Praag, 1971; Van Praag and Kapteyn, 1973) but a small body of research has sought to investigate the impact of climate on household cost of living using this approach (Van Praag, 1988; Frijters and Van Praag, 1998).

Survey respondents are asked to answer an income evaluation question (IEQ) to attach a monetary value to a verbally defined level of welfare. An example of an IEQ is

> *"What would, in your opinion, be the lowest income amount your household would have to have in order to live comfortably without problems?"*

A household requiring a higher minimum income to live comfortably without problems has a higher cost of living to maintain a constant level of welfare. This may vary according to household composition, socioeconomic characteristics and the climate.

1.3.3 Social discounting and climate change

The physical impacts of climate change itself will occur in the future. However, the economic cost of mitigating GHG emissions is applicable to the present. Social discounting is a key tool in estimating the present value of the costs and benefits of climate change. The choice of discount rate plays determines the present value costs and benefits of future climate change and the optimal GHG reductions path estimated in IAMS. Social discounting is also widely using in policy areas to maximise social welfare such as optimal redistribution of taxation, inequality aversion and social cost benefit analysis.

Social discounting is an important policy tool for two key reasons identified above (Ramsey, 1928). The first is because households are impatient and prefer to consume today. Secondly, households expect to be richer in the future leading to a diminishing effect on each additional pound earned (the elasticity of marginal utility (ρ)).

Small changes in these values, however, can have large impacts on present value costs and whether a proposed policy option is cost effective. Stern et al (2007) choose a STPR of 1.4% compared to Nordhaus (2007) who chooses a STPR to match the estimated market return on future capital.[8] The consequence is vastly different estimates for the present value costs and benefits of climate change.

Chapter 5 investigates the value of ρ using SWB data. SWB can be used to identify a point estimate of the value of ρ by analysing the change in utility households obtains from changes in income. The advantage of this approach is its ability to compare a wide number of households with differing incomes. It assumes however that cross-sectional variation in income is equivalent to changes in income over time.

[8] Stern takes $\delta = 0.1$, $g = 1.3$ and $\rho = 1$. Nordhaus (2007) DICE mode estimates the return on capital to be about 4% on average over the next century.

CHAPTER 2

INTERNATIONAL RETIREMENT MIGRATION AND CLIMATE PREFERENCES

2.1 Introduction

Europe is home to a significant and growing population of elderly people (Moro, 2006; Dwyer and Papadimitriou, 2006). In 2010 the old-age dependency ratio for the EU27 was 25.9 and is projected to increase steadily to 50.2 by 2050[9]. But despite this their migration remains little studied, even though retired migrants differ substantially from archetypical job-seeker migrants.[10] Retired migrants are no longer obliged to follow daily schedules and can come and go, geographically redistributing and concentrating themselves according to the advantages or disadvantages of particular locations (Wiseman and Roseman, 1979; Wiseman, 1980; Ekerdt, 2009). For this kind of migrant, work and job opportunities are no longer relevant to the migration decision allowing other factors to come to the fore (Serow, 2003; Ekerdt, 2009).[11]

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[9] Old age dependency ratio is defined as number of persons aged 65 and over expressed as a percentage of the projected number of persons aged between 15 and 64. See http://epp.eurostat.ec.europa.eu/statistics_explained/index.php?title=File:Old-age_dependency_ratio,_1960-2060_(1)_(population_aged_65_years_and_over_as_%25_of_population_aged_15-64).png&filetimestamp=20120321111604 for further information.

[10] The migration patterns of the elderly have by contrast been studied to a greater extent in the United States (see Walters, 2002, for a literature review).

[11] During the last century Europe was characterised by significant migration flows, most of them people in the early years of their working lives, seeking better job opportunities, motivated mainly by wages (Haug et al., 2002). The first wave of migrant workers flowed into the steel and mining industries during the interwar years. A second wave of migrant labour followed after the Second World War. These migration flows were of people moving between European countries and people coming from outside of Europe (Poulain and Perrin in Haug et al., 2002).

The purpose of this chapter is to analyse, by means of empirical study, the geographical pattern of international retirement migration (IRM). Using data on the number of individuals in 165 countries entitled to a UK state pension we determine the extent to which socioeconomic, geographical, healthcare and climate variables influence the choice of retirement destination.[12]

By contrast discussion on climate change and migration is currently focussed on 'forced' migration in developing countries (see e.g. Grote and Warner, 2010 and Reuveny and Moore, 2009).[13] The IPCC (2007) report on impacts, adaptation and vulnerability of does not mention the possibility of migration caused by changes in climate amenities in developed countries although Kahn (2009) discusses urban growth and climate change in the context of the United States.

To anticipate the main findings of the chapter, IRM is sensitive to the estimation method adopted. Regression analysis suggests Poisson estimation violates the assumption of equidispersion leading to the negative binomial model to be favoured. UK pensioners migrate to countries with the highest average hottest months and lowest average driest months. Furthermore, UK pensioners are averse to countries with the least cloudy months. Conversely, countries with highest vapour pressure in the most humid months serve to attract UK pensioners.

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[12] Wiseman and Roseman (1979) and Wiseman (1980) point out that migration encompasses three different decisions. These are (a) the decision to move (b) the decision of where to move and (c) the decisions about housing unit type and living arrangements. Our research mainly involves the decision where to move.

[13] Forced migration is prompted by loss of livelihood, repeated crop failures, desertification weather-related disasters, rising sea levels, political instability, armed conflict etc. Current estimates suggest that by 2050 there may be between 150 and 200 million climate change forced migrants (Stern, 2007).

To predict the impact of climate change on the retirement migration patterns of UK pensioners it is necessary to use the model which best explains actual pensioner flows with current climate levels. Surprisingly a Poisson model is found best to predict the flow of pensioners despite suffering from overdispersion. We find climate change, as predicted by a set of IPCC scenarios, increases UK pensioner migration towards Northern and Eastern Europe as these climates become more amenable. However non-climate variables such as historical colonial links, the presence of language barriers and maintaining a pension that increases with inflation appear more important determinants of future migration patterns than climate itself.

The remainder of this chapter is structured as follows. Section two reviews the literature beginning with the theory of migration before turning to explore the factors underlying the recent growth in IRM, the challenge of defining IRM, existing studies of IRM and its consequences for destination countries. Particular attention is paid to the evidence currently linking IRM and climate. Section three presents data on the demographic structure of the UK and the evolution of IRM for that country. We expect the situation of the UK to be very similar to that of other Northern European countries. Section four presents a cross country statistical analysis of IRM emanating for the UK based on the payment of state pensions. This analysis presents alternative specifications for countries' climates. The final section concludes.

2.2 Literature review

2.2.1 Migration theory

Basic migration theory emphasises the importance of differences in the supply and demand for labour (Sjaastad, 1962; Todaro, 1969; and Cohen, 1996). The resulting wage differentials precipitate migration from low-wage to high-wage countries (Borjas, 1989; Massey et al., 1993, 1998; Bauer and Zimmerman, 1995; Jennissen, 2007)[14]. A complementary theory argues that households avoid the risk of insufficient income by sending a family member to work elsewhere.[15] Such theories however do not explain IRM. For retirees, the existence of wage differentials and uncertainty over employment are irrelevant. Arguably the principal objectives of retirees are recreation and leisure, the pursuit of longevity and the maintenance of independence (King et al., 1998; Bahar et al., 2009; Ekerdt, 2009; Williams et al, 1997; Hardill et al., 2005 and Casado-Díaz, 2006). Retirement migration is a consequence of differences in the abundance of location specific amenities meeting the needs and tastes of elderly people. This is referred to as amenity-led migration.

Not all retirement migration can however be described in these terms. Some retirement migration consists of return migration. This involves individuals who, having migrated for

[14]Jennissen (2007) suggests that large inflows of international migrants could create linkages between population in origin and destination area, facilitating the migration decision. These linkages could reflect historical, cultural, colonial or technological conditions, or could be reflected in the existence of a migrant network.

[15] Indeed, the spatial gravitation tradition (Öberg, 1997) highlights the idea that the volume of migration is determined by distance (Jennissen, 2007).

work purposes, then return to their place of origin at the point of retirement (Bolzman et al., 2006; Rodríguez and Egea, 2006; Gibler et al., 2009).[16,17]

Theories of migration can describe both internal (domestic) and external (international) migration. The only difference involves the cost and the barriers to migration (clearly far higher in the case of international migration). For reviews of the literature on international migration (without focus on retirement migration) see Massey et al (1993) and Borjas (1994).

In the absence of significant costs of migration hedonic (compensating) differences in wage rates and house prices may arise (Roback, 1982). Labourers locate to areas where marginal willingness to pay for amenities is equal to the sum of the derivative of the hedonic house price function plus the derivative of the hedonic wage rate function both taken with respect to the level of the amenity.

2.2.2 Disequilibrium in the hedonic technique: the problem of retired migrants

The hedonic technique has been implemented to assess retired migrants' implicit price for amenities. Since retired households do not take part in the labour market, it follows they benefit by migrating to locations where amenities are predominantly capitalised into the wage rates. The process of equilibration requires house prices to change to reflect the influx of retired migrants until the utility benefits are eliminated. However, if retired migrants

[16] Research highlights the importance of family ties in determining the extent of return migration (Waldorf, 1994, 1996). Several studies show that the propensity to return declines with the time spent in the host country (Dustmann, 1996; Edin et al., 2000; Klinthäll, 2003, 2006; Coulon and Wolff, 2005). Another reason for return migration is in the event of disability or frailty. In this case, some migrants might decide to face these issues in their countries of origin (King and Patterson, 1998)

[17] Return migration can also be affected by amenities. Those who migrated for work purposes may not wish to return to their place of origin if it has fewer amenities (Klinthäll, 2006).

constitute only a small percentage of the overall migrating population equilibrium is unlikely to hold. Their actions will not exert upward pressure on the price of housing market through demand for amenities. They benefit by having to pay only the partial implicit value of the amenity. Relocation to areas where amenities are predominantly capitalised into wages will lead to a constant utility gain for retired households over time.

Graves and Waldman (1991) use the case of the retired to test whether their consumption of amenities is reflected exclusively in the housing market or whether they relocate to areas in which amenity capitalisation is predominantly in wages. Using the same county level US dataset, they use the estimated compensatory amenity prices in the wage and housing markets from Blomquist et al (1988). The total implicit price of amenities is simply taken as the sum of both these markets. This is the same summation used to construct the quality of life index in Blomquist et al (1988). Algebraically this can be given as:

$$f_i = h_i(\frac{dz_i}{dp_i}) + \frac{dz_i}{dw_i} \quad \textbf{(2.1)}$$

the marginal rate of substitution between amenity z and house prices p multiplied by the quantity of housing (h) consumed plus the marginal rate of substitution between z and wage rate w gives the overall implicit price f of z for region i.

These determinants are then correlated with net in-migration to estimate the significance of the implicit price of the amenity compensated in wages. Separate regressions are run for the elderly (over 65) and the working population (under 55). Those aged between 55 and 64 are dropped from the analysis to remove early retirees. For the over 65's the implicit price of amenity compensated by wage rates is a positive and statistically significant determinant of net in-migration. This confirms that retirees are attracted to counties where the implicit price captured in wages is higher. Conversely, there is no clear relationship that exists for the working population.

These findings have important implications because it establishes an opportunity for migrants to make a utility gain upon retirement, even if the nonmarket amenities are fully equalised in the housing and labour markets.

Let us take the indirect utility function of a household in region *i*, given the fixed level of amenity z and corresponding wage rate and housing rents. Individuals residing in a region with more desirable amenities will pay for this benefit either through accepting lower wages, higher house prices or a combination of the both.[18]

$$v_i = (w_i, h_i p_i; z_i) \quad \textbf{(2.2)}$$

Where the monetary value of z_i is taken to be the implicit price function given equation 2.1

$$v_i = \left(w_i, h_i p_i; \left(h_i \left(\frac{dz_i}{dp_i}\right) + \frac{dz_i}{dw_i} \right) \right) \quad \textbf{(2.3)}$$

[18] We cannot know the extent to which an amenity is capitalised into either market without first accounting for its productive value in the production function of firms. If the amenity has no productive value to firms (i.e. is neutral) then the amenity will be capitalised in both wages and house prices (Roback, 1982).

The standard hedonic technique assumes that, in equilibrium, the labour and housing markets will adjust accordingly to the level of amenity to equalise utility across all *i*.

$$v = v_i \quad \text{for all } i \qquad \textbf{(2.4)}$$

However, this equalisation of utility does not occur for the retired. As they no longer demand a wage, its direct impact on utility disappears. However, as the retired still benefit from amenity values being capitalised in wage rates, its implicit price remains:

$$v_i = \left(h_i \, p_i ; \left(h_i \left(\frac{dz_i}{dp_i}\right) + \frac{dz_i}{dw_i} \right) \right) \qquad \text{and } v = v_i \text{ iff } \frac{dz_i}{dw_i} = 0 \text{ for all i} \qquad \textbf{(2.5)}$$

Utility equalisation will fail to hold unless the implicit price of z is fully capitalised into the housing market. If this is not the case then, as found empirically by Graves and Waldman (1991), the rational retired individual should relocate upon retirement. The highest utility gains are achieved by migrating to regions where the implicit price of the amenity is predominantly capitalised into wages rates, all else being equal.

2.2.3 The growth of IRM

The key driver underlying growth in IRM is (a) an increase in the number of individuals reaching retirement age (b) and an increase in life expectancy of individuals conditional on reaching this age and (c) changes in the cost / barriers to migration (King et al, 2000 and

Rowthorn, 2009).[19,20] Such changes amplify migration arising because of enduring differences in the regional distribution of amenities of interest to retirees.

IRM within the EU is underpinned by a number of important treaties which have significantly diminished the barriers to IRM. These include articles 48 and 49 of the Treaty of Rome allowing free movement and the Single European Act removing barriers to the ownership of property across the European Union and the 1994 Maastricht treaty bestowing electoral rights on the non-national residents from other EU member states.[21]

Access to the welfare state and a variety of benefits and free or subsidised health care has also increased within the European Union. And the continuing expansion of the EU has lowered the cost of IRM to an increasingly large number of individuals (Sriskandarajah and Drew, 2006 and Balkir and Kirkulak, 2009).

Outside the EU discriminatory access to social entitlements and other obstacles might significantly influence the pattern of IRM.[22]

Differences in the cost of living also affect IRM to specific destinations. Researchers have for example pointed to what were at one time very considerable differences in the price of

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[19] Statutory retirement age has until recently been falling in many countries. This trend has now been reversed with several EU countries planning to increase the official age of retirement e.g. France and the UK.

[20] Increased life expectancy reduces the barrier presented by one-off moving costs.

[21] See http://www.hri.org/MFA/foreign/treaties/Rome57/ and http://www.eurotreaties.com/maastrichtec.pdf.

[22] For retirees from the United Kingdom there are countries where there are reciprocal relationships, non-reciprocal relationships and reciprocal (frozen) relationships where pensions are not annually increased. Significant IRM emanating from the United Kingdom occurs despite these financial disadvantages. (See http://www.dwp.gov.uk/international/benefits/state%2Dpension/)

property between Northern Europe and the Mediterranean (Williams et al., 1997; Dwyer, 2000; Dwyer and Papadimitriou, 2006; Bahar et al., 2009).[23]

Because of larger more fuel efficient aircraft, as well as greater competition, the cost of air travel has fallen thus reducing the cost making occasional return visits. IRM has also responded to low cost telephone calls, the internet and satellite television (King et al, 2000). Many authors have also pointed to a link between international tourism and retirement migration (e.g. Bell and Ward, 2000; Gustafson, 2002; McHugh, 1990; Cuba, 1989; Cuba and Longino, 1991; and Rodríguez, 2001). This can be thought of as having provided information about alternative lifestyles necessary to make an informed choice. A pattern of short stays frequently evolves into more or less permanent residency (McHugh, 1990).[24]

2.2.4 Defining and measuring IRM

Williams et al (1997) define IRM as

> "...a highly selective migration process which redistributes retired individuals – and their concomitant incomes, expenditures, health and care needs – across international boundaries". Providing an operational definition of IRM is however somewhat more difficult.[25]

Retirement might refer to an individual becoming eligible to particular age-related benefits. But retirement can also mean withdrawal from the labour market at any age. And many people refer to themselves as being 'partially retired'.

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[23] The inflow of retired migrants has, in preferred destinations such as Tuscany, caused the price of housing to soar to the point that it is now choking off IRM to that part of Italy (King and Patterson, 1998).
[24] Casado-Díaz (2006) conducted a survey among some older British, German, and Nordic residents living on the Costa Blanca discovering that in most cases, before deciding to migrate to retirees have usually spent time in the preferred locations as tourists, this help migrants to become familiar with the lifestyle, and facilitates the integration process once they decide to settle as permanent residents.
[25] Warnes (2009) suggests that the word 'international' poses little or no ambiguity compared to the words 'retirement' and 'migration'.

How much time must an international retiree spend abroad before he or she no longer qualifies as a long stay tourist? One common pattern seems to be that of seasonal migration. Many retirees are second home owners with properties in more than one country. At the other end of the spectrum many international retirees have sold up and no longer possess a property in the country of origin (King et al, 2000 and Williams and Hall, 2000). Individuals may of course transition from long-stay international visitors to permanent residents and vice versa (see Hugo, 1987; Attias-Donfut, 2004; Casado-Díaz et al., 2004; Moro, 2006, 2007).

For these reasons there is accordingly no unique definition of IRM. In any case, preferred definitions of IRM need to yield to whatever data is available. Yet collecting data on IRM from official sources also presents significant difficulty. International port departure statistics do not typically include questions concerning IRM. Estimates of IRM relying on national censuses do not account for individuals who are seasonal migrants. And data drawn from the compulsory registration of foreign nationals staying for more than a certain period of time may aggregate together people from different countries (King et al, 2000).[26]

International retired migrants also need to think very carefully how they describe themselves to the authorities. Key considerations are tax-liability and access to anything other than emergency health care.[27]

The only reliable information on the geographical pattern of IRM is through the disbursement of state pensions to those living abroad (Sriskandarajah and Drew 2006). Such figures exclude

[26] Whilst the OECD and EUROSTAT have data on foreign residents these figures do not disaggregate by age and inevitably therefore contain a majority of economically active persons (King et al, 2000).
[27] It is alleged that many United Kingdom expatriates fail to declare their residency status in order to maintain the right to non-emergency treatment in the United Kingdom (Coldron and Ackers, 2009 and King et al, 2000).

those who for whatever reason do not draw their pension abroad e.g. seasonal migrants. But although they are satisfactory for the purposes of cross country comparisons clearly such data do not capture IRM in all its diverse forms.

2.2.5 Current methodological approaches to the study of IRM

Relatively few papers analyse time trends in IRM. Almost none explain the geographical pattern of IRM.[28] Most research on IRM instead focuses on identifying the main push and pull factors by means of in-situ surveys. For examples of such surveys see Friedrich and Kaiser (2002), Breuer (2003), Casado-Diaz et al (2004), Huber and O'Reilly (2004), King et al (2000) and Helset et al (2005). Virtually all of this literature deals with retirement migration from Northern Europe to the Mediterranean although studies for Mexico and Panama are also available.[29]

Most in-situ surveys collect data by contacting expatriate associations and individuals and then 'snowballing' outwards (see Warnes and Williams, 2006 for a discussion). Although this procedure might generate an unrepresentative sample it is from such studies that researchers attempt to infer the socio-economic characteristics of international retirees.

[28] Klinthäll (2006) uses the Swedish Longitudinal Immigrant Database (SLID) to study flows from 16 major sending countries over a 28 year period. The investigation employed binomial techniques to establish that as immigrants approach retirement age (which is 65 in Sweden) that there is increased probability of return to country of origin especially for migrants from Greece and Italy. The probability of return migration was found to decline again after the age of 65. De Coulon and Wolff (2006) investigated the determinants of the choice of destination of migrants after retirement using the Multinomial Logit model on cross-sectional survey data on 6211 individuals aged 45-75 born of foreign nationality and resident in France. Their findings suggest that the location intention of the migrants, after retirement, was largely influenced by the location of their family members especially with those from southern Europe, Northern Africa and the Middle East.

[29] For the United States, within country retirement migration literature focuses on the north-south movement of elderly people within the country towards Sunbelt destinations (See for example Biggar, 1980; Longino and Biggar, 1981; Sullivan and Stephens, 1982, Hugo, 1987; Gibler et al., 2009).

Few papers employ purely theoretical approaches to studying IRM. Moro (2007) describes the economic impact of IRM within the EU taking as its point of departure the principle of non-discriminatory access to welfare systems. This model appears to capture the characteristic features of IRM. In his model young people live in countries with large amounts of capital per capita but on retirement move to countries with a better environment. Such behaviour places prolonged and significant pressure on host countries.

2.2.6 Policy concerns of IRM

The chief concern about the number of retirees moving from Northern Europe to the Mediterranean is that EU citizens are entitled to state benefits in other member states (Rodriguez et al, 1999). At the same time retirees may avoid taxation by failing to register with the authorities (Coldron and Ackers, 2009). Thus IRM potentially worsens the demographic imbalance currently threatening national budgets (Dwyer and Papadimitriou, 2006).

On the other hand investments in property and income transfers associated with IRM are likely provide a major boost to the economies of receiving countries (King et al, 1998). Some have argued that any negative consequences associated with the influx of retired migrants into Mediterranean coastal areas is more than offset by the creation of thousands of jobs and businesses (Lardies, 1999).[30] International retirees create employment, particularly in the form

[30] Rodriguez et al (1998) discuss the boom in residential construction that occurred throughout the Mediterranean.

of home-helpers (Hardill et al, 2005).[31] For a study on retirement migration and its effects on economic growth see Day and Barlett (2000).

IRM does however present a policy challenge in the form of locals competing with affluent retirees in the housing market. Koch-Schulte (2008) describes the environmental impacts of IRM namely landscape degradation, deforestation, reduction of local biodiversity and desertification among others.

Bahar et al (2009) refer to the contribution of migrant communities in terms of exchanging knowledge, extending values and transferring resources, one of the most important contributions being concern for the environment. Whether such transfers are possible is debatable since international retirees do not invariably mix with host communities.[32]

Finally the fact that a foreign migrant from an EU member state retains the right to vote in local elections poses interesting political questions. And although King et al (1998) observe that electoral rights are not normally exercised international retirees have in some instances been known to exert considerable influence over communities' affairs.

2.2.7 The influence of climate on national and IRM

In-situ studies investigating IRM from Northern European to Mediterranean countries typically ask international retirees to explain their motives for migrating. Climate is not the

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[31] An example of this phenomenon is the case of Italy, where public policies have strongly favoured the hiring of migrant care workers in response to the needs of elderly care (Hooren, 2008).

[32] According to King et al (1998) most international retirees live in enclaves with fellow nationals thus diminishing the need to learn the local language. The widespread availability of satellite TV and foreign newspapers diminishes further the need to integrate (Balkir and Kýrkulak, 2009).

main focus of such investigations, but almost invariably turns out to be the single most important factor in terms of (a) leaving the home country and (b) selecting the destination country.

Casado-Diaz et al (2004) report findings from a suite of studies using the same basic questionnaire to investigate IRM from Northern Europe to the Mediterranean. These studies defined an international retired migrant as 55 or more years old and living abroad for at least 4 months out of 12. These studies provide evidence on the overwhelming importance of climate in explaining IRM to particular European countries (see Table 2.1). [33,34]

Further insights emerge from interviews carried out by King et al (2000) in which international retirees emanating from the United Kingdom wanted to escape the cold, grey and damp winters. The study also revealed a pattern of seasonal residence involving returning to the United Kingdom during the summer. When asked why they liked the Mediterranean climate retirees responded that it promoted health and outdoor recreation whilst cutting home heating costs. The most appreciated aspect of the Mediterranean climate was the sunshine, dry winters and the infrequency of frosts.

Bahar et al (2009) conduct a study of IRM in Turkey. The main push factor was retirees' preference for warmer temperatures. Also in Turkey, Balkir and Kýrkulak (2009) interviewed predominantly British, German and the Dutch retirees. Once more climate turns out to be the

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[33] The only exception is Tuscany, a fact which might be due to the fact that winters there are unexpectedly severe by Mediterranean standards (King et al, 1998). Retired migrants in Tuscany tended to be motivated by cultural factors and feelings of antipathy towards their country of origin (King and Patterson 1998).
[34] Authors such as Molin et al (1996), Lam et al (2001), Kasof (2009), Radua et al (2010) have researched on the impact of climate on the Seasonal Affective Disorder (SAD).

principal push and pull factor. Lazaridis et al (1999) interviewed retired migrants from Britain resident on the island of Corfu. Yet again climate was the main push and pull factor.

Although these studies attest to the importance of the climate they seldom record what aspect of 'the climate' encourages or discourages retirees. They analyse retirees' preferences in particular Mediterranean countries (whose behaviour may be unrepresentative of the population of international retired migrants). Above all they provide only qualitative insights.[35]

Unlike most European countries the United States territory includes different climatic zones. This has led several researchers to undertake studies of the impact of climate on migration. Although our focus is on IRM we review this literature whilst acknowledging barriers to IRM are much higher.

Graves (1980) analyses gross migration flows by age category including a category for over 65s. Climate has a significant impact on migration decisions. Migrants over 65 years prefer a lower temperature variance across the year.[36] Clark and Hunter (1992) study United States migration over the life-cycle. Their model of gross migration includes several climate variables. Sunnier climates are found to attract over 60s as do climates with lower variation in annual temperatures.[37] Also in the United States, Cragg and Kahn (1999) find that the average retiree 'consumes' February temperatures nearly 2.8^{o}C higher than in 1960. In addition implicit expenditure on climate has increased more for retired households (climate is

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[35] They are unable to make predictions e.g. about the potential impact of climate change on IRM.
[36] Temperature variance is calculated using the formula for variance applied to the average temperature in each month of the year.
[37] Similar results can be found in Haas and Serow (1993), Clark et al (1996), Newbold (1996).

increasingly capitalised into rents rather than wages). Using the population growth rates of United States counties as a proxy for net migration, Rappaport (2005) detects a preference for warmer wintertime temperatures and lower summer heat (using an index which combines both temperature and relative humidity). These preferences are noticeably more marked for retirees.

Table 2.1 The most common reasons for moving to study area

Notes: n.c. means not collected. The data are the percentage references to the named factors among three 'main reasons' or 'main advantages'. Many respondents in Tuscany expressed 'admiration of the country'. There were two independent studies of Costa del Sol.

	Tuscany	Malta	Costa del Sol (1)	Algarve	Costa del Sol (2)	Torrevieja	Mallorca	Costa Blanca	Canary Isles
Reasons for moving abroad									
Climate	25.5	62.3	72.8	72.2	91.3	93.9	79.4	70.2	92.4
Financial reasons	5.1	37.4	31.0	42.4	31.5	37.4	9.4	45.7	30.3
Way of life	41.8	19.1	30.3	31.2	60.1	38.0	41.7	10.1	n.c.
Health reasons	9.2	12.8	23.2	19.0	23.0	54.6	25.8	29.9	62.1
Social life	5.1	27.6	8.4	10.7	11.3	n.c.	n.c.	n.c.	n.c.
Work related	25.5	6.2	4.6	8.8	0.0	0.6	6.4	1.9	5.3
Leisure activities	1.0	5.1	5.3	7.8	9.3	n.c.	9.2	n.c.	26.5
Environmental	15.3	2.7	3.7	5.4	0.8	n.c.	21.7	n.c.	n.c.
Advantages of living in the area									
Climate	42.9	75.9	80.2	83.9	42.3	n.c.	80.8	96.0	95.6
Social life	41.8	42.2	39.9	37.6	n.c.	n.c.	2.7	n.c.	37.3
Way of life	62.2	26.5	36.5	47.8	64.9	n.c.	40.0	49.7	48.0
Financial reasons	6.1	38.5	29.4	31.7	n.c.	n.c.	7.5	79.4	59.8
For health reasons	11.2	10.9	18.6	15.6	41.5	n.c.	16.1	57.1	n.c.
Environmental	36.7	2.7	8.0	11.2	58.9	n.c.	21.7	72.2	n.c.
Leisure activities	3.1	4.7	11.1	15.6	n.c.	n.c.	15.8	38.9	95.5
Personal	12.2	5.1	1.5	1.0	n.c.	n.c.	0.0	n.c.	n.c.
Easy access	0.0	1.6	5.3	4.4	n.c.	n.c.	3.6	37.1	67.0
Avoid home country	5.1	0.4	1.5	2.4	2.4	n.c.	3.3	22.4	48.0
Work related	2.0	0.0	0.6	1.5	n.c.	n.c.	1.4	7.6	n.c.

This table is adapted from Casado-Diaz et al (2004).

2.3. Analysing IRM emanating from the United Kingdom

Rather than using surveys to investigate a sample of international retired migrants in-situ the research undertaken for the CIRCE Integrated Project analyses the observed behaviour of the entire population of international retired migrants emanating from a particular country.[38] More specifically we use multiple regression analysis to explain the observed number of individuals in receipt of a UK state pension and present in each of 210 foreign countries and territories in the year 2005. This data is obtained from the Institute for Public Policy Research and is based on unpublished Department of Work and Pensions data (Sriskandarajah and Drew 2006).

The data indicate there are in excess of one million people living abroad receiving a UK state pension. Table 2.2 contains a list of the top ten retirement destinations. The most popular Mediterranean destination for UK pensioners is Spain, which ranks fifth. Australia, Canada, the United States and Ireland all have over 100,000 retired migrants in receipt of UK state pensions.

Table 2.2 Top 10 UK pensioner destinations

Country	Total pensions
Australia	245,311
Canada	157,435
USA	132,083
Ireland	104,650
Spain	74,636
New Zealand	46,560
South Africa	38,825
Italy	33,989
France	33,854
Germany	33,034

[38] The CIRCE Integrated Project is an EU funded research project on climate change and impact research across the Mediterranean. It was funded under the EC's Sixth Framework Programme. CIRCE consists of 14 research lines including the economic impacts of climate change. A work package within this research line was migration.

It is important to understand that foreign nationals who have spent their working lives in the UK paying National Insurance are entitled to receive a state pension upon retirement. A large number of migrants travelled from the Caribbean to the UK in the 1950s and 1960s seeking employment fully intending to return to their country of origin upon retirement. For such people it is likely that the primary reason for return migration is family reunification. By contrast UK born nationals retiring to the Caribbean probably have a very different set of motives. A key limitation of the endeavour described below is that no information exists that would help to identify individuals born overseas who spent their working lives in Britain, and British nationals who have decided to retire abroad.

Although it is the focus of attention here IRM is based on more than seeking out a better climate. Accordingly it is important to control for a range of factors. Data for these control variables come from the Population Reference Bureau, the 2005 World Population Data Sheet, the CIA World Factbook, freedomhouse.org and the World Health Organisation's World Health Statistics 2007 (the latter containing 2005 statistics). Explanatory variables are shown in Table 2.3. Summary statistics are provided in Table 2.4.

Table 2.3 Variables and their definitions

Variable	Definition
TOTPEN	Number of UK state pensioners living in each destination country (2005)
POP	Population in 2005
U15	Percentage of individuals who are under 15
OVER65	Percentage of individuals who are over 65
POPDEN	Persons per square kilometres
URBAN	Percentage of population living in urban areas
UNFROZEN	Unity if unfrozen pension or UK has reciprocal agreements
ENGLISH1	Unity if first language is English, 0 otherwise
ENGLISH2	Unity if second language is English or widely understood, 0 otherwise
FREEDOM	Freedom index
CWEALTH	Unity if country is in the Commonwealth, 0 otherwise
LIFEEXP	Life Expectancy in each destination country
LATITUDE	Latitude (decimalised degrees)
LONGITUDE	Longitude (decimalised degrees)
DISTANCE	Greater Circles distance from UK midpoint to destination mid-point
ELEV_LOW	Elevation at the lowest point of the country
ELEV_HIGH	Elevation at the highest point of the country
HEALTH	Per capita expenditure on health (2005 USD)
GDPPC	GDP purchasing power parity per capita (2005 USD)
EU	Unity if a EU, 0 otherwise
COAST	Total coastline (kilometres)
TMIN	Mean temperature in the hottest month (^oC)
TMAX	Mean temperature in the coolest month (^oC)
PMIN	Precipitation in the driest month (mm)
PMAX	Precipitation in the wettest month (mm)
VMIN	Vapour pressure in the least humid month (Pa)
VMAX	Vapour pressure in the least humid month (Pa)
CMIN	Cloud cover in the clearest month (%)
CMAX	Cloud cover in the cloudiest month (%)

Table 2.4 Summary statistics

Total Observations: 165

Variable	Mean	Std. Dev.	Min.	Max.
TOTPEN	6261.491	27115.06	0	245311
POP	37.80715	136.6024	0.03	1303.7
U15	30.50303	10.27762	14	51
OVER65	7.339394	4.91575	1	20
POPDEN	168.4713	562.2568	1.54	6928.99
URBAN	54.47879	23.0666	12	100
UNFROZEN	0.212121	0.410055	0	1
ENGLISH1	0.206061	0.405706	0	1
ENGLISH2	0.266667	0.443563	0	1
FREEDOM	3.266667	1.926653	1	7
CWEALTH	0.278788	0.449768	0	1
LIFEEXP	66.71206	11.84752	35	82
LATITUDE	-19.358	24.45338	-65	41
LONGITUDE	16.07964	64.43396	-175	175
DISTANCE	6175.17	3664.171	411.99	18539.26
ELEV_LOW	30.82461	172.6741	-408	1400
ELEV_HIGH	2829.396	2022.802	2.4	8850
HEALTH	686.6121	1258.087	5	6096
GDPPC	10906.7	11213.37	667	60228
EU	0.145455	0.353632	0	1
COAST	4131.618	17072	0	202080
TMIN	12.19909	12.36336	-25.2	27.2
TMAX	24.26545	5.345749	8.5	36.8
PMIN	39.24727	42.71082	0	219.9
PMAX	171.8018	117.3727	8.1	595.5
VMIN	12.43727	7.864916	0.7	28.4
VMAX	20.87909	6.5819	3.7	31.8
CMIN	42.4997	15.87784	2.9	79.7
CMAX	67.76424	13.90143	31.3	93.9

Some explanation is required regarding the specification of control variables in a regression equation predicting the stock of individuals in each country drawing a UK state pension.

Population is included in expectation that more pensioners migrate to more populous countries. GDP per capita in US dollars is included as a proxy for development. Higher GDP per capita should mean better infrastructure and more public goods. The percentage of individuals over 65 years of age is included to determine the extent to which pensioners follow each other into retirement destinations. We also include the percentage of individuals less than 15 years of age. The percentage of urbanised area is a proxy for environmental quality. We expect that UK pensioners will prefer countries with superior environmental quality.

The dummy variable ‘unfrozen’ reflects UK agreements in the European Economic Area and other reciprocal agreements with countries elsewhere to increase state pensions at the same rate as for those residing in Britain. In countries where these agreements do not exist pensions are permanently frozen at the time of emigration. One would expect that UK pensioners are more likely to migrate to countries where their pension entitlements are not frozen.

Distance is calculated using the great circles method. Greater distance is expected to serve as a deterrent to migration particularly for those wishing to make frequent return trips to the UK. Latitude and longitude are included controlling for geographical location of destination countries. Latitude captures preferences for UK retirement migration between South and North which includes variation in daylight hours of the annual cycle. Longitude captures preferences for destinations between East and West. We also include length of coastline. Insofar as some IRM is prompted by the same set of variables that explain international tourism coastline ought to be important.

Language is a significant barrier to migration. Retirees from the UK may therefore be drawn towards English speaking countries or places where English is widely understood. Two dummies are included for countries with English as a first language and countries with English as a second language.

Two further dummies are included denoting countries which are members of the British Commonwealth and countries within the European Union. Commonwealth countries, many of which are in the Caribbean, have historical and employment links to the UK and this variable could therefore help explain the extent of return migration whereas European Union membership requires the free movement of individuals across European Union borders and guarantees access to welfare and health care benefits. Such factors could potentially be very important in determining the geographical distribution of IRM.

We also control for differences in the extent of political freedoms by including a ‘freedom’ index. Countries are ranked between one and seven where one denotes the most free and seven the least free country. One might expect UK pensioners to avoid repressive countries in which inhabitants enjoy few political freedoms.

Old age inevitably leads to increased dependence on the healthcare system and two health related variables are included. These are life expectancy and total expenditure on health per capita. It seems probable that pensioners will prefer areas offering a higher life expectancy and higher spending on health.

Elevation at the lowest and the highest points of the country are included to capture the topological characteristics of each country. Countries with mountainous regions may provide scenic and recreational benefits.

Climate variables correspond to country averages measured over the period 1961-1990 and these are taken from Mitchell et al (2003). The data includes months with the highest and lowest mean temperature, total precipitation, average vapour pressure and percentage cloud cover.[39] The precise specification of the climate variables is discussed in more depth in the empirical analysis.

It is appropriate to acknowledge here two important data problems.

Cities in geographically larger countries frequently differ widely in terms of climate. For example, Darwin in North Australia offers a much more tropical climate compared to Melbourne's temperate climate. Using climate data averaged over each country's terrain may serve to bias coefficients of interest.

Rules on emigration constrain the pattern of IRM in ways that are not easy to capture empirically. This is less of a consideration for IRM within the European Union because these rules are evenly applied. Gaining permanent residency in some countries is very difficult requiring significant personal wealth or evidence of close genealogical ties.

Unfortunately rules on emigration cannot be readily quantified and are therefore necessarily consigned to the error term. Nevertheless these rules are likely to be stringent in some countries and this might obscure the role of climate in shaping IRM. [40]

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[39] Vapour pressure is the pressure at which water in the atmosphere evaporates in to vapour at a given temperature. Both temperature and vapour pressure determine relative humidity.

[40] For UK nationals over the age of 55 and hoping to retire to Australia, for example, a strict set of criteria need to be followed to be granted a retirement visa. This includes being sponsored by an Australian state/ territory, having no dependents and private health insurance. Most restrictive are financial requirements which require

The pensioner data set includes pensioner counts for 210 different countries. Dropping observations with missing values for key variables reduces the number of observations from 210 to 165 of which 45 have no more than 10 recorded UK state pensioners (see Table 2.5).[41] This makes an Ordinary Least Squares an unattractive way of modelling the data pointing instead to the use of Poisson regression techniques. But since the problem of over-dispersion often affects the Poisson regression model our research will also make use of the Negative Binomial regression model which is a generalisation of the Poisson model (Winkelmann and Zimmermann, 1995).

Table 2.5 The distribution of UK overseas state payments

TotPen	No. of Countries	Per cent	Cumulative Distribution
0	4	2.41	2.41
1-10.	41	24.70	27.11
11-100	49	29.52	56.63
101-1000	35	21.08	77.71
1001-10000	25	15.06	92.77
10001-100000	8	4.82	97.59
More than100000	4	2.41	100.00

Source: Own calculations.

transferring at least A$500,000 to Australia, receive at least $50,000 minimum annual income stream and are able to make an investment of a further minimum investment of A$500,000. These assets all need to be in place 2 years before lodging the retirement visa application. Further details of Australian retirement visas see http://www.skillclear.co.uk/australia/retirementVisa.asp

[41] UK Pension claimant data was available for British territory overseas (for example the Channel and Falkland Islands) and other territories which are not independent countries (e.g. Greenland, Faroe Islands). However, climate and demographic data were not available at this level.

2.4 Econometric model

The Poisson regression model is the standard econometric technique for analysing count data (Cameron and Trivedi, 1998). This model allows the conditional mean μ_i to depend on covariates x_i. The density function for the Poisson regression model is given by

$$f(y_i|x_i) = \frac{e^{-\mu_i}\mu_i^{y_i}}{y_i!}, y_i = 0,1,2,... \quad \textbf{(2.6)}$$

Where μ_i is modelled as

$$\mu_i = e(x_i^{'}\beta) \quad \textbf{(2.7)}$$

Consistency does not require the dependent variable to be Poisson distributed. Correct specification of the conditional mean and conditional variance is however required for the purposes of valid statistical inference.

The chief limitation of the Poisson regression model is the assumption that the conditional mean is equal to the conditional variance (equidispersion)

$$V[y_i|x_i] = E[\mu_i|x_i] \quad \textbf{(2.8)}$$

In many applications this assumption is not satisfied. Violation of this assumption leads to overdispersion (underdispersion) with conditional variance being greater (less) than the conditional mean. It is possible to account for the more commonly encountered problem of overdispersion using the Negative Binomial regression model (Cohen et al, 2003). In this model conditional variance assumed to be a quadratic function of the conditional mean.

$$V\left[y_i \middle| x_i\right] = \mu_i + \alpha\mu_i^2 \tag{2.9}$$

Where α is known as the dispersion parameter. In this case the conditional mean becomes

$$\mu_i = e(x_i^{'}\beta + \varepsilon_i) = e(x_i^{'}\beta)\mu_i \tag{2.10}$$

Where μ_i is a random variable which captures any unobserved heterogeneity and is uncorrelated with any of the explanatory variables. Letting μ_i be gamma distributed with $\Gamma(\alpha,\alpha)$ then μ_i becomes gamma distributed with $\Gamma(\alpha,\frac{\alpha}{\mu_i})$. Thus the negative binomial density function is given by

$$f(y_i \middle| \mu_i) = \frac{\Gamma(y_i + \alpha^{-1})}{\Gamma(y_i + 1)\Gamma(\alpha^{-1})}\left(\frac{\alpha^{-1}}{\alpha^{-1} + \mu_i}\right)^{\alpha^{-1}}\left(\frac{\mu_i}{\alpha^{-1} + \mu_i}\right)^{y_i}, y_i = 0,1,2,... \tag{2.11}$$

For $\alpha \geq 0$. Note that if $\alpha = 0$ this reduces to the Poisson regression model. The null hypothesis $\alpha = 0$ may be tested against the alternative that $\alpha > 0$.

2.5 Empirical analysis

This section presents results from a statistical analysis aiming to determine the extent socioeconomic, demographic, healthcare, geographical, and climate variables influence UK IRM decisions. These statistical models will subsequently be used to predict the impact that a set of climate change scenarios will have on patterns of UK IRM.

Four distinct statistical models are developed. Models 1 and 2 employ Poisson estimation, a standard econometric technique to analyse count data. Model 1 represents the climate in terms of annual averages and their squares. Model 2 represents the climate in terms of the temperatures of the hottest and coldest months, and precipitation in the wettest and driest months and so forth. We also in Models 3 and 4 present results for the Negative Binomial extension of the Poisson model to observe any evidence of overdispersion or underdispersion. Models 3 and 4 also specify the climate in terms of annual averages and their squares, and in terms of the temperatures of the hottest and coldest months, and precipitation in the wettest and driest months. Full regression results of all four Models are provided in Table 2.6.

Focussing first on the results from the Poisson regressions it is immediately clear that even though Models 1 and 2 differ only in respect of the climate variables this nevertheless impacts on the significance of the non-climate variables. Model 1 finds population has a positive, statistically significant impact at the five per cent level of confidence. Model 2 by contrast, finds no statistically significant relationship between population and UK IRM even though the coefficients are comparable in terms of magnitude.

Both Models find statistically significant evidence of a negative relationship between population density and UK IRM. By contrast the percentage of individuals living in urban areas does not seem to be important. There is no evidence in either Model 1 or 2 to suggest that UK IRM patterns are determined by the demographic structure of the destination countries. The percentage of population under 15 and over 65 are both statistically insignificant even at the ten per cent level of confidence.

Earlier we hypothesised that UK pensioners should be much more likely to retire to countries where statutory increases in state pensions are safeguarded. This hypothesis receives strong empirical support. Models 1 and 2 find that countries offering ‘unfrozen’ state pensions receive significantly higher levels of UK IRM. The coefficient on the relevant dummy variable is statistically significant at the one per cent level of confidence in either model.

Model 1 finds statistically significant evidence at the one per cent level of confidence that pensioners are more likely to live in countries where the first language is English. But in Model 2 the language denoting English as a first language is not statistically significant. Interestingly, both models find that countries where English is the second language or merely widely understood is negative and statistically at the five per cent level of confidence.

Historical and political relationships with other countries play an important role in UK IRM decisions. The Commonwealth and European Union dummies are statistically significant in both models albeit to varying degrees. In the case of the Commonwealth variable this probably points to the phenomenon of return migration. This is statistically significant at the one per cent level of confidence in Model 1 and then ten per cent level of confidence in

Model 2. The statistical significance of the European Union dummy, at the ten per cent and one per cent levels of confidence in Models 1 and 2 respectively, points to the effect of close political ties and the existence of treaties described earlier serving to lower the cost of IRM. Neither the variable describing political freedom, nor its squared value is statistically significant even at the ten per cent level of confidence.

Unsurprisingly the coastline variable is statistically significant at the one per cent level of confidence in both models emphasising the similarity between IRM and international tourism. There is further evidence of the importance of outdoor recreation with a positive and statistically significant coefficient for countries with high and low elevations. These effects are apparent in both Model 1 and Model 2.

The absolute value of latitude is statistically significant at the one per cent level of confidence in Model 1. The positive coefficient indicates that UK IRM is drawn to the poles. In Model 2 by contrast the absolute value of latitude is not statistically significant. Absolute longitude is statistically insignificant at the ten per cent level of confidence in both Model 1 and Model 2.

Proximity to the United Kingdom is very important in Model 1. Distance is negative and statistically significant at the one per cent level. Evidently pensioners want to be able to return the United Kingdom for frequent visits or if things go wrong. But in Model 2 this variable is not statistically significant.

Per capita expenditure on health is positively signed but not statistically significant. Given the reliance of the elderly on health services this is somewhat surprising. GDP per capita is not statistically significant either. One possible explanation for the fact that neither of these variables is statistically significant in either Model 1 or Model 2 is that GDP per capita and health expenditure per capita are highly correlated. Model 1 finds statistically significant evidence at the five per cent level of confidence that UK IRM is greater in countries with a higher life expectancy.

Turning now to the climate variables we note that in both Model 1 and Model 2 a joint test of significance confirms that the climate variables are statistically significant at the one per cent level of confidence. This confirms our main hypothesis that climate is an important determinant of the pattern of UK IRM.

Model 1 finds that average annual temperature is positive and statistically significant at the five per cent level of confidence implying a preference for warmer climates. The coefficient on its squared value is negative as might be expected but is statistically insignificant. Average annual precipitation and its squared value are statistically insignificant. Whilst average annual vapour pressure is statistically insignificant its squared value is significant at the one per cent level of confidence. Temperature and vapour pressure are highly correlated and both are important in determining comfort.

There appears to be a U-shaped relationship between average annual cloud cover and UK IRM. Average annual cloud is negative and statistically significant at the one per cent level of confidence whilst its squared value is positively signed and also statistically significant at the same level of confidence. The turning point is 56 per cent cloud cover.

Moving to Model 2 none of the maximum or minimum monthly values of climate variables are individually significant. Even so the climate variables are jointly significant at the one per cent level of confidence. This implies that climate plays an important role in IRM but it is not certain which variables are the most important.

Comparing the pseudo R^2 and pseudo log-likelihood of each model indicates that Model 1 provides the best fit.

Model 3 and Model 4 resemble Model 1 and Model 2 respectively but are estimated using the Negative Binomial model.

It is evident that the assumption of equidispersion is violated. More specifically, the hypothesis that $\alpha=0$ is rejected at the one per cent level of confidence. The pseudo log-likelihood and pseudo R^2 are marginally higher in Model 4 where climate is specified in terms of minimum and maximum monthly values.

Despite their apparent superiority Models 3 and 4 still display many similarities with the Poisson estimates and so we only comment here on any differences.

Model 3 finds a negative and statistically significant relationship at the five per cent level of confidence between UK IRM and the percentage of the population under 15. Population density is no longer statistically significant at any level conventional level of confidence and there is a noticeable weakening of the statistical significance of the dummy variables indicating countries in which state pensions are automatically increased rather than frozen.

Interestingly, the second English language dummy has a positive coefficient in both Model 3 and Model 4 albeit statistically insignificant at the ten per cent level of confidence.

Model 4 finds an inverted U-shaped relationship between freedom and UK IRM. This relationship gives a turning point of 3.12, where a score of 3 on the freedom index is given to countries such as Turkey, the Seychelles and Colombia.

Model 3 and Model 4 now find a positive and statistically significant relationship between per capita expenditure on health and UK IRM and a negative relationship between GDP per capita and UK IRM. This suggests a desire to move to countries with high levels of expenditure on health, but also countries in which it is cheaper to live.

Climate variables are once again jointly significant at the one per cent level of confidence. In Model 3 only vapour pressure is now statistically significant at the one per cent level of confidence. Average temperature squared is negative and statistically significant at the five per cent level of confidence. In marked contrast to Model 2 in Model 4 several climate variables are individually statistically significant. The coefficient on temperatures in the hottest month is negative as is the coefficient on cloud cover in clearest month. Both of these variables are statistically significant at the one per cent level of confidence. Conversely the coefficient on average vapour pressure in the most humid month is positive and significant at the one per cent level. Precipitation in the driest month is negatively signed and significant at the five per cent level of confidence.

The statistical significance of the estimated α values in the Negative Binomial regressions combined with the fact that Model 4 enjoys a higher pseudo R^2 would suggest that Model 4 is the best model. One of our goals however is to predict the impact of various climate change scenarios on the pattern of UK IRM. This might suggest using the model which best predicts actual UK IRM under the current climate. The model which best predicts UK IRM should have the lowest mean square error.

Notwithstanding arguments in favour of using the Negative Binomial models it is evident that these perform poorly in terms of predictive ability relative to the two Poisson models. Model 2 has the lowest mean square error with a value of 1.76e+07. In order to predict the impact of climate change scenarios on UK IRM we therefore use Model 2.

Table 2.6 Regression results

	Model 1 Poisson	Model 2 Poisson	Model 3 Neg. Binomial	Model 4 Neg. Binomial
POP	0.00231**	0.00280	0.00895**	0.00574
	(2.56)	(1.55)	(2.36)	(1.43)
U15	0.0125	-0.0125	-0.107**	-0.0650
	(0.26)	(-0.19)	(-2.32)	(-1.36)
OVER65	0.128	0.0782	0.0142	0.0729
	(1.63)	(0.72)	(0.17)	(0.91)
URBAN	0.000228	0.00900	-0.00632	0.00144
	(0.02)	(0.60)	(-0.63)	(0.15)
POPDEN	-0.00245***	-0.00220**	0.0000648	-0.0000432
	(-2.60)	(-2.03)	(0.12)	(-0.12)
UNFROZEN	2.835***	2.627***	1.072**	0.841*
	(3.98)	(3.47)	(2.07)	(1.65)
ENGLISH1	1.807***	1.206	2.576***	2.655***
	(3.56)	(1.61)	(5.05)	(5.01)
ENGLISH2	-1.281**	-1.001**	0.682	0.619
	(-2.44)	(-2.08)	(1.56)	(1.39)
CWEALTH	1.491***	1.856*	1.295***	1.659***
	(2.65)	(1.88)	(3.04)	(3.77)
FREEDOM	-0.0544	0.648	0.310	0.823*
	(-0.10)	(0.94)	(0.65)	(1.78)
$FREEDOM^2$	-0.0119	-0.0930	-0.0734	-0.132**
	(-0.17)	(-1.14)	(-1.26)	(-2.32)
LIFEEXP	0.0744**	0.0377	0.0127	0.0648**
	(2.00)	(0.96)	(0.42)	(2.08)
LATITUDE	0.0674***	0.0412	0.0361**	0.0357*
	(3.58)	(1.53)	(2.09)	(1.93)
LONGITUDE	0.00340	0.00264	0.00819***	0.00952***
	(1.64)	(0.83)	(2.65)	(3.11)
DISTANCE	-0.000271***	-0.000144	-0.000202*	-0.000229**
	(-3.07)	(-0.96)	(-1.82)	(-2.02)
ELEV_LOW	-0.00179	-0.00348**	-0.00357***	-0.00356***
	(-1.53)	(-2.15)	(-3.30)	(-3.10)
ELEV_HIGH	0.000407***	0.000266*	0.000224**	0.000201*
	(4.40)	(1.91)	(2.32)	(1.83)
HEALTH	0.000276	0.000553	0.00131***	0.00108***
	(0.84)	(1.60)	(4.30)	(3.48)
GDPPC	-0.0000132	-0.0000311	-0.0000893**	-0.0000779*
	(-0.33)	(-0.66)	(-2.34)	(-1.92)
EU	0.851*	1.298***	1.868***	1.841***
	(1.70)	(2.91)	(2.84)	(2.68)
COAST	0.0000341***	0.0000302***	0.0000276***	0.0000238**
	(4.73)	(3.61)	(2.72)	(2.43)
AVGTEMP	0.209**	-	0.0458	-
	(2.22)		(0.56)	

AVGPREC	-0.0107 (-0.74)	-	-0.0206* (-1.92)	-
AVGVAP	-0.0486 (-0.34)	-	0.336*** (5.05)	-
AVGCLOUD	-0.373*** (-3.04)	-	-0.0158 (-0.20)	-
$AVGTEMP^2$	-0.00640 (-1.50)	-	-0.00532** (-2.05)	-
$AVGPREC^2$	0.0000208 (0.49)	-	0.0000482 (1.24)	-
$AVGVAP^2$	0.00397*** (3.31)	-	-0.00150* (-1.67)	-
$AVGCLOUD^2$	0.00333*** (3.18)	-	-0.000459 (-0.63)	-
TMIN	-	0.130* (1.94)	-	0.0607 (1.24)
TMAX	-	-0.0300 (-0.28)	-	-0.209*** (-3.04)
PMIN	-	-0.00420 (-0.59)	-	-0.0124** (-2.48)
PMAX	-	-0.00214 (-0.34)	-	-0.00245 (-1.33)
VMIN	-	-0.0486 (-0.47)	-	-0.00285 (-0.04)
VMAX	-	-0.0778 (-0.64)	-	0.192*** (2.64)
CMIN	-	0.00495 (0.23)	-	-0.0532*** (-2.76)
CMAX	-	-0.0277 (-1.21)	-	-0.0228 (-1.16)
CONSTANT	9.096* (1.94)	4.984 (0.98)	7.576* (1.75)	6.576 (1.48)
Alpha	-	-	1.787*** (10.46)	1.778*** (10.45)
Log Pseudolikelihood	-153585.4	-168325.55	-	-
Log Likelihood	-	-	-1067.0366	-1066.6186
Pseudo R^2	0.9404	0.9347	0.1224	0.1228
Mean Square Error	1.81e+07	1.76e+07	2.41e+13	5.71e+10
N	165	165	165	165

t statistics in parentheses * $p<0.10$, ** $p<0.05$, *** $p<0.01$

2.6 Discussion

We now turn to the task of estimating the impact of various climate change scenarios on UK IRM. Four different IPCC emission scenarios are used to generate four possible future climates for the year 2080. A description of the four emission scenarios is provided in Table 2.7.

Table 2.7 IPCC Climate change scenarios

Climate Change Scenario	IPCC Description
A1Fi	Fossil fuel intensive future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and rapid introduction of new and more efficient technologies.
A2	A heterogeneous world with continuously increasing global population and regionally orientated economic growth that is more fragmented and slower than in other storylines.
B1	A convergent world with the same global population as A1 but with rapid changes in economic structures towards a service and information economy, with reductions in material intensity, and the introduction of clean and resource-efficient technologies.
B2	A world in which the emphasis is on local solutions to economic, social, and environmental sustainability, with continuously increasing population (lower than A2) and intermediate economic development.

Source: The IPCC (2007)

In order to estimate the changed pattern of UK IRM it is necessary to make assumptions about the value of the remaining variables even if they are not the focus of attention. We choose hold these variables constant. In other words we assume that all current socioeconomic, demographic and political conditions of each destination country remain exactly the same apart from the climate. Our strategy avoids having to make assumptions about the value of variables which are consistent with the four scenarios of the IPCC and focuses attention on the role of the climate.

Using the results of Model 2 we compare predicted UK IRM under the current climate with predicted UK IRM under each of four alternative climates. Since we do not know how climate change in the UK will alter the propensity to retire abroad we present our results in terms of changes in the share of UK international retirees residing in each particular country. [42]

Appendix A.1 contains a set of country rankings where 1 is the country with the greatest predicted share of UK international retired migrants and 165 is the country with the smallest predicted share of UK international retired migrants. The second column gives the predicted share of UK international retired migrants under the current climate for each country in rank order. The remaining columns give predicted shares, in rank order, for each of the four alternative climate change scenarios described in Table 2.7. Note that the ranking based on model predictions is somewhat different from the actual ranking due to the fact that Model 2 does not provide a perfect fit to the UK IRM data.

Analysing these results it appears that climate change causes little actual change in the ranking of countries. The most obvious change is that under the A1Fi, A2 and B2 scenarios Canada overtakes Australia as the most popular destination. However, the rankings of the remaining countries in the top ten do not change: they are USA, Ireland, Italy, New Zealand, Spain, France, South Africa and Cyprus.

The volume of information provided in Appendix A.1 however makes it hard to identify the effect of climate change on UK IRM for particular countries. Appendix A.2 provides the same list of countries but in alphabetical order.

[42] The total volume of UK pensioners choosing to emigrate is itself dependent on whether climate change improves or reduces the quality of climate in the UK relative to climate abroad.

The second column gives the predicted rank of each country, under the current climate, by share of UK IRM. For example, Albania is ranked 125 out of 165 countries for predicted share of pensioners based on current climate. The third column gives the predicted rank of a country for the A1Fi scenario and the fourth column the corresponding change in rank compared to current climate. It can be seen that Albania moves up 9 places to 116. The remaining columns give the rankings of the three other climate change scenarios.

Whilst in many cases the changes in rank are small, the direction of change in rank is consistent for all four climate change scenarios. Continuing with the example of Albania, the A1Fi scenario improves Albania's rank by 9 places. The A2, B1 and B2 scenarios improve Albania's rank by 8, 4 and 5 places respectively. Overall, the country that gains most in terms of UK IRM is Egypt, which moves up between 24 and 27 places depending on the climate scenario. Anecdotally, Egypt's position bordering the Mediterranean means projected climate change will improve the amenity value of the climate. All other North African countries bordering the Mediterranean (Morocco, Algeria, Tunisia and Libya) also experience an unequivocal improvement in rank. The country that performs worst is Ecuador which moves down between 14 and 15 places depending on the climate scenario. This is due to its obvious location on the equator where year round temperatures are high and vapour pressure relatively low and its tropical nature meaning precipitation is high.

Despite these movements up and down it is important to remember that the UK IRM is dominated by the top ten countries, that the ranking of the top ten countries does not change (apart from Canada and Australia) and that the number of UK pensioners choosing to retire outside the top ten countries is very small and remains so under all of the climate change scenarios.

Appendix A.3 contains one final analysis. This involves listing those countries that have seen an increase or decrease in the percentage share of UK IRM for all four climate change scenarios. The majority of countries that have seen an unequivocal increase in UK IRM are predominantly Northern and Eastern European countries. Interestingly, several North African countries such as Egypt, Algeria and Morocco also have an increased share of UK IRM. The results are not without some anomalies however as several West African countries such as Burkina Faso and Senegal and Southern African countries such as Lesotho and Swaziland also experience an increase in UK IRM. Once again however actual migration flows in these countries are very small indeed.

Countries experiencing a fall in the share of UK IRM include Central Africa and East Africa, the Caribbean, Central and Latin America and South-East Asia.

On the whole these findings appear plausible. The pattern appears to be one of UK IRM increasing somewhat in North America, and Northern and Eastern Europe. But overall UK IRM remains focussed on a handful of countries that are either English speaking or in the Mediterranean.

2.7 Conclusions

Because IRM is partly the result of differences in countries' climates IRM is potentially impacted by climate change. Given that current patterns of IRM in Europe are resulting in a geographical imbalance in the distribution of old people with consequences for almost every aspect of spatial and social planning it is important to predict how IRM might respond to climate change. Any empirical analysis will however, necessarily be imperfect because of the difficulty of capturing IRM in all its diverse forms.

This chapter presents a statistical model intended to reveal the quantitative significance of the main 'pull' factors that underlie IRM from the UK where IRM is measured by the payment abroad of the UK state pension.

Depending on which of four statistical models is chosen UK retirees are drawn to destinations with warm winters, cool summers, less precipitation and cloud coverage. The analysis also reveals the likely importance of return migration, historical linkages to the former colonies and the English language. UK retirees are attracted to more mountainous countries and countries with long coastlines.

We use our results to investigate the possibility that some retirement destinations, although unpopular at present, might become more attractive in the future. Other destinations, currently popular due to their agreeable climate, might turn out to be much less desirable in the future. In the four climate scenarios that we investigate there is an increase in the share of people predicted to retire to Northern European and Eastern European countries and a reduction in the number of individuals choosing to retire to Asia and central Africa. But the identity of the ten most popular countries for UK IRM does not change. Partially this is because the climate of these countries does not become unfavourable in the climate change scenarios investigated but also climate is not as important as other variables. It is also clear that certain policy changes, such as automatically increasing pensions in all countries, would have a far more profound effect on the pattern of IRM.

Whilst results presented in this chapter refer only to UK retirees we anticipate that the same basic set of findings are likely to hold true for many Northern European countries. Future researchers might find it fruitful to analyse IRM from other countries and thereby try to deduce how retirees' propensity to migrate in the first place changes with the climate.

Appendix A.1 Countries ranked by share of total UK pensioners

Rank	Country	Current	Country	A1Fi	Country	A2	Country	B1	Country	B2
1	Australia	23.71287	Canada	28.46114	Canada	26.08881	Australia	22.2879	Canada	22.40973
2	Canada	15.15205	Australia	20.81817	Australia	21.32816	Canada	20.09473	Australia	22.39423
3	USA	12.91234	USA	12.404	USA	12.48662	USA	12.45251	USA	12.73355
4	Ireland	10.22794	Ireland	7.37564	Ireland	7.784876	Ireland	8.079909	Ireland	7.94923
5	Italy	4.603756	Italy	4.224895	Italy	4.353574	Italy	4.269424	Italy	4.292223
6	New Zealand	4.372111	New Zealand	3.418362	New Zealand	3.611962	New Zealand	3.915725	New Zealand	3.933296
7	Spain	3.748378	Spain	3.025741	Spain	3.15215	Spain	3.268211	Spain	3.283695
8	France	3.618306	France	2.961166	France	3.087368	France	3.132032	France	3.180153
9	South Africa	1.895393	South Africa	1.8106	South Africa	1.851325	South Africa	1.814083	South Africa	1.821969
10	Cyprus	1.608143	Cyprus	1.086113	Cyprus	1.181009	Cyprus	1.281822	Cyprus	1.23794
11	Portugal	1.454411	Germany	1.072978	Germany	1.135612	Portugal	1.186462	Portugal	1.176461
12	Germany	1.380722	Portugal	1.050903	Portugal	1.115988	Germany	1.11119	Germany	1.109636
13	Jamaica	1.339768	Greece	1.018726	Greece	1.035991	Greece	1.0199	Greece	1.016564
14	Malta	1.210518	Malta	0.91826	Malta	0.977799	Malta	1.015575	Malta	1.012432
15	Greece	1.191215	Jamaica	0.838381	Jamaica	0.925909	Jamaica	0.973934	Jamaica	0.940476
16	Namibia	0.857169	Norway	0.703718	Namibia	0.73529	Namibia	0.684083	Namibia	0.681058
17	Austria	0.702289	Namibia	0.703595	Norway	0.678109	Austria	0.612901	Norway	0.647806
18	Kenya	0.641598	Austria	0.635879	Austria	0.647606	Norway	0.610374	Austria	0.622354
19	Barbados	0.602889	Kenya	0.458839	Kenya	0.487796	Kenya	0.516278	Kenya	0.513105
20	Norway	0.550785	Switzerland	0.399696	Switzerland	0.411065	Barbados	0.430596	Barbados	0.413647
21	Belgium	0.467614	Belgium	0.375702	Barbados	0.396927	Switzerland	0.406871	Switzerland	0.412751
22	India	0.453913	India	0.364121	Belgium	0.391351	Belgium	0.382778	Belgium	0.384237
23	Switzerland	0.444304	Barbados	0.357123	India	0.377061	India	0.366232	India	0.365014
24	Luxembourg	0.410903	Luxembourg	0.327986	Luxembourg	0.3382	Luxembourg	0.340158	Luxembourg	0.344277
25	Chile	0.395294	Chile	0.292312	Chile	0.312533	Chile	0.319831	Chile	0.312467

26	Israel	0.345701	Slovenia	0.280684	Israel	0.293992	Israel	0.284963	China	0.287288
27	Seychelles	0.340662	Israel	0.278796	Slovenia	0.285534	China	0.283508	Slovenia	0.284321
28	Slovenia	0.330188	China	0.273087	China	0.279849	Slovenia	0.281769	Israel	0.283078
29	Argentina	0.329289	Sweden	0.25844	Argentina	0.271579	Argentina	0.276786	Argentina	0.272068
30	China	0.307696	Argentina	0.256363	Seychelles	0.253443	Sweden	0.215856	Sweden	0.229359
31	Turkey	0.224647	Seychelles	0.242235	Sweden	0.246536	Seychelles	0.204749	Turkey	0.192624
32	Nigeria	0.212821	Turkey	0.192181	Turkey	0.201087	Turkey	0.190652	Seychelles	0.190484
33	Sweden	0.198557	Finland	0.160786	Nigeria	0.162666	Nigeria	0.176737	Nigeria	0.176389
34	Denmark	0.170937	Denmark	0.153965	Denmark	0.156979	Denmark	0.143929	Denmark	0.145554
35	Cameroon	0.140258	Nigeria	0.148217	Finland	0.144936	Iceland	0.134117	Iceland	0.141381
36	Poland	0.127923	Iceland	0.131434	Iceland	0.139148	Finland	0.108849	Finland	0.117131
37	Mauritius	0.126232	Poland	0.113255	Poland	0.115642	Poland	0.107696	Poland	0.107207
38	Iceland	0.109993	Hungary	0.082523	Mauritius	0.085085	Mauritius	0.092041	Mauritius	0.087442
39	Trin. and Tob.	0.102905	Croatia	0.081176	Hungary	0.083384	Cameroon	0.089425	Cameroon	0.084714
40	Fiji	0.095524	Gambia	0.07727	Cameroon	0.083226	Gambia	0.082083	Gambia	0.082239
41	Finland	0.088595	Mauritius	0.076101	Croatia	0.082811	Croatia	0.078521	Croatia	0.081195
42	Gambia	0.088141	Cameroon	0.074517	Gambia	0.079605	Trin. and Tob.	0.075114	Hungary	0.075591
43	Croatia	0.087759	Algeria	0.072876	Algeria	0.073816	Hungary	0.074077	Trin. and Tob.	0.072612
44	St Vincent	0.086134	Swaziland	0.069177	Swaziland	0.073669	Swaziland	0.072858	Swaziland	0.072119
45	Bahamas	0.085884	Czech Rep.	0.068896	Czech Rep.	0.071103	Czech Rep.	0.068785	Algeria	0.069466
46	Hungary	0.085192	Trin. and Tob.	0.064338	Trin. and Tob.	0.070564	Algeria	0.067172	Czech Rep.	0.069037
47	Czech Rep.	0.082414	Netherlands	0.062794	Netherlands	0.064198	Bahamas	0.06684	Bahamas	0.065041
48	Swaziland	0.082167	Estonia	0.061866	Bahamas	0.060044	Fiji	0.066445	Fiji	0.063788
49	Grenada	0.077453	Latvia	0.061803	Latvia	0.059404	St Vincent	0.062641	Netherlands	0.062756
50	Netherlands	0.077024	Bahamas	0.054491	Fiji	0.059149	Netherlands	0.062412	St Vincent	0.060443
51	Peru	0.075623	Bosnia-Herz.	0.053663	Estonia	0.058222	Peru	0.061274	Peru	0.059778
52	Tanzania	0.073034	Morocco	0.052055	Zimbabwe	0.054732	Grenada	0.056649	Grenada	0.054637
53	Ecuador	0.06964	Zimbabwe	0.051974	Peru	0.054597	Antigua	0.055239	Antigua	0.054303
54	Dominica	0.068533	Fiji	0.050737	St Vincent	0.054368	Morocco	0.052827	Morocco	0.053775
55	Antigua	0.068292	Peru	0.050027	Morocco	0.054176	Tanzania	0.05158	Bosnia-Herz.	0.052659

56	Zimbabwe	0.066744	Dominica	0.048513	Bosnia-Herz.	0.054084	Bosnia-Herz.	0.051088	Latvia	0.050375
57	Algeria	0.065396	St Vincent	0.048088	Antigua	0.051919	Dominica	0.050149	Tanzania	0.049727
58	Pakistan	0.061326	Antigua	0.047795	Tanzania	0.050469	Zimbabwe	0.050074	Dominica	0.049258
59	Bosnia-Herz.	0.059004	Tanzania	0.046324	Grenada	0.049829	Latvia	0.048874	Zimbabwe	0.048669
60	Morocco	0.056175	Grenada	0.044052	Dominica	0.049723	Pakistan	0.046694	Estonia	0.046791
61	Latvia	0.052459	Mexico	0.04193	Pakistan	0.045088	Bolivia	0.045192	Bolivia	0.045832
62	Philippines	0.052268	Pakistan	0.040799	Mexico	0.043725	Estonia	0.045023	Pakistan	0.044505
63	Uganda	0.051004	Lithuania	0.040121	Uruguay	0.040729	Uruguay	0.042537	Uruguay	0.042601
64	Mexico	0.05097	Uruguay	0.039345	Bolivia	0.040644	Mexico	0.042485	Mexico	0.042108
65	Bolivia	0.050703	Jordan	0.038202	Jordan	0.039781	Uganda	0.036817	Jordan	0.036112
66	Zambia	0.049192	Bolivia	0.037712	Lithuania	0.039351	Jordan	0.036186	Uganda	0.034824
67	Uruguay	0.049163	Zambia	0.034069	Zambia	0.035887	Ecuador	0.035554	Zambia	0.034365
68	Estonia	0.044099	Ecuador	0.031523	Ecuador	0.034123	Zambia	0.035341	Ecuador	0.034115
69	Venezuela	0.042757	Venezuela	0.031027	Venezuela	0.032924	Philippines	0.035056	Philippines	0.033601
70	Indonesia	0.039823	Philippines	0.028778	Philippines	0.032168	Venezuela	0.033392	Lithuania	0.033561
71	Jordan	0.039812	Malawi	0.025409	Uganda	0.030381	Lithuania	0.032828	Venezuela	0.032708
72	Malawi	0.038046	Egypt	0.025408	Malawi	0.027688	Indonesia	0.029275	Indonesia	0.028543
73	Lithuania	0.037918	Uganda	0.025046	Egypt	0.026261	Malawi	0.02508	Egypt	0.023996
74	Tonga	0.036071	Indonesia	0.023492	Indonesia	0.025999	Tonga	0.024198	Malawi	0.023912
75	W. Samoa	0.031095	Iran	0.022482	Tonga	0.022688	Egypt	0.02414	Tonga	0.02289
76	Colombia	0.026953	Saudi Arabia	0.020512	Iran	0.022656	Iran	0.021539	Iran	0.021914
77	Saudi Arabia	0.02673	Tonga	0.019714	Saudi Arabia	0.021984	Saudi Arabia	0.021382	Saudi Arabia	0.020611
78	Solomon Isl	0.026583	Paraguay	0.017153	Yemen	0.018881	W. Samoa	0.021054	W. Samoa	0.020009
79	Yemen	0.026159	Yemen	0.016541	W. Samoa	0.018433	Colombia	0.020318	Colombia	0.019872
80	Iran	0.023568	W. Samoa	0.01622	Paraguay	0.018308	Yemen	0.020235	Solomon Isl	0.019685
81	Sierra Leone	0.021638	Colombia	0.016167	Colombia	0.018118	Solomon Isl	0.020188	Paraguay	0.019247
82	Paraguay	0.021564	Solomon Isl	0.015091	Solomon Isl	0.016824	Paraguay	0.019427	Yemen	0.018824
83	Djibouti	0.020691	San Marino	0.014663	San Marino	0.014801	Sierra Leone	0.01533	San Marino	0.014758
84	Pap. New G.	0.019682	Libya	0.014145	Libya	0.014032	Pap. New G.	0.014604	Sierra Leone	0.014499
85	Malaysia	0.018943	Japan	0.012841	Japan	0.013538	San Marino	0.014559	Japan	0.014287

86	Brazil	0.017774	Brazil	0.012724	Brazil	0.013516	Japan	0.014117	Pap. New G.	0.014065
87	Cape Verde	0.017366	Cape Verde	0.012028	Djibouti	0.013166	Brazil	0.013999	Brazil	0.013728
88	Japan	0.017141	Tunisia	0.011933	Cape Verde	0.012881	Cape Verde	0.013994	Cape Verde	0.013699
89	Madagascar	0.016757	Djibouti	0.011588	Sierra Leone	0.012653	Djibouti	0.0135	Libya	0.013016
90	San Marino	0.015529	Malaysia	0.011417	Malaysia	0.012609	Malaysia	0.013263	Malaysia	0.012847
91	Ethiopia	0.014243	Ethiopia	0.011183	Pap. New G.	0.012501	Libya	0.012769	Djibouti	0.012437
92	DRC	0.013486	Sierra Leone	0.01097	Tunisia	0.012082	Ethiopia	0.01216	Ethiopia	0.012268
93	Sri Lanka	0.012963	Pap. New G.	0.010966	Ethiopia	0.01169	Madagascar	0.011727	Tunisia	0.01154
94	Libya	0.01283	Madagascar	0.010535	Madagascar	0.011686	Tunisia	0.011447	Madagascar	0.010942
95	Tunisia	0.012355	Sudan	0.009603	Sudan	0.010159	Belize	0.010078	Belize	0.010045
96	Sudan	0.012221	Belize	0.009375	Belize	0.009825	DRC	0.010026	DRC	0.009806
97	Belize	0.012203	Niger	0.008523	Niger	0.009075	Niger	0.009422	Niger	0.009323
98	Eritrea	0.012012	DRC	0.008173	DRC	0.009031	Sudan	0.009272	Sudan	0.009034
99	Egypt	0.011254	Syria	0.008123	Eritrea	0.008673	Eritrea	0.008433	Mali	0.008342
100	Mozambique	0.011097	Chad	0.007972	Syria	0.008313	Mali	0.008395	Eritrea	0.008054
101	Ghana	0.011034	Eritrea	0.007719	Mozambique	0.008245	Sri Lanka	0.0083	Chad	0.008002
102	El Salvador	0.010817	Mozambique	0.00767	Chad	0.00806	St Kitts	0.008016	Syria	0.007906
103	Niger	0.010791	Mali	0.007297	Mali	0.007869	Chad	0.007878	St Kitts	0.007826
104	St Kitts	0.010706	Honduras	0.00711	Sri Lanka	0.00766	Syria	0.007858	Sri Lanka	0.007801
105	Mali	0.010685	Sri Lanka	0.00679	Honduras	0.007462	Ghana	0.007607	Honduras	0.007322
106	Panama	0.009416	St Kitts	0.006669	St Kitts	0.007334	Mozambique	0.007572	Ghana	0.007314
107	Honduras	0.00907	Ghana	0.006559	Ghana	0.007288	Honduras	0.007462	Mozambique	0.007149
108	Syria	0.008668	Senegal	0.006143	Panama	0.00658	Panama	0.006643	Senegal	0.006877
109	Chad	0.008268	Georgia	0.005914	Senegal	0.006411	Senegal	0.006616	Panama	0.006335
110	Dom. Rep.	0.007767	Panama	0.005864	Georgia	0.006241	Dom. Rep.	0.006218	Dom. Rep.	0.006129
111	St Lucia	0.007268	Bulgaria	0.005857	Bulgaria	0.005945	Georgia	0.00586	Georgia	0.005965
112	Georgia	0.006964	Kuwait	0.005787	Kuwait	0.005629	Bulgaria	0.005347	Bulgaria	0.005463
113	Senegal	0.006452	Macedonia	0.005011	Dom. Rep.	0.005376	St Lucia	0.005136	Kuwait	0.005058
114	Nicaragua	0.006429	Dom. Rep.	0.004794	Nicaragua	0.00502	Nicaragua	0.005088	St Lucia	0.00494
115	Vanuatu	0.006377	Nicaragua	0.004646	Macedonia	0.005015	Kuwait	0.004882	Nicaragua	0.004916

116	Benin	0.006291	Albania	0.004584	El Salvador	0.004792	El Salvador	0.004775	Guinea	0.004742
117	Gabon	0.006241	El Salvador	0.004399	Albania	0.004596	Gabon	0.004749	Macedonia	0.004643
118	Bulgaria	0.00594	Guinea	0.004369	Guinea	0.004595	Guinea	0.004667	Gabon	0.004586
119	Guinea	0.005511	Kyrgyzstan	0.00415	St Lucia	0.004316	Macedonia	0.004523	El Salvador	0.004547
120	Macedonia	0.005248	Azerbaijan	0.004141	Gabon	0.004303	Benin	0.004425	Albania	0.004428
121	Oman	0.005185	Gabon	0.003967	Benin	0.00427	Albania	0.004348	Benin	0.004237
122	Brunei	0.00517	St Lucia	0.00395	Azerbaijan	0.004266	Vanuatu	0.00422	Vanuatu	0.004015
123	Cuba	0.004941	Kazakhstan	0.003932	Kyrgyzstan	0.004092	Oman	0.00379	Kazakhstan	0.003861
124	Arab Emirates	0.00483	Benin	0.003879	Vanuatu	0.00393	Azerbaijan	0.003784	Azerbaijan	0.003839
125	Albania	0.004794	Lebanon	0.003624	Kazakhstan	0.003881	Lebanon	0.003783	Lebanon	0.003777
126	Kuwait	0.004746	Vanuatu	0.003498	Lebanon	0.003805	Kazakhstan	0.003704	Kyrgyzstan	0.003683
127	Lebanon	0.004475	Oman	0.003466	Oman	0.003793	Cuba	0.003691	Burkina Faso	0.003612
128	Azerbaijan	0.004314	Slovakia	0.003297	Burkina Faso	0.003475	Brunei	0.003601	Oman	0.003598
129	Togo	0.004043	Burkina Faso	0.003222	Cuba	0.003451	Kyrgyzstan	0.003559	Cuba	0.003548
130	Guatemala	0.004023	Cuba	0.003182	Brunei	0.003399	Burkina Faso	0.003515	Brunei	0.003436
131	Congo	0.003959	Ukraine	0.003114	Slovakia	0.00331	Botswana	0.003332	Botswana	0.003293
132	Burkina Faso	0.003938	Guatemala	0.003094	Guatemala	0.00327	Guatemala	0.00332	Guatemala	0.003247
133	Botswana	0.003727	Brunei	0.003053	Botswana	0.003191	Arab Emirates	0.003245	Slovakia	0.003138
134	Surinam	0.003722	Lesotho	0.003034	Ukraine	0.003164	Slovakia	0.003061	Arab Emirates	0.003039
135	Kazakhstan	0.003642	Botswana	0.003024	Lesotho	0.003104	Lesotho	0.002922	Lesotho	0.002934
136	Kyrgyzstan	0.003623	Arab Emirates	0.002635	Arab Emirates	0.003012	Congo	0.002894	Surinam	0.002821
137	Slovakia	0.00357	Romania	0.002527	Congo	0.002687	Surinam	0.002854	Congo	0.002814
138	Lesotho	0.003209	Surinam	0.002492	Surinam	0.002638	Togo	0.002672	Ukraine	0.002723
139	Qatar	0.003174	Congo	0.002464	Romania	0.002519	Ukraine	0.002647	Togo	0.002563
140	Ukraine	0.002928	Russia	0.002423	Qatar	0.002485	Qatar	0.002532	Qatar	0.002485
141	Costa Rica	0.002717	Qatar	0.002311	Togo	0.002431	Romania	0.00221	Romania	0.002285
142	Romania	0.002547	Togo	0.002187	Russia	0.0023	Costa Rica	0.001922	Russia	0.001961
143	Cen. Afr. Rep.	0.002532	Costa Rica	0.001856	Costa Rica	0.002053	Russia	0.001869	Costa Rica	0.001799
144	Haiti	0.002152	Cen. Afr. Rep.	0.001556	Cen. Afr. Rep.	0.001727	Cen. Afr. Rep.	0.001855	Cen. Afr. Rep.	0.00179
145	Thailand	0.001797	Tajikistan	0.001524	Haiti	0.001517	Haiti	0.001635	Haiti	0.00159

146	Russia	0.001743	Turkmenistan	0.00142	Tajikistan	0.001486	Turkmenistan	0.001393	Turkmenistan	0.001419
147	Myanmar	0.001624	Armenia	0.001403	Turkmenistan	0.001454	Thailand	0.001286	Tajikistan	0.001323
148	Turkmenistan	0.001542	Haiti	0.001395	Armenia	0.001452	Tajikistan	0.001277	Armenia	0.001262
149	Nepal	0.001426	Myanmar	0.00112	Myanmar	0.001205	Myanmar	0.001268	Thailand	0.001262
150	Armenia	0.001378	Moldavia	0.001055	Thailand	0.001134	Armenia	0.001225	Myanmar	0.001239
151	Tajikistan	0.001298	Nepal	0.001023	Nepal	0.001087	Nepal	0.001134	Nepal	0.001133
152	Vietnam	0.001252	Thailand	0.001016	Moldavia	0.001077	Vietnam	0.00099	Vietnam	0.000971
153	Moldavia	0.001046	Uzbekistan	0.000929	Uzbekistan	0.000938	Moldavia	0.00092	Moldavia	0.000949
154	Maldives	0.000963	Vietnam	0.000847	Vietnam	0.000917	Uzbekistan	0.000878	Uzbekistan	0.000891
155	Cote D'Ivoire	0.000956	Bahrain	0.000596	Cote D'Ivoire	0.000617	Maldives	0.00068	Cote D'Ivoire	0.000642
156	Uzbekistan	0.000954	Cote D'Ivoire	0.000551	Bahrain	0.000612	Cote D'Ivoire	0.000667	Maldives	0.000637
157	Bahrain	0.00062	Maldives	0.000508	Maldives	0.000582	Bahrain	0.00059	Bahrain	0.000597
158	Rwanda	0.0006	Rwanda	0.000369	Rwanda	0.000413	Rwanda	0.00044	Rwanda	0.000428
159	Cambodia	0.000437	Belarus	0.000355	Belarus	0.000351	Cambodia	0.000327	Cambodia	0.000319
160	Belarus	0.000355	Cambodia	0.000259	Cambodia	0.000292	Belarus	0.000297	Belarus	0.000302
161	Laos	0.000198	Laos	0.000146	Laos	0.000154	Laos	0.000159	Laos	0.000157
162	South Korea	0.000113	Mongolia	8.08E-05	South Korea	8.61E-05	South Korea	8.89E-05	Mongolia	8.84E-05
163	Mongolia	9.95E-05	South Korea	8.05E-05	Mongolia	8.46E-05	Mongolia	8.81E-05	South Korea	8.8E-05
164	Bangladesh	2.73E-05	Bangladesh	1.94E-05	Bangladesh	2.08E-05	Bangladesh	2.28E-05	Bangladesh	2.29E-05
165	Singapore	7.35E-09	Singapore	4.61E-09	Singapore	5.01E-09	Singapore	5.25E-09	Singapore	5.11E-09

Appendix A.2 Country ranks and changes in rank by climate change scenario

Country	Current Rank	A1Fi Rank	Δ	A2 Rank	Δ	B1 Rank	Δ	B2 Rank	Δ
Albania	125	116	9	117	8	121	4	120	5
Algeria	57	43	14	43	14	46	11	45	12
Antigua	55	58	-3	57	-2	53	2	53	2
Arab Emirates	124	136	-12	136	-12	133	-9	134	-10
Argentina	29	30	-1	29	0	29	0	29	0
Armenia	150	147	3	148	2	150	0	148	2
Australia	1	2	-1	2	-1	1	0	2	-1
Austria	17	18	-1	18	-1	17	0	18	-1
Azerbaijan	128	120	8	122	6	124	4	124	4
Bahamas	45	50	-5	48	-3	47	-2	47	-2
Bahrain	157	155	2	156	1	157	0	157	0
Bangladesh	164	164	0	164	0	164	0	164	0
Barbados	19	23	-4	21	-2	20	-1	20	-1
Belarus	160	159	1	159	1	160	0	160	0
Belgium	21	21	0	22	-1	22	-1	22	-1
Belize	97	96	1	96	1	95	2	95	2
Benin	116	124	-8	121	-5	120	-4	121	-5
Bolivia	65	66	-1	64	1	61	4	61	4
Bosnia-Herzeg.	59	51	8	56	3	56	3	55	4
Botswana	133	135	-2	133	0	131	2	131	2
Brazil	86	86	0	86	0	87	-1	87	-1
Brunei	122	133	-11	130	-8	128	-6	130	-8
Bulgaria	118	111	7	111	7	112	6	112	6
Burkina Faso	132	129	3	128	4	130	2	127	5
Cambodia	159	160	-1	160	-1	159	0	159	0
Cameroon	35	42	-7	40	-5	39	-4	39	-4
Canada	2	1	1	1	1	2	0	1	1
Cape Verde Isl	87	87	0	88	-1	88	-1	88	-1
Cen. Afr. Rep.	143	144	-1	144	-1	144	-1	144	-1
Chad	109	100	9	102	7	103	6	101	8
Chile	25	25	0	25	0	25	0	25	0
China	30	28	2	28	2	27	3	26	4
Colombia	76	81	-5	81	-5	79	-3	79	-3
Congo	131	139	-8	137	-6	136	-5	137	-6
Costa Rica	141	143	-2	143	-2	142	-1	143	-2
Cote D'Ivoire	155	156	-1	155	0	156	-1	155	0
Croatia	43	39	4	41	2	41	2	41	2
Cuba	123	130	-7	129	-6	127	-4	129	-6
Cyprus	10	10	0	10	0	10	0	10	0
Czech Rep.	47	45	2	45	2	45	2	46	1
DRC	92	98	-6	98	-6	96	-4	96	-4
Denmark	34	34	0	34	0	34	0	34	0

Djibouti	83	89	-6	87	-4	89	-6	91	-8
Dominica	54	56	-2	60	-6	57	-3	58	-4
Dom. Rep.	110	114	-4	113	-3	110	0	110	0
Ecuador	53	68	-15	68	-15	67	-14	68	-15
Egypt	99	72	27	73	26	75	24	73	26
El Salvador	102	117	-15	116	-14	116	-14	119	-17
Eritrea	98	101	-3	99	-1	99	-1	100	-2
Estonia	68	48	20	51	17	62	6	60	8
Ethiopia	91	91	0	93	-2	92	-1	92	-1
Fiji	40	54	-14	50	-10	48	-8	48	-8
Finland	41	33	8	35	6	36	5	36	5
France	8	8	0	8	0	8	0	8	0
Gabon	117	121	-4	120	-3	117	0	118	-1
Gambia	42	40	2	42	0	40	2	40	2
Georgia	112	109	3	110	2	111	1	111	1
Germany	12	11	1	11	1	12	0	12	0
Ghana	101	107	-6	107	-6	105	-4	106	-5
Greece	15	13	2	13	2	13	2	13	2
Grenada	49	60	-11	59	-10	52	-3	52	-3
Guatemala	130	132	-2	132	-2	132	-2	132	-2
Guinea	119	118	1	118	1	118	1	116	3
Haiti	144	148	-4	145	-1	145	-1	145	-1
Honduras	107	104	3	105	2	107	0	105	2
Hungary	46	38	8	39	7	43	3	42	4
Iceland	38	36	2	36	2	35	3	35	3
India	22	22	0	23	-1	23	-1	23	-1
Indonesia	70	74	-4	74	-4	72	-2	72	-2
Iran	80	75	5	76	4	76	4	76	4
Ireland	4	4	0	4	0	4	0	4	0
Israel	26	27	-1	26	0	26	0	28	-2
Italy	5	5	0	5	0	5	0	5	0
Jamaica	13	15	-2	15	-2	15	-2	15	-2
Japan	88	85	3	85	3	86	2	85	3
Jordan	71	65	6	65	6	66	5	65	6
Kazakhstan	135	123	12	125	10	126	9	123	12
Kenya	18	19	-1	19	-1	19	-1	19	-1
Kuwait	126	112	14	112	14	115	11	113	13
Kyrgyzstan	136	119	17	123	13	129	7	126	10
Laos	161	161	0	161	0	161	0	161	0
Latvia	61	49	12	49	12	59	2	56	5
Lebanon	127	125	2	126	1	125	2	125	2
Lesotho	138	134	4	135	3	135	3	135	3
Libya	94	84	10	84	10	91	3	89	5
Lithuania	73	63	10	66	7	71	2	70	3
Luxembourg	24	24	0	24	0	24	0	24	0
Macedonia	120	113	7	115	5	119	1	117	3

Madagascar	89	94	-5	94	-5	93	-4	94	-5
Malawi	72	71	1	72	0	73	-1	74	-2
Malaysia	85	90	-5	90	-5	90	-5	90	-5
Maldives	154	157	-3	157	-3	155	-1	156	-2
Mali	105	103	2	103	2	100	5	99	6
Malta	14	14	0	14	0	14	0	14	0
Mauritius	37	41	-4	38	-1	38	-1	38	-1
Mexico	64	61	3	62	2	64	0	64	0
Moldavia	153	150	3	152	1	153	0	153	0
Mongolia	163	162	1	163	0	163	0	162	1
Morocco	60	52	8	55	5	54	6	54	6
Mozambique	100	102	-2	101	-1	106	-6	107	-7
Myanmar	147	149	-2	149	-2	149	-2	150	-3
Namibia	16	17	-1	16	0	16	0	16	0
Nepal	149	151	-2	151	-2	151	-2	151	-2
Netherlands	50	47	3	47	3	50	0	49	1
New Zealand	6	6	0	6	0	6	0	6	0
Nicaragua	114	115	-1	114	0	114	0	115	-1
Niger	103	97	6	97	6	97	6	97	6
Nigeria	32	35	-3	33	-1	33	-1	33	-1
Norway	20	16	4	17	3	18	2	17	3
Oman	121	127	-6	127	-6	123	-2	128	-7
Pakistan	58	62	-4	61	-3	60	-2	62	-4
Panama	106	110	-4	108	-2	108	-2	109	-3
Pap.New Guin.	84	93	-9	91	-7	84	0	86	-2
Paraguay	82	78	4	80	2	82	0	81	1
Peru	51	55	-4	53	-2	51	0	51	0
Philippines	62	70	-8	70	-8	69	-7	69	-7
Poland	36	37	-1	37	-1	37	-1	37	-1
Portugal	11	12	-1	12	-1	11	0	11	0
Qatar	139	141	-2	140	-1	140	-1	140	-1
Romania	142	137	5	139	3	141	1	141	1
Russia	146	140	6	142	4	143	3	142	4
Rwanda	158	158	0	158	0	158	0	158	0
San Marino	90	83	7	83	7	85	5	83	7
Saudi Arabia	77	76	1	77	0	77	0	77	0
Senegal	113	108	5	109	4	109	4	108	5
Seychelles	27	31	-4	30	-3	31	-4	32	-5
Sierra Leone	81	92	-11	89	-8	83	-2	84	-3
Singapore	165	165	0	165	0	165	0	165	0
Slovakia	137	128	9	131	6	134	3	133	4
Slovenia	28	26	2	27	1	28	0	27	1
Solomon Islands	78	82	-4	82	-4	81	-3	80	-2
South Africa	9	9	0	9	0	9	0	9	0
South Korea	162	163	-1	162	0	162	0	163	-1

Spain	7	7	0	7	0	7	0	7	0
Sri Lanka	93	105	-12	104	-11	101	-8	104	-11
St Kitts	104	106	-2	106	-2	102	2	103	1
St Lucia	111	122	-11	119	-8	113	-2	114	-3
St Vincent	44	57	-13	54	-10	49	-5	50	-6
Sudan	96	95	1	95	1	98	-2	98	-2
Surinam	134	138	-4	138	-4	137	-3	136	-2
Swaziland	48	44	4	44	4	44	4	44	4
Sweden	33	29	4	31	2	30	3	30	3
Switzerland	23	20	3	20	3	21	2	21	2
Syria	108	99	9	100	8	104	4	102	6
Tajikistan	151	145	6	146	5	148	3	147	4
Tanzania	52	59	-7	58	-6	55	-3	57	-5
Thailand	145	152	-7	150	-5	147	-2	149	-4
Togo	129	142	-13	141	-12	138	-9	139	-10
Tonga	74	77	-3	75	-1	74	0	75	-1
Trin. and Tob.	39	46	-7	46	-7	42	-3	43	-4
Tunisia	95	88	7	92	3	94	1	93	2
Turkey	31	32	-1	32	-1	32	-1	31	0
Turkmenistan	148	146	2	147	1	146	2	146	2
Uganda	63	73	-10	71	-8	65	-2	66	-3
Ukraine	140	131	9	134	6	139	1	138	2
Uruguay	67	64	3	63	4	63	4	63	4
USA	3	3	0	3	0	3	0	3	0
Uzbekistan	156	153	3	153	3	154	2	154	2
Vanuatu	115	126	-11	124	-9	122	-7	122	-7
Venezuela	69	69	0	69	0	70	-1	71	-2
Vietnam	152	154	-2	154	-2	152	0	152	0
W. Samoa	75	80	-5	79	-4	78	-3	78	-3
Yemen	79	79	0	78	1	80	-1	82	-3
Zambia	66	67	-1	67	-1	68	-2	67	-1
Zimbabwe	56	53	3	52	4	58	-2	59	-3

Appendix A.3 Countries with complete increasing or decreasing shares of pensioners for all climate change scenarios

Increase in Share of UK Pensioners	Decrease in Share of UK Pensioners
Albania	Arab Emirates
Algeria	Bahamas
Armenia	Barbados
Azerbaijan	Brunei
Belize	Cameroon
Bosnia-Herzegovina	Central African Republic
Bulgaria	Colombia
Burkina Faso	Congo
Chad	Costa Rica
China	Cuba
Croatia	DRC
Czech Republic	Djibouti
Egypt	Dominica
Estonia	Ecuador
Finland	El Salvador
Georgia	Eritrea
Greece	Fiji
Guinea	Ghana
Hungary	Grenada
Iceland	Guatemala
Iran	Haiti
Japan	Indonesia
Jordan	Jamaica
Kazakhstan	Kenya
Kuwait	Madagascar
Kyrgyzstan	Malaysia
Latvia	Maldives
Lebanon	Mauritius
Lesotho	Mozambique
Libya	Myanmar
Lithuania	Nepal
Macedonia	Nigeria
Mali	Oman
Morocco	Pakistan
Niger	Panama
Norway	Philippines
Romania	Poland
Russia	Qatar
San Marino	Seychelles
Senegal	Sierra Leone
Slovakia	Solomon Islands
Swaziland	Sri Lanka

Sweden Switzerland Syria Tajikistan Tunisia Turkmenistan Ukraine Uruguay Uzbekistan	St Lucia St Vincent Surinam Tanzania Thailand Togo Trinidad and Tobago Uganda

CHAPTER 3

DO GEOGRAPHICAL VARIATIONS IN CLIMATE INFLUENCE LIFE SATISFACTION?

3.1 Introduction

Scientific research summarised by the IPCC (2007) indicates that climate change is expected to lead to predominantly negative consequences for biodiversity. In addition, agricultural production in many African countries will be severely compromised. The increasing frequency of heat waves may lead to greater numbers of heat-related deaths. And sea levels are expected to rise threatening low-lying coastal areas.

Given knowledge of these impacts economists have boldly attempted to conduct cost-benefit analysis of global GHG emissions targets.[43]

But relatively little attention has been paid to certain other impacts of climate change and in particular, the direct value to households of changes in the climate. This is a surprising

[43] Integrated Assessments Models attempt to determine the optimal path for greenhouse gas emissions reductions. The seminal contribution is Nordhaus (1993) who develops a Dynamic Integrated Climate-Economy (DICE) model employing a Ramsey economic growth framework. The model includes an impacts function linking damage costs with increases in temperature.

omission. Climate patently affects households' most basic wants, namely the need for warmth, food, clothing and shelter.

To understand better the role of climate in meeting households' needs (basic or otherwise) previous studies have made reference to the Household Production Function (HPF) theory of Becker (1965). According to Becker households do not consume directly marketed commodities but instead combine these with nonmarket goods using 'household production technologies' in order to generate 'service flows' and it is the latter which are of direct value to the household.

The presumed importance of an amenable climate in the production of service flows explains why households inhabiting different climates enjoy different levels of well-being. Particular climates imply differences in the cost of service flows. The HPF framework also explains why otherwise identical households exhibit different expenditure patterns. Households adjust their expenditure patterns in order to substitute for nonmarket inputs like an amenable climate. Consumption of service flows (such as the need for heating and cooling) are dependent on the existence of an amenable climate and costs of production are higher in its absence.

Although logical to enquire after the cost of supplanting a hostile climate in terms of additional expenditures, estimating the direct value to households of a change in climate is difficult. This is partly because of the ubiquity of climate (arguably it is an input in the production of many diverse service flows) and partly due to the fact that service flows are not directly observable. With some justification many researchers therefore regard the HPF as a purely heuristic device explaining the importance of nonmarket goods, but not providing a basis for estimating the value of changes in their availability. Generally, alternative techniques have proven more practicable.

This chapter contributes to the literature by analysing the climate preferences of European households. Although these preferences arise because of the role of an amenable climate in producing service flows of value to households, the technique involves neither estimating household production functions nor estimating the demand for unobservable service flows. Instead our approach involves examining how households inhabiting different climates, and differing also in terms of possessing incomes capable of supplanting a hostile climate, fare in terms of self-reported life satisfaction.

Although previous studies have used self-reported life satisfaction or other measures of subjective well-being to analyse households' preferences for climate, earlier applications all suffer from important limitations. Some seek to explain cross-country variations in life satisfaction by reference to climate variables but struggle with the inconvenient fact that even within countries there is often significant variation in climate. Such papers often average the climates of major population centres to obtain a 'representative' climate with unpredictable empirical consequences. Country specific studies are by contrast, often unable to identify the role played by climate variables because of insufficient variation in the dataset.

This chapter overcomes the limitations of existing research by using data on life satisfaction from the 1999 / 2000 third wave of the European Values Survey (EVS). This data contains observations from 24 European countries at the NUTS level.[44] The size of NUTS regions is such that it is plausible to assume they possess homogeneous climates thereby obviating the

[44] NUTS stands for Nomenclature des Units Territoriales Statistiques and provide a regional disaggregation of European countries. Further discussion of the NUTS data is provided in Section 3 of this Chapter.

need for any kind of averaging procedure. Furthermore the EVS dataset includes observations from the Northern-most tip of Europe in the Arctic Ocean to its Southern-most point in the Mediterranean Sea guaranteeing significant variation in the climate.

To anticipate our main findings it appears that lower average percentage sunshine and higher average relative humidity lowers life satisfaction, as does a significant variation in monthly mean temperatures and rain days. Households strongly prefer the climate of the Mediterranean to that of Northern Europe.

The remainder of the chapter is structured as follows. Section 2 reviews other researchers' attempts to estimate the value of climate to households using a range of revealed preference valuation techniques. This section also explains in detail an approach to environmental valuation based on self-reported life satisfaction. Section 3 presents an empirical model and describes the data underlying the analysis. Section 4 econometrically analyses the impact of climate on self-reported life satisfaction whilst simultaneously controlling for a range of known contributory factors. Section 5 estimates marginal willingness to pay for a range of climate variables. Further analyses estimate households' compensating surplus for non-marginal changes in climate. We also create an index describing the quality of regions' climates. Section 6 concludes.

3.2 Literature review

In assessing the direct impact of climate change on households the key question is what is the maximum that a household would be willing to pay (WTP) for moving to a superior climate or alternatively, what is the minimum that the household would be willing to accept (WTA) as compensation for a move to an inferior climate. Together these are the compensating surplus (CS) measures of welfare change. [45]

A variety of suitable techniques exist to estimate the value of climate to households. These techniques use present day spatial variation in climate as an analogue for future climate change. And in so doing they address what many perceive to be the key issue of adaptation by drawing comparisons between households that have already perfectly adapted to the climate of their current location.[46]

It is clear that the direct impact of climate change on households does not constitute a complete account of the socioeconomic impacts of climate change. The reason is that climate change might also affect households' incomes and commodity prices. It may also affect the quality of environmental goods, such as biodiversity, which may hold non-use values. In addition, the household may have preferences over the climates of other locations.[47]

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[45] For a textbook approach to compensating surplus see, for example, Freeman (1999)

[46] The fact that a household has 'perfectly adapted' to the climate does not mean that households inhabiting different climates enjoy the same level of wellbeing. It means that households have had time to implement fully all cost effective adaptations and that any remaining differences represent the CS for one climate rather than another.

[47] Higher taxes may be required to pay for the construction of sea defences whilst climate change may cause changes in the price of food on world markets. Households may have preferences for the survival of ecosystems reliant on particular types of climate in other parts of the world. These are all examples of indirect impacts not captured by the valuation techniques discussed below.

3.2.1 The hedonic technique

Although a household cannot directly purchase nonmarket goods hedonic theory suggests that their value will be capitalised into land prices.

In the most basic model households are assumed to maximise utility (*u*) through consumption of a marketed good (*x*) and a nonmarket good (*z*). The household's maximisation problem is constrained by household income (*y*) which is divided between the marketed commodity and the purchase of one unit of housing whose price (*h*) is a function of the level of the nonmarket good. The household maximises the following expression

$$u(x,z) + \lambda(y - x - h(z)) \quad \textbf{(3.1)}$$

Where λ denotes marginal utility of money. Taking the derivative with respect to z gives the following first order condition

$$u_z / \lambda = h_z(z) \quad \textbf{(3.2)}$$

This equation states that marginal willingness to pay (henceforth MWTP) for the nonmarket good is equal to the derivative of the hedonic price of housing with respect to the level of the nonmarket good.

This technique has been used to value a wide range of environmental goods and has been refined to deal with situations in which (a) the value of nonmarket goods is simultaneously capitalised into both house prices and wage rates, (b) the number of hours and the amount of residential land purchased are choice variables, and (c) residential land and wages are subject to taxation.

With respect to valuing climate variables however, the hedonic technique faces some significant limitations. Rehdanz and Maddison (2009) argue that as climate varies only over relatively large geographical distances the assumption of a unified market for housing and labour becomes untenable. Inadvertently combining data from separate markets essentially fits a single regression to two or more spline functions resulting in biased estimates of the implicit prices (Straszheim, 1974).

Empirical applications of the hedonic technique to the task of valuing climate variables are largely concentrated in the US. The itinerant nature of the US population implies that interstate hedonic analyses can more plausibly assume the absence of barriers to mobility. And the diverse climate of the US permits researchers to estimate with greater precision the slope of the hedonic price function with respect to climate variables.

We structure our review of the empirical literature to distinguish between those studies which have included climate variables incidental to the main purpose of the study and those studies where climate has been the main focus. We also distinguish between those studies undertaken in the US and those undertaken elsewhere. A further important distinction is that whereas some studies look for compensating differentials for climate in either the housing market or the labour market, theory indicates that they can simultaneously appear in both.

Roback (1982) presents an empirical analysis incorporating the 98 largest metropolitan areas in the US. Heating degree days, total snowfall and cloudy days are a disamenity whilst clear days are an amenity. Amenity values are capitalised mainly into wage rates rather than land prices. Hoehn et al (1987) present a hedonic analysis with separate regressions for house prices and wage rates. Sunshine and precipitation are found to be amenities whilst humidity and wind speed are disamenities. Surprisingly heating and cooling degree days are not statistically significant. Climate amenities are capitalised into both house prices and wage rates[48].

Clark and Cosgrove (1990) use the hedonic technique to assess the impact of public safety programmes on house prices. They control for average rainfall, cooling and heating degree days. They find a weak negative relationship between rainfall and cooling degree days and house prices.[49]

Albouy and Leibovici (2009) gauge the importance of climate to the quality of life for cities in Canada. The number of days below 20°F and snowfall are both found to reduce the quality of life.

Turning now to analyses where climate has been the main focus of interest Hoch and Drake (1974) test whether differences in US wage differentials are due to the climate. High summertime temperatures reduce wages to a statistically significant extent. Englin (1996) analyses the effect of rainfall on house prices in Washington State. Average annual rainfall is a disamenity but greater seasonal variation in rainfall has a positive effect on house prices.

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[48] Blomquist et al (1988) report the same empirical findings as Hoehn et al (1987) and a third paper by Gyourko and Tracy (1991) utilises the same dataset as the aforementioned at the city level and includes the same six climate variables. Gyourko and Tracy (1991) include further variables to account for intercity differences in fiscal conditions such as local tax rates. They obtain positive implicit prices for sunshine and wind speed and negative prices for precipitation and relative humidity.

[49] Clark and Cosgrove (1991) find that decreasing temperature range and more sunshine significantly increase the distance a migrant will move.

Nordhaus (1996) presents a hedonic real wage regression where real wages are net of the cost of housing.

Mendelsohn (2001) analyses the significance of climate on land rents and sector-specific wage rates for 3000 counties across the US. He includes January, April, July and October averages for temperature and precipitation in his hedonic regression. Warmer temperatures reduce both wages and rents. Precipitation also reduces wages but has no significant impact on rents. Mendelsohn then estimates the implications of six different climate change scenarios. He discovers that 1-2^{o}C temperature increases will benefit the US and that negative effects appear only when considering a more pronounced 3.5^{o}C rise in temperature.

Mueller and Sheriff (2007) present results for the impact of higher annual mean temperature in Brazil. They find that downward pressures on house prices is more than outweighed by lower wages indicating higher temperatures are an amenity to Brazilian households.

Albouy (2008) conducts a comprehensive study of US households using census data. He demonstrates households prefer cities with more sunshine and fewer heating and cooling degree days. Using his results he constructs a quality of life index ranking 290 cities. The majority of variation in the quality of life index is determined by environmental factors including climate.

Kahn (2008) attempts to assess the impact of climate on US house prices using county level data. The only explanatory variables are January and July average temperatures and rainfall. Households display a preference for warmer Januarys and drier and cooler Julys. Kahn then investigates the welfare impacts arising from particular climate change scenarios using the estimated coefficients of the climate variables.

Moving to Europe in their hedonic analysis of the climate of Italy Maddison and Bigano (2003) represent the climate by means of January and July averages.[50] Analysing provincial level differences in household disposable incomes they find that Italian households prefer less precipitation in January combined with clearer skies and cooler July temperatures.

Srinivasan and Stewart (2004) conduct a hedonic analysis of households in England and Wales. Their analysis includes county level averages for wage rates and for the price of four different types of property. They find that sunshine has a statistically significant effect on house prices whereas temperature, precipitation and frost days are all insignificant.

In France Cavailhes et al (2008) use the hedonic technique to estimate implicit prices for a range of climate variables. The amenity value of the climate is capitalised mainly into differences in house prices. Very high July temperatures (over 30^{o}C) reduce the price of both owner-occupied and rental properties. The number of July rain days has a positive effect on the price of both owner-occupied and rental property whereas January rain days have the opposite effect.

Finally Rehdanz and Maddison (2009) estimate separate house price and wage rate regressions for Germany. They find that German households prefer warmer Januarys and cooler Julys. Precipitation in January is a disamenity but precipitation in July is statistically insignificant.

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[50] Maddison and Bigano (2003) also include clear days as well as dummies for regions bordering a coastline and/or in an alpine region.

3.2.2 The household production function approach

In the household production function theory of Becker (1965) households do not consume directly marketed commodities but instead combine *x* and *z* in order to produce 'service flows'. Although not directly observable themselves it is these service flows that are of direct value to the household. Given that these service flows are not directly observable Becker's insight serves mainly to explain the presence on nonmarket goods in the utility function

$$u = u(x, z) \tag{3.3}$$

The household maximises its utility function subject to the budget constraint given a vector of prices (*p*) for *x*.

$$y \geq \sum px \tag{3.4}$$

Solving for the optimal levels of x and inserting these into the direct utility function gives the indirect utility function

$$v = v(p, y, z) \tag{3.5}$$

Applying Roy's theorem results in a system of Marshallian demand equations. Roy's theorem states that the derivative of the indirect utility function with respect to price (v_p) divided by the derivative of the indirect utility function with respect to income (v_y) yields the negative of the demand function.

$$\frac{v_p(p,y,z)}{v_y(p,y,z)} = -x(p,y,z) \qquad \textbf{(3.6)}$$

Unfortunately, in order to ensure that all the parameters of the indirect utility function can be obtained from the Marshallian demand curves requires further restrictions household preferences (Bradford and Hildebrand, 1977). This is the assumption of demand dependency. Demand dependency means that a price vector exists such that the marginal utility of the nonmarket good is zero. For example, we it would require us to assume households do not care about extremely cold conditions outside provided the price of heating is low enough. The compensating surplus (CS) is implicitly defined by the difference in income required to maintain welfare constant as the level of the nonmarket good changes from z^0 to z^1.

$$v(p,y,z^0) = v(p,y-CS,z^1) \qquad \textbf{(3.7)}$$

Compared to the hedonic technique this approach has the advantage that one need not assume that the household is in hedonic equilibrium. The weakness of the approach is obviously the need to assume demand dependency.

Invoking procedures identical to those used to incorporate demographic variables into systems of demand equations, Maddison (2003) uses the household production function approach to estimate the value of climate to households using cross-country data on household expenditures taken from 88 countries. Maddison investigates an equilibrium CO_2 doubling scenario and its impacts on the cost of living. Whilst most of Northern Europe benefits Asia and many poor countries suffer harm.

3.2.3 Hypothetical equivalence scales

Hypothetical equivalence scales are calculated by asking survey respondents to report the minimum income necessary for their household to reach a verbally specified level of utility *. This is defined as

$$y^{(*)} = c^{(*)}(p, z) \quad \textbf{(3.8)}$$

Where $y^{(*)}$ is the minimum cost of achieving utility level * as a function $c^{(*)}$ of p and level z of the nonmarket good. The hypothetical equivalence scale for a household with z^1 relative to a household with only z^0 is given by

$$\frac{c^{(*)}(p, z^1)}{c^{(*)}(p, z^0)} \quad \textbf{(3.9)}$$

Choosing a different utility level may result in a different hypothetical equivalence scale. The CS for utility level * is simply

$$CS = c^{(*)}(p, z^1) - c^{(*)}(p, z^0) \quad \textbf{(3.10)}$$

Van Praag (1988) uses hypothetical equivalence scales to analyse the impact of climate on household costs. He asks survey respondents to provide the minimum income required for their household to reach a variety of welfare levels from “very bad” to “very good”. Investigating 90 different climatic regions in 8 Western European countries his results suggest that higher annual mean temperatures, greater annual precipitation and higher average relative humidity reduce household costs.

Frijters and Van Praag (1998) adopt the same approach for Russian households located in 35 different regions. They find that higher mean January temperatures and lower mean July temperatures significantly reduce household costs. Frijters and Van Praag then analyse the implications of their results by comparing 6 cities in different regions of Russia using Moscow as a reference. Households residing in the city of Gurjew, neighbouring the Caspian Sea, require only half the income of Muscovite households to enjoy the same level of welfare. But residents of Dudinka, located near the Arctic Circle, need five times the income required in Moscow.

Whilst the hypothetical equivalence scale technique does not rely on the untestable assumptions of demand dependency or the existence of hedonic equilibrium it is obviously necessary to assume that households have an identical understanding of the verbally defined level of welfare.

3.2.4 Random utility models

The random utility model (RUM) assumes that households choose from a set of substitute sites characterised by different price levels, available incomes and bundles of nonmarket goods. Households locate in sites offering the highest level of utility and in so doing reveal their preferences. More specifically the household will move to site i provided that

$$v(p_i, y_i, z_i) \geq v(p_j, y_j, z_j) \forall i \neq j \quad \textbf{(3.11)}$$

Cragg and Kahn (1997) use the RUM framework to assess migrants' willingness to trade off consumption against a bundle of climate amenities. Consumption for households is determined by both wage rates and house prices. Climate variables include summer and winter temperatures, yearly rainfall, hours of sunshine, humidity and proximity to the coast. Willingness to pay for climate is found by calculating the amount of compensation that would be required if an individual's climate were changed to the national average.

There are two key limitations of this 'migration based' approach. Firstly, it is assumed there are no costs to mobility which may hinder migration. Secondly, the migrant population in the US only represents a very small sample of total population so the results may not be representative.

3.2.5 Subjective well-being and climate

Economists also use survey data on subjective well-being (SWB) in order to value nonmarket goods. Easterlin (1974) conducted the first empirical economic analysis of SWB, estimating at both the national and international level how changes in income impact on happiness. A large literature now links SWB to economic indicators. For the effects of income on SWB see Easterlin (1974 and 1995) and Ng (1997). Clark and Oswald (1994), Oswald (1997) and Di Tella et al (2003) find unemployment negatively impacts SWB whilst Di Tella et al (2001) discover SWB is higher during periods of low unemployment and low inflation. See Frey and Stutzer (2002) for an overview of the literature.

Survey respondents are confronted with questions such as

> *'How satisfied are you with your life on a 1 to 10 scale where 1 means completely dissatisfied and 10 means completely satisfied?'*

Alternatively the question might refer not to satisfaction but to happiness.[51] Interpreting the response as a measure of the utility of the respondent requires that respondents are able accurately to map their true utility onto a discrete integer scale

$$LS_i = g_i(u_i) \tag{3.12}$$

Where LS_i is the reported life satisfaction of individual i and g_i describes the monotonic function used by individual i to convert utility u_i to reported satisfaction. In order to compare survey responses from more than one individual it is necessary to make the further assumption that all survey respondents to use a common function g to convert utility to LS

$$g_i = g \forall i \tag{3.13}$$

It is important to note that the assumption made in Equation 3.13 cannot be tested and validated. The function that respondents use to convert u_i into LS_i cannot be observed. It also requires interpersonal comparisons of utility. All respondents who give a score of 7 out of 10 on a LS scale are taken to have the same level of utility. We note these are potential limitations of the SWB approach. At this point it is useful to remind the reader that the choice of the SWB approach is not because it doesn't have assumptions of its own, but instead that its assumptions are different to the environmental valuation techniques reviewed above.

[51] It should be noted here that a life satisfaction question is asked to an individual representative of a household. Both individual characteristics (e.g. age, gender) and household characteristics (household income) are often found to be important determinant of individuals' life satisfaction. We focus on preferences at the household level given the specification of income and the fact climate is likely to affect decisions at the household level.

Furthermore, it is plausible that the reported SWB level of respondents could be influenced by momentary moods. Local weather conditions, for example, may artificially raise or lower reported SWB. Both Schwarz and Clore (1983) and more recently Tsutsui (2011) find evidence that the weather conditions at the time of questioning can significantly affect SWB responses. The day reconstruction method can be implemented which ask respondents to break the previous into episodes. They then report the context of their feelings during this period (Kahneman et al, 2004). An alternative method to day reconstruction is that of experience sampling where respondents are asked about their wellbeing over a given time period e.g. a number of days. It also asks about aspects of their mental state. See, for example, Mackerron (2011) for a review.[52]

The functional relationship g between LS and utility is of central importance since it raises the question how one should econometrically analyse respondents' reported satisfaction. Given that the function g is unknown it may be prudent to assume only an ordinal association between reported satisfaction and utility. In other words if an individual reports a value of 8 we should merely assume that they are more satisfied than if they had reported a value of 7. By contrast if g were a linear function then it would be possible to estimate respondents' utility functions with OLS using LS as the dependent variable.

Whilst the majority of economics literature on SWB appears to assume that LS is an ordinal function of utility Ferrer-i-Carbonell and Frijters (2004) find that assuming LS to be a linear function of utility does not make any significant difference to their empirical findings. It is

[52] Mackerron (2012) undertakes a comprehensive experienced sampling method to SWB by utilising global positioning satellite data via a mobile data 'application' called Mappiness. Those who download the application are asked a SWB a number of times a day and encouraged to provide information on their surroundings, who they are with and what they are doing. Their location can then be correlated with local environmental quality and control for immediate weather conditions.

for this reason that we will begin our empirical analysis using OLS. Using OLS also enables us to tackle the problem of errors in variables using standard econometric techniques.

$$LS = g(u(p, y, z)) \tag{3.14}$$

MWTP for the nonmarket good is given by

$$MWTP_z = \frac{\partial g(u)/\partial u \times \partial u/\partial z}{\partial g(u)/\partial u \times \partial u/\partial y} = \frac{\partial u/\partial z}{\partial u/\partial y} \tag{3.15}$$

The SWB approach is a potentially powerful tool to estimate the value of climate to households but only a few papers have used it for this purpose.

Van der Vliert et al (2004) examine how temperature and temperature squared affect nationally averaged measures of SWB whilst simultaneously controlling for GDP per capita. In total 55 countries were included in their analysis and for large countries temperature data was averaged over major population centres. For poor countries the paper points to an inverted U-shaped relationship between SWB and temperature. But for rich countries the data point instead to a U-shaped relationship. Such hard to explain results may be due to the absence of any controls apart from GDP per capita and in particular, no control for seasonal variation in temperature.

Rehdanz and Maddison (2005) conduct a panel data study across 67 countries between 1972 and 2000.[53] They test a number of different specifications for climate. It transpires that a specification including temperature in the coolest month and temperature in the hottest month provides the best fit. Societies prefer a climate characterised by cooler temperatures in the hottest month and warmer temperatures in the coolest month. The dataset was restricted to a four-point happiness scale, aggregated by country, (not at all happy, not very happy, quite happy and very happy).

The critical shortcoming of both Van der Vliert et al (2004) and Rehdanz and Maddison (2005) paper is that they use nationally aggregated data. More specifically some countries are large and possess diverse climates e.g. the US and Russia.

In their study of Ireland Brereton et al (2008) and Ferreira and Moro (2010) use a Geographical Information Systems (GIS) approach providing highly detailed information on households' immediate surroundings including their climate. Brereton et al (2008) find annual average wind speed negatively impacts LS. Higher January minimum night-time temperatures and higher July maximum daytime temperatures both increase LS. Ferreira and Moro (2010) also find a positive coefficient for January minimum night-time temperatures which is significant at the one per cent level of confidence.

The limitation of these two studies is that the small size of Ireland severely curtails the ability to identify preferences for climate variables.

[53] A growing number of studies make cross-country comparisons of SWB. Di Tella et al (2001) analyse LS across 12 European countries. They find that unemployment and inflation reduce life satisfaction even after controlling for country specific effects. Di Tella et al remark that whilst questions relating to overall happiness as opposed to LS were available the meaning of happiness may translate somewhat imprecisely.

3.2.6 Environmental quality and subjective well-being

A small body of research uses a SWB approach to value local non-marketed environmental amenities other than the climate. SWB offers an ex-post measure of self-reported utility given a set of characteristics, including environmental quality.

The majority of research into environmental quality using this approach has focused on the impact of air and noise pollution on SWB. Standard air pollutants include a nitrogen dioxide (NO_2), sulphur dioxide (SO_2) and small particulate matter. However, there has been little conformity in the methodological approach to estimating, with researchers employing both cross-sectional data at the national level and at the individual level within a single country. Whilst some of the individual level data explain regional differences in pollution, others focus within a single city. Another disparity is the use of both objective and subjective measures of pollution. Furthermore, some researchers have estimated the value of pollution for repeated cross-sections at the individual level and panel data at both the national and individual level.

Welsch (2002, 2007) conducts a cross-sectional analysis regressing air and water pollutants against self-reported happiness, averaged at the national level, for 54 countries. Welsch (2002) tests both a linear and log-linear functional form in his analysis and regresses all pollutants together and individually, whilst always controlling for GNP per capita and a variable giving the numbers of scientists or engineers per 1000 population. Notwithstanding the limitation of assuming the pollutants are non-transboundary in nature and the simplicity of the model, he finds some evidence that NO_2 negatively impacts on happiness at the national level. All other pollutants are estimated to be statistically insignificant in all models and specifications.

Welsch (2007) uses the same dataset to estimate a log-linear income equation as well as a linear happiness equation. The role of the income equation is to capture infra-marginal changes in NO_2 without losing the possible direct impact the pollutant could have on income that is available for expenditure. This allows pollution to be captured as a production input in determining national income itself as well as pure well-being effects. Only the latter would be captured in a more conventional CS approach. Whilst the linear specification of the happiness equation gives a single MWTP for an additional kiloton of NO_2, the marginal product of different income per centiles can be estimated using the log-linear income specification.

Furthermore, Welsch (2007) extends the analysis to estimate optimal abatement of NO_2 emissions by equating the marginal rate of substitution in the happiness equation (a proxy for the external costs of pollution) to the marginal product of NO_2 in the production function. He finds median optimal abatement level for all 54 countries to be an 88% reduction.

In a very different approach to Welsch (2002; 2007), Mackerron and Mourato (2009) correlate individual LS responses of a small sample of London residents with NO_2 and small particular matter. GIS is used to provide high resolution data at the location of each respondent's reported address. The benefit of such an approach is that it is able to capture very local environment effects and doesn't assume homogeneity within countries. Naturally, it is limited by the intensity of information required at the individual level making it difficult to ensure a representative sample. NO_2 is found to be statistically significant and negatively impact on life satisfaction. Small particulate matter plays no role in life satisfaction. Ferreira et al (2006) also adopts a GIS approach using Irish data and finds weak evidence that small particulate matter has a negative impact on life satisfaction.

Rehdanz and Maddison (2008) analyse the impact of perceived quality of air and noise pollution on LS using German Socio-Economic Panel data. This follows a different approach whereby respondents are asked to state how adversely affected they are by the given pollutant from 1 (not at all) to 5 (very strongly). This raises the question of what is the preferable measure of pollution. Whilst Rehdanz and Maddison (2008) show variation in perceived air and noise quality to correspond with expectations, they acknowledge that it could suffer from some degree of strategic bias. The analysis is cross-sectional as self-reported questions on air and noise pollution are only asked in three time periods. Perceived poor air and noise quality are both found to be statistically significant and negatively impact on LS.

Van Praag and Baarsma (2005) conduct an empirical study on the effect of noise pollution at Schiphol Airport, Amsterdam, on local residents. Information on postcodes of each household allows for a high resolution analysis, where LS is correlated with localised aircraft noise pollution estimates. They argue that if house prices are in equilibrium then they should perfectly capture aircraft pollution and can be estimated using a hedonic price function. Disequilibrium implies the hedonic technique is not capturing the full cost of aircraft noise. The LS approach is then able to capture the additional affects, provided household income is controlled for[54]. A latent noise pollution variable is created which includes an objective measure of aircraft noise as well as specific household characteristics. It is found to have a detrimental effect on LS. This implies that households are not currently being fully compensated for the cost of aircraft noise.

[54] This concept of a direct relationship between the hedonic technique and the LS approach is a potentially important one and is discussed in Section 3.6.2.

Levinson (2009) matches US General Social Survey data with Environmental Protection Agency data on air quality at the nearest monitoring station on the day the respondent was interviewed. The data is repeated cross-sections between 1984 and 1996. Air quality is given by concentrations of small particulate matter. Weather on the day of interview is also controlled for by local weather conditions in the form of temperature and precipitation to avoid for potential omitted variable bias. The ability to control for both is dependent on knowing the exact dates that interviews were conducted. This leads to a fair degree of interpolation to overcome intensive data requirements. It is important to note that momentary weather conditions are not the same as long-term climate values. Particulate matter is found to be a negative and statistically significant determinant of happiness. This remains a consistent finding after allowing for alternative specifications.

Di Tella and MacCulloch (2008) follow a similar approach for European and US data on happiness and include national SO_2 emissions per capita in their regression. Their empirical strategy differs however as they control for both microeconomic and macroeconomic effects. Their primary aim is to analyse the role of GDP per capita in individual well-being and the case for a gross national happiness indicator. SO_2 is statistically significant and negatively impacts on individual happiness. However, there is no consideration for within country variations of SO_2 and the localised consequences of deposits.

Welsch (2006) uses panel data on national level data for 10 European countries for concentrations of NO_2, particulates and lead. He controls for GNP per capita whilst assuming all other unobserved determinants of LS are captured by country and year dummies. Both

NO_2 and lead concentrations negatively impact on LS. This leads to a conclusion that life satisfaction is increasing in most of the ten countries as concentrations are falling over time.

Luechinger (2009) undertake a panel study at the individual level to determine the role of SO_2 emissions on LS in Germany. SO_2 concentrations are mapped to individual responses to LS at the county level based on nearest monitoring station data. He finds it to have detrimental impact on LS. This implies that substantial reductions in SO_2 emissions over time have led to improvements in LS. Luechinger (2010) analyses the impact SO_2 on LS at the individual level in 13 European countries. In order to overcome the transboundary nature of emissions, regional SO_2 concentrations are instrumented with estimated emissions from foreign countries. Once again higher SO_2 concentrations reduce LS.

A number of researchers with high resolution datasets have analysed other determinants of local environmental quality using mainly categorical variables. Examples include proximity to the coast, which Brereton et al (2008) find to be positive and significant in determining LS for households who live within 2km. Moro et al (2008) include a dummy variable for bordering the coast which is weakly significant and positive in determining LS. Brereton et al (2008) finds those who live within 30km of an airport a more satisfied whilst those who live near a major road or a landfill site are less satisfied. Moro et al (2008) also include a continuous variable capturing regional waste facilities and find it to negatively impact on LS. Ferreira et al (2006) find living within two kilometres of a seriously polluted river is detrimental to LS.

SWB has also been investigated as a possible methodology to assess the importance of natural capital. This has predominantly been to determine the role of natural capital in sustainable development objectives. Engelbrecht (2009) analyses cross-sectional national data on SWB for 58 countries. SWB is measured using three indicators: LS, happiness and a combination of both LS and happiness. Natural capital is taken as a monetary estimate of the sum of national stocks of non-renewable energy sources, metals and minerals as well as a wide set of renewable resources. Whilst natural capital appears to improve all measures of SWB it is only statistically significant when certain outliers are removed from the dataset. The difficulty in defining, measuring and monetising natural capital is a clear limitation to a study of this nature.

In summary it appears each approach has its own limitations. National aggregates of air pollution cannot help understand the impact on individual well-being. This is a fundamentally more important question for policymakers given the uneven impact of these pollutants within countries. At the individual, using GIS allows for a very high resolution of localised effects, but the data intensive nature makes it difficult to ensure a representative sample. Individual based studies with very large datasets forgo some resolution and match respondent characteristics with local monitoring station data. However, interpolation inevitably creates averaging error.

Asking individuals to respond to questions on their perceived air and noise quality has the ability to capture very localised environmental quality. It also avoids the need to match survey data to objective environmental data. However, it could invoke strategic bias as individuals may seek to overstate the problem of pollution in the hope it encourages a policy response.

Repeated cross-sectional and panel studies have the ability to track pollution over time and captures. This is important given the short time period between air and noise pollutions' emission and subsequent deposition. Simple cross-sectional datasets are unable to capture whether a pollutant is rising or falling in a particular area.

3.3 Model specification and data sources

The goal of the econometric analysis presented in this chapter is to isolate the effect of climate variables whilst simultaneously controlling for a range of other factors known to impact on LS. The basic model employed for this purpose is

$$LS_i = \alpha + \sum_j \gamma_j H_{ji} + \sum_k \delta_k G_{ki} + \sum_m \phi_m Z_{mi} + \varepsilon_i \qquad \textbf{(3.16)}$$

Where H represents a set of socioeconomic and demographic characteristics for individual *i* (including net household income), G represents a set of geographical variables (including country dummies but excluding climate variables) and Z represents a set of climate variables (separately identified as they are the main focus of interest). The symbol ε represents an idiosyncratic error term and γ_j, δ_k and φ_m are parameters to be econometrically estimated.

Dealing first with the dependent variable, data on LS is taken from the 1999/2000 third wave of the EVS.[55] For our purposes the key question, translated by country-specific research agencies, is

> *'All things considered, how satisfied are you with your life as a whole these days?'*

Respondents were invited to give a response between 1 and 10 where 1 is "entirely dissatisfied" and 10 "completely satisfied".

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[55] Available online at http://www.europeanvaluesstudy.eu/evs/surveys/survey-1999-2000.html

Turning now to the set of socioeconomic and demographic variables we include the logarithm of net household income to account for the declining marginal utility of income. After experimentation we also found it necessary to include the squared value of the logarithm of household income in order to improve the fit of the ensuing regressions.

In the literature it is common to find evidence of a U-shaped relationship between age and the various measures of subjective well-being. To capture any such relationship we include both age and age squared. Gender is included to account for the possibility that females are more satisfied with their lives than males (or vice versa). Dummy variables identify whether the respondent is the head of the household and whether they are an EU citizen. A dummy variable denotes whether the respondent is religious because religion may provide support, purpose and hope. Even though health status is identified by many papers as an important determinant of LS the 1999/2000 EVS does not, unfortunately, include any questions on the respondent's health status.[56]

We include the number of individuals present in the household separately identifying four different age categories (<5, 5-12, 13-17 and >18). The demographic composition of the household is a potentially important determinant of living costs. Eight dummy variables identify the employment status of the respondent. These are full-time, part-time, self-employed, retired, housewife, student, unemployed and other.

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[56] This is indeed an unfortunate omission and is a limitation of using this dataset. Whilst an objective measure of health quality was searched for 1999/2000, the NUTS resolution of the data meant that too many regions (and entire countries) would have been omitted. These losses would undermine the ability to analyse geographical variation in climate and so we prefer to omit it. We acknowledge that self-reported health might be correlated with climate (e.g. through psychological sense of wellbeing effects) which could bias coefficients. For example, there is evidence that increasing exposure to sunlight has a positive impact on human health (Butler and Nicholson, 2000) and reduce mental health disorders such as bi-polar depression (Benedetti et al, 2001).

Separate dummies identify those who are married, living together, single, divorced, separated or widowed. Dummies for educational attainment include not finished primary school, finished primary education, incomplete secondary education, completed secondary education, incomplete higher education and finished university degree. We also include the age the respondent finished their education. All these variables are taken from the EVS.

Next we turn attention to the set of geographical variables (excluding climate). A set of dummy variables categorises observations by settlement size (varying from <2000 to 500,000+) effectively comparing the LS of those inhabiting small towns against large cities. Elevation controls for topographical features of the NUTS region. A dummy identifies NUTS regions bordering the sea. Latitude is included to capture the variation in hours of daylight over the annual cycle. Longitude is included to control for the fact that daylight arrives later in the Western part of any given time zone.[57] Information on latitude and longitude refer to the centroid of each NUTS region.

Data on the population density of each NUTS region is taken from the EUROSTAT website. Lastly a set of country dummies is included accounting for amongst other things differences in prices between countries, differences in political systems, any cultural differences and possible differences in the way in which the question on LS is perceived.

Turning finally to the set of climate variables, we obtain gridded climate data for the period 1961-1990 from New et al (2002). Using GIS software this data is aggregated to individual NUTS regions. The data include monthly averages for temperature, precipitation, frost days,

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[57] For example, Olders (2003) finds that individuals who get up closer to dawn, which is dependent on average sunrise time, are less likely to suffer from depression.

relative humidity, rain days, percentage possible sunshine and wind speed. A correlation matrix for the climate variables is contained in Appendix B.1. The highest correlation is observed for average annual temperature and frost days (the correlation is -0.947).

Before proceeding any further we note several problems with the data. Respondents were not required to reveal exact figures for net household income only to identify the income decile that contained their household's net income. All questions on household income were answered in national currencies. For example, Germans were asked to provide their income in Deutschmarks. These currencies were then converted into Euros.[58] We take the midpoint of the relevant net household income range for each respondent. For example, a net household income range between 20,000€ and 25,000€ is recorded as 22,500€. We address the possible problem of measurement error in Section 3.4.

Climate data for Iceland is not available and that country is dropped. Data on net household income is not at all available for four countries: Finland, Romania, Poland and Hungary. Data on the number of individuals over-18s present in the household was not available for Greece. For Greece we replace the missing values for the number of over-18s with the sample average but drop countries systematically missing data for net household incomes. Other observations are dropped for a miscellany of reasons (typically the failure of respondents to provide answers to specific questions). In total the data consist of slightly in excess of 17,500 observations across 209 NUTS regions in 19 different countries. Table 3.1 provides summary statistics.

[58] Currencies were converted to Euros using average exchange rates across the time period when the surveys were conducted in each individual country. Information was available on survey start and finish dates at the national level.

Information on the location of respondents available from the EVS was used to place them into the relevant NUTS regions. NUTS are divided into 3 categories (1, 2 and 3) where 1 represents the largest geographical areas and 3 the smallest.[59] NUTS regulations dictate that regions should be divided according to population. [60] The mean size across the EU27 countries is 44,335km^2 for NUTS1 15,869km^2 for NUTS2 and 3,300km^2 for NUTS3 (EUROSTAT, 2007). Unfortunately the survey conducted in each country followed different degrees of resolution when reporting regional location. Of the 209 NUTS regions in our dataset, 39 are at the NUTS1 level, 80 are NUTS2 and 90 are NUTS3.

Finally, a common limitation of using cross-sectional data is that it can be difficult to establish the causal link between life satisfaction and its determinants. This is because LS, or SWB more generally, is so broadly defined (Mackerron, 2011). This can make it difficult to identify whether LS can be a cause of an explanatory variable (e.g. more satisfied people are more likely to be married) or the opposite (marriage makes people happier).[61] Another important question is whether any unobserved variables are important in determining LS. This could be self-reported health in the case of this study and lead to omitted variable bias.

[59] To illustrate, London in the UK represents a NUTS1 region. NUTS2 further disaggregates the capital into Inner and Outer London. NUTS3 divides Inner London into two subsets (West, East) and Outer London into three (East and North East, West and North West, South).
[60] These are populations between 3-7million for NUTS 1, 0.8-3million for NUTS 2 and 0.15-0.8 million for NUTS 3
[61] Stutzer and Frey consider this question, albeit using panel data as opposed to cross-sectional.

Table 3.1 Summary statistics

Number of Observations: 17923

Variable	Mean	Std.Dev	Min	Max
Life Satisfaction	6.897841	2.265173	1	10
Log Net Household Income (€)	9.113244	1.161421	6.087942	12.36177
Log Net Household Income^2(€)	84.40004	20.68122	37.06304	152.8135
Citizen	0.962283	0.190516	0	1
Age	46.25677	16.8579	17	98
Age-Squared	2423.861	1656.39	289	9604
Number of Children	1.63293	1.350479	0	11
Are you head of household?	0.575741	0.494244	0	1
Are you religious	0.681694	0.465832	0	1
Number Children 18+	2.218114	0.987029	1	20
Number Children 13-17	0.216816	0.524452	0	5
Number Children 5-12	0.279139	0.630497	0	8
Number Children <5	0.164984	0.48692	0	8
Do you live with your parents?	0.144953	0.352064	0	1
Latitude (^{o})	49.03031	5.882035	28.344	64.4165
Longitude (^{o})	12.77605	9.28733	-15.6668	27.9279
Coastline	0.410534	0.491944	0	1
Population Density (per km^2)	484.1794	1067.501	6	6047.6
Elevation	0.305934	0.281299	-0.003	2.071
Are you male? (1 = Yes)	0.466719	0.498905	0	1
Size of Town	4.684307	2.433765	1	8
Age finished education	18.59281	4.998384	5	74
Age finished education squared	370.6752	233.2955	25	5476
Marital Status				
Married	0.590526	0.491751	0	1
Living Together	0.002846	0.053269	0	1
Divorced	0.073035	0.260201	0	1
Separated	0.016683	0.128082	0	1
Widowed	0.093176	0.290688	0	1
Single	0.2417309	0.4281393	0	1
Employment Status				
Full-time working	0.424594	0.494295	0	1
Part-time working	0.068962	0.253396	0	1
Self-employed	0.043687	0.204403	0	1
Retired	0.247224	0.43141	0	1
Housewife	0.079786	0.270969	0	1
Student	0.046644	0.210881	0	1
Unemployed	0.071193	0.257155	0	1
Other	0.0217596	0.1459	0	1
Education Level				
Education level 1 (lowest)	0.044468	0.206138	0	1
Education level 2	0.192658	0.394397	0	1
Education level 3	0.13067	0.337049	0	1
Education level 4	0.11834	0.323019	0	1

Education level 5	0.121799	0.327062	0	1
Education level 6	0.184456	0.387866	0	1
Education level 7	0.088657	0.284256	0	1
Education level 8 (highest)	0.1052472	0.3068769	0	1
Climate Variables				
Avg. Ann. Temperature (^oC)	9.19942	3.073961	0.169	17.64033
Avg. Ann. Rel. Humidity (%)	77.4479	5.453713	62.03709	86.78125
Avg. Ann. Percentage Sunshine	39.5269	9.489894	24.88392	70.77666
Avg. Ann. Wind Speed (km/hr)	3.722753	0.859835	1.18	5.768167
Total Rain Days	159.0843	33.23068	38.127	231.907
Total Frost Days	104.5497	44.54415	2.008	229.84
Total Precipitation (mm)	763.3058	214.379	313.065	1886.699
Std. Dev. Temperature (^oC)	6.803596	1.147536	2.821783	9.178075
Std. Dev. Rel. Humidity (%)	6.158531	2.009897	0.898016	12.94981
Std. Dev. Percentage Sunshine	11.21042	2.701234	3.357005	18.7455
Std. Dev. Wind Speed (km/hr)	0.410723	0.130445	0.088741	0.831676
Std. Dev. Total Rain Days	2.066037	0.773249	0.949252	4.855168
Std. Dev. Total Frost Days	8.092289	3.131567	0.177184	12.95019
Std. Dev. Total Precip (mm)	17.86652	9.213001	4.571394	72.56667

3.4 Empirical analysis

Regression results from seven different models are displayed in Tables 3.2 and 3.3. These models are characterised by different estimation techniques and different specifications of the climate. We begin by discussing the results from Model 1 in some detail.

The logarithm of net household income is positive whilst the square of the logarithm of net household income is negative. Both are significant at the one per cent level of confidence confirming the importance of net household income to LS. The negative sign on the quadratic term for the logarithm of net household income implies the existence of a point where additional net household income fails to increase further LS (and indeed starts to decrease it).

Being a citizen of the country in which one is resident a positive effect on LS and is statistically significant at the one per cent level of confidence. Consistent with earlier studies the coefficients on age and age squared are respectively negative and positive. Together these point to a U-shaped relationship between LS and age and our findings indicate that LS is at a minimum at the age of 53.

The coefficient for religion is positive and significant at the one per cent level of confidence. Males appear to be less satisfied with their lives than females, though this is only statistically significant at the ten per cent level of confidence. Marriage has a strong positive influence on LS. The number of children does not have a statistically significant effect on LS and, somewhat surprisingly, neither does the number of people in each different age category present in the household.

Being the head of the household has no statistically significant impact on LS. Individuals who live with their parents are statistically speaking no different to those who do not in terms of LS. Married people are more satisfied with their lives than those who are single. Those who are divorced, separated or widowed are less satisfied than those who are single. People who are living together are no different from those who are single in terms of LS.

Consistent with earlier studies unemployment has a large and negative impact on LS compared to the 'other' category. By contrast those who are self-employed or who are retired have higher LS. The negative coefficient on all education levels apart from the highest level possible indicates that those who have obtained a degree enjoy greater LS. The variable describing age the respondent finished education and its squared value are not statistically significant.

Turning to the geographical variables, the coastline dummy is negative but significant only at the ten per cent level of confidence. Population density is negative and significant at the one per cent level of confidence. Amongst other things, this variable may capture households' preferences for air quality, noise nuisance and other disamenities associated with urban living. Paradoxically however, the size-of-settlement variables are all statistically insignificant. Whilst latitude has no statistically significant impact on LS, longitude is negative and significant at the five per cent level of confidence. This may be because households are disadvantaged by living in the Western most part of any given time zone. Elevation has no significant impact on LS.

None of the climate variables (annual averages for temperature, relative humidity, percentage sunshine, wind speed as well as annual totals for rain days, frost days and precipitation) are individually significant even at the ten per cent level of confidence. A joint F-test on the slopes of the climate variables is also insignificant.

Model 2 adds quadratic terms for all of the climate variables. We include these terms in order to determine whether climate preferences depend on the baseline level of climate see e.g. Maddison and Bigano (2003). The inclusion of quadratic terms allows for possible non-linearity of the relationship between the climate variable and life satisfaction.[62] There are no notable changes in the coefficients of the control variables or their significance and we do not discuss these any further. The R-squared increases only marginally. Total rain days and its squared value now become significant at the one per cent level of confidence. The joint F-test for the climate variables and their squares remains insignificant at the ten per cent level of confidence.

Model 3 drops the squared terms and replaces them with the standard deviation of the monthly values for each of the seven climate variables.[63] These additional variables are included to investigate whether individuals have preferences for the variation in climate across the annual cycle (e.g. see Englin, 1996). For example, the standard deviation σ_T of monthly mean temperature T is given by

$$\sigma_T = \sqrt{\frac{\left(T_{JAN} - \overline{T}\right)^2 + \left(T_{FEB} - \overline{T}\right)^2 + \ldots + \left(T_{DEC} - \overline{T}\right)^2}{12}} \qquad \textbf{(3.17)}$$

[62] For example, a positive coefficient for the climate variable and a negative coefficient for its quadratic tell us that there exists a maximum, after which the climate variable will begin to decrease life satisfaction. Obviously this is conditional on these variables being statistically significant to a conventional level of confidence.

[63] This model has a better fit than an alternative regression including January and July averages of climate variables (results not shown). Cushing (1987) discusses the specification of climate in models of migration.

The R-squared value improves markedly in relation to Model 2. The inclusion of standard deviations also has a profound effect on the perceived importance of climate variables which are now jointly significant at the one per cent level of confidence.[64]

Higher relative humidity has a negative effect on LS whilst a greater percentage of possible sunshine improves LS. Both these climate variables are individually significant at the one per cent level of confidence. Large standard deviations in monthly mean temperatures and the number of rain days reduce LS. Both variables are statistically significant at the one per cent level of confidence. No other climate variables are significant.

Given the apparent importance of standard deviations Model 4 reinstates the squared terms in case they are now important. But they remain jointly insignificant even at the ten per cent level of confidence.

To assess the robustness of our results we ran an additional regression for Model 3 excluding the geographically larger NUTS1 regions from the sample (results not shown). Average relative humidity, average sunshine, the standard deviation of temperature, and the standard deviation of rain days remain statistically significant, and their coefficients virtually unchanged. Average wind speed becomes statistically significant but only at the 10 per cent level of confidence. Additionally, we investigated the effect of interacting climate variables contained in Model 3 with income levels. As a group these interacted terms are, however, statistically insignificant, even at the ten per cent level of confidence $F(14, 208) = 1.47$ $Prob > F = 0.1231$. Note that although the impact of certain climate variables might depend on the level of other climate variables we abstain from presenting a regression equation including all

[64] Separate significance tests for annual climate variables only and standard deviations only are also significant at the one percent level.

possible cross-product terms. To do so would have resulted in an additional 91 variables when there are only 209 climatic zones in the entire dataset.

So far it has been assumed that OLS is a suitable estimator for LS. This requires the assumption that the function *g*, used to convert utility to reported satisfaction, is linear. Using the Ordered Logit estimator Model 5 in Table 3.3 assumes instead only an ordinal relationship between utility and reported LS. This generates very small changes to the coefficients the most notable of which is a slight change in the magnitude of the coefficients on the logarithm of net household income and its quadratic. There is little change in the coefficients of the climate variables barring the coefficient on the standard deviation of rain days which increases slightly. The absence of any major differences implies that OLS is a suitable estimator.

Model 6 estimates Model 3 using instrumental variables (IVs) to deal with possible errors in the measurement of net household income.[65] The standard practice in LS literature has been to take the mid-point of the reported range as a point estimate for household income. In the case of the EVS, net household income is reported only in terms of income deciles. However, this will lead to measurement error that could cause household income to be correlated with the residual error term. Furthermore, observing income in only a single time period may suffer measurement error caused from transitory movements away from permanent household income level.[66]

[65] Higher response rates is usually the reason for selecting income ranges over actual income questions. This is a common occurrence in many household surveys and stated preference surveys.
[66] Section 5.4.5 algebraically derives the impact of permanent and transitory income on a regression model. For brevity we do not repeat it here

The EVS requires respondents to provide household income using a single-question approach.[67] IVs deal with measurement error by finding a variable which is correlated with actual income but not with the measurement error. This results in consistent parameter estimates.

Constructing suitable IVs is relatively straightforward in a panel study where lagged values of net household income may suffice (e.g. Oswald and Powdthavee, 2008). Such an approach is not possible in a cross-sectional dataset and our IVs are the logarithm of average net household income of all other survey respondents belonging to the same NUTS 3 region and the logarithm of average net household income of all other survey respondents belonging to the same NUTS 3 region squared.

We evaluate the IVs by means of a Durbin-Wu-Hausman test (Davidson and MacKinnon, 1993). This test involves obtaining residuals from an auxiliary regression of the IVs against the explanatory variables potentially afflicted by measurement error. The residuals from the auxiliary regressions can be obtained using the “predict, res” function in Stata. The residuals are then included as an explanatory variables into the main OLS regression. Given we have two IVs a joint test of statistical significance will determine whether OLS is consistent or not. If they are jointly significant this means OLS is non-consistent and that a two-staged least squares IV approach is necessary. Model 6 finds a joint test of significance of the residuals is statistically insignificant at the ten per cent level of confidence. This leads us to believe any measurement error associated with net household income does not significantly impact the results.

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[67] Micklewright and Schnepf (2010), for example, find that surveys using a single question to frame household income are likely to induce a lower response rate compared to individual income questions and also lead to significant underestimation of actual household income.

Easterlin (1974) commented on the possibility that SWB might depend on individuals' reference income. Whilst some researchers (e.g. Layard et al 2009) find evidence that reference income is important others do not (e.g. Stevenson and Wolfers, 2008). In order to test for the importance of reference income we include in Model 7 the difference between net household income and average net household income for the NUTS3 region. This variable is statistically insignificant at the ten per cent level of confidence.

Table 3.2 OLS regression results

Variable	Model 1	Model 2	Model 3	Model 4
Log Net Household Income (€)	1.855625*** (6.05)	1.846406*** (6.04)	1.831099*** (5.99)	1.824506*** (5.96)
Log Net Household Income Squared (€)	-0.0758998*** (-4.55)	-0.0755806*** (-4.55)	-0.07475*** (-4.50)	-0.0744212*** (-4.47)
Citizen	0.3235857*** (4.39)	0.320691*** (4.35)	0.3209257*** (4.31)	0.3179906*** (4.26)
Age	-0.0727415*** (-8.97)	-0.0727479*** (-8.98)	-0.073456*** (-9.09)	-0.0734476*** (-9.08)
Age-Squared	0.0006883*** (8.39)	0.0006888*** (8.41)	0.0006924*** (8.48)	0.0006938*** (8.49)
Number of Children	0.0179828 (1.05)	0.0178022 (1.04)	0.0188476 (1.10)	0.017929 (1.05)
Are you head of household?	0.0226402 (0.45)	0.0196414 (0.39)	0.0229801 (0.46)	0.0219365 (0.44)
Are you religious	0.1062832*** (2.77)	0.1004003*** (2.61)	0.1093013*** (2.88)	0.1065997*** (2.79)
Number Children 18+	-0.0232059 (-1.01)	-0.0206208 (-0.90)	-0.0215194 (-0.95)	-0.0202596 (-0.89)
Number Children 13-17	-0.014197 (-0.51)	-0.014816 (-0.53)	-0.0139005 (0.50)	-0.0139734 (-0.50)
Number Children 5-12	-0.0385389 (-1.41)	-0.0392505 (-1.45)	-0.0395657 (-1.46)	-0.0400139 (-1.48)
Number Children <5	0.0143537 (0.47)	0.0139301 (0.45)	0.0141514 (0.46)	0.0141176 (0.46)
Do you live with your parents?	-0.1032898 (-1.36)	-0.1094791 (-1.44)	-0.1017784 (-1.35)	-0.1046362 (-1.38)
Latitude (^{o})	0.0458342 (0.87)	0.049926 (1.15)	0.0476773 (1.00)	0.041471 (0.86)
Longitude (^{o})	-0.0301983** (-2.06)	-0.0215153* (-1.84)	-0.0087455 (-0.59)	0.0001144 (0.01)
Coastline	-0.1388125* (-1.84)	-0.1254454 (-1.53)	-0.1570126** (-2.00)	-0.1624362** (-2.02)
Population Density (per km^2)	-0.0000895*** (-3.31)	-0.0000936** (-3.06)	-0.0001088*** (-3.88)	-0.0000996** (-3.28)
Are you male? (1 = Yes)	-0.0732726* (-1.81)	-0.0724939* (-1.78)	-0.0730164* (-1.81)	-0.0729724* (-1.81)
Married	0.3702062*** (6.64)	0.3717723*** (6.69)	0.3760254*** (6.77)	0.3774512*** (6.82)
Living Together	0.0604787 (0.38)	0.0433278 (0.28)	0.0430146 (0.28)	0.0349104 (0.23)
Divorced	-0.1710892** (-2.14)	-0.1660419** (-2.08)	-0.1666583** (-2.10)	-0.1633042** (-2.06)
Separated	-0.5935067*** (-4.14)	-0.5949659*** (-4.15)	-0.5960403*** (-4.18)	-0.5939918*** (-4.15)
Widowed	-0.1871124**	-0.1816164**	-0.1853174**	-0.1800282**

	(-2.28)	(-2.21)	(-2.26)	(-2.19)
Full-time working	0.2546977* (1.79)	0.2607956* (1.84)	0.2568565* (1.80)	0.2576518* (1.81)
Part-time working	0.2246654 (1.47)	0.2343785 (1.53)	0.2290126 (1.49)	0.2317772 (1.51)
Self-employed	0.3657712** (2.33)	0.37145** (2.38)	0.3679186** (2.33)	0.367163** (2.33)
Retired	0.3490392** (2.30)	0.3533194** (2.34)	0.3540532** (2.34)	0.3516963** (2.33)
Housewife	0.2367635 (1.54)	0.2412856 (1.58)	0.2404917 (1.57)	0.2423687 (1.59)
Student	0.2906298* (1.73)	0.3060839* (1.84)	0.2919284* (1.75)	0.2984246* (1.79)
Unemployed	-0.7237268*** (-4.14)	-0.7170088*** (-4.10)	-0.720327*** (-4.11)	-0.7184927*** (-4.10)
Size <2,000	0.0659828 (0.84)	0.0543906 (0.71)	0.0596377 (0.78)	0.0529705 (0.69)
Size 2,000 – 5,000	0.0220486 (0.26)	0.0212471 (0.25)	0.026916 (0.32)	0.0263113 (0.69)
Size 5,000 – 10,000	0.139886 (1.51)	0.1293143 (1.41)	0.1396166 (1.52)	0.1368066 (1.49)
Size 20,000 – 50,000	0.0343953 (0.42)	0.0283719 (0.35)	0.0221698 (0.28)	0.0227634 (0.28)
Size 50,000 – 100,000	-0.0718612 (-0.83)	-0.0684992 (-0.79)	-0.074417 (-0.86)	-0.0710396 (-0.82)
Size 100,000 – 500,000	-0.0519341 (-0.58)	-0.0619322 (-0.69)	-0.0434402 (-0.49)	-0.050196 (-0.56)
Size 500,000+	0.0669042 (0.61)	0.0562634 (0.52)	0.084141 (0.76)	0.0702444 (0.64)
Age finished education	0.0223429 (1.05)	0.0204999 (0.99)	0.0172571 (0.85)	0.0164628 (0.82)
Age finished education squared	-0.0003157 (-0.84)	-0.0002848 (-0.78)	-0.0002218 (-0.62)	-0.0002129 (-0.59)
Education level 1	-0.3260271** (-2.06)	-0.3335181** (-2.13)	-0.3372334** (-2.15)	-0.3438946** (-2.20)
Education level 2	-0.2842646*** (-2.78)	-0.2956985** (-2.39)	-0.2955142*** (-2.98)	-0.3031151*** (-3.05)
Education level 3	-0.2404874** (-2.56)	-0.2478674*** (-2.70)	-0.251198*** (-2.77)	-0.2563885*** (-2.84)
Education level 4	-0.240136*** (-3.05)	-0.2439317*** (-3.15)	-0.2440943*** (-3.18)	-0.2482547*** (-3.25)
Education level 5	-0.2063999** (-2.32)	-0.210602** (-2.39)	-0.218049** (-2.51)	-0.2201942** (-2.54)
Education level 6	-0.1459005** (-2.06)	-0.1510944** (-2.15)	-0.1544166* (-2.23)	-0.1576375* (-2.27)
Education level 7	-0.0990984 (-1.35)	-0.1045809 (-1.43)	-0.1056099 (-1.45)	-0.1105388 (-1.52)
Elevation (m)	0.1247077 (0.23)	0.0159717 (0.03)	-0.5476876 (-0.96)	-0.5915534 (-0.99)

Average Annual Temperature (^oC)	0.0149282 (0.14)	0.2641135 (1.47)	-0.0136167 (-0.14)	0.0344868 (0.17)
Average Annual Relative Humidity (%)	-0.0201267 (-1.19)	-0.1283909 (-0.69)	-0.0467358** (-2.59)	-0.3307896 (-1.69)
Average Annual Percentage Sunshine (%)	0.0117317 (0.86)	0.0526692 (0.92)	0.0356521*** (2.62)	0.0668563 (1.24)
Average Annual Wind Speed (km/hr)	-0.021707 (-0.34)	-0.2037298 (-0.74)	-0.1263797 (-1.42)	-0.3981965 (-1.36)
Total Rain Days	0.0003625 (0.10)	-0.0305926*** (-2.74)	0.0044009 (1.21)	-0.0076393 (-0.62)
Total Frost Days	-0.0004801 (-0.12)	-0.0091796 (-1.01)	0.0039451 (0.98)	0.0049096 (0.35)
Total Precipitation (mm)	0.0001053 (0.53)	0.0000337 (0.04)	-0.0000871 (-0.42)	-0.0004625 (-0.53)
Average Annual Temperature Squared (^oC)	-	-0.014558 (-1.65)	-	-0.003457 (-0.34)
Average Annual Relative Humidity Squared (%)	-	0.0006635 (0.55)	-	0.001867 (1.48)
Average Annual Percentage Sunshine Squared (%)	-	-0.0003338 (-0.54)	-	-0.0004269 (-0.72)
Average Annual Wind Speed Squared (km/hr)	-	0.0201604 (0.57)	-	0.0339243 (0.91)
Total Rain Days Squared	-	0.0001063*** (2.96)	-	0.000037 (0.92)
Total Frost Days Squared	-	0.0000424 (0.98)	-	6.10e-07 (0.01)
Total Precipitation Squared (mm)	-	-2.38e-08 (-0.08)	-	1.53e-07 (0.46)
Standard Deviation Average Annual Temperature (^oC)	-	-	-0.4198457*** (-2.85)	-0.4161345** (-2.48)
Standard Deviation Average Annual Relative Humidity (%)	-	-	0.0093058 (0.31)	0.0105146 (0.29)
Standard Deviation Average Annual Percentage Sunshine (%)	-	-	0.002436 (0.10)	-0.0011376 (-0.04)
Standard Deviation Average Annual Wind Speed (km/hr)	-	-	0.3130407 (0.91)	0.2965248 (0.84)
Standard Deviation Total Rain Days	-	-	-0.226752*** (-3.25)	-0.1826252** (-2.17)
Standard Deviation	-	-	0.008418	-0.0197899

Total Frost Days			(0.24)	(-0.33)
Standard Deviation Total Precipitation (mm)	-	-	0.0001803 (0.03)	0.0020849 (0.28)
Constant	-4.097704 (-0.91)	1.431863 (0.17)	0.028259 (0.01)	12.31019 (1.31)
Country Dummies?	YES	YES	YES	YES
Observations	17923	17923	17923	17923
R^2	0.2200	0.2210	0.2218	0.2222
AIC	4.233	4.233	4.232	4.232
BIC	-99042.710	-98997.508	-99016.007	-98956.857
Joint Significance Test of Insignificant Climate Variables	F(7, 208) =0.53 Prob > F = 0.8135	F(14, 208)=1.54 Prob > F = 0.1002	F(14, 208)=2.80 Prob > F = 0.0008	-
Joint Significance Test of Insignificant Squared Climate Variables	-	-	-	F(7, 208) =1.30 Prob > F = 0.2501

*Source: See text. *** means significant at the one per cent level of confidence, ** means significant at the five per cent level of confidence and * means significant at the ten per cent level of confidence.*

Table 3.3 Ordered logit, instrumental variables and relative income models

Variable	**Model 5**	**Model 6**	**Model 7**
Log Net Household Income (€)	1.493714*** (5.80)	4.087619*** (2.88)	2.046224*** (5.96)
Log Net Household Income Squared (€)	-0.0597922*** (-4.27)	-0.1919657** (-2.42)	-0.074129*** (-4.51)
Log Difference In Household Income	-	-	-0.2362405 (-1.25)
Citizen	0.2308307*** (3.60)	0.3238825*** (4.34)	0.3205656*** (4.30)
Age	-0.0646489*** (-8.87)	-0.0733273*** (-9.06)	-0.0734627*** (-9.08)
Age-Squared	0.0006113*** (8.11)	0.0006912*** (8.46)	0.0006924*** (8.48)
Number of Children	0.0143382 (0.91)	0.0186397 (1.09)	0.0189863 (1.11)
Are you head of household?	0.0009777 (0.02)	0.0220074 (0.44)	0.0225784 (0.45)
Are you religious	0.1025496*** (3.07)	0.1074256*** (2.83)	0.1074072*** (2.84)
Number Children 18+	-0.0199125 (-1.03)	-0.0209469 (-0.92)	-0.020737 (-0.91)
Number Children 13-17	-0.0223342 (-0.87)	-0.0132414 (-0.48)	-0.0137526 (-0.49)

Number Children 5-12	-0.0385437 (-1.63)	-0.0389712 (-1.44)	-0.0392661 (-1.45)
Number Children <5	-0.0029032 (-0.11)	0.0156208 (0.51)	0.0147454 (0.48)
Do you live with your parents?	-0.0742467 (-1.11)	-0.1027 (-1.36)	-0.1023003 (-1.35)
Latitude (°)	0.0459814 (0.99)	0.0480563 (0.98)	0.0371971 (0.76)
Longitude (°)	-0.0088083 (-0.62)	-0.0134167 (-0.95)	-0.0070927 (-0.49)
Coastline	-0.1245485* (-1.79)	-0.1829266** (-2.20)	-0.163804** (-2.12)
Population Density (per km^2)	-0.0001032*** (-4.11)	-0.0001085*** (-3.90)	-0.0001078*** (-3.95)
Are you male? (1 = Yes)	-0.0698544** (-2.01)	-0.0719614* (-1.79)	-0.0725073* (-1.80)
Married	0.3453115*** (6.58)	0.3769915*** (6.80)	0.3763282*** (6.78)
Living Together	-0.0483126 (-0.37)	0.0423706 (0.27)	0.0428625 (0.28)
Divorced	-0.1355669** (-1.98)	-0.1692233** (-2.13)	-0.1666545** (-2.10)
Separated	-0.469995*** (-3.83)	-0.5951064*** (-4.18)	-0.5968084*** (-4.19)
Widowed	-0.1594085** (-2.14)	-0.1863668** (-2.27)	-0.1866457** (-2.27)
Full-time working	0.1321309 (1.03)	0.2570637* (1.81)	0.2591815* (1.82)
Part-time working	0.0927899 (0.67)	0.2276384 (1.48)	0.2288452 (1.49)
Self-employed	0.2225918 (1.56)	0.3677078** (2.33)	0.3704655** (2.35)
Retired	0.281682** (2.02)	0.3529572** (2.33)	0.3555222** (2.35)
Housewife	0.1538906 (1.13)	0.2375374 (1.55)	0.2424918 (1.59)
Student	0.1477291 (1.03)	0.2951203* (1.77)	0.2947534* (1.77)
Unemployed	-0.6668934*** (-4.20)	-0.7176768*** (-4.09)	-0.7173757*** (-4.09)
Size <2,000	0.0644363 (0.95)	0.062533 (0.82)	0.0627696 (0.82)
Size 2,000 – 5,000	0.0097197 (0.13)	0.0221255 (0.27)	0.0265562 (0.32)
Size 5,000 – 10,000	0.1380862* (1.72)	0.1352441 (1.49)	0.1339072 (1.47)
Size 20,000 – 50,000	0.0195254 (0.29)	0.0204576 (0.26)	0.0223424 (0.28)
Size 50,000 – 100,000	-0.0698194	-0.07195	-0.0734738

	(-0.95)	(-0.83)	(-0.85)
Size 100,000 – 500,000	-0.0422233 (-0.56)	-0.060238 (-0.68)	-0.0515832 (-0.58)
Size 500,000+	0.0551996 (0.55)	0.0545706 (0.49)	0.0616239 (0.56)
Age finished education	0.0128753 (0.73)	0.016619 (0.82)	0.0174364 (0.86)
Age finished education squared	-0.0002317 (-0.73)	-0.0002134 (-0.59)	-0.0002261 (-0.62)
Education level 1	-0.3218205** (-2.43)	-0.3375601** (-2.15)	-0.337703** (-2.15)
Education level 2	-0.2660081*** (-3.14)	-0.296889*** (-2.98)	-0.2975559*** (-2.99)
Education level 3	-0.2234029*** (-2.95)	-0.2512222*** (-2.77)	-0.251047*** (-2.77)
Education level 4	-0.2237435**** (-3.54)	-0.2469948*** (-3.21)	-0.2470201*** (-3.21)
Education level 5	-0.1819952** (-2.51)	-0.2177034** (-2.50)	-0.2193079** (-2.52)
Education level 6	-0.1318581** (-2.28)	-0.1533889** (-2.20)	-0.1545939** (-2.23)
Education level 7	-0.0752844 (-1.18)	-0.1044994 (-1.43)	-0.1053217 (-1.44)
Elevation (m)	-0.4846422 (-0.92)	-0.4993421 (-0.90)	-0.6389077 (-1.12)
Average Annual Temperature (^oC)	-0.0018669 (-0.02)	0.0163297 (0.17)	-0.0231531 (-0.23)
Average Annual Relative Humidity (%)	-0.0393301** (-2.36)	-0.0369813** (-2.12)	-0.0445171** (-2.48)
Average Annual Percentage Sunshine (%)	0.0343523*** (2.86)	0.0366921*** (2.67)	0.0384529*** (2.80)
Average Annual Wind Speed (km/hr)	-0.1112643 (-1.32)	-0.1425713 (-1.63)	-0.1215321 (-1.40)
Total Rain Days	0.0036379 (1.11)	0.0048367 (1.32)	0.0049458 (1.36)
Total Frost Days	0.0054185 (1.50)	0.0048124 (1.23)	0.004214 (1.08)
Total Precipitation (mm)	-0.0001347 (-0.68)	-0.0000613 (-0.30)	-0.0000738 (-0.36)
Standard Deviation Average Annual Temperature (^oC)	-0.4006336*** (-3.05)	-0.3364966** (-2.47)	-0.3998023*** (-2.76)
Standard Deviation Average Annual Relative Humidity (%)	0.0099821 (0.37)	-0.0015291 (-0.05)	0.0084084 (0.28)
Standard Deviation Average Annual Percentage Sunshine	0.0045774 (0.19)	0.0066802 (0.26)	0.0035506 (0.14)

(%)			
Standard Deviation Average Annual Wind Speed (km/hr)	0.3530553 (1.03)	0.4694543 (1.35)	0.4050041 (1.16)
Standard Deviation Total Rain Days	-0.1719488*** (-2.58)	-0.2250001*** (-3.13)	-0.2159266*** (-3.06)
Standard Deviation Total Frost Days	0.0058146 (0.18)	-0.0075391 (-0.21)	0.0037423 (0.11)
Standard Deviation Total Precipitation (mm)	-0.0007382 (-0.12)	-0.0002357 (-0.04)	0.0005176 (0.09)
Predicted Residuals Log Household Income	-	-2.369064* (-1.66)	-
Predicted Residuals Log Household Income Squared	-	0.1229535 (1.54)	-
Constant	-	-11.48241 (-1.44)	-1.471688 (-0.32)
Country Dummies?	YES	YES	YES
Observations.	17923	17923	17923
R^2	-	0.2222	0.2220
Pseudo R^2	0.0569	-	-
AIC		4.232	4.232
BIC		-99005.260	-99009.653
Joint Significance Test Predicted Residuals		F(2, 208) = 1.71 Prob > F = 0.1827	

*Source: See text. *** means significant at the one per cent level of confidence, ** means significant at the five per cent level of confidence and * means significant at the ten per cent level of confidence.*

3.5 Post-estimation analysis and discussion

The chief objective of this paper is to measure in monetary terms European households' preferences for particular types of climate.[68] Such estimates can refer to marginal or non-marginal changes. Our approach however also permits us to describe preferences for climate directly in terms of utility as opposed to money. Depending on the audience non-monetary measures of households' preferences may find greater acceptability.[69] This is not least due to the assumption that reported LS is an accurate measure of true utility (see Section 3.2.5), on which the foundations of CS are based. The monetary valuations estimated in the next two tables should be seen as exploratory in nature the reader is reminded that climate is a complex suite of variables for which individual values are difficult to isolate.

We first focus attention on estimating the monetary value of marginal changes in climate variables. Whilst we consider the LS of individuals the values displayed in Table 3.4 represent the MWTP of the household because they refer to the marginal rate of substitution between climate variables and net household income.

As outlined earlier MWTP may be calculated by dividing the estimated coefficient of the climate variable by the estimated marginal utility of money. Due to the inclusion of the logarithm of net household income (as well as the squared value of the logarithm of net

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[68] In the context of global climate change as opposed to a European one, it is important to acknowledge that impacts are more likely in the most vulnerable developing countries. This may affect developed country SWB through concern about these adverse impacts. If so, it could merit redistribution to developing countries hit hardest.

[69] Monetary valuation of environmental goods allows them to be incorporated into cost-benefit analysis where money is the metric for comparison. Whilst this ensures they accounted for in economic decision-making, it requires ethical judgements on what constitutes value. Economic analysis is anthropocentric in nature and may ignore intrinsic environmental values.

household income) MWTP for climate variables depends on the net income of a household.[70] In order therefore to display a single value for MWTP we evaluate MWTP at the sample mean for net household income which is 15880.70€. MWTP is calculated as follows

$$MWTP_i = \frac{\phi_i y}{\beta_1 + 2\beta_2 Log(y)} \quad \textbf{(3.18)}$$

Where ϕ_i is the coefficient on climate variable i, β_1 is the coefficient on Log(y) (the logarithm of net household income) and β_2 the coefficient on $[Log(y)]^2$. Note that the results contained in Table 3.4 are based on the coefficients of Model 3 which is the preferred model.

Table 3.4 Marginal willingness to pay for climate variables

Climate Variable	Coefficient	MWTP / €	95% Confidence Interval/ €
Average Relative Humidity	-0.0467358	-1927.75***	-468.91, -3386.59
Average Sunshine	0.0356521	1470.57***	370.45, 2570.70
Average Temperature	-0.0136167	-561.66	-8424.90, 7301.58
Average Wind Speed	-0.1263797	-5212.89	-12408.20, 1982.37
Total Rain Days	0.0044009	181.5278	-112.52, 475.57
Total Frost Days	0.0039451	162.727	-162.73, 488.18
Total Precipitation	-0.0000871	-3.59269	-20.36, 13.17
Temperature Std Dev	-0.4198457	-17317.70***	-29227.50, -5408.00
Relative Humidity Std Dev	0.0093058	383.8445	-2043.04, 2810.73
Sunshine Std Dev	0.002436	100.4798	-1868.92, 2069.89
Wind Speed Std Dev	0.3130407	12912.27	-14898.80, 40723.30
Rain Days Std Dev	-0.226752	-9353.04***	-14993.60, -3712.44
Frost Days Std Dev	0.008418	347.2247	-2488.44, 3182.89
Precipitation Std Dev	0.0001803	7.436993	-478.45, 493.32

*Source: See text. *** means significant at the one per cent level of confidence, ** means significant at the five per cent level of confidence and * means significant at the ten per cent level of confidence.*

It is unfortunately difficult readily to compare these MWTP estimates with equivalent estimates from elsewhere. One reason is that other studies into the MWTP for climate

[70] It is not unusual in the LS and environmental valuation literature to interpret MWTP estimates at the household level. See, for example, Van Praag and Baarsma (2005) and Rehdanz and Maddison (2008).

variables have used alternative, generally far simpler specifications of the climate than the one adopted here. But because climate variables are often highly correlated such a strategy risks wrongly attributing to one climate variable variation more correctly attributed to another. A second obstacle to comparing the results of different studies is the fact that researchers have often measured particular variables in different ways e.g. annual mean temperature versus heating and cooling degree days versus January and July maximum daytime temperatures. A final reason why it is difficult to compare these results to those of other studies is because of differences in geographical context and socioeconomic development, particularly if MWTP is related to income.

Despite these difficulties it is possible to make a number of interesting observations. To begin with, and in spite of the fact that annual mean temperature and annual precipitation are included in many studies of the value of the climate, in neither case is MWTP statistically significant even at the ten per cent level of confidence. It is of course important to avoid the trap of assuming that because a variable is not statistically significant it is therefore unimportant. Temperature and precipitation might be very important but MWTP for these variables is not sufficiently precise to exclude the possibility that MWTP is zero.

In complete contrast MWTP for relative humidity and percentage of possible sunshine are statistically significant at the one per cent of level of confidence. More specifically, the average European household would be willing to pay 1470.57€ to increase the amount of sunshine by a single percentage point (the corresponding 95 per cent confidence interval ranges from 370.45€ to 2570.70€). A one percentage point increase in average relative humidity is worth -1927.70€ to the average European household (the corresponding 95 per cent confidence interval ranges from -468.91€ to -3386.59€).

Many studies into the value of the climate omit both relative humidity and sunshine. But it is interesting to note that the study of Blomquist et al (1988), which includes both of these variables, also finds that MWTP for sunshine is positive ($48.42 per percentage point) and MWTP for relative humidity is negative ($43.42 per percentage point).[71]

Our analysis includes a number of variables that are clearly related such as (a) average mean temperature and the number of frost days and (b) annual precipitation and the number of rain days. MWTP estimates for these climate variables are not statistically significant even at the ten per cent level of confidence.[72] At the same time however, the standard deviation in monthly mean temperatures is statistically significant at the one per cent level of confidence as is the standard deviation in the monthly number of rain days. The implication is that households prefer a situation in which temperature is approximately constant throughout the year, rather than very cold in some months and very hot in other months.[73] The estimate of -17,317.70€ for a one unit change in the standard deviation of temperature is however remarkably large, particularly when one considers that our data include locations with a standard deviation of temperature ranging from 2.8 to 9.1. The value of -9,353.04€ per standard deviation for rain days is also surprisingly large given that this variable ranges from 0.9 to 4.9.

[71] In psychiatry research interest revolves around the possible use of bright light therapy for the treatment of non seasonal depression (see e.g. Tuunainen et al 2004).
[72] Srinivasan and Stewart (2004) conduct a hedonic analysis of households in England and Wales. They find that hours of sunshine has a positive effect on house prices whereas temperature, precipitation and frost days are all insignificant.
[73] Although latitude and the standard deviation in monthly mean temperatures are correlated latitude is included as a separate control in the regression equation.

The preference for climates, not characterised by annual extremes of temperature, manifests itself in other studies. In their hedonic analysis of the climate of Germany, Rehdanz and Maddison (2009) find that the implicit price of mean January temperatures is positive but the implicit price of July temperatures is negative. For Munich, the city closest to the mean sample latitude of the respondents in our study, they place MWTP for mean January temperature at 1568DM. The estimated MWTP for mean July temperatures for Munich is minus 1927DM.[74]

The finding that households prefer climates where the number of rain days per month is approximately equal rather than climates characterised by very wet months followed by very dry months appears new to the literature. Englin (1996) presents a hedonic analysis with a positive and statistically significant implicit price for seasonal variation in precipitation. But his analysis relates only to Washington State and to precipitation rather than rain days which are excluded from his analysis.

Although we investigate a somewhat different set of climate variables, methodologically our research has most in common with Brereton et al (2008) and Ferreira and Moro (2010). Although large, the magnitude of our MWTP estimates actually appears conservative compared to the findings of Ferreira and Moro (2010) who estimate the MWTP for January mean daily temperatures for the average household in Ireland to be 15585€. Whilst Brereton et al (2008) do not present MWTP estimates for climate variables it is easy to construct them using the regression coefficient on minimum January temperatures (0.8082) and the coefficient on income (0.2649). Combining this information with the sample mean value for

[74] Rehdanz and Maddison's (2005) global study also finds strong preferences for warmer temperatures in the coldest month and cooler temperatures in the hottest month.

net household income in our study gives a MWTP for minimum January temperatures of 48,643€, which is over three times net household income.

Brereton et al (2008) do not include relative humidity in their analysis and sunshine is statistically insignificant at the 10 per cent level of confidence. Ferreira and Moro (2010) omit both variables.

We now turn to consider the present value of non-marginal changes in climate. We make the assumption that households have property rights to their existing climate and that consequently, for a change to a more preferred climate the appropriate measure of welfare change is willingness to pay (WTP). For a change to a less preferred climate, the appropriate measure is willingness to accept (WTA). The essential difference between these two measures is that whereas WTP is constrained by household income WTA compensation is unbounded and may be infinite. WTP for an improvement and WTA compensation for any deterioration suffered are together jointly referred to as the compensating surplus (CS) measures of welfare change. This approach makes the strong assumption the sample average household is able to adapt perfectly to their new climate and ignores the costs of relocation.

We calculate the CS for a household with sample average characteristics moving from one European city to another. We hold all site characteristics other than climate at their sample average values. Strictly speaking therefore the CS estimates refer to an average household e.g. moving from a location with a climate 'like that of London' to a location with a climate 'like that of Rome'.

Table 3.5 displays results for a selection of 10 major European cities. The table should be read vertically, with columns indicating the origin and the rows the destination. A positive value indicates that the climate of the destination is superior to that of the origin. Thus for example a household inhabiting a climate like that of London would be WTP 6449.48€ to move to a location with a climate like that of Rome. A negative value means that the climate of the destination is inferior to that of the origin and accordingly that compensation is required. Thus for example, a household with a climate like that of London would need 9434.01€ to move to a location with a climate like that of Paris. The possible reason for this is a lower and more consistent relative humidity in London, which is partially a function of lower average temperatures. Interestingly there are a number of instances in which no amount of compensation is sufficient to induce a household to move from one location to another (the compensation required is infinite).

From Table 3.5 it is clear that Madrid has the best climate. Households would require infinite compensation to leave a location with a climate like that of Madrid to move to a location with a climate similar to that of seven destination cities, and would require compensation of 86,100.07€ to move to a location with a climate similar to that of Rome and 13,642.40€ to move to a location with the climate similar to that of Athens. The worst climate of all is that of Stockholm. Households inhabiting a climate similar to that of Stockholm would be willing to pay almost all of their income to move to any of nine other cities. Only households from Copenhagen could be induced to move a location with a climate like that of Stockholm and even then would require compensation of 87,121.09€. For reasons that we do not completely understand these estimates appear implausibly large.

Table 3.5 Implicit value of climate matrix for European Cities

		Origin									
		London	Rome	Paris	Berlin	Stockholm	Madrid	Amsterdam	Copenhagen	Prague	Athens
Destination	London	0.00	-14749.05	5183.37	7338.31	13512.98	∞	9209.66	10877.21	8401.78	-97441.37
	Rome	6449.48	0.00	9140.54	10347.13	14158.88	-86100.07	11430.33	12450.45	10958.27	-17837.13
	Paris	-9434.01	-45465.95	0.00	3614.83	12835.88	∞	6553.51	9088.24	5306.73	∞
	Berlin	-20552.91	-137236.29	-5268.68	0.00	12274.93	∞	4097.27	7495.01	2380.71	∞
	Stockholm	∞	∞	∞	∞	0.00	∞	∞	-87121.09	∞	∞
	Madrid	11918.02	10015.53	12849.52	13301.33	14936.51	0.00	13733.47	14156.29	13541.32	6137.17
	Amsterdam	-47607.55	∞	-15312.76	-6346.04	11449.25	∞	0.00	4958.83	-2623.74	∞
	Copenhagen	∞	∞	-44220.97	-21698.48	10027.33	∞	-8729.76	0.00	-13806.80	∞
	Prague	-31766.36	∞	-9839.53	-3003.98	11863.66	∞	2168.25	6260.09	0.00	∞
	Athens	10131.84	6968.48	11593.16	12284.45	14646.94	-13642.40	12924.60	13547.03	12647.21	0.00

3.6 A life satisfaction approach to estimating quality of climate

Estimating quality of life (QOL) has received much academic attention as researchers attempt to explain the important determinants in an individual's well-being. Traditional economic indicators of welfare, such as GDP per capita have been criticised as being one-dimensional and fail to capture the diverse components which makes one happy. Alternative measures, such as the Human Development Index, rank countries on a mix of GDP per capita, life expectancy and literacy. QOL may also be subjectively measured, by surveying individuals on life experiences and perceptions to which human needs are being met. Costanza et al (2007) call for research to integrate both objective and subjective measures in defining QOL. Given the nature of this study, the focus of literature on QOL will focus purely on the role of constructing climate indices.

The purpose of constructing QOL indices is to provide an objective preferential ranking for a suite of climate variables. The complexity of the climate system means that it can be misleading to consider climate variables individually rather than together. It also avoids the need to use CS techniques to calculate WTP for individual climate variables which rely on estimating the marginal utility of money.

3.6.1 Quality of life in the literature

QOL indices are not a new concept to comparing climate consumption across different regions using the hedonic technique. Roback (1982) provides an example of a QOL index by ranking 20 US cities including the number of clear days to represent climate preferences. Blomquist et al (1988) construct a QOL index for 253 US counties by simply multiplying implicit values from hedonic wage rate and house price regressions by the quantity of each amenity:

$$\text{QOL}_k = \sum_{i=1}^{n} \pi_i z_{ik} \qquad \textbf{(3.19)}$$

Where π_i is the implicit value of amenity *i* and z_{ik} is quantity of amenity *i* in county *k*. The full index includes a total of *n* amenities. Sub-indices also rank counties on the basis of climate, environmental quality and provision of public goods. Their quality of climate index (QOC) index has the highest rank order correlation with QOL suggesting that climate is the most important determinant of QOL.

The benefit of this methodology is that it weights each amenity in the index by its relative magnitude in the regression model. However, the nature of the hedonic technique makes it necessary to assume homogeneity at the regional level; it cannot account for individual characteristics which may also play an important role in the demand for environmental amenities.

Albouy (2008) follows a similar approach to rank 241 US regions by QOL using the standard hedonic technique and an adjusted QOL rank accounting for federal taxes, non-housing costs and non-labour income. He finds that the adjusted QOL rank is positively correlated with other valuation methods. Regions located near the Pacific coast are revealed to have the highest QOL. Albouy and Leibovici (2009) also rank 19 Canadian metropolitan area by QOL using the hedonic technique. Larger cities are found to have higher levels of QOL.

Srinivasan and Stewart (2004) construct a QOL index for 55 counties across England and Wales. Sunshine is the only climate variable included in the estimated model and has a positive impact on QOL. Welsh counties perform particularly strongly in the index, whilst East and South East have the lowest QOL.

Only Moro et al (2008) use a life satisfaction approach to QOL including a set of climate variables. Using data for 34 regions across Ireland, three indices are constructed based on simple unconditionally averaging of individually reported LS, predicted life satisfaction of the nationally average individual given a set of regional characteristics and ranking locations weighted by the marginal rate of substitution of local amenities given by regression results. They conclude all three indices are positively correlated and geographic variations in life satisfaction are driven by local amenities. Galway county has the highest QOL in all indices whilst Dublin is consistently records the lowest.

3.6.2 Theoretical considerations of quality of life indices

Van Praag and Baarsma (2005) and Van Praag and Ferrer-i-Carbonell (2010) identify a complementarity between the hedonic technique and life satisfaction approach with application to QOL indices. Under the hedonic technique, non-marketed goods are perfectly compensated through the housing and labour market.

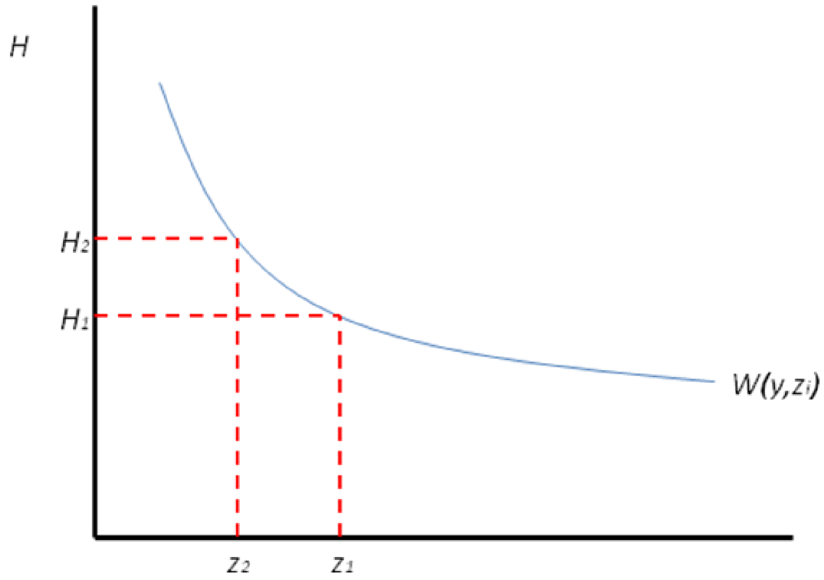
If two individuals have the same income and consume different amounts of the non-market good then utility must be equalised as follows:

$$W(y, h(z_1), z_1) = W(y, h(z_2), z_2) \text{ where } z_2 > z_1 \quad \textbf{(3.20)}$$

Assume z is an environmental amenity. We obtain an indifference curve where individuals trade-off rent paid and a set of goods which includes the environmental amenity (see Figure

3.1). It infers that individuals can be at different points on the same indifference curve and therefore have the same level of utility. Given the set environmental characteristics of an area, income and house rents are adjusted until utility differences are eliminated.

Figure 3.1 Trade off of house price and environmental amenity with constant income



Assuming z is an environmental amenity and it is the only determinant (or the only observable difference) of house prices it follows that the reduced form equation is:

$$W(y, z_1) = W(y, z_2) \quad \textbf{(3.21)}$$

This requires that the utility observed for both individuals is equal despite the fact one consumes more of the environmental amenity. However, environmental amenities are often estimated to be statistically significant determinants of LS whilst controlling for household income. Assuming utility and LS are synonymous means the previous equation cannot hold.[75]

$$W(y, z_1) \neq W(y, z_2) \tag{3.22}$$

Van Praag and Ferrer-i-Carbonell (2010) attribute this to disequilibrium in the housing market and that the amenity value of the set of environmental goods is not being fully captured by the hedonic technique. It also implies that the hedonic and LS techniques individually give partial values of environmental goods and both are required to obtain a true value of the amenity value of the climate.

This sits uneasily with the common assumption that LS is an alternative approach to the hedonic technique as opposed to a complementary one (Van Praag and Ferrer-i-Carbonell, 2010). It also disputes researchers' attempts to measure cross-country preferences unless one controls for house prices itself at a sub country level. In our study it would require us to assume that the housing market is in equilibrium at the national level and there is no inter-regional disequilibrium. Whilst individual country dummies capture national differences in the housing market, it is also catching all other unobserved heterogeneity. Ideally this would lead us to control for house prices at the regional level. Unfortunately, to our knowledge, data European data on house prices at the NUTS level is unavailable and represents a limitation of our study.

[75] This assumes that the LS approach is able to ensure there are no unobserved geographical variations in house prices which are being omitted in the model otherwise it risks ignoring the value of environmental amenities that households do implicitly pay for.

The theory of Van Praag and Ferrer-i-Carbonell (2010) is then applied to a set of specific case studies in a variety of Latin American urban neighbourhoods (see Cruces et al, 2010; Medina et al, 2010; Hall et al, 2010; Alqázar and Andrade, 2010 and Ferre et al, 2010). In these studies the hedonic technique is applied within urban areas of a single city to estimate residents' quality of life. QOL in the same areas is then estimated using a LS approach.

3.6.3 Estimating the quality of climate

We now consider a non-monetary indicator of households' preferences for climate. Table 3.6 ranks countries by the quality of their climate (QOC). More specifically, countries are ranked from 1-19 with 1 being the country with the best climate and 19 being the country with the worst climate. This index is calculated as follows

$$QOC_j = \sum_i \phi_i z_{ij} \qquad \textbf{(3.23)}$$

Where ϕ_i is the coefficient on climate variable i and z_{ij} is the level of climate variable i in location j.

The QOC index for a country is obtained by averaging the QOC in the country's constituent regions

$$QOC = \overline{QOC_j} \qquad \textbf{(3.24)}$$

The resultant country ranking is not implausible. Mediterranean countries appear to have the best climate and Scandinavian and Baltic countries have the worst. The country with the best climate is Spain and the country with the worst climate is Sweden.

Table 3.6 Climate index by country

Rank	Country	Climate Index Score
1	Spain	-3.97488
2	Greece	-4.12965
3	Portugal	-4.17681
4	Italy	-4.52121
5	France	-4.524
6	Belgium	-4.62178
7	Great Britain	-4.67563
8	Bulgaria	-4.79969
9	Austria	-4.8022
10	Germany	-4.84643
11	Slovenia	-4.88362
12	Netherlands	-4.94874
13	Czech Republic	-4.9683
14	Slovakia	-5.01237
15	Denmark	-5.34637
16	Lithuania	-5.52366
17	Latvia	-5.59306
18	Estonia	-5.77243
19	Sweden	-5.8583

Our QOC index, although similar to that proposed in Moro et al (2008), differs in a fundamental way from other indices which combine environmental indicators using weights that are mostly based on expert judgement. Blomquist et al (1988) construct a QOL index for 253 US counties, using implicit prices from hedonic wage rate and hedonic house price regressions. Counties are ranked on the basis of climate, environmental quality and public goods. Their QOC index has the highest rank order correlation with overall QOL suggesting that climate is the most important determinant of QOL.

Appendix B.2 ranks 209 NUTS3 regions from 1-209 with 1 being the NUTS region with the best climate and 209 being the NUTS region with the worst climate. The NUTS region with the best climate is the Canary Islands. The NUTS region with the worst climate is Northern Sweden. Note that the poor performance of Northern Sweden is not attributable to latitude because this was included as a control variable.

A number of Northern Italian and Austrian destinations also appear in the top 20 climates. Without exception these regions are popular skiing destinations e.g. Valle d'Aosta in Italy which is ranked as having the second best climate and Tirol in Austria which is ranked as having the seventh best climate. Climates that permit skiing and other winter sports appear to boost LS.[76]

3.6.4 Quality of climate by demographic

An advantage of this construction of QOC indices using the LS approach is that it is possible to rank preferences for climate for different subsections of respondents. Appendix B.3 provides regression results for LS by gender and age, using the same specification as Model 3. Age is divided into three categories (age>37, 37≤age<55 and age≥55) with care taken to split observations approximately equally.

A small number of observations are worth making at this point. With respect to gender, an interesting finding is that being household head is positive and statistically significant at the five per cent level for men yet negative and statistically significant at the same level for women. Furthermore, it appears the benefits of employment (full-time, part-time and self-

[76] An alternative explanation is that those with higher LS relocate to areas in which such activities are possible. This raises a causality issue of whether a local amenity increases well-being or if those with the highest wellbeing are more likely to relocate close to desired amenities.

employed) are attributed to men as is being a student. However, unemployment is only negative and statistically significant for women. The negative well-being effect of wider variations of temperature and rain days also appears to impact on men relatively more than women.

Dividing according to age also has some interesting effects. Confirming the findings of the U-shaped relationship between age and LS, we find a negative and statistically significant relationship for middle-aged respondents at the five per cent level whilst older respondents are more satisfied, albeit only weakly significant. Living with their parents is a significant source of dissatisfaction for young people too. Furthermore, being widowed is only statistically significant cause of dissatisfaction for middle-aged respondents, whilst the same group are more satisfied if in full-time employment. Unemployment, on the other hand is having the largest negative effect on older respondents though remains statistically significant for all age groups. With respect to the climate variables, variations in temperature older individuals are not statistically significant for older individuals but remain so for the other two categories, whilst average relative humidity becomes statistically insignificant for the middle-aged. Conversely, average percentage of sunshine is only statistically significant for middle-aged respondents. Previously insignificant variables of total and variation in frost days become statistically significant for the middle-ages as well.

Table 3.7 presents QOC by gender. Visually it is clear that the Mediterranean climate is very important for women, with the top six countries all bordering it. Conversely, Scandinavian and Baltic countries perform badly, very similar to the findings of Table 6. QOC ranking for men is somewhat more volatile however. Whilst Spain remains the most preferred climate, temperate countries of Northern Europe appear to perform consistently better This is perhaps due to the larger negative coefficient on variations in temperature for men which makes the Mediterranean relatively less attractive.

Table 3.7 Quality of climate ranks by gender

Rank	FEMALE	Score	MALE	Score
1	Greece	-3.65	Spain	-4.01
2	Spain	-3.80	Great Britain	-4.07
3	Portugal	-3.91	Germany	-4.21
4	Italy	-4.23	Austria	-4.22
5	France	-4.54	Belgium	-4.25
6	Bulgaria	-4.74	Portugal	-4.27
7	Belgium	-4.86	Czech Republic	-4.31
8	Slovenia	-4.91	France	-4.32
9	Great Britain	-4.95	Slovakia	-4.45
10	Austria	-5.10	Netherlands	-4.51
11	Germany	-5.13	Latvia	-4.63
12	Netherlands	-5.14	Slovenia	-4.64
13	Slovakia	-5.29	Italy	-4.66
14	Czech Republic	-5.33	Greece	-4.68
15	Denmark	-5.69	Lithuania	-4.71
16	Lithuania	-6.02	Denmark	-4.77
17	Latvia	-6.22	Bulgaria	-4.79
18	Estonia	-6.37	Estonia	-4.84
19	Sweden	-6.43	Sweden	-5.02

Table 3.8 gives the Pearson's product moment correlation coefficient for the female and male indices against the overall index. It is evident that the female climate index is highly correlated with the overall index and is statistically significant at the 0.1% level of confidence. The correlation coefficient between the males and overall indices is noticeably lower but is significant at the one per cent level of confidence. The correlation coefficient between males and females is only significant at the five per cent level of confidence.

Table 3.8 Pearson's product moment correlation coefficient for gender

	Full Model	Female	Male
Full Model	X	X	X
Female	0.98*** (0.000)	X	X
Male	0.67*** (0.002)	0.51** (0.026)	X

Table 3.9 provides similar set of QOC indices for the three age categories. For those under 38 the preference still remains firmly for the Mediterranean climate, with Spain, Greece and Portugal forming the top three. Interestingly, Mediterranean climates in Eastern Europe, such as Slovenia and Bulgaria, perform very well but only for the youngest age group. Eastern European Baltic states perform worst.

The distinctive feature of respondents' ages between 38 and 54 is that the QOC plays a distinctively more positive role in well-being. The top five countries, again all bordering the Mediterranean, have positive values. Greece is the most favourable climate for this age group. This is likely caused by the positive coefficient on average temperature, despite its individual statistical insignificance. Sweden once again performs the worst and the index looks very similar to Table 3.6 from a visual perspective. For those aged 55 and above it is clear that more temperate climates are preferred and Austria now becomes the most preferable climate. The Czech Republic, Germany and Belgium also perform well which are all geographically close to Austria. Even Lithuania makes it into the top 10. Whilst the Spanish climate still found to be desirable, other Mediterranean climates all perform badly. Greece drops 16 places from the full model to 18th. The reason for this appears due to a complex mix of multiple climate variables rather than particularly strong preferences for a single variable.

Table 3.9 Quality of climate ranks by age

Rank	AGE<38	Score	38<=AGE<55	Score	AGE>=55	Score
1	Spain	-7.36	Greece	1.10	Austria	-5.17
2	Greece	-7.50	Portugal	0.94	Spain	-5.29
3	Portugal	-7.58	Spain	0.78	Czech Republic	-5.29
4	Slovenia	-7.86	Italy	0.14	Germany	-5.40
5	Bulgaria	-7.90	France	-0.13	Belgium	-5.41
6	France	-7.91	Belgium	-0.30	Great Britain	-5.43
7	Italy	-7.92	Great Britain	-0.33	Slovakia	-5.46
8	Austria	-8.02	Netherlands	-0.71	France	-5.51
9	Great Britain	-8.16	Bulgaria	-0.71	Slovenia	-5.53
10	Germany	-8.18	Germany	-0.76	Lithuania	-5.65
11	Belgium	-8.29	Slovakia	-0.94	Italy	-5.67
12	Czech Republic	-8.34	Austria	-0.97	Netherlands	-5.69
13	Slovakia	-8.42	Czech Republic	-1.07	Latvia	-5.71
14	Netherlands	-8.44	Slovenia	-1.09	Bulgaria	-5.77
15	Sweden	-8.69	Denmark	-1.23	Portugal	-5.77
16	Denmark	-8.76	Lithuania	-1.51	Estonia	-5.77
17	Lithuania	-9.12	Latvia	-1.61	Denmark	-5.94
18	Latvia	-9.17	Estonia	-1.96	Greece	-6.13
19	Estonia	-9.25	Sweden	-2.38	Sweden	-6.31

Table 3.10 presents the rank order correlations for the full model and age sub-categories. Whilst the full model is statistically significant and positively correlated with the under 37 and middle aged group, there is no such relationship with those who are 55 and above. It is also clear that the under 38 index and the middle age category are positively correlated too.

Table 3.10 Pearson's product moment correlation coefficient for age

	Full Model	Age<38	38≤Age<55	Age≥55
Full Model	X	X	X	X
Age<37	0.93*** (0.000)	X	X	X
37≤Age<55	0.96*** (0.000)	0.84*** (0.000)	X	X
Age≥55	0.35 (0.140)	0.22 (0.375)	0.16 (0.505)	X

These results suggest that there exists a degree of heterogeneity for climate preferences amongst different demographic groups. This infers that QOL indices which account for the climate should not be arbitrarily determined for different groups of people who may live in the same location. This may be of particular relevance for those who have retired and are no longer captured in the hedonic wage model. Perhaps then it is no coincidence that those of 55 and over exhibit significantly different preferences for consumption of climate.[77] This technique of ranking QOC by demographic status could be achieved for any number of socio-economic variables provided there exist enough observations to ensure representative regression results.

3.7 Conclusions

Previous researchers have most often used the hedonic technique to answer questions about the value of climate to households. Far fewer researchers have attempted to explore the value of climate using survey data on LS. Economic research on LS has instead focussed on the impact of economic growth and on economic variables such as inflation and unemployment.

In this chapter we use survey data on LS to determine the value of climate to European households. We do so using NUTS level data over an area sufficiently large to ensure significant variation in climate. Compared to other studies of the value of climate to households we include a far more comprehensive set of climate variables. We also investigate households' preferences for intra-annual variation in climate variables.

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[77] It is enticing to draw comparisons between the over 55's life satisfaction Model (6) in Appendix B.2 and the pensioner migration models in Chapter 2. However, the individual insignificance of the climate variables in Model 6 makes any firm conclusions impossible. Direct comparison is made more difficult by the differences in the specification of climate variables in these models.

European households prefer more sunshine and lower relative humidity. Households also obtain satisfaction from climate characterised by lower intra-annual variation in temperature and rain days. Annual mean temperature and annual precipitation have no statistically significant effect on reported life satisfaction. Throughout key control variables such as the effect of age, unemployment, income and marital status exert an impact on LS very similar to that suggested by previous research.

Our analysis also allows us to rank countries and regions in terms of the quality of their climate. We are also able to determine preferences for climate according to specific demographic features of individuals. On the whole we find that it is not just the classic Mediterranean climate that promotes LS. Regions where winter sports are possible also lead to high levels of LS. The climate of Scandinavia is associated with low levels of LS. However, quite independently of latitude, there are clear preferences for men and those who are older to prefer temperate as opposed to Mediterranean climates. Anecdotally, it is possible that this could be because men are more likely to work outdoors. This has an important implication for ranking countries or regions by QOC which are determined purely by consumption and not the specific preferences of the individuals who inhabit them. More research is needed into the climatic preferences of different types of individual.

Our analysis also throws up a number of difficult to explain findings. More specifically, estimates of the CS for non-marginal changes in climate variables are implausibly large. It is possible that this is due to the specification of household income used in the EVS. However, it was found that the statistical insignificance of IVs suggests there was no observable measurement error. Resolving why this is so will require additional research. Attention should be placed on survey data that asks for exact household income values. A process of validation could occur if surveys were to ask for both exact household income and a range to allow for direct comparison. Until then the technique is not yet ready to use for the purposes of valuing anthropogenic changes in climate.

Appendix B.1 Correlation Matrix of Climate Variables

	Average Annual Temperature (°C)	Average Annual Relative Humidity (%)	Average Annual Percentage Sunshine (%)	Average Annual Wind Speed (km/hr)	Total Rain Days	Total Frost Days	Total Precipitation (mm)
Average Annual Temperature (°C)	1	-	-	-	-	-	-
Average Annual Relative Humidity (%)	-0.714	1	-	-	-	-	-
Average Annual Percentage Sunshine (%)	0.7996	-0.8928	1	-	-	-	-
Average Annual Wind Speed (km/hr)	-0.2917	0.5845	-0.5194	1	-	-	-
Total Rain Days	-0.6883	0.8417	-0.8549	0.5047	1	-	-
Total Frost Days	-0.9473	0.5379	-0.6501	0.1399	0.5156	1	-
Total Precipitation (mm)	-0.1367	0.1588	-0.0467	-0.1814	0.3255	0.072	1

Appendix B.2 Climate index by region

Rank	Nutscode	Climate Index	Freq.	Elevation	Region Name
1	ES70	-2.95929	31	0.565	Canarias
2	ITC2	-3.51565	3	2.071	Valle dAoste
3	ES24	-3.56803	22	0.791	Aragon
4	ES52	-3.65398	85	0.506	C Valenciana
5	ES51	-3.79022	93	0.663	Cataluna
6	ES41	-3.80317	51	0.944	Castilla Leon
7	AT33	-3.81569	67	1.706	Tirol
8	ES62	-3.84529	27	0.506	Murcia
9	PT150	-3.87104	28	0.186	Algarve
10	ES22	-3.87538	7	0.58	Navarra
11	GR244	-3.89173	4	0.488	Fthiotida
12	GR413	-3.89739	7	0.266	Chios
13	GR144	-3.89942	31	0.783	Trikala
14	GR253	-3.90253	19	0.614	Korinthia
15	ITD2	-3.90614	11	1.376	Trentino-Alto Adige
16	AT34	-3.91104	32	1.355	Vorarlberg
17	ES23	-3.91684	6	0.834	Rioja
18	GR421	-3.93144	14	0.266	Dodekanisos
19	ES30	-3.93295	55	0.844	Madrid
20	GR141	-3.93834	20	0.56	Karditsa
21	GR252	-3.94753	2	0.741	Arkadia
22	BG424	-3.96733	16	1.198	Smolian
23	ES42	-3.97322	32	0.827	Castilla-Mancha
24	GR241	-3.97617	1	0.371	Voiotia
25	ES13	-3.98486	7	0.606	Cantabria
26	GR14	-3.99162	1	0.536	Thessalia
27	GR143	-3.99812	17	0.421	Magnisia
28	ES12	-4.00945	20	0.667	Asturias
29	FR8	-4.01212	179	0.677	Méditerranée
30	GR231	-4.01952	17	0.381	Aitoloakarnania
31	GR422	-4.03398	4	0.221	Kyklades
32	GR242	-4.04674	27	0.284	Evvoia
33	PT11	-4.06175	230	0.52	North
34	PT16	-4.06379	80	0.377	Center
35	GR251	-4.06693	4	0.366	Argolida
36	GR142	-4.06919	5	0.421	Larisa
37	PT17	-4.09435	230	0.089	Lisbon & Tagus Valley
38	GR43	-4.09435	6	0.503	Kriti (rest)
39	GR254	-4.1077	9	0.525	Lakonia
40	GR300	-4.14311	651	0.26	Attiki
41	BG413	-4.14486	78	1.059	Blagoevgrad/Razlog

42	PT18	-4.14756	29	0.185	Alentejo
43	ES21	-4.15777	39	0.442	Pais Vasco
44	FR7	-4.16274	149	0.758	Centre Est
45	ITC3	-4.16872	51	0.529	Liguria
46	ES43	-4.17022	17	0.424	Extremadura
47	AT32	-4.1725	55	1.41	Salzburg
48	GR434	-4.1787	6	0.555	Chania
49	ES61	-4.19758	156	0.524	Andalucia
50	BG425	-4.22999	25	0.502	Kardjali
51	ES11	-4.23169	58	0.508	Galicia
52	GR255	-4.23287	1	0.459	Messinia
53	FR6	-4.2442	128	0.351	Sud Ouest
54	ITC1	-4.28595	82	0.804	Piemonte
55	ES53	-4.30669	15	0.135	Baleares
56	SI018	-4.32809	17	0.746	Kraska
57	SI023	-4.33449	25	0.817	Goriska
58	ITF1	-4.36282	23	0.79	Abruzzo
59	ITE2	-4.38295	27	0.478	Umbria
60	ITE4	-4.39064	116	0.423	Lazio
61	ITE3	-4.39716	38	0.412	Marche
62	ITC4	-4.40067	207	0.656	Lombardia
63	ITD4	-4.40655	26	0.539	Friuli-Venezia Giulia
64	UKC	-4.40798	23	0.183	North East
65	BG423	-4.40842	34	0.876	Pazardijk
66	UKM	-4.41278	49	0.231	Scotland
67	ITF5	-4.46434	16	0.559	Basilicata
68	BE35	-4.4762	37	0.24	Namen
69	ITE1	-4.47681	92	0.361	Toscana
70	ITF4	-4.48902	81	0.197	Puglia
71	BG415	-4.49492	40	0.935	Kyustendil
72	BE10	-4.50048	319	0.033	Brussel
73	ITF3	-4.50743	98	0.443	Campania
74	DE1	-4.50944	115	0.484	Baden-Wurttemberg
75	DEB	-4.5108	34	0.314	Rheinland-Pfalz
76	UKD	-4.51186	68	0.154	North West
77	AT21	-4.51475	93	1.161	Kaernten
78	ITF2	-4.5174	19	0.518	Molise
79	BG422	-4.52887	30	0.235	Haskovo
80	ITD3	-4.53914	107	0.427	Veneto
81	BE34	-4.54317	37	0.385	Luxemburg
82	GR222	-4.54342	12	0.175	Kerkyra
83	SI022	-4.55202	65	0.923	Gorensjka
84	UKG	-4.55307	53	0.12	West Midlands
85	ITG1	-4.56067	113	0.428488	Sicilia
86	BE24	-4.56131	95	0.056	Vlaams Brabant
87	FR4	-4.56884	75	0.373	Est

88	FR5	-4.57272	165	0.09	Ouest
89	BE33	-4.57609	134	0.302	Luik
90	DEC	-4.59499	9	0.312	Saarland
91	UKK	-4.59618	40	0.117	South West
92	BE31	-4.59741	33	0.115	Waals-Brabant
93	ITF6	-4.60587	32	0.515	Calabria
94	UKE	-4.60921	25	0.13	Yorks & Humberside
95	UKJ	-4.61157	114	0.079	South East
96	UKI	-4.61683	42	0.05	London
97	DE2	-4.62369	146	0.506	Bayern
98	UKL	-4.63116	30	0.196	Wales
99	DE7	-4.64882	45	0.299	Hessen
100	BE21	-4.65165	198	0.014	Antwerpen
101	BG421	-4.65214	80	0.5	Plovdiv
102	FR301	-4.65857	59	0.077	Nord
103	BG412	-4.66291	159	0.916	Sofia-City
104	BG414	-4.66429	19	0.874	Pernik
105	BE32	-4.66761	212	0.101	Henegouwen
106	UKF	-4.66833	35	0.089	East Midlands
107	FR2	-4.67957	242	0.178	Bassin Parisien
108	DEA	-4.68651	205	0.176	Nordrhein-Westfalen
109	DEG	-4.70221	114	0.368	Thueringen
110	UKH	-4.71088	23	0.044	Eastern
111	ITG2	-4.73268	40	0.343	Sardegna
112	BE25	-4.74262	122	0.014	West-Vlaanderen
113	BG344	-4.74494	34	0.382	Stara Zagora
114	BE22	-4.75017	58	0.057	Limburg
115	SI021	-4.77275	145	0.524	Osrednja Slovenska
116	FR1	-4.77541	225	0.108	Ile De France
117	SI015	-4.77644	71	0.558	Zasavska
118	SI016	-4.77762	13	0.222	Spodnje Posavska
119	BE23	-4.7873	159	0.017	Oost-Vlaandere
120	AT22	-4.79024	181	0.949	Steiermark
121	ITD5	-4.79279	94	0.287	Emilia-Romagna
122	CZ041	-4.79374	136	0.61	Západoèeský kraj
123	SI014	-4.79578	92	0.525	Savinjska
124	AT31	-4.79822	220	0.586	Oberoesterreich
125	DEE	-4.80445	146	0.117	Sachsen-Anhalt
126	NL42	-4.80449	24	0.05	NL42
127	SI012	-4.80818	84	0.36	Podravska
128	DED	-4.81209	240	0.286	Sachsen
129	DE9	-4.8153	100	0.071	Niedersachsen
130	NL4	-4.81802	180	0.024	Zuid-Holland
131	NL41	-4.82548	123	0.012	Noord-Brabant
132	DE6	-4.83015	11	0.013	Hamburg
133	CZ031	-4.8474	137	0.563	Jihoèeský kraj

134	BG343	-4.85612	14	0.187	Yambol
135	NL22	-4.8629	124	0.018	Gelderland
136	SK041	-4.86779	181	0.569	Presov County
137	DE3	-4.87987	79	0.041	Berlin
138	NL31	-4.8877	29	0.003	Utrecht
139	CZ051	-4.8931	195	0.444	Severoèeský kraj
140	NL21	-4.89769	71	0.012	Overijssel
141	SK042	-4.89937	175	0.37	Kosice County
142	CZ080	-4.8995	289	0.458	Severomoravský kraj
143	SK022	-4.90286	124	0.439	Trencin County
144	DE4	-4.90343	92	0.061	Brandenburg
145	DE5	-4.90512	19	0.004	Bremen
146	SI011	-4.90578	22	0.222	Pomurska
147	SK031	-4.90846	155	0.773	Zilina County
148	SI013	-4.91644	12	0.696	Koroska
149	NL34	-4.91829	20	0.001	Zeeland
150	BG322	-4.92306	19	0.564	Gabrovo
151	CZ020	-4.92568	326	0.341	Východoèeský kraj
152	CZ01	-4.94444	133	0.286	Prague - Praha
153	NL13	-4.94969	29	0.011	Drenthe
154	NL23	-4.95706	13	-0.003	Flevoland
155	DE8	-4.97172	83	0.037	Mecklenburg-Vorpommern
156	BG315	-4.99403	19	0.567	Lovech
157	NL1	-5.0016	173	0.004	Noord-Holland
158	SK023	-5.0048	159	0.177	Nitra County
159	AT12	-5.00604	253	0.46	Niederoesterreich
160	DEF	-5.0105	15	0.022	Schleswig-Holstein
161	CZ062	-5.01561	302	0.325	Jihomoravský kraj
162	AT11	-5.01708	51	0.255	Burgenland
163	NL11	-5.02239	29	0.002	Groningen
164	NL12	-5.03459	28	0.001	Friesland
165	AT13	-5.03476	239	0.168	Vienna
166	SK021	-5.04524	132	0.191	Trnava County
167	SK032	-5.0526	146	0.484	B. Bystrica County
168	SK010	-5.06481	146	0.211	Bratislava County
169	BG334	-5.09417	20	0.332	Targovishte
170	BG311	-5.13853	14	0.319	Vidin
171	DK011	-5.14067	68	0.002	København
172	DK007	-5.14283	8	0.065	Bornholms Amt
173	DK012	-5.15623	73	0.021	Københavns Amt
174	BG321	-5.15663	40	0.221	Veliko Tarnavo
175	DK021	-5.15978	36	0.022	Roskilde Amt
176	BG333	-5.19254	30	0.26	Shumen
177	DK013	-5.20088	59	0.022	Frederiksborg Amt
178	BG331	-5.20234	48	0.182	Varna

179	DK005	-5.21132	56	0.021	Vestsjællands Amt/ Storstoms
180	DK00D	-5.21596	122	0.045	Århus Amt
181	BG312	-5.22314	29	0.321	Montana
182	BG324	-5.2395	9	0.232	Razgrad
183	DK008	-5.24476	68	0.032	Fyns Amt
184	BG323	-5.28825	28	0.146	Ruse
185	BG313	-5.29795	29	0.262	Vtatsa
186	BG332	-5.34894	27	0.204	Dobrich
187	DK009	-5.35039	64	0.034	Sønderjyl. og Ribe Amt/Vejle
188	BG325	-5.35142	20	0.133	Silistra
189	SE2	-5.37362	180	0.123	Syd
190	BG314	-5.37746	36	0.137	Pleven
191	DK00F	-5.38669	91	0.019	Nordjyllands Amt
192	SE23	-5.39201	87	0.117	Väst
193	DK00C	-5.39914	50	0.032	Ringkøbing Amt
194	LT008	-5.41545	215	0.127	Zemaitija
195	LV003	-5.43479	126	0.057	Kurzeme
196	SE1	-5.44468	105	0.071	Öst
197	LT004	-5.46321	160	0.105	Suvalkija
198	LT001	-5.49784	50	0.132	Dzukija
199	LV006	-5.50731	272	0.011	Riga
200	LV009	-5.51103	136	0.072	Zemgale
201	LT00A	-5.52088	368	0.153	South East Lithuania
202	EE00803	-5.5718	195	0.077	South-Eastern Estonia
203	EE00402	-5.58631	104	0.021	South-Western Estonia
204	LV008	-5.60668	206	0.118	Vidzeme
205	SE11	-5.61502	17	0.025	Stor Stockholm
206	LV005	-5.68558	151	0.136	Latgale
207	EE00701	-5.68681	151	0.049	North-Eastern Estonia
208	EE00101	-5.68693	360	0.05	North-Western Estonia
209	SE3	-5.78596	99	0.409	Norr

Appendix B.3 Regression results by gender and age

	(1) Model 3	(2) Male	(3) Female	(4) Age<37	(5) 37≤Age<55	(6) Age≥55
Log Net Household	1.831***	1.873***	1.845***	1.147**	1.300***	2.068***
Income (€)	(5.99)	(4.90)	(4.86)	(2.55)	(2.62)	(4.36)
Log Net Household	-0.075***	-0.075***	-0.078***	-0.041*	-0.042	-0.091***
Income Squared (€)	(-4.50)	(-3.60)	(-3.78)	(-1.67)	(-1.58)	(-3.50)
Citizen	0.321***	0.266**	0.364***	0.328**	0.082	0.444***
	(4.31)	(2.20)	(3.35)	(2.54)	(0.53)	(2.83)
Age	-0.073***	-0.077***	-0.068***	-0.55	-0.206**	0.097*
	(-9.09)	(-6.69)	(-6.05)	(-0.98)	(-2.05)	(1.70)
Age-Squared	0.0006***	0.007***	0.0006***	0.0003	0.002*	-0.0006
	(8.48)	(6.27)	(5.69)	(0.37)	(1.95)	(-1.53)
Number of	0.019	0.012	0.022	-0.040	0.018	0.022
Children	(1.10)	(0.49)	(0.94)	(-0.73)	(0.59)	(0.88)
Are you head of	0.023	0.197**	-0.128**	0.003	0.030	0.018
household?	(0.46)	(2.41)	(-2.07)	(0.05)	(0.41)	(0.22)
Are you religious?	0.109***	0.083*	0.126**	0.087	0.097	0.153**
	(2.88)	(1.74)	(2.23)	(1.45)	(1.49)	(2.18)
Number Children 18+	-0.022	0.009	-0.048	0.076**	-0.070**	-0.037
	(-0.95)	(0.32)	(-1.43)	(1.17)	(-2.28)	(-0.79)
Number Children 13-17	-0.014	-0.008	-0.018	0.087	0.012	-0.115
	(0.50)	(-0.18)	(-0.45)	(1.45)	(0.27)	(-1.04)
Number Children 5-12	-0.040	-0.044	-0.032	0.023	-0.033	0.039
	(-1.46)	(-1.05)	(-0.99)	(0.46)	(-0.68)	(0.26)
Number Children <5	0.014	-0.012	0.024	0.045	0.034	-0.123
	(0.46)	(-0.26)	(0.59)	(0.89)	(0.69)	(-0.93)
Do you live with	-0.102	-0.072	-0.116	-0.260***	-0.198	0.007
your parents?	(-1.35)	(-0.74)	(-1.19)	(-3.17)	(-1.49)	(0.04)
Latitude (^{o})	0.048	-0.027	0.105*	0.076	0.091	-0.044
	(1.00)	(-0.43)	(1.81)	(1.17)	(1.46)	(-0.52)
Longitude (^{o})	-0.009	-0.022	0.002	-0.015	-0.018	-0.008
	(-0.59)	(-1.11)	(0.11)	(-0.73)	(-0.89)	(-0.37)
Coastline	-0.157**	-0.141	-0.167*	0.028	-0.344***	-0.144
	(-2.00)	(-1.51)	(-1.84)	(0.32)	(-3.26)	(-1.07)
Population Density	-0.0001***	-0.0001***	-0.0001***	-0.0001***	-0.00007*	-0.00009**
(per km^2)	(-3.88)	(-3.87)	(-3.24)	(-4.41)	(-1.85)	(-2.51)
Are you male? (1=	-0.073*	.	.	-0.012	-0.193***	0.011
Yes)	(-1.81)	.	.	(-0.22)	(-3.00)	(0.15)
Married	0.376***	0.332***	0.340***	0.380***	0.387***	0.321**
	(6.77)	(3.81)	(4.31)	(5.11)	(3.82)	(2.04)
Living Together	0.043	-0.221	0.312	-0.086	1.074**	0.046
	(0.28)	(-0.83)	(1.63)	(-0.28)	(2.43)	(0.14)
Divorced	-0.167**	-0.156	-0.167	-0.241	-0.051	-0.273
	(-2.10)	(-1.18)	(-1.84)	(-1.55)	(-0.40)	(-1.41)
Separated	-0.596***	-0.578**	-0.599***	-0.519*	-0.463**	-0.959***
	(-4.18)	(-2.33)	(-2.68)	(-1.78)	(-2.03)	(3.37)
Widowed	-0.185**	-0.404**	-0.088	-0.513	-0.510**	-0.157
	(-2.26)	(-2.59)	(-0.81)	(-1.30)	(-2.20)	(-0.91)
Full-time working	0.257*	0.724***	0.0018	0.182	0.709***	-0.066
	(1.80)	(3.16)	(0.01)	(1.00)	(0.25)	(-0.25)
Part-time working	0.229	0.620**	-0.004	0.111	0.657**	0.075
	(1.49)	(2.47)	(-0.02)	(0.56)	(2.48)	(0.24)
Self-employed	0.370**	0.780***	0.209	0.362*	0.638**	0.238

	(2.33)	(3.20)	(1.23)	(1.67)	(2.55)	(0.84)
Retired	0.354**	0.885***	0.044	0.764	0.491*	-0.048
	(2.34)	(3.63)	(0.25)	(1.47)	(1.72)	(-0.19)
Housewife	0.240	0.438	-0.025	0.219	0.529**	-0.095
	(1.57)	(1.03)	(-0.16)	(1.07)	(1.99)	(-0.38)
Student	0.292*	0.887***	-0.031	0.249	0.640	-0.987
	(1.75)	(3.52)	(-0.17)	(1.26)	(1.11)	(-0.73)
Unemployed	-0.720***	-0.195	-1.013***	-0.625***	-0.483*	-1.394***
	(-4.11)	(-0.79)	(-5.13)	(-2.75)	(-1.72)	(-4.12)
Size <2,000	0.060	0.103	0.027	0.243*	-0.007	-0.061
	(0.78)	(0.95)	(0.26)	(1.73)	(-0.06)	(-0.53)
Size 2,000 – 5,000	0.027	0.152	-0.091	0.135	-0.050	-0.008
	(0.32)	(1.36)	(-0.81)	(0.90)	(-0.43)	(-0.06)
Size 5,000 – 10,000	0.140	0.191	0.083	0.209	0.017	0.146
	(1.52)	(1.60)	(0.67)	(1.38)	(0.13)	(1.10)
Size 20,000 – 50,000	0.022	0.069	-0.021	0.130	-0.151	0.070
	(0.28)	(0.68)	(-0.19)	(0.99)	(-1.20)	(0.61)
Size 50,000 – 100,000	-0.074	-0.109	-0.040	-0.071	-0.177	0.023
	(-0.86)	(-0.93)	(-0.39)	(-0.49)	(-1.48)	(0.15)
Size 100,000 – 500,000	-0.043	-0.035	-0.049	0.130	-0.222*	-0.077
	(-0.49)	(-0.29)	(-0.47)	(0.92)	(-1.96)	(-0.56)
Size 500,000+	0.084	0.204	-0.004	0.345*	-0.083	-0.013
	(0.76)	(1.48)	(-0.03)	(1.88)	(-0.61)	(-0.08)
Age finished education	0.017	0.006	0.032	0.056	0.003	0.021
	(0.85)	(0.24)	(1.09)	(1.23)	(0.10)	(0.70)
Age finished	-0.0002	-0.00006	-0.0004	-0.001	-0.00005	-0.0002
education squared	(-0.62)	(-0.12)	(-0.80)	(-1.05)	(-0.09)	(-0.37)
Education level 1	-0.337**	-0.259	-0.402**	-0.453	-0.171	-0.284
	(-2.15)	(-1.11)	(-2.19)	(-1.09)	(-0.60)	(-1.43)
Education level 2	-0.296***	-0.328***	-0.274**	-0.379**	-0.352**	-0.173
	(-2.98)	(-2.69)	(-1.99)	(-2.38)	(-2.22)	(-1.16)
Education level 3	-0.251***	-0.255**	-0.249**	-0.220*	-0.342**	-0.100
	(-2.77)	(-2.07)	(-2.10)	(-1.73)	(-2.22)	(-0.68)
Education level 4	-0.244***	-0.260***	-0.235*	-0.310**	-0.285***	-0.089
	(-3.18)	(-2.63)	(-1.96)	(-2.41)	(-2.62)	(-0.64)
Education level 5	-0.218**	-0.185*	-0.250**	-0.279**	-0.246*	0.003
	(-2.51)	(-1.85)	(-2.08)	(-2.40)	(-1.85)	(0.02)
Education level 6	-0.154**	-0.227**	-0.109	-0.193*	-0.229**	-0.043
	(-2.23)	(-2.48)	(-1.23)	(-1.93)	(-2.19)	(-0.36)
Education level 7	-0.106	0.013	-0.202*	-0.157	-0.173	0.090
	(-1.45)	(0.14)	(-1.80)	(-1.31)	(-1.56)	(0.64)
Elevation (m)	-0.548	-1.038	-0.162	-0.516	0.101	-1.556
	(-0.96)	(-1.44)	(-0.24)	(-0.62)	(0.13)	(-1.60)
Average Ann.	-0.014	-0.083	0.043	-0.124	0.183	-0.131
Temp (^{o}C)	(-0.14)	(-0.63)	(0.39)	(-0.92)	(1.33)	(-0.73)
Standard Dev. Average	-0.420***	-0.456***	-0.367**	-0.407**	-0.397*	-0.357
Ann. Temp. (^{o}C)	(-2.85)	(-2.65)	(-2.18)	(-2.06)	(-1.92)	(-1.58)
Average Ann.	-0.047**	-0.046*	-0.049**	-0.053**	-0.032	-0.065*
Rel. Hum. (%	(-2.59)	(-1.92)	(-2.33)	(-1.99)	(-1.16)	(-1.97)
Standard Dev. Average	0.009	0.028	-0.008	0.058	-0.028	-0.006
Ann. Rel. Hum. (%)	(0.31)	(0.77)	(-0.24)	(1.41)	(-0.72)	(-0.13)
Average Ann.	0.036***	0.037**	0.035**	0.028	0.041**	0.040
% Sunshine (%)	(2.62)	(2.23)	(2.10)	(1.39)	(2.05)	(1.59)
Standard Dev. Average	0.002	0.007	-0.008	-0.051	0.057	-0.006
Ann. Sunshine (%)	(0.10)	(0.22)	(-0.27)	(-1.26)	(1.57)	(-0.14)

Average Annual	-0.126	-0.063	-0.184*	-0.151	-0.113	-0.074
Wind Speed (km/hr)	(-1.42)	(-0.56)	(-1.87)	(-1.01)	(-1.17)	(-0.57)
Standard Dev. Average	0.313	-0.050	0.698	0.405	-0.139	0.777
Ann. Wind Speed (km/hr)	(0.91)	(-0.11)	(1.63)	(0.75)	(-0.31)	(1.27)
Total Rain Days	0.004	0.009**	0.0009	-0.003	0.008	0.009
	(1.21)	(2.24)	(0.30)	(-0.68)	(1.60)	(1.26)
Standard Deviation	-0.227***	-0.264***	-0.193**	-0.188*	-0.217*	-0.243*
Total Rain Days	(-3.25)	(-3.10)	(-2.32)	(-1.71)	(-1.90)	(-1.91)
Total Frost Days	0.004	0.006	0.002	-0.005	0.014**	0.003
	(0.98)	(1.26)	(0.34)	(-0.86)	(2.45)	(0.51)
Standard Deviation	0.008	0.024	0.004	0.067	-0.105*	0.053
Total Frost Days	(0.24)	(0.50)	(0.09)	(1.25)	(-1.77)	(0.82)
Total Precipitation (mm)	-0.00008	-0.0004	0.0001	0.002	-0.0002	-0.0001
	(-0.42)	(-1.60)	(0.52)	(0.50)	(-0.52)	(-0.31)
Standard Deviation	0.0001	0.007	-0.005	0.0003	-0.0002	0.003
Total Precip (mm)	(0.03)	(0.90)	(-0.76)	(0.04)	(-0.52)	(0.32)
Constant	0.028	3.407	-2.406	4.881	-1.512	-0.410
	(0.01)	(0.61)	(-0.47)	(0.81)	(-0.25)	(-0.05)
Country Dummies?	YES	YES	YES	YES	YES	YES
N	17923	8365	9558	6070	5946	5907
R^2	0.2218	0.2348	0.2179	0.19	0.26	0.24

*Source: See text. *** means significant at the one per cent level of confidence, ** means significant at the five per cent level of confidence and * means significant at the ten per cent level of confidence.*

CHAPTER 4

HOUSEHOLD AND CLIMATE EQUIVALENCE SCALES USING THE INCOME EVALUATION QUESTION TECHNIQUE

4.1 Introduction

The purpose of this chapter is to use the 'income evaluation question' to generate household and climate equivalence scales for Croatia. More precisely, this technique involves asking a representative sample of households about the minimum income necessary for a household in identical circumstances to achieve a verbally defined level of welfare e.g. 'a comfortable standard of living'. This follows a subjective approach to estimate equivalence scales developed originally by Van Praag (1968) and later contributions including Van Praag and Van der Sar (1988). Reported minimum income levels are then correlated with variables describing the demographic composition of the household, distance to environmental amenities and climate in the location of the household e.g. the number of frost days and hours of sunshine. This method offers an alternative way of performing environmental valuation.

The vast majority of the subjective equivalence scales literature has sought to explain the financial compensation required to maintain a constant level of welfare when household composition changes. Early empirical studies such as Van Praag (1971) and Van Praag and Kapteyn (1973) consider simply the size of the family. Subsequent research investigates how costs differ when accounting for the gender and age of the head of household using dummy variables (e.g. Danziger et al, 1984). However, there is a devoid in the current literature of empirical evidence for the financial cost of specific household compositions. The first aim of this chapter is to test empirically these intricate relationships.

Existing applications of the technique (Van Praag, 1988 and Frijters and Van Praag, 1998) have considered the climate but largely because of shortcomings in the spatial resolution of the data, apparent lack of correction for the adiabatic lapse rate and sometimes questionable specification of the climate variables are best described as exploratory in nature.[78] The second aim of this chapter is to conduct a robust empirical investigation of the role of climate on household costs.

The final objective of this chapter is to unite the separate empirical investigation on household and climate equivalence scales by testing whether particular types of household are more sensitive to certain climatic conditions. The purpose is to answer the question whether households with specific demographic features need to be financially compensated different monetary amounts for inhabiting less amenable climates. Some households may be capable of adapting to climate change by changing their composition. This has been overlooked as a possible adaptation to climate change.

This reflects an innovative new approach to analyse distributional impacts of the climate and is the key contribution of this Chapter. Climate change is likely to affect households in

[78] The adiabatic lapse rate is the rate at which temperature decreases with a fall in atmospheric pressure as altitude increases. The adiabatic lapse rate can be dry or saturated depening on the water content of the air (Calow, 1998)

different ways. Households with certain socioeconomic features may be more vulnerable to the climate they inhabit than ours.

It is important to understand whether particular households are more or less vulnerable to changes in climate, particularly given the ageing nature of many developed countries.[79] This could dictate how public money is redistributed to aid the most vulnerable. To our knowledge there exists no other research that analyses this link between household composition and climate.

A range of other more familiar environmental valuation techniques have also been used to estimate the amenity value of climate. These include the hedonic technique (Englin, 1996, Mendelsohn, 2001, Maddison and Bigano, 2003 and Rehdanz and Maddison, 2009), a technique based on the observed choices of migrants (Cragg and Kahn, 1997), analyses of subjective well-being (Rehdanz and Maddison, 2005) and the household production function technique (Maddison, 2001 and Maddison, 2003).[80]

These studies uniformly suggest that households have strong preferences for particular sorts of climate.[81] Despite this, however, the methodologies upon which they are based depend on potentially invalid assumptions. The hedonic technique for example, assumes that households

[79] Whilst Chapter 2 of this thesis focused its attention on the possible benefits of climate of retired migrants, the approach taken here identifies whether particular types of households (e.g. ageing ones) face differing costs to maintain a constant level of welfare in the same climatic conditions.

[80] The role of climate variables in generating determining cost of living differences for households is best explained by the household production function theory of Becker (1965) and from which the household production function valuation technique acquires its name.

[81] Such results are hardly surprising. 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 many households.

are able to relocate without cost in order to eliminate utility differentials.[82] The household production function approach requires restrictions on preferences, the validity of which cannot be tested. These restrictions are often referred to as 'demand dependency'.[83] Some studies also encounter empirical obstacles. Spatially disaggregated data on household SWB for example requires making assumptions about the monotonic transformation that occurs as true utility is placed on a bounded integer scale. These potential shortcomings suggest using the income evaluation technique, not because it does not have limitations of its own, but rather because it has different shortcomings and data requirements.

The underlying stimulus for this and earlier research looking at the amenity value of climate are ongoing attempts to monetise the impacts of climate change as an input to analyses aiming to assess the benefits and costs of measures to limit the emissions of GHGs such as Stern et al (2007).[84] These reasons have already been discussed in the previous chapters of this thesis are not repeated here.

This chapter analyses empirically the income evaluation question using data from a cross-sectional household survey of Croatia. Both the regional economic disparity and diverse climate of Croatia make it appealing country to study. The motivation for studying Croatia is twofold. Firstly, it offers the opportunity to explore the importance of household composition in cost of living. The estimation of household equivalence scales has long been the focus of academic research. It is possible to estimate the cost of adding additional individuals to a

[82] The hedonic technique would be unlikely to succeed in the Croatian context. In Croatia up to 7,000 refugees remain internally displaced by the 1992-1995 conflict and border disputes still exist with Slovenia and Bosnia Herzegovina.

[83] See Bradford and Hildebrand (1977) for details.

[84] At the expense of stating the obvious, changes in household amenity values are not the only impacts of climate change. This includes anthropogenic emissions of greenhouse gases and resulting rise in global temperatures, sea level rise and the loss of low lying coastal areas and impacts on agricultural productivity to name a few.

defined reference household. We are able to differentiate between the age and gender of these household members. Secondly, the high spatial detail of the survey allows us to obtain accurate measures of the climate that individual households inhabit. Long-term averages of climate variables are mapped to the geographical location of households. This provides a total of 365 climatically different locations.

The remainder of the chapter is structured as follows. Section two provides a brief overview of the volatile recent history of Croatia. Section three considers the theoretical underpinnings of the income evaluation technique and compares them to the more conventional approach to calculating household equivalence scales. Section four conducts a review of the empirical literature with respect to the traditional and subjective approaches to estimating equivalence scales. Section five provides the empirical methodology and section six describes the data for the present exercise. Sections seven and eight present the empirical analysis and discussion of household and climate equivalence scales respectively. Section nine empirically tests the relationship between household and climate equivalence scales and the section ten concludes.

4.2 A brief history of Croatia

Croatia has endured an unsettled history since its declaration as an independent state from the former republic of Yugoslavia on 25th June 1991. Officially independence is celebrated on the 8th October of the same year. What followed was a 4 year war of independence between Croat and entrenched Serbian armies on the present day border territories in North East and South Croatia. However, since the end of conflict, GDP has almost tripled from $22.05bn in 1995 to $60.85bn in 2011, not adjusting for inflation (World Bank, 2011). The most successful sector in Croatia's recent history has been tourism. According to EUROSTAT almost 1.5 million tourists spent at least 4 nights in "collective or private accommodation". Whilst inflation remains stable, at 1.1% for 2010, unemployment rates remain high at 21.92% (CIA World Factbook).

Despite Croatia's rapid economic growth since 1995, there remains a large degree of regional disparity in development. Croatia consists of 20 administrative regions, of which the capital Zagreb can be divided into two, the city area and the surrounding country. Figure 4.1 provides a colour coded map of Croatia.

Figure 4.1 Regional map of Croatia

Labour demand is only strong in a small number of regions, such as Zagreb, with excess labour supply in most regions (UNDP Human Development Report: Croatia, 2006). The majority of seasonal tourist trade is to regions located by the Adriatic Coast. Regional GDP as of 2008 shows a discrepancy of 19,100€ for Zagreb and as little as 6,000€ in Brodsko-posavska (EUROSTAT).

Regional disparity makes it very difficult to assume a unified market across Croatia. A huge proportion of homeowners in Croatia own a property without any form of mortgage or loan. This ranges from 57% is Primorje-Gorski kotar to 94% in Krapina-Zagorje (UNDP, 2007).

There is also a substantial proportion of accommodation for which the occupying households do not pay any rent. These values are highest in regions most affected by war (UNDP, 2007). Individual responses to the income evaluation question (henceforth IEQ) are able to capture the specific circumstances of each household. It is likely that household composition will play an important role in determining level of income needed to reach a particular level of welfare.

Another key regional disparity is the climate. Despite its relatively small size Croatia possesses a diverse climate due to its peculiar shape and topographic features. In the north and east are the Pannonian plains; fertile lowlands with a continental climate of cold winters and hot summers. Central Croatia consists of the mountainous Dinara region rising up to 1,800m. These mountains are covered with large forests and possess a climate broadly similar to that of the Alps. The Adriatic coast by contrast, enjoys a Mediterranean-type climate of warm, rainy winters and hot, dry summers. This region includes that part of Croatia best known and most visited by tourists namely the Dalmatian coast and the islands. A topographic map of Croatia is displayed in Appendix C.1.

4.3 Theoretical framework

We begin with the textbook approach to calculating household cost of living indices e.g. Deaton and Muellbauer (1980).[85] This involves assuming a household cost function

$$y=c(u,p,z) \qquad \textbf{(4.1)}$$

[85] Most of the literature is concerned with calculating cost differences for households with a different demographic composition. However, the procedures used to incorporate environmental variables into systems of demand equations are typically borrowed direct from the literature (Smith, 1991).

where y is income, u is utility, p is a vector of prices, and z is a vector of demographic – and environmental – characteristics. Inverting the household cost function results in the formulation of an indirect utility function such that:

$$u=v(p,y,z) \qquad \textbf{(4.2)}$$

Applying Roy's theorem results in a system of demand equations which can be estimated econometrically on a vector of Marshallian commodity demands:

$$x=d(p,y,z) \qquad \textbf{(4.3)}$$

The household equivalence scale is the ratio of household costs to some reference household:

$$m=c(u,p,z)/c(u,p,z^R) \qquad \textbf{(4.4)}$$

where z^R is some reference household. The compensating variation (CV) is implicitly defined by:

$$v(p,y,z) = v(p,y\text{-}CV,z^R). \qquad \textbf{(4.5)}$$

If the equivalence scale is independent of a base level of utility level then we have a generalised equivalence scale which can be written as:

$$m(p,z,z^R) \quad \textbf{(4.6)}$$

This requires the estimated household equivalence scale ratios to hold for all levels of utility. Hence, the cost of household characteristics is only determined by *p* and *z* (Lewbel, 1989).

The alternative approach presented in this chapter assumes that the minimum income necessary to reach a verbally specified level of utility $i=\{1,\ldots,k\}$ is given as:

$$y_i=c_i(p,z) \quad \textbf{(4.7)}$$

The household equivalence scale is therefore:

$$m_i=c_i(p,z)/c_i(p,z^R) \quad \textbf{(4.8)}$$

The CV at utility level *i* is defined as

$$CV_i=c_i(p,z)-c_i(p,z^R) \quad \textbf{(4.9)}$$

In the same manner as the traditional approach, if the equivalence scale is independent of the base level of utility then we have a general equivalence scale

$$m(p,z,z^R) \quad \textbf{(4.10)}$$

The first approach requires that all parameters of the cost function can be obtained from econometric estimation of the Marshallian demand functions. This requires the imposition of untestable restrictions on preferences (Bradford and Hildebrand, 1977). The alternative approach assumes that individuals react to identical verbal descriptions in the same way. Formally, this can be written as:

$$u_i = y_{in} \quad \textbf{(4.11)}$$

where y_{in} is the income necessary to reach utility level i for household n. Both approaches require interpersonal comparisons for a given level of utility i.

The choice of approach to adopt then falls onto which assumptions are likely to be least restrictive and be most acceptable given the context of our study. Samuelson (1954) outlines using private goods to observe public good value. Demand dependency requires us to assume there exists a price vector of an observable private good at which the value of the public good turns to zero (Bradford and Hildebrand (1977). This seems a plausible assumption if we can imagine a particular private good which acts as a complement to the public good.[86] This is harder to believe with respect to climate variables where one can imagine it partially

[86] Bradford and Hildebrand (1977) give such examples as the complementarity of public highways and transport and publicly broadcasted television and television sets.

complements service flows, such as the demand for heating or cooling and temperature. It would assume that if the cost of, say, air conditioning was zero then we would not care about the searing heat outside.

It can also be argued that demand dependency may be a restrictive assumption when considering demographic changes to the household. This requires observing differences in expenditure of private goods for various household compositions. By logic if the price of a common observed good, such as food, was to fall to zero then households would not care about the size of the family. Pollak and Wales (1979) argue that demand analysis cannot be used to make welfare comparisons for families with different demographic characteristics. This is because it is able to value only the impact of additional children on expenditure ('conditional' preferences) and ignores the well-being effect associated with having children ('unconditional' preferences).

To illustrate further the alternative approach suppose that the utility level i corresponds to a 'comfortable' standard of living. The associated minimum income level y_i is obtained by asking a sample of $n=\{1,\ldots,n\}$ respondents the IEQ: "What is the minimum monthly after tax income necessary for a family like yours to achieve a comfortable standard of living?" The determinants of y_i can then be analysed as follows:

$$y_{in} = \alpha_i + \sum_{j=1}^{j=m} \beta_{ij} p_{jn} + \sum_{k=1}^{k=m} \gamma_{ik} z_{kn} + \varepsilon_n \qquad \textbf{(4.12)}$$

Where α_i, β_{ij} and γ_{ik} are parameters to be estimated and ε_n is an idiosyncratic error term. Different utility levels e.g. 'just able to get by' or 'very comfortable indeed' result in separate but not unrelated regression equations that may be linked through the error term. Note that the technique admits the possibility that house prices, p^h, are a function of environmental characteristics, z^e. In situations where hedonic markets operate it will be important to control for variations in the price of property. For the case of Croatia there are reasons to believe that there is not a fully capitalised housing market. This is discussed later in the Chapter. Except in data possessing a times series component other elements of p will not generally vary and the β_{ij} parameters will become subsumed into the constant term.

4.4 Literature review

4.4.1 Household cost of living: a traditional approach

Interest in equivalence scales, determining how expenditure for particular observable goods changes with income, is first attributed to Engel (1895). He observed that households with lower incomes spend a larger proportion of their total income on food expenditure than high income households. A similar trend was also identified for the effect of household size on food expenditure. In its simplest possible format we can consider two households of different sizes which allocate exactly the same proportion of income on food expenditure. If households 1 and 2 have incomes of y_1, y_2 and household size h_1, h_2 respectively, where $y_2>y_1$ and $h_2>h_1$, then it follows that the difference in household size $h_2 - h_1$ is being accounted for by the additional income household 2 earns ($y_2 - y_1$). Given both households spend the same proportion of income on food the resulting equivalence scale is simply y_2/y_1.

This provides a basic claim that household welfare is based upon the quantity of a particular commodity bought e.g. bread, which is constrained by income and the composition of the household. It is clear that a larger household requires more bread in order to maintain a constant level of welfare to a smaller household and requires a relatively higher income to finance this need. Naturally the equivalence scale is going to vary according to the observed commodity in question. However, due to comparisons being made across different households it is required to assume that the observable behaviour of these households identically reflects their welfare position (Deaton and Muellbauer, 1980). Correspondingly, households with the same demographic composition and income must have identical welfare levels. All households are assumed to transform income into welfare in the same way.

The Engel approach can be derived algebraically as follows. The cost function of household h is given by:

$$c(u, p, z) = c^h (u^h, p, z^h). \qquad \textbf{(4.13)}$$

In this context, p reflects the price of a composite food product which is some proportion of total costs. Total quantity (q) consumed by each household is dependent on z. The reference household is represented by superscript r:

$$c^r (u^r, p, z^r). \qquad \textbf{(4.14)}$$

Let these two cost functions be denoted c^h and c^r respectively. Given p and q consumed by each household, u is constant at the point where the budget share on food as a percentage of total income is equal.

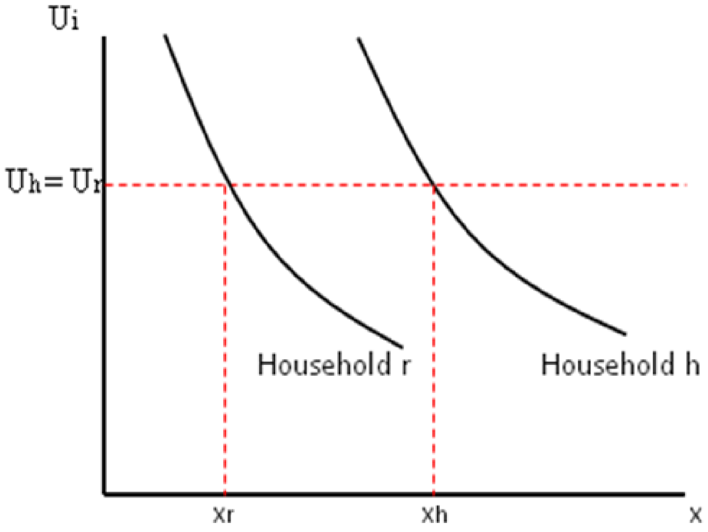
$$u^h = u^r = pq^h/c^h = pq^r/c^r \quad \textbf{(4.15)}$$

The theoretical underpinnings of the Engel approach have developed by allowing various household compositions to have separate effects on the equivalence scales of specific commodities (see Deaton and Muellbauer, 1980). Given welfare/ utility is determined only by observable expenditure, the cost function of household h can be separated into two:

$$c^h\ (u^h, p, z^h) = m(u^h, z^h)c(u^h, p) = x^h \quad \textbf{(4.16)}$$

where *m(.)* captures expenditure requirements based on the demographic composition of the household and *c(.)* actual costs. These Engel curves are illustrated in Figure 4.2 below.

Figure 4.2 Illustration of Engel's approach



Household composition is an important aspect to consider as it is possible to calculate families' needs from a welfare state perspective, such as defining poverty and the scale of benefits payment. This provides solutions to such questions as the extra income required to support an additional dependent in a household to maintain a constant level of welfare.

There is a belief that the number and gender of adults and their children may alter the consumption of particular commodities in different ways (e.g. see Brown and Deaton, 1972). Brown (1954) analyses the varying effects of different households on their consumption of food and nutritional intakes. He finds evidence that different household compositions are relatively homogenous in the way they react to changes in income on their food purchases. Households are grouped into 16 categories according to demographic composition. Income elasticity of food consumption is estimated for each group and exhibit little variation. This is an important finding because it implies that the behaviour of different types of household can be captured in a single behaviouristic model.

Barten (1964) hypothesised that for utility to remain constant for households of varying composition, the relative quantities of all goods consumed must change as a consequence. This emphasises that changes in household composition, for example in number of male and female adults and children, affects the demand and therefore relative price that household pays for specific commodities. In short, it requires the original Engel approach to account for a specific set of commodities which have independent equivalence scales rather than assume a composite good.

The direct utility function under the Engel approach is given by

$$u = v(q^h/m(z^h)) \quad \textbf{(4.16)}$$

where m is the equivalence scale to maintain constant welfare to the reference household. Under the Barten approach, there is a set of commodities q_i with individual equivalence scales m_i. The corresponding direct utility function now becomes:

$$u = v\left(\frac{q_1^h}{m_1(z^h)}, \frac{q_2^h}{m_2(z^h)}, \ldots, \frac{q_n^h}{m_n(z^h)}\right) \quad \textbf{(4.17)}$$

A limitation of the Barten model is caused by the presence of children increasing the variety of goods consumed. The model is constrained to the expenditure patterns of the reference household (a childless couple) and cannot explicitly capture goods which are only demanded by couples with children (Deaton and Muellbauer, 1986). This could be goods such as baby food, toys or nappies. Gorman (1976) modifies the Barten model by introducing fixed costs of children into the cost function for particular household characteristics.

Muellbauer (1977) tests empirically the Barten (1964) hypothesis that household composition determines relative price which then generates individual equivalence scales for each commodity. Ten separate commodity groups are analysed including food, fuel, clothing, alcohol and tobacco. It is found that following the Barten hypothesis leads to unexpectedly low equivalence scales when accounting for additional children. Muellbauer (1977) investigates further by disaggregating additional children further by dividing them into two categories; younger children (under 5) and older children (5-16). Whilst older children impose a relatively higher cost on household's than younger children, both types still appear to have a relatively small effect in absolute terms. This predominantly leads Muellbauer (1977) to suggest a rejection of the Barten model as means to capture changes in the relative prices of goods in equivalence scales.

Another theoretical model offering a method to calculate household equivalence scales is Rothbarth (1943). He estimates the cost of additional children to adult households by observing changes in household expenditure of particular adult goods. Typically, adult goods would include commodities such as tobacco, alcohol and adult clothing. An underlying assumption of the model is of 'separability' which requires adults to have a utility function not influenced by their own children's consumption. Deaton et al (1989) describe that separability holds if children are defined as an additional demographic and their presence only detracts from consuming adult goods through an income effect. Then cost function of the household can be given as:

$$c(u,p,z) = c_a(u,p_g,z_a) + c_b(u,p_g^*,z_b) \quad \textbf{(4.18)}$$

The subscript *a* accounts only for adults whilst *b* includes both adults and additional children. Subscript p_g denotes prices for a specific adult good *g*, for example alcohol, and p_g^* is a vector of prices for all other (non-adult) goods. Thus, c_a gives the cost function for the adult only good, dependent on utility, the price of g and the number of adults. The second cost function c_b therefore captures expenditure on all non-adult goods which are demanded by all household members.

This theoretical model allows a direct comparison of childless couples to with-child ones, provided that expenditure on adult goods is only constrained by income. Empirically, the welfare change of having children on adult couples is estimated by observing household expenditure on adult goods (see, for example, Deaton and Muellbauer, 1986 and Nelson, 1992). It is assumed that welfare is constant at the point where households of varying size spend equal proportions of their income on these adult goods.

Deaton and Muellbauer (1986) test empirically the Engel, Rothbarth and a Gorman version of the Barten models for measuring the cost of additional children on households. Anecdotally, they find that the Engel model appears to overestimate significantly the cost of additional children, a finding they explain by the failure of food expenditure to proxy appropriately for welfare. Conversely, Deaton and Muellbauer (1986) believe the Rothbarth model to underestimate the costs of children may be due to the 'Barten-type' effect that having children will make adult goods cheaper for households with children relative to the non-adult goods.

Finally a Gorman-Barten model is introduced and found to exhibit results in between the Engel and Rothbarth models by avoiding their respective over and underestimation issues.

Lancaster and Ray (1998) estimate the sensitivity of household equivalence scales using the Engel and Rothbarth approaches for Australian expenditure survey data. They question the dependence of empirical estimations on the various classifications that exist for household expenditure. The purpose is to determine whether estimates of household equivalence scales are sensitive to the observed commodities bundles selected. Household equivalence scales using the Engel approach are compared using food including and excluding expenditure on takeaways. Equivalence scales are found to be higher for every household composition when takeaways are excluded. Greater sensitivity is found when classifying adult goods under the Rothbarth approach. For example, when defining an adult good as eating out, a household with 2 adults and 3 children need only 17.5% additional income to be equally as well off as a 2 adult household. This increases to 100% when the adult good is changed to expenditure on alcohol outside the home and falls by 30% for expenditure on tobacco. Poor households expenditure on the set of adult goods are also found to be most sensitive to changes in household composition.

The previous literature is all based on the assumption that welfare can be definitively estimated through demand analysis of observed consumption patterns of households with different compositions. However, the theoretical underpinnings of such an approach have been rejected by Pollak and Wales (1979) who assert that the demand analysis approach fails to account for the unconditional welfare effects of additional children; it is only conditional on the financial needs to allow for the necessary consumption changes.

This is a key limitation of the aforementioned theoretical models. Children are seemingly delivered by storks in the night and only determine utility by altering observable expenditure. Pragmatism demands that observable expenditure should only play one part of a representative welfare function.

The unconditional welfare effect of children, or additional household members, is not the only variable ignored under the traditional approach to equivalence scales. There exist public goods which are a function of utility but cannot be bought or sold in an observable marketplace. The climate is a fundamental public good. Of course climate may determine households observed expenditure on goods. Maddison (2001, 2003) estimates the value of climate whilst subscribing to the assumptions required for demand analysis. However, this is conditional on the observed expenditure of households fully capturing the value of climate. It ignores any pure welfare effect of the amenity value of the climate. Furthermore, Maddison (2001;2003) ignores differences in demographic composition and analyse only per capita expenditures which could be potentially misleading.

4.4.2 Household cost of living: a subjective approach

The theoretical foundations of the subjective approach to equivalence scales analysis are contained in the doctoral thesis of Van Praag (1968). Subsequent research has led to this approach to be coined as the ‘Leyden Individual Welfare Function of Income’ (LIWFI) or more simply the ‘Welfare Function of Income’. Rather than assuming the observable behaviour of households identically reflects welfare, like the traditional methodology of the previous section, the subjective approach directly asks survey respondents to state a minimum income they require to reach a set of verbally defined levels of welfare. Individually, we call these IEQs.

This subsection is structured to demonstrate how the subjective approach to household equivalence scales has developed in three different ways. Firstly, the original LIWFI approach requires multiple verbal welfare responses and assumes they reflect equidistant points on a uniformly distributed utility scale. A second method only requires a single verbal welfare response referring to a specific level of utility. Finally, a slightly different approach employs subjective well-being (SWB) as an alternative to the IEQs.

4.4.2.1 The LIWFI approach

For the purpose of a visual example a set of IEQs, used to estimate the LIWFI, is given in Figure 4.3.

Figure 4.3 Example of LIWFI survey question

Taking into account your own situation with respect to family and job you would call your annual net income (including fringe benefits and subtraction of social security premiums)

Excellent	if it were above	……..
Good	if it were between	…….. and ……..
Amply sufficient	if it were between	…….. and ……..
Sufficient	if it were between	…….. and ……..
Barely sufficient	if it were between	…….. and ……..
Insufficient	if it were between	…….. and ……..
Very insufficient	if it were between	…….. and ……..
Bad	if it were between	…….. and ……..
Very bad	if it were below	……..

Source: adapted from Van Praag and Kapteyn (1973)

Van Praag (1971) was the first empirically to test survey data including a set of IEQs for a study in Belgium. Subsequent empirical research has also been conducted using Dutch data (Van Praag and Kapteyn, 1973). The underlying method is that individual respondents are asked to provide a number of welfare evaluations of income levels across a hypothetical distribution [*a*,*b*] scale. The value *a* corresponds to the worst possible welfare position and *b* the best possible welfare position and replicates a hypothetical uniform distribution. This allows for discrete number of responses in the $\Re^{+}$ space, i.e. between 0 and ∞. Thus respondents provide a set of income ranges for a number of welfare points which lie between *a* and *b* e.g. from 'very bad' to 'excellent'. In practical terms the hypothetical distribution scale is a [0,1] uniform distribution. An assumption of cardinal utility is inherently assumed to reflect the multiple welfare levels across the hypothetical distribution scale. This requires survey responses of each IEQ to represent fixed and equidistant welfare positions along the [0,1] scale.

It is clear that the complexity of the individual welfare function presented some difficulty to respondents leading to partial completed scales to be included. Van Praag (1971) divides households into sub-categories dependent on a number of characteristics including primary language (French or Flemish/Dutch) and various employment, housing and residence groups.

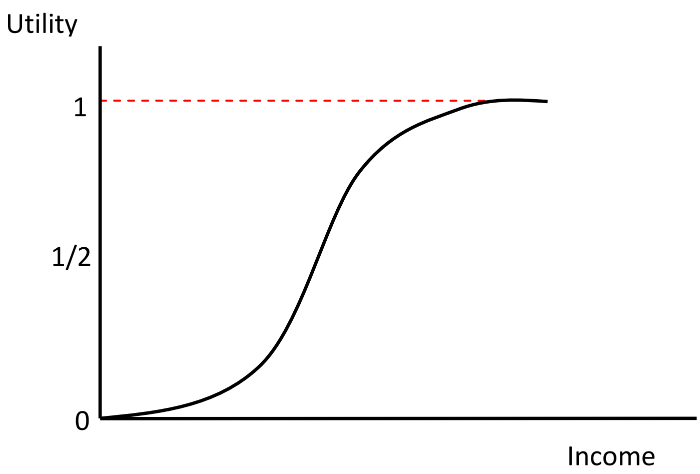
A log-normal distribution function is assumed:

$$\Lambda(y;\mu,\sigma^{2}) \qquad \textbf{(4.19)}$$

Here μ is the mean of the lognormal distribution and is taken as the mid-point of the constructed [0,1] uniform distribution scale, i.e. 0.5. The larger the value of μ the higher income required for a respondent to evaluate their welfare level at 0.5. The standard deviation of lognormal distribution, σ, captures the slopes of the self-reported individual welfare functions and has been coined welfare sensitivity. Responses to the IEQs which span a wide income range exhibit a large σ.

The values of μ and σ can be directly estimated and taken to illustrate the LIWFI across the uniform distribution function. The typical finding is an S-shaped function shown in Figure 4.3 (e.g see Van Praag, 1971):

Figure 4.4 The welfare function of income



This forms the basis for which a set of simple regressions are computed, by sub-category, to estimate the impact of family size (*fs*) and current annual household income (*y*) on the estimated σ and μ and income welfare function as follows

$$\sigma = \beta_1 + \beta_2 \ln(fs) + \beta_3 \ln(y) + \varepsilon \tag{4.20}$$

$$\mu = \beta_1 + \beta_2 \ln(fs) + \beta_3 \ln(y) + \varepsilon \tag{4.21}$$

Where β_1 is the intercept and β_2, β_3 are elasticity parameters to be determined and ε *is* a random error term with zero expectation. The first and second equations estimate the role of logged family size and logged household income on the slope and intercept of the welfare function respectively[87]. Accordingly, constant β_1 captures a 'frame of reference' effect capturing the heterogeneity of individual household's welfare functions.

A positive β_2 is a 'family elasticity' and means a larger family requires greater compensation, but at a decreasing rate, to maintain a constant welfare level. Although, dditional family members increase the requirements of a household's income, there appears to be an economy of scale effect. A fourth addition to the family will continue to increase the income required to maintain constant welfare but to a lesser extent than the third member.

The role of β_3 is to test whether a household's income welfare function is partially determined by the size of their actual income. This captures a 'preference drift' effect where a positive β_3 signifies that as household income rises there is an increasing but diminishing effect on the impact on welfare. When a household's income level rises so do perceptions on what they consider, for example, to be a 'satisfactory' or 'good' income level. This provides evidence of the adaptive capabilities of households to adjust expectations when their income changes.

[87] The theoretical underpinnings of the LIWFI is assumed to take a log-normal distribution function. See Van Praag (1968) for the complete theoretical framework.

Van Praag (1971) and Van Praag and Kapteyn (1973) discover that whilst personal circumstances, based on various household characteristics, have a marked effect on β_2 and β_3 with respect to μ, when regressed against σ there is no statistically significant correlation. This implies that whilst family size and household income has no effect on the slope of the welfare function it does effect the intercept; the baseline welfare level. Positive and statistically significant coefficients reveal that increases in family size and income are more elastic and reduce its relative importance in the welfare function.

Kapteyn and Van Praag (1976) investigate the importance of particular family compositions on the welfare function. They use the same Dutch dataset as Van Praag and Kapteyn (1973) but restrict the observations to married couples and specifically consider the effect children have on income welfare and whether their age(s) alter financial requirements. They find that additional children require financial compensation to maintain constant welfare. However, there is no attributable evidence that as children get older so does the financial burden to the household. However, this effect could be being cancelled out by their parents' incomes rising over time.

The empirical application of the LIWFI approach has received criticism. Wierenga (1978) tests the lognormal distribution of the welfare function of income using random computer simulations of monotonically increasing responses to the IEQs. He finds evidence that a lognormal distribution fits the simulated data as well as the real survey data.. The implication of this is that survey respondents could provide random increasing responses to the IEQs within their reference income and with little impact on the empirical findings. Furthermore, Wierenga (1978) finds that restricting the random simulations to income changes of equal length for each welfare level further improves the goodness of fit. This undermines the specification of a log-normal distribution because increasing income intervals by a fixed amount should not lead to linear increases in utility.

Seidl (1994) criticises the theoretical approach of Van Praag (1968). The use of multiple welfare levels as a representative measure of utility scale requires potentially restrictive assumptions. The first assumes utility can be interpreted on bounded scale. The highest verbal welfare level (e.g. 'excellent' in Figure 2) reflects the top of the uniform distribution scale. Reported income at this level represents the very highest attainable utility level. Utility remains constant if reported income were to be any higher.

4.4.2.2 The ordinal approach to hypothetical equivalence scales

The cardinal measurement of utility employed in the Leyden School methodology is an assumption which has attracted criticism from economists, who are wary of making such untestable assumptions. Hartog (1988) summarises the cardinality assumption to require the verbally defined welfare levels represent equidistant welfare differences along the hypothetical distribution scale. These welfare differences must also characterize the common verbal response behaviour across all respondents.

The use of ordinal equivalence scales with the Leyden School methodology has been used in the study of poverty. Conceptually, emphasis shifts from multiple points on the welfare distribution scale to the income required to reach a verbal welfare point *i* on the IEQ.[88] The poverty line represents a specific reference point which can be estimated by a single IEQ welfare level without having to make a priori assumptions about cardinality.

Hagenaars (1986) comments that since poverty concerns the well-being of individuals it makes sense that the perception people have of their situation is important in deriving the poverty line. Goedhart et al (1977) analyse the individual IEQ question requiring the respondent to state the absolute minimum income a family in their circumstances could live on to make ends meet. This provides the reported value of what the respondent considers to be their family's poverty line, given their household characteristics. Those who evaluate their actual household income to also be their absolute minimum income then provide reference points for the poverty line.

Algebraically, this is the specific point on the income welfare equation, where respondents are required to state the minimum amount a family in exactly the same circumstances as their own needs to 'make ends meet'. Let us call this level $y_{\min}$.

$$y_{\min} = \beta_1 + \beta_2 \ln(fs) + \beta_3 \ln(y) \qquad \textbf{(4.21)}$$

The parameter β_3 in this case represents the income elasticity of the poverty line. A family can be considered exactly on the poverty line if they respond to the question with a minimum income exactly equal to their own household income level. Analogously, a family with

[88] It is this approach that we take in the empirical analysis in this Chapter, although not in reference to the poverty line

income level $y > y_{\min}$ consider themselves above the poverty line and those with $y_{\min} > y$ are below the poverty line. Therefore, the poverty line should be set at the point $y = y_{\min}$.

$$y_{\min} = \beta_1 + \beta_2 \ln(fs) + \beta_3 \ln(y_{\min}) \quad \textbf{(4.22)}$$

Rearranging gives:

$$y_{\min} = \frac{\beta_1 + \beta_2 \ln(fs)}{1 - \beta_3} \quad \textbf{(4.23)}$$

Clearly, an ordinal approach is unable to provide as much information about the relationship between household income levels and income welfare as a 5 or 11 point cardinal measure associated with the classic Leyden School methodology (Ferrer-i-Carbonell and Van Praag, 2001). However, the relative simplicity of 'make ends meet' question compared to the cardinal measure makes it a great deal easier for respondents to provide meaningful answers.

Goedhart et al (1977) then test this model empirically using Dutch survey data. They estimate the income elasticity of the poverty line to be 0.60 and a low family elasticity of 0.12. Estimated levels of the minimum income necessary for different household sizes are compared against the statutory minimum for the Netherlands and found to be consistently lower. This implies that the subsistence level (i.e. a perceived poverty line) that households require to survive is lower than is set by policymakers.

Further work in this area includes Van Praag et al (1980, 1982_a, 1982_b) and Hagenaars and Van Praag (1985) for Europe and Danziger (1984) for the US. The methodology is the same as Goedhart et al (1977). Van Praag et al (1980) consider a sample across the European Community from 1976. Although sample sizes within each country are rather low, there appears to be conspicuous differences in the perceived poverty line of different European countries. For example, the poverty line for a 4-person household varies from $2,736 (50% of average income) in the UK compared to $5,804 (44% of average income) in Denmark.

Van Praag et al (1982_a) compare the cardinal Leyden School methodology and an alternative food ratio poverty line measure for Dutch data. The food ratio measure is simply food consumption as a proportion of after-tax income. The same explanatory variables are regressed against both measures. For the Leyden school methodology multiple welfare levels between 0.4 and 0.6 on the uniform distribution scale are assumed. In both models family size increases the household income to match the poverty line. Interestingly, the family size elasticity is noticeably higher on the food ratio measure, which the authors believe to be a factor of substituting other expenditures towards food as a household increases in size.

Van Praag et al (1982_b) use a similar cross-sectional European dataset to Van Praag et al (1980), but from 1979 and use a slightly different set of countries. Further to the standard variables of household income and family size, variables such as respondent age, urbanisation, employment status and education are also controlled for. These provide an indication of the individual traits of households which has been ignored in earlier work. For example, living in an urban area increases the level of the poverty line, as does the breadwinner being in the highest education bracket. Poverty lines are estimated for individual

European countries. For a four person household France is estimated to have the highest poverty line, whilst the lowest belongs to Ireland. However, the within-country variations in the poverty line for different types of household are high.

Hagenaars and Van Praag (1985) use the same dataset as an empirical illustration to investigate the extent to which the poverty line is an absolute or relative income phenomenon. If it is absolute income then a country's poverty line will be determined by some factor of national income. If it is relative income then the poverty line is dependent on the individual characteristics of households and is explained by the preference drift effect.

Danziger et al (1984) estimate the poverty line for a U.S study. Estimating Equation 4.22 provides a lower income elasticity of the poverty line with 0.376 and a family elasticity of 0.351. Furthermore they expand the model by controlling for dummy variables on the age (<65, 65+) and gender of household heads. The subsistence level is lower if the household is either over 65 or female. The inclusion of these dummy variables reduces the family elasticity coefficient to 0.21 whilst there is little change in the income elasticity.

Moving away from the poverty literature, Van Praag and Van der Sar (1988) adopt an ordinal approach to the original LIWFI scale. They regress an econometric model to analyse the impact of household income and family size on the household cost function (c) to reach welfare level i for the same set of 8 European countries as Van Praag et al (1980). They also include some 1983 data from Boston, USA. The income welfare level i represents 6 survey responses to a 'very bad' income to a 'very good' income. These welfare levels are regressed individually following the ordinal approach to equivalence scales.

$$\ln(c_i) = \beta_{1i} + \beta_{2i} \ln(fs) + \beta_{3i} \ln(y) + \varepsilon_{in} \quad \textbf{(4.24)}$$

This provides an estimate for family size and household income elasticities for each welfare level which can be directly compared. There is a general trend in most countries that the coefficient of household income is increasing as verbal welfare level i increases. Once again, this purports the existence of the preference drift effect: a higher household income increases the income required to reach the verbally defined welfare level. There is also some evidence of the welfare impact of family size, with the lowest verbal welfare levels yielding higher coefficients than the highest verbal welfare levels. Van Praag and Van der Sar (1988) interpret this as the need for poorer families to focus expenditure on food and clothing, which are strongly related to family size.

Relying on a single IEQ, as opposed to the LIWFI approach, requires assumptions of its own. A single IEQ fixes the base level of utility for which households are compared. This requires the assumption that the financial costs of a set of household characteristics and other determinants of the cost of living are independent of the chosen base level of utility. If independence of base was not to hold then corresponding equivalence scales would only be consistent with the fixed level of utility and not for all utility levels (Lewbel, 1989). The obvious way to overcome this would be to analyse individually multiple welfare levels in the manner of Van Praag and Van der Sar (1988).

4.4.2.3 A SWB approach to hypothetical equivalence scales

A different approach uses data on SWB to estimate household equivalence scales. A SWB scale infers that the dependent variable is self-reported measure (such as life satisfaction, denoted *LS* below) given on an integer scale rather than requiring the respondent to provide specific monetary values to reach a verbally specified level of welfare.

$$LS = \beta_1 + \beta_2 \ln(fs) + \beta_3 \ln(y) + \varepsilon \qquad \textbf{(4.24)}$$

Rearranging with respect to y gives

$$y = e^\wedge((LS - \beta_1 + \beta_2 \ln(fs)) / \beta_3 + \varepsilon \qquad \textbf{(4.25)}$$

Compensatory income required for changes in family size can then be calculated to maintain a constant level of utility $LS = LS_i$.

Rojas (2007) uses this methodology for a study of Mexico. A measure of economic satisfaction is calculated by combining four economic domain satisfaction questions using principal component analysis. Household composition is disaggregated by identifying whether each family member is an adult, a teenager or child. Whilst it is found there is an economy of scale effect as family size increases, counter-intuitively additional children appear to place a higher economic burden on families than adults.[89] Household income is found to have the same effect as the Leyden School conclusions.

Rojas (2007) then compares SWB equivalence scales to two generic alternative welfare measurement scales and compares the resulting proportion of Mexican households considered to below the poverty line[90]. He finds the alternative scales substantially underestimate the economies of scale of family size compared to the subjective equivalence scale developed. Consequently, he concludes that the alternative approaches are more biased in estimating a household's relative position across Mexico's income distribution and therefore likely to overestimate the number of number of poverty stricken households. The subjective equivalence scale has the ability to adapt to a country's particular characteristics.

The SWB approach is able to choose the empirical specification. The well-being question can be assumed to follow a cardinal or ordinal process. The limitation of such approach assumes individuals are able to report their true level utility on any numbered integer scale. It also requires respondents to interpret the well-being question in exactly the same way. Individuals cannot apply their own monotonic transformation to report their true utility.

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[89] For example, the Oxford scale weights additional adults at 0.7 and non-adults at 0.5. Thus, adding one adult to a 2-adult house is estimated to increase households costs by 35%. Adding a non-adult only increases costs by 25%.

[90] The alternative equivalence scales are a per capita unit scale and the Oxford (or OECD) scale. The per capita unit assumes no economies of scale (i.e. a 2 adult household incurs twice the cost of a 1 adult household). The Oxford scale sets an economies of scale factor at 0.7 for adults and 0.5 for children, so a typical 2 adult, 2 child household will require an income 2.7 times higher than a 1 adult household. It is noted that a 'modified OECD' scale reduces these levels to 0.5 and 0.3 for adults and children respectively. A fourth recently developed scale is the 'Square Root' scale which estimates households need the household income of a 1 adult household multiplied by the square root of the household size in question (e.g. a household of size 4 requires twice the income of a household of size 1). See http://www.oecd.org/dataoecd/61/52/35411111.pdf for details.

4.4.3 Alternative applications of the IEQ

Most empirical applications of the IEQ technique involve estimating equivalence scales for households with different numbers of individuals. Such exercises complement approaches based on the econometric estimation of cost functions, or more traditional approaches based nutritional needs, the proportion of income spent on necessities or simple normative judgements. The additional focus of this chapter however, is the application of the IEQ technique to the task of uncovering the cost of living in different climates.

Only a small number of papers use a subjective approach to equivalence scales to analyse the effect of climate on household costs. Furthermore, these papers follow the cardinal approach to estimating equivalence scales as opposed to the ordinal approach.

Van Praag (1988) applies the IEQ to eight countries in Western Europe. Ninety different regions are identified and the climate of each is represented by annual averages for temperature, precipitation and humidity. Whilst the cardinal approach is adopted, they find little variation between the estimated climate coefficients and simply report a combined average of multiple verbal welfare levels. Warmer temperatures, greater precipitation and higher humidity are statistically significant at the one per cent level and all serve to reduce household costs. Humidity has the largest effect in absolute value although there is likely to be a degree of correlation between the three. A climate index is estimated for a set of 9 cities and regions. Northern European cities such as Berlin and Copenhagen have the least amenable climates, whilst Mediterranean locations such Sicily and Nice are more amenable. Perhaps surprisingly the most amenable climate is found to be St. Helier on the channel island of Jersey. This can only be explained by high levels of humidity and precipitation and could be a consequence annual averages being a rather limited measure of climate. Another criticism is that the climate variables are not corrected for differences in site elevation.

Frijters and Van Praag (1998) apply the IEQ technique to Russia. One hundred and thirty one different locations are identified and these are matched to 35 different climates on the basis of their geographical proximity. A greater breadth of climate variables are available compared to Van Praag (1988), with some seasonal effects controlled for (such as January and July or averages) as well as the inclusion of a number of interacted terms. It is unclear whether the climate data has been corrected for differences in elevation between the location and the weather monitoring station (although the regressions include a term measuring the average elevation of the region this is not the same thing). All climate variables are included in logarithmic form. The authors find that higher temperatures in January and lower temperatures in July both serve to reduce household costs. There is also financial burden of high January wind speeds. January temperature and January wind speed is interacted and found to be negative and statistically significant. This implies that falls in January temperatures serves to amplify the financial cost of high January wind speeds. The estimated coefficients are large, being approximately 4 for both January wind and July temperature.

Van Praag (1988) estimates climate equivalence scales relative to the climate of Paris and finds only moderate variations in responses to the IEQ. Whilst those in Berlin require an additional 11% in income relative to Paris, those in St. Helier require 13% less income. Frijters and Van Praag (1998) find the financial variation in climate costs evidently higher across Russia. Relative to the capital Moscow, those residing in Gurjew are estimated to require only half the necessary income to maintain a constant welfare. Dudinka, near the arctic circle requires over 5 times the necessary income.

Both papers employ data having poor spatial resolution and (seemingly) fail to correct for differences in the elevation of the weather station and average elevation of the region. The adiabatic lapse rate for temperature is defined by the International Civil Aviation Organisation to be approximately 6.49°C per 1,000 metres so this adjustment is potentially very important. Neither paper demonstrates that the estimated effect of climate variables on household living costs is geographically stable across sub-regions. Indeed, when Frijters and Van Praag (1998) compare the results for Russia with those for Western Europe taken from Van Praag (1988) substantial differences emerge.

Our empirical investigation will overcome these limitations in the quality of the climate data. Geographical coordinates of each household allows a much higher resolution of climate to be analysed.

We also follow a different methodological approach to Van Praag (1988) and Frijters and Van Praag (1998) by implementing an ordinal approach for a IEQ for a single verbally defined level of welfare. This is not least because the survey only asked respondents to provide the income necessary to reach a single welfare level. Nevertheless, the untestable assumption of cardinality is restrictive and the Leyden School methodology has received strong criticism for assuming welfare can be measured on a bounded scale (Seidl, 1994).

4.5 Methods to estimating the amenity value of the climate

The IEQ approach is a little used technique to estimates various cost of living factors. Its predominant use is to calculate household equivalence scales but it can also value non-marketed environmental amenities including climate. It is one of numerous climate valuation techniques that have received much greater attention in the academic literature. These include the hedonic pricing method, the household production function approach, migration based analysis and the LS approach. The theoretical underpinnings of these techniques have already been introduced in Chapter 2. In this Section, we discuss the limitations of their application in the case of Croatia and why the IEQ approach offers can be considered a suitable alternative.

The hedonic pricing method can be used to reveal the amenity value of the climate through a observable marketed good such as housing. It relies on the assumption that households are able to relocate without cost. Equilibrium is reached when utility differentials across regions are eliminated. For this condition to be satisfied households require perfect knowledge of the housing market. It is difficult to justify these assumptions in the case of Croatia.

Firstly, given the tumultuous recent history that has occurred across the administrative regions of Croatia it is difficult to imagine a housing market in equilibrium. Secondly, there are no studies that employ the hedonic technique in Croatia with respect to housing. The only hedonic technique research paper that we could find with respect to Croatia uses the personal computer market (Botric, 2004). Thirdly, the survey on which our empirical investigation is based attempted to ask households to estimate the price of a house of similar condition to their own. This question had to be dropped from the survey as respondents were unable to answer.

A number of studies do use the hedonic pricing method to estimate the amenity value of the climate in specific European countries. These include Italy (Maddison and Bigano, 2003), the UK (Srinivasan and Stewart, 2004), France (Cavailhes et al, 2008) and Germany (Rehdanz and Maddison, 2009). The key findings of these studies have already been discussed in

Chapter 3 and shall not be repeated here. Unlike with the hedonic technique it is straightforward to value discrete changes in the level of climate using the IEQ approach, and see how these values depend on household demographic characteristics.

Migration based analysis is a random utility model framework applied to migrants must choose between relocating between a set of substitute locations. Cragg and Kahn (1997) account for the climate as one determining factor. This model assumes that there are no migration costs and is also dependent on the availability of house price data. It also assumes migrants are of representative of society as a whole. The IEQ approach need not rely on a particular element of society

The SWB approach to the valuation of climate has found to be correlated with certain climate variables. This includes a positive relationship with January temperature (for example Rehdanz and Maddison, 2005; Brereton et al, 2008 and Ferreira and Moro, 2010) The Croatian survey used in this Chapter does include a self-reported LS question. However the size of the survey may limit the efficiency of the parameter estimates . Whilst some studies have relied on relatively small sample sizes (e.g. Brereton et al, 2008 and Ferreira and Moro, 2010), they employ Geographical Information Systems (GIS) to obtain a highly localised set of climate and other environmental variables.

The only studies that employ the household production function approach with respect to climate are Maddison (2001, 2003). This technique assumes the full amenity value of climate is a function of expenditure flows of observed marketed goods. Household expenditure patterns for certain goods may be determined to some extent by the climate they are exposed to. Maddison (2001, 2003) estimates the value of climate whilst subscribing to the assumptions required for demand analysis. However, this is conditional on the observed expenditure of households fully capturing the value of climate. It ignores any pure welfare effect of the amenity value of the climate. Furthermore, he ignores differences in demographic composition and analyses only per capita expenditures which could be potentially misleading. With the IEQ approach it is unnecessary to impose restrictions on preferences to ensure that all relevant parameters of the household cost function may be obtained from information on household expenditures

The IEQ approach to estimate the amenity value of the climate is not without its own limitations. It requires us to assume that all survey respondents interpret the IEQ in the same way. This is not a testable assumption. However, it is important to put this into the context of other possible valuation techniques and the availability of data. A lack of house price data rules out the hedonic technique and the number of observations limits the applicability of SWB with respect to climate. Compared to the household production function approach, it has the ability to capture unconditional climatic preferences and does not assume the only role played by climate is replacing the need for marketed commodities. It also removes the need to assume demand dependency, another untestable assumption. Last but certainly not least, the income evaluation technique is a good deal easier to explain to policy makers.

Furthermore, the IEQ offers the advantage that households are responding to a welfare question for a household in identical circumstances. This overcomes the clear issue of regional disparity in Croatia provided a household can relate to their own situation.

Furthermore it is able to capture the full amenity values of the climate. It is not restricted to estimating only variations in expenditure costs caused by the climate.

4.6 Methodology

The empirical strategy of this chapter is threefold. Firstly, we investigate responses to the IEQ for different types of households. We estimate household equivalence scales for a variety of demographic compositions and compare our findings to the previous literature. Secondly, we study the role of climate in determining responses to the IEQ. A set of climate variables are included in the empirical analysis. It is then possible to estimate climate equivalence scales and to determine where the differences of climate costs of living across Croatia. Finally, it is possible to analyse whether particular demographics of household are more susceptible to climate costs.

To estimate household equivalence scales it is necessary to regress a set of demographic variables against the IEQ. Taking y_{in} to represent household n's response to the IEQ for a specific utility level i, the regression is estimated as follows:

$$y_{in} = \alpha_i + \sum_{j=1}^{j=m} \beta_{ij} z_{jn} + \varepsilon_n \qquad \textbf{(4.26)}$$

Where α_i, and β_{ij} and are parameters to be estimated and ε_n is an idiosyncratic error term. In this case z corresponds to a set of specific set of household composition variables. In practice this could be a single component such as family size or a wide set of dummy variables capturing the specific numbers of adults and children.

Empirical work on household equivalence scales (e.g. Van Praag, 1971) also controls for a preference drift effect of income. This means households adapt to increasing incomes leading to a diminishing effect on welfare. It may therefore be important to control for actual income in the model.

$$y_{in} = \alpha_i + \sum_{j=1}^{j=m} \beta_{ij} z_{jn} + \gamma_i y_n + \varepsilon_n \quad \textbf{(4.27)}$$

Where y_n is actual household after tax income and γ_i is its parameter to be estimated. Note that household income and any categorical demographic variables could also be included in its logarithmic form.

The estimation of household equivalence scales itself depends on the manner in which household composition is incorporated into the empirical framework. A quantitative variable, such as family size, is calculated as follows:

$$y_i = \alpha + \beta fs_i + \varepsilon_i \quad \textbf{(4.28)}$$

Household equivalence scales can be estimated by comparing various compositions to a defined reference household. Typically the reference might be a single person household.
The household equivalence scale for a two person household is given as:

$$HES_i = \frac{\alpha + 2\beta}{\alpha + \beta} \quad \textbf{(4.29)}$$

All household equivalence scales for larger family sizes are simply a linear transformation of the above. If family size is included in its logarithmic function then additional family members would simply increase the household equivalence scale at a constant diminishing rate.

The limitation of estimating household equivalence scales in this manner is that it does not provide any information about specific differences in family size. The addition of a family member has the same financial cost on the household and does not account for the possibility that adults and children or males and females may have different impacts.

Household equivalence scales could also be estimated by including each family size as a dummy variable and treating the information as categorical. This allows the precise marginal changes in family size to be estimated without the need to make judgements on functional form. It is then necessary to drop the dummy variable capturing reference household (again the single family household).

$$y_i = \alpha + \sum_{j=2}^{j=m} \beta_j fs_j + \varepsilon_i \qquad \textbf{(4.30)}$$

The income necessary for the reference household *j*=1 is given by α. The household equivalence scale for family size j can then be estimated as follows:

$$HES_{ij} = \frac{\alpha + \beta_{ij}}{\alpha} \qquad \textbf{(4.31)}$$

It is possible to disaggregate further the data using a set of dummies capturing the number of adults and the number of children (*hhcomp*$_k$) who reside in each household. This model would now be estimated as follows:

$$y_i = \alpha + \sum_{k=2}^{k=m} \beta_j hhcomp_k + \varepsilon_i \tag{4.32}$$

With the corresponding equivalence scale for household composition *k* relative to the reference households being:

$$HES_{ik} = \frac{\alpha + \beta_{ij}}{\alpha} \tag{4.33}$$

The econometric methodology to estimate climate equivalence scales is similar to the household approach. Whilst controlling for important demographic features, again given by z, we also include a set of geo-referenced climate variables c for each household.

$$y_{in} = \alpha_i + \sum_{j=1}^{j=m} \beta_{ij} z_{jn} + \sum_{k=1}^{k=m} \delta_{ik} c_{kn} + \varepsilon_n \tag{4.34}$$

It is then possible to estimate the climate cost of living (CCOL) at the regional level by multiplying the implicit price of the climate variables (given by δ_{ik}) by regional climate averages.

$$CCOL_k = \sum_{k=1}^{k=m} \delta_k c_k \qquad \textbf{(4.35)}$$

From this the regional climate equivalence scale (CES_p) is calculated relative to the reference region *r*.

$$CES_p = \frac{\sum_{i=1}^{k=m} \delta_k c_{kp}}{\sum_{i=1}^{k=m} \delta_k c_{kr}} \qquad \textbf{(4.36)}$$

Any region with a climate equivalence scale greater (less) than one implies the climate cost living is more (less) expensive relative to the reference.

It is possible to bring together the empirical analysis of household composition and climate to investigate whether the welfare costs of climate are felt more severely by particular sections of society. Identifying those most vulnerable to particular types of climate is potentially an important factor in government climate change policy objectives.

The empirical methodology applied in section 4.2 can be extended to account for a specific household feature z_{jn} interacted with the set climate variables. Household features could capture anything from family size and house size to the number of elderly in the household.

$$y_{in} = \alpha_i + \sum_{j=1}^{j=m} \beta_{ij} z_{jn} + \sum_{k=1}^{k=m} \delta_{ik} c_{kn} + \sum_{q=1}^{q=m} \lambda_{im} c_{mn} z_{jn} + \varepsilon_n \qquad \textbf{(4.37)}$$

A test of joint statistical significance of $\lambda_{1,\ldots,m}$ will confirm whether the interacted variables add any explanatory power to the regression model.

4.7 Data

The data for this chapter is drawn from an unpublished survey undertaken by the UNDP in 2008. The telephone survey was administered to 1000 households in Croatia. Figures estimate that 1.86 million Croatian households have landlines, across a population of 4.48 million. This corresponds to a fixed line teledensity of 40 per 100 persons (CIA World Factbook). This compares to a fixed line teledensity of about 45 per 100 persons in the USA and 50 per 100 persons in the UK. Furthermore the total number of mobile phone subscriptions in Croatia exceeds the total population (CIA World Factbook). This leads us to conclude that the telephone interview process has the ability to be representative. The prime purpose of the exercise was to survey attitudes to climate change and to collect data for a WTP survey for projects intended to reduce energy use in Croatia.[91]

Respondents were asked about the minimum after tax household income necessary to live ‘comfortably and without problems’ for a household in identical circumstances to their own.

[91] The results of this survey have not been published.

They were also asked about their actual current monthly after tax income of the household. This was to include both Government transfers, and income from property and investments.[92] Unfortunately the question inviting respondents to report their net household income was not exact and respondents were only required to provide income deciles. We take the mid-point of the reported income decile as a point estimate. This clearly could lead to measurement error and subsequently cause income to be correlated with the error term. This may require the implementation of instrumental variables (IVs) which are discussed in Section 7. In addition, the survey recorded the number of males and females less than 15 years of age, the number of males and females between 15 and 65 years, and the number of males and females over 65 years.

The survey sampled households from each of the 21 administrative regions of Croatia and identified the name of the village, town or city of residence. The geographical coordinates (decimalised latitude and longitude) of each location are taken from an online gazetteer.[93] Unfortunately it proved impossible to identify a handful of settlements, presumably on grounds of their size or because they had undergone recent name changes.

This information is used to link each location to a climate database developed by New et al (2000). The database consists of a 10×10 minute grid of monthly climate data correct for average elevation. It includes precipitation, wet-day frequency, temperature, diurnal temperature range, relative humidity, sunshine duration, ground frost frequency, and wind speed. The data themselves are interpolated from a data set of station means for the period centred on 1961 to 1990. See New et al (2000) for details on all the procedures adopted.

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[92] The currency of Croatia is the Kuna, which at the time of the survey was equal to 0.1405 Euros.

[93] The online gazetteer is available at: http://www.fallingrain.com/world/HR.

Following Cushing (1987) we prefer January and July averages to annual averages. Furthermore, a wide number of climate specifications were considered, including those analysed in Chapter 2 and Chapter 3 of this thesis (results not shown). January and July averages were found to provide to provide the best fit for the data and so we present only these here.

We include the decimalised value of latitude as an explanatory variable. Latitude determines the variation of hours of daylight over the annual cycle. During the summer solstice the northern most settlement in Croatia enjoys an extra 30 minutes of daylight when compared to the southernmost settlement. Furthermore, average elevation by town in kilometres above sea-level is included to account for the possible variation in climate variables due to altitude.

We also account for the value Croatians may place on proximity to the Adriatic coast, stretching for much of the western border of Croatia. A distance to coast variable was created using GIS. A set of polylines were constructed portraying the length and shape of the Croatian coast and its offshore islands. It was then possible to estimate the distance from the geographical coordinates of each respondent's household to the nearest point of the coastal polylines. A similar technique was followed to obtain data on distances from a selection of Croatian National Parks (Paklenica, Krka and Mjlet) to capture any welfare effects of living near amenable public goods.

The theoretical section drew attention to the potential importance of controlling for variations in house prices. But the recent history of conflict and the continued existence of internally displaced refugees both suggest that any utility differences are unlikely to result in migration and concomitant adjustments in house prices. Anecdotally, most respondents appear to live in dwellings that they have inherited rather than ones that they have bought. House prices ordinarily capture the presence of neighbourhood quality and local public goods including climate. If there were to exist a transparent housing market which our model fails to capture this could bias coefficients of the climate variables

We nevertheless include four dummy variables identifying settlements of less than 2,000 people, 2,000-10,000 people, 10,000-50,000 people, 50,000-100,000 people and more than 100,000 people. We would of course ordinarily expect that house prices will be higher in the larger towns and cities. This would reflect higher average wage rates, better infrastructure and scarcity of available land. Furthermore, respondents were asked to report the size of their house in metres squared. This is to capture the additional costs of maintaining a larger home. Lastly, to account for differences in commuting costs, we generate information on distance in miles from each location to Zagreb, Osijek, Split and Rijeka each containing more than 100,000 people.

Table 4.1 provides summary statistics. We note that the total observations falls for a number of variables. This stems from a combination of incomplete surveys responses. 95 respondents failed to answer the IEQ, 149 for net income and 80 for floor space. The problem of identifying a small number of settlements led to the loss of 24 observations.

Table 4.1 Summary statistics

Variable	Obs	Mean	Std. Dev.	Min.	Max.
Minimum reported income to live 'comfortably and without problems' (Kuna/month)	907	9489.085	4810.071	1000	30000
Net income (Kuna/month)	851	6688.014	4017.23	1000	16000
Family Size	1000	3.208417	1.49913	1	10
Males < 15 yrs	1000	0.247495	0.56642	0	5
Males 15-65 yrs	1000	1.126253	0.822266	0	4
Males > 65 yrs	1000	0.199399	0.407206	0	3
Females < 15 yrs	1000	0.250501	0.583435	0	4
Females 15-65 yrs	1000	1.137275	0.817434	0	4
Females > 65 yrs	1000	0.247495	0.43409	0	2
Size of settlement < 2,000	1000	0.333667	0.471759	0	1
Size of settlement 2,000-10,000	1000	0.130261	0.336759	0	1
Size of settlement 10,000-50,000	1000	0.067134	0.25038	0	1
Size of settlement 50,000-100,000	1000	0.216433	0.412019	0	1
Size of settlement >100,000	1000	0.252505	0.434667	0	1
Floor space (m^2)	920	101.5717	56.53929	18	400
Distance to Zagreb (miles)	976	76.82377	61.10079	0	255.4107
Distance to Split (miles)	976	136.2864	54.38232	0.000177	207.1959
Distance to Osijek (miles)	976	129.0583	62.42403	0	250.7743
Distance to Rijeka (miles)	976	115.8946	60.73102	0.000339	277.0211
Distance to Coast (miles)	976	105.1084	79.22794	0.014119	258.9338
Distance to Paklenica (miles)	976	175.036	64.33229	10.14081	325.7636
Distance to Krka (miles)	976	200.0002	74.82503	6.068944	312.5748
Distance to Mjlet (miles	976	306.4934	95.25394	3.169375	436.5044
Latitude (decimalised degrees)	976	45.21005	0.875276	42.583	46.583
Elevation	976	0.215115	0.164282	0.028	0.934
January frost days (days)	976	22.10912	4.37762	8.9	28
July frost days (days)	976	0.032787	0.072259	0	0.4
January precipitation (mm)	976	82.69201	26.45845	41.5	147.2
July precipitation (mm)	976	78.61865	19.81537	30.5	122.4
January sunshine (%)	976	28.04795	6.52172	20.4	42
July sunshine (%)	976	61.70031	4.188765	56.3	74.6
January wind speed (m/s)	976	2.068852	0.529299	1.5	4.1
July wind speed (m/s)	976	1.914754	0.228636	1.6	2.7
January humidity (%)	976	80.63555	5.003707	66.7	88.1
July humidity (%)	976	67.98719	4.824592	57.2	78.7

4.8 Croatian households and equivalence scales

4.8.1 Empirical analysis of household equivalence scales

We start with some basic regression models following the household equivalence scales estimation in the methodology. The aim is to test the additional income required for a change in family size to maintain household at a constant level of welfare (the IEQ). We then add net household income to account for the preference drift effect commonly identified in previous literature. Table 4.2 considers both a linear and logarithmic specification. The following regression is estimated for each household *n*

$$x_n = \beta_1 + \beta_2 fs_n + \beta y_n + \varepsilon_n \qquad \textbf{(4.37)}$$

$$\ln(x_n) = \beta_1 + \beta_2 \ln(fs_n) + \beta_3 \ln(y_n) + \varepsilon_n \qquad \textbf{(4.38)}$$

Where x is the minimum reported income to live comfortably and without problems. Equation 4.38 most closely estimates the model from Van Praag and Van der Sar (1988). Table 4.2 gives the regression results.

Table 4.2 Basic linear and logarithmic models

	Model 1 Dep Var: x	**Model 2 Dep Var: ln(x)**	**Model 3 Dep Var: x**	**Model 4 Dep Var: ln(x)**
Family Size	1330.642*** (13.62)	-	753.01*** (9.32)	-
Net Income	-	-	0.7701*** (25.60)	-
Logged Family Size	-	0.502*** (16.58)	-	0.226*** (8.56)
Logged Net Income	-	-	-	0.505*** (25.73)
Constant	5277.414*** (15.44)	8.507*** (243.52)	2006.688*** (6.97)	4.455*** (28.11)
No. Obs	907	907	829	829
Adjusted R^2	0.1691	0.2329	0.5518	0.5894
F-Statistic	$F(1, 905) = 185.39^{***}$	$F(1, 905) = 274.73^{***}$	$F(2, 826) = 510.76^{***}$	$F(2, 826) = 592.94^{***}$

*Source: See text. *** means significant at the one per cent level of confidence, ** means significant at the five per cent level of confidence and * means significant at the ten per cent level of confidence.*

It can be seen from Model 1 that family size has a positive coefficient statistically significant at the one per cent level of confidence. This confirms that extra household members increase the minimum income required. The family size coefficient indicates an additional family member needs about 1331 Kuna per month for the household to maintain constant income welfare. The same level of statistical significance is observed in the logarithmic specification of Model 2, where the coefficient on logged family size now represents the family elasticity. This corresponds to an additional 1297 Kuna for a marginal change from the sample average family size.

The addition of net household income makes a large difference to both the linear and logarithmic models as shown in Models 3 and 4 respectively. The Adjusted R^2 rises substantially in both models. In the linear model the coefficient on family size decreases to 753 Kuna. The coefficient on net income represents the preference drift effect. If the coefficient is positive but less than one it can be concluded that an increase in net income increases *x* but by less than the absolute increase in income. The estimated coefficient is 0.77 and confirms the existence of preference drift. To illustrate, if net income were increased by 1000 Kuna then *x* will only need to rise by 770 Kuna to maintain the minimal standard of living. Adding logged income to the logarithmic model more than halves the family elasticity to 0.226 and estimates the income elasticity to be 0.505. The larger coefficient for logged income implies that the role of actual income on minimum income required diminishes at a faster rate than family size.

The linear models above automatically restrict the costs of additional family members to a constant level. The logarithmic models assume a particular path of economies of scale which is diminishing at a constant rate. Furthermore, both models ignore or the varying costs of different types of family members. [94]

To gain a better understanding of the varying effects of age and gender it is possible to split family size into 6 different categories. Household members are separated by gender and placed into one of three age groups (0-15, 15-65 and over 65). It is anticipated that households should require greater financial compensation to house an additional adult compared to children and men more costly than women. The results are given in Table 4.3; Model 5 controls only for these household member characteristics and Model 6 includes net income.

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[94] Whilst much of the literature assumes a lognormal distribution, we find little difference in results obtained using logged and linear models. Indeed, Van Praag and Van der Sar (1988) concede that their use of a double-log model is chosen as 'empirical evidence that it fits rather well.' We therefore maintain our regressions in linear form.

Table 4.3 Linear regression of household by age group

	Model 5 **Dep Var: x**	**Model 6** **Dep Var: x**
Net Income	-	0.7445*** (24.46)
Males < 15	724.3232*** (2.77)	514.49** (2.45)
Males 15-65	1802.027*** (9.03)	895.84*** (5.29)
Males > 65	1340.621*** (3.34)	714.00** (2.25)
Females < 15	874.6926*** (3.40)	418.43** (2.06)
Females 15-65	1267.575*** (6.16)	917.45*** (5.61)
Females > 65	-532.7005 (-1.40)	-18.94 (-0.06)
Constant	5563.467*** (14.63)	2194.57*** (6.80)
No. Obs	907	829
Adjusted R^2	0.2089	0.5593
F-statistic	F(6,900) = 40.88***	F(7,821) =151.13***

*Source: See text. *** means significant at the one per cent level of confidence, ** means significant at the five per cent level of confidence and * means significant at the ten per cent level of confidence.*

In both Models, the additional cost to the household of particular types of family members is clear with all but elderly females leading to a statistically significantly higher minimum income required to maintain constant welfare. Males in the 15-65 age range have the greatest additional cost at 1802 Kuna per month in Model 5. Males over 65 and females aged 15-65 also reflect large costs at 1341 and 1268 Kuna per month respectively. A lower minimum income for additional children is needed, as one would expect, with another female aged 0-15 requiring 875 Kuna and the equivalent males 724 Kuna. These values substantially fall with the addition of net income in Model 6. The large rise in the adjusted R^2 once again demonstrates the importance of controlling for net household income.

Most notably the additional costs for males aged 15-65 and females under 15 have halved. Additional females aged 15-65 now have the greatest financial burden on the household.

Whilst Table 4.3 identifies the additional costs of family members by age and gender, it doesn't provide a reference point to compare various household compositions. A set of dummy variables can identify the additional cost of specific household compositions relative to reference household.

This reflects a move from the typical subjective equivalence scale literature by regressing exact household composition rather than different types of individual in a similar fashion to Table 4.2. This allows us to compare directly households exhibiting exactly the same composition characteristics and should give us a more realistic idea of the actual costs.

There are a number of options available when considering which household characteristics to analyse. For example this could be the gender of occupants, their age or employment status. However, the total number of observations available restricts the number of dummy variables it may be sensible to use. Accounting for too many types of household could result in the data being spread too thinly across dummies for much meaning to be derived from them.

Table 4.4 investigates the role of additional family members on household costs. Model 7 accounts for only family size dummies whilst Model 8 also includes net household income. In both Models the reference household is a family size of 1, which is the omitted dummy variable. The additional minimum income required for each family size is given by the corresponding coefficient on each dummy. The coefficient of the constant term gives the reference household. We note that for large family sizes (of 7 and above), very low observation numbers make it difficult to interpret the coefficients. These are given in italics in Table 4.4 and are provided for information only.

Model 7 shows a clear increase in the income required to support additional family members. Adding a second person increases income necessary by 2028.98 Kuna relative to the reference. Adding two members requires an extra 4567.77 Kuna to the reference. Interestingly, the additional income appears to plateau when family size gets to four and above at approximately 6000 Kuna. This implies an economies of scale effect as family size increases.

Controlling for net household income in Model 8 almost halves the coefficient on the constant. This means actual income is, to an extent, capturing the financial requirements of the household. As family size increases in both Models it is clear the minimum income necessary also rises. Once again, however, minimum income appears almost to plateau when family size gets above 4.

Table 4.4 Cost of additional family members

Variable	Model 7 Dep Var: x	Model 8 Dep Var: x
Net	-	0.753734*** (24.52)
Family Size 1	-	-
Family Size 2	2028.98*** (4.11)	427.939 (1.10)
Family Size 3	4567.769*** (9.05)	1838.204*** (4.48)
Family Size 4	6061.636*** (11.97)	2816.935*** (6.60)
Family Size 5	6024.536*** (9.76)	2870.577*** (5.61)
Family Size 6	6451.162*** (9.24)	3623.608*** (6.42)
Family Size 7	*6560.811**** *(3.65)*	*2869.611*** *(2.09)*
Family Size 8	*4277.477*** *(2.18)*	*1413.145* *(0.85)*
Family Size 9	*2477.477* *(0.58)*	*2554.949* *(0.78)*
Family Size 10	*16477.48**** *(3.83)*	*13540.01**** *(4.15)*
Constant	5522.523*** (13.58)	2806.981*** (8.46)
No. Obs	907	829
Adjusted R2	0.2065	0.5591
F-Statistic	F(9, 897) = 27.20***	F(10, 818) = 106.01***

*Source: See text. *** means significant at the one per cent level of confidence, ** means significant at the five per cent level of confidence and * means significant at the ten per cent level of confidence.*

From Table 4.3 it is clear that the financial cost of additional children is substantially lower than adults. The family size component of Table 4.4 cannot identify the number of adults and children in each household. It is possible to extract more precise information about the costs of specific household composition by further disaggregating our dataset. For example, a household consisting of 4 adults may need a higher income to reach the same welfare level as a household consisting of 2 adults and 2 children.

In Table 4.5 we account for combinations of adults (males and females aged 15 or over) and children (males and females aged under 15).[95] The maximum number of adults and children found in any one household is 6 for both. This leads to creation of 42 separate dummy variables, given there are no observations where only children reside in a household. The reference household is taken as a single adult living alone. The minimum income required to live comfortably for the reference household is given by the coefficient of the constant.

Table 4.5 Linear regression of household type dummies

Dependent Variable: Minimum income to live comfortably and without problems
Reference Household: One Adult Household

	Coefficient (T-statistic)	**No. Dummy Obs**	**Equivalence Scale**	**95% Conf. Interval**
1 Adult	DROPPED	109	1	-
2 Adults	2074.823*** (4.18)	226	1.38	0.73 – 2.02
3 Adults	4356.324*** (8.20)	156	1.79	1.36-2.22
4 Adults	6409.516*** (10.95)	103	2.16	1.77 – 2.55
5 Adults	7767.80*** (8.94)	31	2.41	1.88 – 2.94
6 Adults	5164.977*** (3.30)	8	-	-
2 Adults, 1 Child	5020.031*** (6.74)	47	1.91	1.35 – 2.47
3 Adults, 1 Child	5552.477*** (7.04)	40	2.01	1.45 – 2.57
4 Adults 1 Child	5442.995*** (6.10)	29	1.99	1.35 – 2.63
5 Adults,	7363.841***	22	2.33	1.71 – 2.95

[95] Only household type dummies significant at the 5% level or above are shown. We do not calculate equivalence scales for dummies with a number of observations less than 10 as this may not provide a realistic reflection of household costs.

1 Child	(7.37)			
1 Adult, 2 Children	8477.477*** (3.39)	3	-	-
2 Adults, 2 Children	5799.511*** (8.41)	59	2.05	1.57 – 2.53
3 Adults, 2 Children	4244.144*** (3.61)	15	1.77	0.81 – 2.73
4 Adults, 2 Children	6366.366*** (5.86)	18	2.15	1.43 – 2.87
2 Adults, 3 Children	4977.477*** (3.52)	10	1.90	0.84 – 2.96
3 Adults 3 Children	4834.62*** (2.90)	7	-	-
4 Adults 3 Children	9477.477*** (3.10)	2	-	-
2 Adults, 3 Children	7977.477*** (2.60)	2	-	-
4 Adults, 4 Children	8477.477** (1.97)	1	-	-
5 Adults, 5 Children	16477.48*** (3.83)	1	-	-
Constant	5522.523*** (13.60)	-	-	-
No. Obs	907	-	-	-
Adjusted R^2	0.2088	-	-	-
F-statistic	F(27,879) = 9.86***	-	-	-

*Source: See text. *** means significant at the one per cent level of confidence, ** means significant at the five per cent level of confidence and * means significant at the ten per cent level of confidence.*

The additional minimum income required for each household composition is given by the corresponding coefficient on each dummy. Initially ignoring children it is clear that including extra adults raises this value, with 2075 additional Kuna per month needed for two adults compared to the reference one adult household. Five adults living together need an extra 7768 Kuna per month. The effect of adding a single child to these households seems to depend on the number of adults. Adding a child to a two adult household requires a large extra minimum income, rising by 2945 Kuna to 5020 per month. This effect is reduced for three adults with a rise of 1196 Kuna per month and appears to fall slightly for four and five adult households.

Interestingly, adding a second child to a two adult house appears to demonstrate the economies of scale effect well, as the second child only raises income required to 5800 Kuna per month from 5020, a change of 780. A third child with two adults, however, appears to return this figure to just under 5000. A second child in three and four adult household has an unclear effect with a fall in costs for the former and a rise in the latter. It is likely the smaller number of observations for these dummies may be having an effect.

Equivalence scales are given in the fourth column of Table 4.5 with their respective 95% confidence intervals in the right hand column. It gives a clearer impression on the additional cost of household members. For example, 2 adults need on average 1.38 times the income of the reference household to maintain constant welfare. 2 adults and 2 children only require just over double the reference households income at 2.05. In all cases the confidence interval is moderately wide revealing the possible limitation of relying on a set of point estimates.

We note that for larger households there appears, at least according to the equivalence scales, to be a cost saving effect. For example, it is cheaper to maintain 3 adults and 2 children than it is for 2 adults and 2 children with the equivalence scale falling to 1.77. However, it rises with the presence of one more adult to 2.15. We concede that this is likely due to an insufficient number of observations and so do not attempt to derive an explanation for these results.

The results of Table 4.5, particularly in households with no children, give an indication of the existence of the economies of scale effect. However, it provides no evidence of a preference drift effect caused by changing perceptions as net income rises. If preference drift is a real phenomenon, it is possible the omission of an income variable may be overestimating the economies of scale effects shown above. Table 4.6 shows the family-type dummies whilst also including a variable for net income.

Table 4.6 Household type dummies and net income variable

Dependent Variable: Minimum income to live comfortably and without problems
Reference Household: One Adult Household

	Coefficient (T-statistic)	**No. Dummy Obs**	**Equivalence Scale**	**95% Conf Interval**
Net Income	0.7489025 (24.12)	-	-	-
1 Adult	DROPPED	104	1	-
3 Adults	1789.592*** (4.21)	209	1.63	0.87 – 2.38
4 Adults	3434.375*** (7.00)	147	2.22	1.60 – 2.84
5 Adults	4383.027*** (5.85)	87	2.55	1.70 – 3.40
2 Adults, 1 Child	1871.492*** (3.07)	25	1.66	0.60 – 2.72
3 Adults, 1 Child	2666.082*** (4.06)	33	1.94	1.00 – 2.88
4 Adults 1 Child	2229.95*** (3.19)	28	1.79	0.69 – 2.89
5 Adults, 1 Child	3799.539*** (4.95)	22	2.35	1.42 – 3.28
1 Adult, 2 Children	4935.869*** (2.60)	3	-	-
2 Adults, 2 Children	2021.089*** (3.62)	56	1.72	0.79 – 2.65
3 Adults, 2 Children	2337.492** (2.45)	13	1.83	0.36 – 3.29
4 Adults, 2 Children	4176.422*** (4.79)	16	2.48	1.47 – 3.49
3 Adults 3 Children	3333.528** (2.25)	5	-	-
4 Adults 3 Children	5249.375** (2.27)	1	-	-
2 Adults,	5434.406**	2	-	-

4 Children	(2.36)			
5 Adults, 5 Children	13559.95*** (4.18)	1	-	-
Constant	2823.277*** (8.55)	-	-	-
No. Obs	829	-	-	-
Adjusted R^2	0.5643	-	-	-
F-statistic	F(28,800) = 39.30***	-	-	-

*Source: See text. *** means significant at the one per cent level of confidence, ** means significant at the five per cent level of confidence and * means significant at the ten per cent level of confidence.*

The large rise in the adjusted R^2 value of the regressions including net monthly income once again demonstrates the importance of including it as an explanatory variable.[96] Its coefficient is 0.749. Once again this demonstrates the existence of preference drift as households adapt to their income level. The inclusion of income has reduced the coefficients of the dummy variables and the constant quite substantially. The coefficient of the constant has almost halved from 5523 to 2823 Kuna per month. Although a two adult household with no children is now insignificant compared to the reference household, a three adult household now only requires an additional income 1790 Kuna per month to maintain a constant welfare. This is a fall from the 4356 Kuna estimated in Table 5. Similar decreases are noted across all the dummy variables.

The equivalence scales show that, relative to the reference household, not much has changed. Additional adults still increase the minimum income consistently. Three adults need 1.63 the income of a single adult whilst 5 require 2.55. This compares with respective values of 1.79 and 2.41 in Table 4.4. The most notable change is the fall in minimum income required for a

[96] Furthermore a likelihood ratio test is statistically significant at the one percent level of confidence ($Chi^2(26)$ = 46.22***) confirming it is not nested in Model 3.

typical 2 adult 2 child family falling from 2.05 in Table 4.5 to 1.72 in Table 4.6. This represents very steep cost savings of additional household members.

The purpose of estimating household equivalence scales in this manner has been to gain an understanding of the interpretation of the dependent variable. Whilst the use of dummy variables seem to suffer when their observation numbers are insufficiently low, it has succeeded in confirming an economy of scales effect of additional household members and preference drift, an adaptation to changes in one's income level. This gives us a strong indication that the IEQ works consistently, as far as the Croatian dataset is concerned.

4.8.2 Discussion of household equivalence scales

Our results find that household composition has a clear effect on raising the amount of additional monthly income required maintain a constant level of welfare. This is most apparent in the number of adults living in the household, who add approximately a third of the cost of the first adult in the household. The effect of additional children appears to depend quite substantially on the number of adults, with children having a greater bearing on cost when there are fewer adults. Rising net monthly incomes also has a positive impact on maintaining this level of welfare confirming the preference drift effect. This is simply identified by the statistical significance of current net income as an explanatory variable in all regressions.

It is difficult to make any direct comparisons to the literature on the ordinal approach to subjective household equivalence scales for a number of reasons. Firstly, it is overwhelmingly focused on the poverty line which represents a different verbal welfare level to the one analysed in this chapter. Secondly, researchers have used different household compositions as the reference point or alternatively solely controlled for family size and ignored the role of gender and age.

Nevertheless, Table 4.7 below presents the estimated income and family elasticities for the Leydon School approach to poverty lines. We also include two verbally defined welfare levels from Van Praag and Van der Sar (1988) which more closely match our IEQ. Where a study has investigated multiple countries, we simply give the cross-country mean and provide the minimum and maximum elasticity estimates in parenthesis. Our estimates are based on the regression results in the final column of Table 4.2.

It is clear that the findings for Croatia follow earlier research by finding that the income elasticity is noticeably higher than the family elasticity. Typically the poverty literature estimates income elasticity to be in the range of 0.4 – 0.7 and a family elasticity between 0.05-0.35. Our estimates fall comfortably within these ranges. Van Praag and Van der Sar (1988) estimate the elasticities for each level of welfare. We provide the estimates for a 'sufficient' and a 'good' level of welfare under the assumption this most closely follows our verbal welfare level. It can be seen the mean estimates and ranges are in fact very similar for both welfare levels. Once again the income and family elasticities for the Croatian dataset fall within the ranges of Van Praag and Van der Sar (1988). This gives us confidence in the plausibility of our results and that the Croatian data is representative.

Table 4.7 Estimates of income and family elasticities

	Study	**Country/ Countries**	**Income Elasticity**	**Family Elasticity**
Poverty	Goedhart et al (1977)	Netherlands	0.60	0.12
	Van Praag et al (1980)	9 Countries	0.537 (0.22 - 0.62)	0.167 (0.04 - 0.38)
	Van Praag et al (1982a)	Netherlands	0.69	0.05
	Van Praag et al (1982b)	8 Countries	0.486 (0.381-0.537)	0.110 (0.059 - 0.169)
	Danziger (1984)	US	0.376	0.351
	Van Praag and Van der Sar (1988)	9 Countries (welfare level 4 - Sufficient)	0.436 (0.254 - 0.684)	0.154 (-0.062 - 0.0260)
	Van Praag and Van der Sar (1988)	9 Countries (welfare level 5 - Good)	0.429 (0.264 - 0.671)	0.147 (-0.042 - 0.265)
	Our estimates	**Croatia**	**0.505**	**0.226**

A number of studies also control for specific composition of households. Some studies have estimated the cost of increasing family size. We present our results in two different ways in Table 4.8 below. Result '**A**' follows the ordinal approach to subjective equivalence scales by the income and family size elasticity estimates. This will lead to a set of equivalence scales which a necessarily increasing at a diminishing rate, given the logarithmic specification of family size. Results '**B**' is the dummy variable approach shown in Table 4.4, whereby family size is compared directly to the reference household. In this case we only estimate an equivalence scale if there are more than 10 observations for each family size.

Note that the findings Goedhart et al (1977) and Van Praag et al (1980) are given by the absolute minimum income necessary to make ends meet whereas Van Praag et al (1982_b) attempt to choose a point on the cardinal scale which they hope to represent most closely the poverty line. Once again, the values given for Van Praag et al (1982, 1982_b) are cross-country averages. Rojas (2007) uses a subjective well-being approach rather than an income evaluation question.

Considering first our estimates for approach **A**, they appear to follow closely the findings of Van Praag et al (1982$_b$), with only modest increases in financial requirements as family size increases. The value of only 1.68 for a household size of 10 in **A** highlight the potential limitation of such a simple regression model. For approach **B** the increase in magnitude of the equivalence scales is much more prevalent for low family sizes, but then plateaus when a family size reaches four. This is likely caused by members of larger households being predominantly children who have lower consumption requirements than adults.

Table 4.8 Equivalence scales by family size

	Family Size									
Study	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Goedhart et al (1977)	1.00	1.24	1.40	1.53	1.63	1.73	1.81	-	-	-
Van Praag et al (1980)	1.00	1.27	1.47	1.63	1.77	1.90	2.01	-	-	-
Van Praag et al (1982b)	1.00	1.15	1.26	1.33	1.42	1.47	-	-	-	-
Rojas (2007)	1.00	1.40	1.70	1.95	2.17	2.36	2.55	2.72	2.87	3.02
Our Estimates A	**1.00**	**1.17**	**1.28**	**1.37**	**1.44**	**1.50**	**1.55**	**1.60**	**1.64**	**1.68**
Our Estimates B	**1.00**	**1.37**	**1.83**	**2.10**	**2.09**	**2.17**	-	-	-	-

Few studies consider the importance of age and gender on household equivalence scales, yet unravelling individual effects of particular household members could be important in determining specific policy recommendations. Danziger et al (1984) includes dummy variables for age and gender of the household head and finds this to have a dramatic negative effect on the family elasticity coefficient. The result is that households whose head are over 65 and those who are female require a lower minimum income to make ends meet. Van Praag et al (1982_b) also control for a number of demographic and socio-economic features. Whilst statistical significance varies by country, minimum income also appears to be greater for those of working age and with a higher education. Those inhabiting large towns and cities also appear to require a higher minimum income.

Rojas (2007) takes a more pragmatic approach by disaggregating family size into number of adults, teenagers and children and estimating the respective elasticities separately. This allows specific household compositions to be considered. Taking a one adult household as a reference, it is found that an extra adult would require approximately 40% additional income whereas an extra child would need over 50%. Adding an adult and a child requires an additional 180% of the reference household's income.

Our results from Table 4.3 confirm that age and sex of additional family members also make a difference to the additional income to maintain constant welfare but find the additional cost of adults to be greater than children. An additional old male, working age male and working age female all require over 1000 Kuna per month whilst children of both sex fall well under 1000 Kuna.

The dummy variables implemented in Tables 4.4 and 4.5 have worked to a certain degree though an obvious limitation is the total number of observations available in this dataset. A larger dataset would allow for a greater discrimination of different household compositions, for example by age, sex and family size. The advantage of using a set of dummy variables is that every 'type' of family is being specifically tested against the reference household. This is different to previous literature which simply multiplies the coefficients of types of individuals within a household by their quantity. Despite the data limitations, it is clear that increasing the number of adults in a household also increases minimum income necessary. The impact of additional children depends on the total number of adults in the household.

4.9 Croatian climate equivalence scales

4.9.1 Empirical analysis of climate equivalence scales

In order to create climate equivalence scales it is necessary to account for variables which could be important in determining the minimum income a household with certain characteristics requires in order to live comfortably and without problems. This is outlined in the data specification section and includes the size of town inhabited, distance to major cities as well as distance to the Croatian coastline and a selection of national parks. Also included but not shown at this stage are the household characteristic dummies provided in Tables 4.6 and 4.7.

The results of the initial analyses are given in Table 4.9. Model 1 shows a linear model whilst Model 2 alters the dependent variable to the logarithm of minimum income required to live comfortably and the logarithm of net income. It is noted that these two models currently ignore the instrumentation of net income to allow a Ramsey RESET test of functional form to be completed. IVs may be necessary to overcome the measurement error of relying on reported income deciles from the survey data. We consider this in Section 4.9.1.1.

In both models it appears that the amount of floor space is not statistically significant in determining the minimum income required. Whilst this is slightly surprising, it is possible that the very high statistical significance of net income is leaving floor space imprecisely determined. Variables describing the size of the settlement and the distance to the major cities of Croatia are all statistically insignificant.

With respect to the distance variables, Model 1 appears to perform better. Most notably, distance to coast is negative at the one per cent level of confidence indicating that it is cheaper to maintain a comfortable standard of living the further one is from the coast. This confirms the amenity value of residing near the Adriatic coast. However, it is possible this could be capturing some effect of property prices which we have been unable to control for explicitly. The statistical significance of distance to coast drops to the five per cent level in Model 2. Also, significant at the five per cent level in Model 1 is distance to Rijeka, the principal seaport of Croatia, and the national park located in central Dalmatia. Distance to Rijeka is negative meaning the minimum income required falls as distance increases from it. Distance from Krka has a positive coefficient and so increases household costs. Model 2 does not find the corresponding relationships as strong as Model 1 with them both falling to the ten per cent level of confidence.

Moving on to the climate variables, Models 1 and 2 provide much more uniform results. January frost days is positive and statistically significant at the one per cent level of confidence despite the inclusion of a large number of alternative climate variables. Both models also find July sunshine and January humidity levels significant at the five per cent. Furthermore, January precipitation is also significant at the five per cent level, but only in Model 2.

Alternative specifications were attempted replacing frost days with temperature or diurnal temperature, and precipitation with the number of rain days. None of these alternative specifications resulted in an increase in fit (results not shown). We also attempted to eliminate climate variables with statistically insignificant T-statistics but discovered that these variables were group-significant (results not shown). Given the high degree of multicollinearity between climate variables we prefer to retain them. In all cases the standard errors are adjusted for heteroscedasticity and for clustering on location (households in the same location are clustered together).

Comparing the linear and the logarithmic model it would appear on the basis of the Ramsey RESET test statistic that the null hypothesis of no omitted variables cannot be rejected. This confirms either model would provide an appropriate fit. A linear specification is taken for all subsequent regressions. This decision is supported by comparing the root mean square error obtained by taking the exponent of the predicted values from the logarithmic regression.

Table 4.10 examines the geographical stability of the linear regression. Observations are divided approximately equally into households located in the north of the country and those located in south (Models 3 and 4 respectively). Observations are also divided into east and west (Models 5 and 6 respectively). Results from a Chow test suggest that the regression is geographically stable along the east-west axis.[97] The Chow test over the north-south axis is also statistically insignificant implying geographical stability of the data.[98]

Despite the statistical insignificance of the Chow tests it is worth identifying any observable differences between geographical regions. It is evident for the majority of variables that the coefficients are imprecisely determined for at least one of the regions. For net income it is apparent there is some variation in the extent of the preference drift effect. The coefficient on

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[97] $F(53, 671) = 1.18$.
[98] $F(53, 672) = 1.00$. Note: A small variation in parameters was observed due to the inclusion of the household characteristic dummies.

southern net income is larger than northern income. This implies that those in the North adapt to higher incomes relatively faster than in the South to maintain constant welfare. A similar finding is found between East and West, with those in the East adapting to increases in income faster.

Further observable differences include the impact of floor space in the north and south. Whilst a larger floor space in the North increases the costs to maintain a constant welfare, it actually reduces costs in the South. This is potentially an important finding. It may be capturing additional cost of maintaining large houses in the less amenable northern climate.

For the East and West the only contrasting coefficients which are statistically significant is for Distance to the National Park of Mjlet. This is likely a consequence of Mjlet being an island location just off the Adriatic coast in the West. The positive coefficient on the West regression concludes that living further from Mjlet increases costs. This may be capturing the positive amenity effects of living near Mjlet. The positive coefficient for the East is more difficult to explain and may be capturing an undetermined effect caused by sub-dividing the regression given Mjlet's location.

Table 4.9 Linear and logarithmic models

Dependent Variables:

Model 1: Minimum income to live comfortably and without problems

Model 2: Logged minimum income to live comfortably and without problems

	Model 1	**Model 2**
Variable	**Coefficient (T-statistic)**	**Coefficient (T-statistic)**
Net Income	0.7008786*** (14.50)	-
Ln Net Income	-	0.4710408*** (18.97)
Floorspace	0.9384638 (0.42)	0.000348 (1.61)
Size < 2,000	-96.94878 (-0.20)	-0.00792 (-0.15)
Size 2,000-10,000	452.0908 (0.81)	0.05584 (1.03)
Size 10,000-50,000	-173.4822 (-0.34)	-0.03521 (-0.67)
Size 50,000-100,000	762.6638 (1.61)	0.067791 (1.37)
Latitude	-1556.813 (-0.69)	-0.08211 (-0.36)
Elevation	1386.04 (0.44)	0.176627 (0.53)
January Frost Days	1346.12*** (3.60)	0.128768*** (3.35)
July Frost Days	-4676.489 (-1.46)	-0.34943 (-1.02)
January Precipitation	-52.33468* (-1.93)	-0.00499** (-2.01)
July Precipitation	-22.7379 (-0.87)	-0.00207 (-0.72)
January Sunshine	-359.817 (-1.47)	-0.03029 (-1.06)
July Sunshine	712.7665** (2.55)	0.064087** (2.06)
January Humidity	-927.1396 (-2.31)	-0.08335 (-2.07)
July Humidity	58.24763 (0.24)	-0.0074 (-0.27)
January Wind Speed	-1278.193 (-0.63)	-0.14829 (-0.7)
July Wind Speed	-1714.974 (-0.44)	-0.18606 (-0.46)

Distance to Zagreb	-3.765016 (-0.18)	0.000364 (0.16)
Distance to Split	24.8696 (0.75)	0.003813 (1.06)
Distance to Osijek	-1.210734 (-0.06)	0.000336 (0.15)
Distance to Rijeka	-50.23897** (-2.51)	-0.00414* (-1.83)
Distance to Coast	-33.90917*** (-2.70)	-0.00295** (-2.28)
Distance to Paklenica	-24.89258 (1.25)	0.001035 (0.44)
Distance to Krka	35.74414** (2.04)	0.003542** (1.96)
Distance to Mjlet	-33.18774 (-1.44)	-0.00354* (-1.77)
Constant	97107.26 (1.03)	11.2725 (1.09)
Household Type Dummies	YES	YES
No. Obs	769	769
R^2	0.6159	0.6426
Ramsey RESET Test	F(3, 713) = 0.34 Prob > F = 0.7987	F(3, 713) = 0.77 Prob > F = 0.5114
RSS	7.008e+09	81.972532

Table 4.10 Tests for geographical stability
Dependent Variable: Minimum income to live comfortably and without problems

	Model 3	**Model 4**	**Model 5**	**Model 6**
Variable	**Coefficient (T-statistic)**	**Coefficient (T-statistic)**	**Coefficient (T-statistic)**	**Coefficient (T-statistic)**
Net Income	0.6423742*** (8.11)	0.7255997*** (13.34)	0.7478027*** (13.37)	0.6834024*** (9.41)
Floorspace	6.703337** (2.56)	-5.73008** (-2.04)	-2.24041 (-0.80)	2.756335 (0.86)
Size < 2,000	-2345.86*** (-2.98)	1108.958 (1.50)	404.0645 (0.53)	-92.1059 (-0.14)
Size 2,000-10,000	-1633.24* (-1.70)	1262.329* (1.71)	1343.353* (1.90)	-466.623 (-0.59)
Size 10,000-50,000	-2268.97*** (-2.58)	227.442 (0.34)	327.0687 (0.47)	-629.461 (-0.65)
Size 50,000-100,000	-939.491 (-1.14)	1567.262 (1.89)	1046.15 (1.49)	692.9838 (1.17)
Latitude	33222.72 (0.45)	3162.585 (0.75)	1539.953 (0.45)	-16477.9 (-1.50)

Elevation	-8889.36 (-0.52)	-1810.89 (-0.43)	-5087.83 (-0.49)	3645.834 (0.63)
January Frost Days	2690.386* (1.81)	2058.163*** (3.82)	2482.719*** (3.17)	1620.644** (2.18)
July Frost Days	-11084.3 (-0.73)	-5691.96 (-1.08)	-4752.71 (-0.69)	2861.774 (0.42)
January Precipitation	3.535569 (0.04)	-90.6195* (-1.81)	-112.328** (-2.05)	-59.5093 (-1.16)
July Precipitation	-6.71393 (-0.07)	-27.3227 (-0.57)	-105.202*** (-2.92)	119.2589 (1.56)
January Sunshine	-289.212 (-0.37)	-110.061 (-0.27)	1018.294* (1.88)	-708.632 (-0.16)
July Sunshine	-110.334 (-0.18)	933.7785** (2.01)	-707.629 (-1.07)	2491.287*** (3.90)
January Humidity	-1743.51** (-2.23)	-798.158 (-1.13)	-1314.05 (-0.36)	-8868.02** (-2.49)
July Humidity	444.9181 (0.57)	-339.085 (-0.76)	-4871.46 (-1.00)	8428.556 (1.27)
January Wind Speed	-6889.59 (-0.99)	-688.241 (-0.28)	-1627.69* (-1.89)	-1319.34 (-1.65)
July Wind Speed	9369.691 (1.12)	-2400.29 (-0.50)	-168.052 (-0.36)	-65.2633 (-0.11)
Distance to Zagreb	116.8663 (1.59)	-6.5992 (-0.20)	-41.2288 (-0.49)	-33.2902 (-0.55)
Distance to Split	6653.257 (0.34)	60.14678 (1.18)	122.5109* (1.77)	-386.633*** (-2.58)
Distance to Osijek	63.13585 (1.45)	51.67908* (1.69)	18.10573 (0.67)	-72.6907 (-0.62)
Distance to Rijeka	19.62643 (0.05)	-18.9764 (-0.37)	267.3774 (1.59)	-45.8218 (-0.88)
Distance to Coast	-49.2216** (-1.98)	-39.1867 (-1.53)	-41.5575** (-2.20)	-10.6328 (-0.26)
Distance to Paklenica	591.4145 (0.21)	3.831323 (0.12)	-361.489*** (-2.73)	14.27421 (0.40)
Distance to Krka	-3635.41 (-0.31)	44.11557** (2.24)	223.806** (2.52)	110.9973** (2.07)
Distnce to Mjlet	-1471.04 (-0.38)	-64.4475** (-2.09)	-91.8342*** (-2.67)	301.7083** (2.49)
Constant	-1289472 (-0.44)	-134235 (-0.69)	68632.46 (0.43)	635712.3 (1.33)
Household Type Dummies	YES	YES	YES	YES
No. Obs	375	394	384	385
R^2	0.6451	0.6402	0.7246	0.5789
RSS	3.308e+09	3.189e+09	2.184e+09	4.227e+09

*Source: See text. *** means significant at the one per cent level of confidence, ** means significant at the five per cent level of confidence and * means significant at the ten per cent level of confidence.*

4.9.1.1. Implementation of instrumental variables.

Whilst the survey included a question on household net income, it did not ask for specific values, but rather provided a set of income ranges for respondents to choose from. This is a limitation of a large number of surveys and, inadequately, tends to be approximated by taking midpoints of each income range.[99] As a result each income observation is likely to have a measurement error attached to it correlating it with the residual error term. In creating an instrumental variable, which is correlated with net household income but not the residual error term, it is possible it overcome the measurement error problem.

The individual characteristics of the survey respondents provides a useful insight in to the net income of each household, particularly education level and employment status. The survey split education level into five categories ranging from ‘not finished elementary school’ to ‘finished university/ post-university degree’. Employment status was split into six categories, namely full-time, part-time, unemployed, student, retired and housewife.

Two methods of instrumentation were carried out to resolve the measurement error problem of net income. The first was to utilise the employment and education variables described above in their current form. The second involved deriving the average income of households based on their socio-economic and regional characteristics.

Two average income instruments were created in this fashion. An average income by socio-economic characteristics instrument was produced by splitting the observations into 30 different categories by employment and education levels (e.g. an individual who had finished a university degree and was in full-time work). The average income of each category was

[99] Higher response rates is usually the reason for selecting income ranges over actual income questions

then calculated[100]. A second instrument was produced in this fashion by taking the average income of all households in each of the 21 administrative regions of Croatia. Table 4.11 gives the results of the goodness of fit of these instruments with net income as the dependent variable.

Table 4.11 Generation of instrumental variables

Dependent Variable: Net Household Income

	Instrument 1	**Instrument 2**
Employment	-593.6343*** (-7.60)	-
Education	1035.326*** (8.61)	-
Average Income by education and employment	-	0.9575858*** (19.63)
Average Income by Region	-	0.6702097*** (6.06)
Constant	4464.939*** (7.64)	-4128.922*** (-5.40)
No. Obs	840	841
R^2	0.2038	0.3619
F-Statistic	F (2, 837) = 107.1***	F (2, 838) = 237.62***

*Source: See text. *** means significant at the one per cent level of confidence, ** means significant at the five per cent level of confidence and * means significant at the ten per cent level of confidence.*

This provided a sufficient average income variable to use to instrument net income. A Sargan test ensures that the instruments are not only correlated with the income variable but also uncorrelated with the error term. However, a prerequisite of the Sargan test is that there have to be over-identifying restrictions, hence the number of instruments needs to be greater than number of endogenous variables. Therefore two instrumental variables are employed as opposed to one to allow us to test their validity using the Sargan test.

[100] We attempted spatially weighting the model using the software 'SpaceStat' by creating an instrument based on the average income of the 20 closest neighbours to each observation. Unfortunately the instrument performed poorly in explaining net income and could not be implemented.

It is evident from the R^2 values shown in Table 4.11 that the two average income instruments explain net income better than the employment and education variables. This is perhaps unsurprising given the simplistic manner of the latter's construction. The average income by socio-economic characteristics captures all the information of both employment status and education level in a single instrument. Furthermore, average income of administrative regions will capture the regional disparity in household income.

Nevertheless, we incorporate both instruments for purposes of comparison to solve the endogeneity problems of net income. This was implemented by means of a two stage least squares regression. This should provide consistent estimates of the net income variables, provided the instrumental variable of choice is not rejected by the Sargan over-identification test. Table 4.12 re-tests Model 1 above with the two instruments.

At a first glance of the two models in Table 4.12 it appears there is very little difference between the two methods of instrumentation adopted. The only noticeable change is the slightly higher t-statistic of the instrumented net income which is higher for the average income instruments leading a relatively lower coefficient, though the effect is fairly small. However, the Sargan test of over-identification rejects the use of employment and education variables as instruments at the five per cent level of confidence, indicating they are likely to be unsuitable estimators of net income. This is likely to be caused by a degree of correlation with the error term, though it could also be due to the fact the instrument may simply not be adequate in estimating net income in the first place. Conversely, the average income instruments appear to work fine and are not rejected by the Sargan test with a Chi^2 value of 0.508.

The climate variables of our preferred Model 8 appear relatively unchanged in relation to the non-instrumented version in Model 1. January frost days remain significant at the one per cent level whilst July sunshine and January humidity remain at the five per cent level of confidence, both now being borderline one per cent. The only noticeable difference is the significance at the five per cent level of confidence for January precipitation

Table 4.12 Linear regression with instrumental variables

Dependent Variable: Minimum income to live comfortably and without problems

	Model 7	Model 8
Variable	Coefficient (T-statistic)	Coefficient (T-statistic)
Instrumental Variables	Employment Status Education Level	Average Income (Characteristics) Average Income (Region)
Net Income	0.853847*** (10.27)	0.786967*** (13.09)
Floorspace	-1.28447 (-0.61)	-0.12573 (-0.06)
Size < 2,000	-173.526 (-0.37)	-34.5541 (-0.37)
Size 2,000-10,000	299.9608 (0.53)	483.4503 (0.89)
Size 10,000-50,000	-307.738 (-0.60)	-150.296 (-0.31)
Size 50,000-100,000	461.095 (0.96)	689.6827 (1.51)
Latitude	-850.441 (-0.44)	-784.211 (-0.40)
Elevation	-531.128 (-0.17)	148.3572 (0.05)
January Frost Days	1337.108*** (3.52)	1317.554*** (3.57)
July Frost Days	-2304.74 (-0.73)	-3206.64 (-1.05)
January Precipitation	-55.6509** (-2.23)	-51.1495** (-2.07)
July Precipitation	-13.6709 (-0.55)	-16.5679 (-0.67)

January Sunshine	-379.359 (-1.62)	-401.694* (-1.73)
July Sunshine	671.7466** (2.49)	686.2754** (2.58)
January Humidity	-1187.91** (-2.46)	-1264.68** (-2.53)
July Humidity	-1678.22 (0.56)	-1490.88 (-0.58)
January Wind Speed	-964.125 (-0.59)	-976.719 (-0.64)
July Wind Speed	129.5694 (-0.44)	133.5062 (-0.40)
Distance to Zagreb	4.35863 (0.24)	3.504076 (0.19)
Distance to Split	13.76053 (0.43)	13.28319 (0.43)
Distance to Osijek	0.342056 (0.02)	0.508931 (0.03)
Distance to Rijeka	-51.6077*** (-2.77)	-50.8646*** (-2.72)
Distance to Coast	-34.2028 (-2.86)	-33.9135 (-2.84)
Distance to Paklenica	19.72703 (0.99)	22.83763 (1.17)
Distance to Krka	43.13819** (2.45)	40.34954** (2.35)
Distnce to Mjlet	-39.6286* (-1.94)	-37.7266* (-1.81)
Constant	68313.99 (0.82)	65194.1 (0.78)
Household Type Dummies	YES	YES
No. Obs	759	759
R^2	0.6130	0.6142
Sargan $N*R^2$ Test	$Chi^2 = 5.822^{**}$	$Chi^2 = 0.508$

*Source: See text. *** means significant at the one per cent level of confidence, ** means significant at the five per cent level of confidence and * means significant at the ten per cent level of confidence.*

4.9.2 Discussion of climate equivalence scales

For the climate variables, the results reveal that Croatian households located in areas characterised by high January frost days systematically require higher monthly net incomes in order to live comfortably and without problems. To our knowledge, frost days have only been included by Srinivasan and Stewart (2004) who apply the hedonic technique for a study of England and Wales. They control for annual frost days and find it to be a statistically insignificant determinant of wages or housing expenditure.

Although not directly comparable, a more common finding is statistical significance of January temperatures as a climatic amenity. Rehdanz and Maddison (2009) find January temperature to increase house prices and have an indeterminate effect on wage rates. The combined effect is that households are willing to pay to increase their consumption of January temperature.

The preference for warmer January temperatures is a common finding in the LS literature. Rehdanz and Maddison (2005), Brereton et al (2008), Ferreira and Moro (2010) and Chapter 2 of this thesis all find January minimum temperature to have a positive and statistically significant influence on LS. The consistent finding of the importance of higher January temperatures on LS has important implications in understanding the costs and benefits of changes in climate.

In the climate equivalence scales literature, Frijters and Van Praag (1998) also find that higher January temperatures in Russia significantly decreases household costs. It is by contrast, impossible to compare the current results to those from Van Praag (1988) because the climate variables are specified in terms of annual averages.

We do not place too much emphasis on the other significant climate variables, as they are only at the five per cent level and so an element of doubt exists due to a possible multicollinearity effect.[101] This appears evident with the negative coefficient on January humidity, suggesting it is compensating for the possible imperfect specification of January frost days as a proxy for cold winters. However, it is noted that the positive coefficient on July sunshine also indicates that higher monthly net incomes are needed to compensate this effect. This reflects a similarity once again to the common finding in hedonic studies of an aversion to hot summers. Unfortunately, Frijters and Van Praag (1998) do not account for seasonal sunshine levels. Although not quite the same variable, Maddison and Bigano (2003) find clear skies in July to have a negative impact on house prices and wage rates in their hedonic regressions for the Italian climate.

[101] Multicollinearity occurs when two or more explanatory variables are highly correlated and can be predicted from one other. This can affect the ability of affected variables to explain the dependent variable and can produce misleading results. The typical consequence is that it inflates standard errors of affected variables making them appear statistically insignificant. Their imprecise estimation may consequently make unimportant covariates appear significant. One should therefore take care in the interpretation of climate variables which are only weakly statistically significant.

4.9.2.3 The impact of climate on the cost of living in Croatian regions

Given the importance of particular types of climate on the cost of living it is necessary to investigate how these costs are felt across Croatia's diverse climate.

$$CCOL_k = \sum_{i=1}^{n} \pi_i z_{ik} \tag{4.39}$$

Where $CCOL_k$ is climate cost of living in region k, π_i is the implicit price of amenity i and z_{ik} the quantity of climate in region k. From this the regional climate equivalence scale (CES_k) can be calculated relative to the reference region r.

$$CES_k = \frac{\sum_{i=1}^{n} \pi_i z_{ik}}{\sum_{i=1}^{n} \pi_i z_{ir}} \tag{4.40}$$

Croatia is divided into the 4 geographic regions of Zagreb, Panonska Hrvatska, Primorska Hrvatska and Gorska Hrvatska. Appendix C.2 shows a colour coded map of Croatia. These four geographic regions can be further divided into 21 administrative regions, also labelled in Appendix C.2. Zagreb represents both a geographic and an administrative region and Gorska Hrvatska the Eastern and Northern administrations of the country. Primorska Hrvatska accounts for the administrations bordering the Adriatic Sea and Panonska Hrvatska the central administrations, including the most mountainous parts of the country.

We start by estimating climate equivalence scales following a similar approach to Frijters and Van Praag (1998) at the geographic region level for the purposes of comparison. We then conduct a considerably higher resolution analysis for the administrative region. Table 4.13 below provides the mean climates variables for the 4 geographic regions based on the regression results of Model 8. The final column gives the estimated marginal cost of each climate variable. A negative (positive) value implies it reduces (increases) the minimum income required to live comfortably and without problems.

The final two rows give the sample mean current income and climate equivalence scale of each region relative to Zagreb. Sample mean income in Gorska and Panonska are only 78% and 83% of incomes earned in Zagreb. This compares to Primorska whose mean income is almost equivalent to Zagreb. Interestingly however the estimated climate equivalence scales reveal the role climate has on household costs. All else being equal, those inhabiting the region of Panonska would require an additional 5% of income compared to Zagreb to compensate for the less amenable climate. The most amenable climate is Primorska where the climate means only 83% of the mean Zagreb income is required to live comfortably and without problems.

Table 4.13 Climate equivalence scales and mean climates by geographic region

	Zagreb (reference)	Panonska	Primorska	Gorska	Marginal Cost
Jan Frost Days	22.6	25.29	17.13	23.43	1317.55
July Frost Days	0	0.023	0.069	0.026	-3206.64
Jan Precipitation	107.2	58.08	98.56	89.35	-51.15
Jul Precipitation	86.9	85.13	61.91	88.12	-16.57
Jan Sunshine	22.4	24.82	36.26	26.85	-401.69
Jul Sunshine	59.1	59.40	66.43	61.65	686.28
Jan Humidity	80.6	84.61	74.84	82.19	-976.72
July Humidity	67.7	70.87	63.75	69.80	133.51
Jan Wind Speed	1.5	1.92	2.63	2.03	-1264.68
July Wind Speed	1.7	1.89	2.08	1.90	-1490.88
Current Income	**1**	**0.83**	**0.99**	**0.78**	
CES	**1**	**1.05**	**0.83**	**0.98**	

Table 4.14 gives the estimated climate equivalence scales of Croatian administrative regions. The reference administrative region is Zagreb in each case. Once again these estimates are based on the regression results obtained in Model 8. The linear specifications of the climate variables make the CCOL appear very large relative to mean household income. However, what is important to note is the absolute difference in costs relative to Zagreb. Climate has the lowest household costs in Dubrovacko-Noretvanska where the saving is 9788.50 Kuna. This is approximately 1.5 times mean household income. Correspondingly, those residing in Dubrivacko-Noretvanska only require two-thirds of the income to those in Zagreb. At the other end of the spectrum, the least amenable climate is the in Bjelovarso-bilogorska which is

2363.90 Kuna higher than Zagreb, or 35% of mean income. This corresponds to household cost of climate being 13% higher than in Zagreb.

For further analysis, Appendix C.3 presents a colour coded map of the 21 administrative regions of Croatia. An administrative region shaded in blue indicates the climate equivalence scale is less than one; the climate is reducing the minimum income necessary to live comfortably and without problems relative to Zagreb. If the administrative region is shaded in red the climate is increasing the minimum income. The shade of the blue or red demonstrates the size of the climate equivalence scale.

The geographical distribution of the welfare cost of climate is clear. The minimum income necessary is lowest in the administrative regions bordering the Adriatic Coast and enjoying a Mediterranean style climate. The minimum income necessary is highest on the North-East Pannonian plains where winters are coldest. There is little doubt that the key contributor to these findings is the increase in income necessary to counter the cost of additional frost days in January which is noticeably lower on the Adriatic Coast regions of Primorska.

Table 4.14 Climate equivalence scales by administrative region

Rank	Administrative Region	CCOL	Difference to Zagreb	CES
1	Dubrovacko-Noretvanska	-29491	-9788.5	0.66808
2	Istarska	-26099	-6397.3	0.75489
3	Primorsko-goranska	-25476	-5774.3	0.77335
4	Splitsko-Yeslmantiska	-21806	-2103.4	0.90353
5	Karlovacka	-21044	-1342.3	0.93621
6	ZaYesrska	-20749	-1046.6	0.94956
7	Licko-senjska	-20142	-440.2	0.97815
8	Sibensko-kninska	-20115	-412.6	0.97948
9	Krapinsko-zagorska	-19839	-136.8	0.9931
10	Vukovarsko-srijemska	-19764	-61.4	0.99689
11	Zagreb	-19702	0	1
12	Zagrebacka	-19625	76.8	1.00391
13	Brodsko-posavska	-19124	578.1	1.03022
14	Osjecko-baranjska	-18727	975.3	1.05208
15	Pozesko-salvonska	-18651	1050.8	1.05634
16	Medjimurska	-18482	1220.6	1.06604
17	Varazdinska	-18464	1238.6	1.06708
18	Sisacko-moslavacka	-17993	1709.2	1.09499
19	Viroviticko-podravska	-17675	2027.3	1.1147
20	Koprivnicko-krizevacka	-17599	2103.6	1.11953
21	Bjelovarsko-bilogorska	-17338	2363.9	1.13634

4.10 The relationship between household composition and climate

The previous empirical analysis considers both the costs associated with household composition and particular types of climate. So far they have been considered separate entities, but it is possible that households with specific traits may exhibit more pronounced preferences for climate. For example, the costs of additional January frost days could plausibly be higher in households with old inhabitants. To our knowledge, the direct relationship between household composition and climate has not been analysed before.

It is intuitive to believe there is a relationship between household composition and the monetary costs of the climate. Certain types of climate require different heating and cooling requirements. Government policies, such as the UK winter fuel payment scheme, compensate certain households during the coldest months (The Social Fund Winter Fuel Payment Regulations, 1998). This aids those in retirement to pay their heating bills.

Change in household composition can also affect the monetary costs of climate. For example, the 2011 Annual Report of Fuel Poverty the Department for Energy and Climate Change (DECC) calculate a UK household to be fuel poor if they spend more than 10% of their income to maintain an adequate level of warmth. 2009 data finds that over 50% of all fuel poor households in the UK contain an individual over 60 (DECC, 2011). Table 4.15 below provides a breakdown of fuel poverty by household composition.

Table 4.15 Average annual income by household composition

Household Composition Group	Average Annual Income (£)	Proportion of group that are fuel poor
Couple with dependent child(ren)	38,200	8.10%
Couple, no dependent child(ren), aged 60 or over	26,200	20.30%
Couple, no dependent child(ren), under 60	38,400	7.10%
Lone parent with dependent child(ren)	19,100	20.50%
One person aged 60 or over	14,100	38.50%
One person under 60	18,100	25.90%
Other multi-person households	28,400	18.00%
All households	27,900	18.40%

Source: DECC (2011)

Perhaps unsurprisingly the household compositions which are most vulnerable to fuel poverty are all single adult households and couples over 60. Fuel poverty appears most prevalent for single adult over 60 years old which stands at 38.5% at all households in this group. Average annual income is also lowest in this group at £14,100.

It is possible to isolate for whom the costs of climate impact on most severely by interacting climate variables with specific household characteristics. We hold the empirical specification the same as Model 8 and isolate household characteristics in five ways. In all subsequent models we include additional variables in their normal format and interact with all climate variables. Firstly we control for the number of individuals in each household who are under 15, between 15 and 65 and over 65. This is to test whether having more of a particular age category makes households more sensitive to certain climates. We expect that households containing more old individuals are more sensitive in particular to cold winters. Next we include a dummy variable equal to one if there is anyone over 65 living in a household. This allows for the possibility that simply having one older person living in the household is sufficient for the costs of climate to be significantly altered to meet their needs. This should follow the expectations of the first model. Thirdly we control for family size and fourthly floor space. It stands to reason that the costs of climate may change as the total number of household members or the size of house increases. Larger houses and families could amplify the costs of less amenable climates. Finally we control for the possibility that larger families could lead to a cost saving if combined with a small living space (floor space divided by family size). We call this square metres per person (SqmPP). It is expected that households with a larger floor space per household member should face higher costs in less amenable climate. The results are provided in Table 4.16.

Model 9 tests for the relationship between the three age categories and climate. There appears little evidence that the number of individuals of particular ages affect the cost of living caused by climate. The only interacted dummy that is individually statistically significant at the one per cent level of confidence is January sunshine for those under 15. The positive coefficient implies additional sunshine in January increases household costs if there are more children in the household. It is difficult to think of a plausible explanation of why this might be the case. However, the interacted terms are jointly statistically significant at the one per cent level and confirm that particular age groups are having some combined effect on household costs with respect to climate.

Model 10 interacts the climate variables with the dummy variable for a household member being over 65. Perhaps volume of older household members is irrelevant and the costs of climate are dependent simply on having an old person present. However, it can be seen that all interacted terms are individually statistically insignificant and are also jointly insignificant.

We therefore conclude that the presence of an old household member does not significantly alter household costs across various climates.

Model 11, Model 12 and Model 13 account for the amount floor space, family size and SqmPP respectively. Once again the interacted terms are jointly insignificant for any conventional level of confidence. We conclude the size of home and the number of household members does not significantly alter household costs.

The lack of statistical significance of the interacted variables is unexpected. It is possible that the small sample utilised in this chapter makes it difficult to precisely determine the magnitude of such effects. The joint statistical significance of the interacted variables in Model 9 tells us that household composition is playing some indeterminate role on the costs of climate.

Table 4.16 Household composition and climate regression results

	Model 9	Model 10	Model 11	Model 12	Model 13
Net	0.75*** (0.07)	0.76*** (0.07)	0.78*** (0.06)	0.78*** (0.06)	0.79*** (0.06)
Floor Space	-0.27 (2.11)	0.65 (2.08)	139.55 (301.76)	-0.43 (2.05)	-0.03 (4.17)
Size < 2,000	116.76 (458.02)	-115.84 (446.10)	85.89 (481.99)	-115.07 (475.95)	-8.67 (492.36)
Size 2,000-10,000	496.17 (535.34)	435.47 (531.70)	502.38 (562.78)	386.54 (555.08)	497.21 (558.56)
Size 10,000-50,000	-55.82 (500.15)	-186.40 (480.46)	16.20 (538.87)	-232.40 (513.41)	-54.18 (515.89)
Size 50,000-100,000	742.36 (453.69)	624.11 (450.50)	805.49* (469.94)	586.01 (467.84)	747.20 (479.90)
Latitude	-791.78 (1822.02)	-617.25 (1992.30)	-809.85 (2011.41)	-546.21 (1925.63)	-1059.64 (1964.143)
Elevation	-878.71 (2945.85)	368.34 (3042.06)	98.65 (2957.28)	150.02 (2959.42)	236.45 (2985.84)
January Frost Days	1396.36*** (458.65)	1198.81*** (399.78)	1302.71** (578.46)	1376.04*** (439.24)	1432.52*** (468.72)
July Frost Days	3075.11 (5862.27)	-2563.77 (3278.81)	-4523.63 (5876.21)	1141.29 (4742.00)	-6866.22* 4040.37
January Precipitation	-57.91** (28.18)	-54.11** (27.13)	-36.16 (28.08)	-53.41** (26.97)	-45.56* (26.92)
July Precipitation	-26.26 (49.70)	-12.08 (27.31)	31.40 (41.38)	-36.52 (44.28)	10.56* (35.81)
January Sunshine	-528.57* (281.59)	-373.60 (238.93)	-492.96* (270.50)	-583.16** (258.85)	-374.06 (236.68)
July Sunshine	785.90** (322.28)	652.45** (274.39)	858.63*** (312.65)	830.44*** (306.09)	683.38** (281.76)
January Humidity	-1137.11*** (440.36)	-896.25** (414.88)	-811.31 (501.53)	-1118.04*** (428.92)	-925.38** (435.02)
July Humidity	254.40 (312.51)	115.98 (242.13)	18.13 (292.81)	300.21 (278.48)	-20.99 (2344.65)
January Wind Speed	1227.11 (3498.49)	-749.90 (2133.96)	3849.75 (3128.80)	24.13 (2964.54)	122.14 (2344.65)
July Wind Speed	-4192.38 (7148.52)	-3194.56 (4181.99)	-9166.49 (7026.14)	-1830.00 (5824.53)	-3906.49 (4851.96)
Distance to Zagreb	1.33 (18.68)	3.87 (18.30)	-0.66 (18.38)	5.01 (18.64)	2.91 (18.45)
Distance to Split	-0.19 (33.44)	11.93 (31.76)	9.54 (31.08)	16.91 (32.25)	14.52 (31.71)
Distance to Osijek	2.99 (16.75)	-1.59 (17.68)	-0.89 (17.53)	3.67 (17.77)	-0.32 (18.22)
Distance to Rijeka	-47.95***	-49.62***	-53.85***	-54.87***	-53.21**

	(17.82)	(19.00)	(18.95)	(18.65)	(18.84)
Distance to Coast	-32.80*** (12.30)	-35.21*** (12.20)	-35.32*** (11.81)	-33.43*** (12.13)	-34.12*** (11.95)
Distance to Paklenica	14.77 (20.17)	20.22 (19.62)	29.82 (20.06)	22.03 (20.02)	25.38 (19.90)
Distance to Krka	54.03*** (17.41)	42.62** (16.91)	38.62** (16.96)	41.23** (17.08)	39.32** (16.91)
Distance to Mjlet	-35.59* (18.38)	-37.74* (21.45)	-37.21* (20.49)	-43.15** (20.84)	-37.68* (20.91)
Old	-24851.08 (16440.39)	-	-	-	-
Prime	-22221.68 (15995.41)	-	-	-	-
Old * January Frost Days	55.23 (200.85)	-	-	-	-
Old * July Frost Days	-3659.84 (3737.25)	-	-	-	-
Old * January Precip	8.78 (10.70)	-	-	-	-
Old * July Precipitation	14.94 (32.31)	-	-	-	-
Old * January Sunshine	81.26 (97.13)	-	-	-	-
Old * July Sunshine	-10.37 (146.18)	-	-	-	-
Old * January Humidity	96.69 (178.82)	-	-	-	-
Old * July Humidity	-91.57 (148.02)	-	-	-	-
Old * January Wind Speed	-412.08 (1747.94)	-	-	-	-
Old * July Wind Speed	562.14 (4010.28)	-	-	-	-
Prime * January Frost Days	-90.62 (115.10)	-	-	-	-
Prime * July Frost Days	-64.87 (2260.73)	-	-	-	-
Prime * January Precip	4.93 (5.56)	-	-	-	-
Prime * July Precipitation	-4.73 (15.38)	-	-	-	-
Prime * January Sunshine	26.52 (51.88)	-	-	-	-
Prime * July Sunshine	-14.73 (69.45)	-	-	-	-
Prime * January Humidity	100.81 (104.00)	-	-	-	-

Prime * July Humidity	-25.88 (70.27)	-	-	-	-
Prime * January Wind Speed	-761.46 (881.41)	-	-	-	-
Prime * July Wind Speed	766.85 (1957.09)	-	-	-	-
Child * January Frost Days	216.53 (183.73)	-	-	-	-
Child * July Frost Days	-7246.28** (3480.60)	-	-	-	-
Child * January Precip	-4.15 (9.38)	-	-	-	-
Child * July Precipitation	15.80 (28.51)	-	-	-	-
Child * January Sunshine	214.40*** (80.23)	-	-	-	-
Child * July Sunshine	-222.81* (121.26)	-	-	-	-
Child * January Humidity	10.26 (173.91)	-	-	-	-
Child * July Humidity	-174.39 (110.52)	-	-	-	-
Child * January Wind Speed	4.93 (1290.65)	-	-	-	-
Child * July Wind Speed	-867.25 (2907.92)	-	-	-	-
Old Dummy	-	-9223.68 (17529.20)	-	-	-
Old Dum * January Frost Days	-	152.62 (204.75)	-	-	-
Old Dum * July Frost Days	-	-1325.65 (4573.27)	-	-	-
Old Dum * January Precip	-	9.83 (12.77)	-	-	-
Old Dum * July Precip	-	-9.81 (30.36)	-	-	-
Old Dum * January Sunshine	-	-59.24 (97.89)	-	-	-
Old Dum * July Sunshine	-	107.92 (161.52)	-	-	-
Old Dum * January Humidity	-	-123.93 (182.79)	-	-	-
Old Dum * July Humidity	-	73.13 (128.53)	-	-	-
Old Dum * January Wind Speed	-	-1114.32 (1705.76)	-	-	-
Old Dum * July	-	3973.46	-	-	-

Wind Speed		(3947.57)			
Floorspace * January Frost Days	-	-	0.11 (3.99)	-	-
Floorspace * July Frost Days	-	-	11.35 (48.62)	-	-
Floorspace * January Precip	-	-	-0.13 (0.13)	-	-
Floorspace * July Precip	-	-	-0.47 (0.33)	-	-
Floorspace * January Sunshine	-	-	0.60 (1.29)	-	-
Floorspace * July Sunshine	-	-	-1.52 (2.00)	-	-
Floorspace * January Humidity	-	-	-1.72 (3.35)	-	-
Floorspace * July Humidity	-	-	1.17 (1.48)	-	-
Floorspace * January Wind Speed	-	-	-43.87** (20.47)	-	-
Floorspace * July Wind Speed	-	-	69.26 (51.88)	-	-
Familysize * January Frost Days	-	-	-	-3.53 (91.52)	-
Familysize * July Frost Days	-	-	-	-1448.24 (1366.31)	-
Familysize * January Precip	-	-	-	-1.07 (4.70)	-
Familysize * July Precip	-	-	-	5.64 (13.27)	-
Familysize * January Sunshine	-	-	-	63.90* (38.18)	-
Familysize * July Sunshine	-	-	-	-61.19 (58.70)	-
Familysize * January Humidity	-	-	-	47.71 (80.39)	-
Familysize * July Humidity	-	-	-	-69.66 (57.71)	-
Familysize * January Wind Speed	-	-	-	-392.71 (631.21)	-
Familysize * July Wind Speed	-	-	-	-37.48 (1424.32)	-
Square Metre Per Person (SqmPP)	-	-	-	-	-18.17 (359.73)
SqmPP * January Frost Days	-	-	-	-	-2.41 (4.48)
SqmPP * July Frost Days	-	-	-	-	85.93 (59.88)

SqmPP * January Precipitation	-	-	-	-	-0.18 (0.17)
SqmPP * July Precipitation	-	-	-	-	-0.64 (0.52)
SqmPP * January Sunshine	-	-	-	-	-1.18 (1.53)
SqmPP * July Sunshine	-	-	-	-	0.23 (2.54)
SqmPP * January Humidity	-	-	-	-	-2.25 (3.37)
SqmPP * July Humidity	-	-	-	-	4.26** (2.03)
SqmPP * January Wind Speed	-	-	-	-	-34.97 (28.89)
SqmPP * July Wind Speed	-	-	-	-	60.05 (67.93)
Constant	84866.03 (83905.48)	59205.47 (85750.90)	52729.31 (95081.10)	53663.41 (82109.39)	80204.61 (86855.11)
Household Composition Dummies?	YES	YES	YES	YES	YES
N **R^2** **Test of Joint Significance**	759 0.6325 Chi(30)= 51.34***	759 0.6206 Chi(10)= 4.31	759 0.6197 Chi(10)= 14.30	759 0.6175 Chi(10)= 10.31	759 0.6160 Chi(10)= 9.08

*Source: See text. *** means significant at the one per cent level of confidence, ** means significant at the five per cent level of confidence and * means significant at the ten per cent level of confidence.*

4.11 Conclusions

This chapter employs the little-used income evaluation technique to examine the impact of demographic composition and climate on household costs in Croatia. It also takes the unique approach of analysing the sensitivity of certain households to particular types of climate. The underlying motivation is to understand better the welfare impacts of climate change.

The results from the household equivalence scales suggest that household costs increase with family size. This is more pronounced for economically active males and females and males aged over 65. There also appears to be an economies of scale effect as household size rises as well as a preference drift effect as income increases. This conforms to the findings of the previous literature.

Application of dummy variables relative to the reference household suggests that the additional costs may plateau as household size goes past four and adults are a greater burden than children. Following the Leyden School approach provides much lower estimates for equivalence scales than the dummy variables approach. The use of a large number of dummy variables ensures that households are being separated into exactly the same types allowing for direct comparison to the reference household.

The results from the climate equivalence scales confirm that household costs increase with the number of January frost days. Such findings resonate with results from other European countries derived using alternative methodologies. Also, compared to two related studies, this exercise uses climate data with higher geographical resolution.

Analysis of the relationship between household composition and climate was inconclusive. Whilst controlling for the costs of climate on different age groups proved statistically significant at the one per cent level, it was only able to determine individually the increased cost of having more children in locations with higher January sunshine. The likely limitation of this analysis is the number of observations. Nevertheless, future research needs to pay attention to this potential relationship. This is necessary to identify particular households that could be more sensitive to changes in climate. Minimising the adaptation costs of climate change may require prioritising the needs of certain households. This can only be tested by collecting detailed information on the demographic composition of all household members.

Advantages of the technique include the ease of collecting survey data on the income evaluation question (compared to data on actual household incomes). Clearly careful phrasing of the income evaluation question is necessary to ensure different households interpret the question in the same way. By providing income requirements for 'households in exact circumstances' it allows respondents to use their current income as a reference point. From this they can determine whether they believe to be above or below 'comfortable level without any problems.'

Future work on climate amenities should focus on larger, more populous countries such as China or India. Clearly, the success of international protocols intended to limit GHGs will in large part be determined by these countries perceptions that their population is risking a significant increase in the cost of living caused by anthropogenic climate change. This chapter has found evidence for Croatian data that the cost of living is higher in locations with more frost days in January. Climate equivalence scales estimated across the administrative regions of Croatia demonstrate a wide variation on the cost of living associated with overall climatic conditions. These findings are likely to be even more pronounced across countries with large variations in climate.

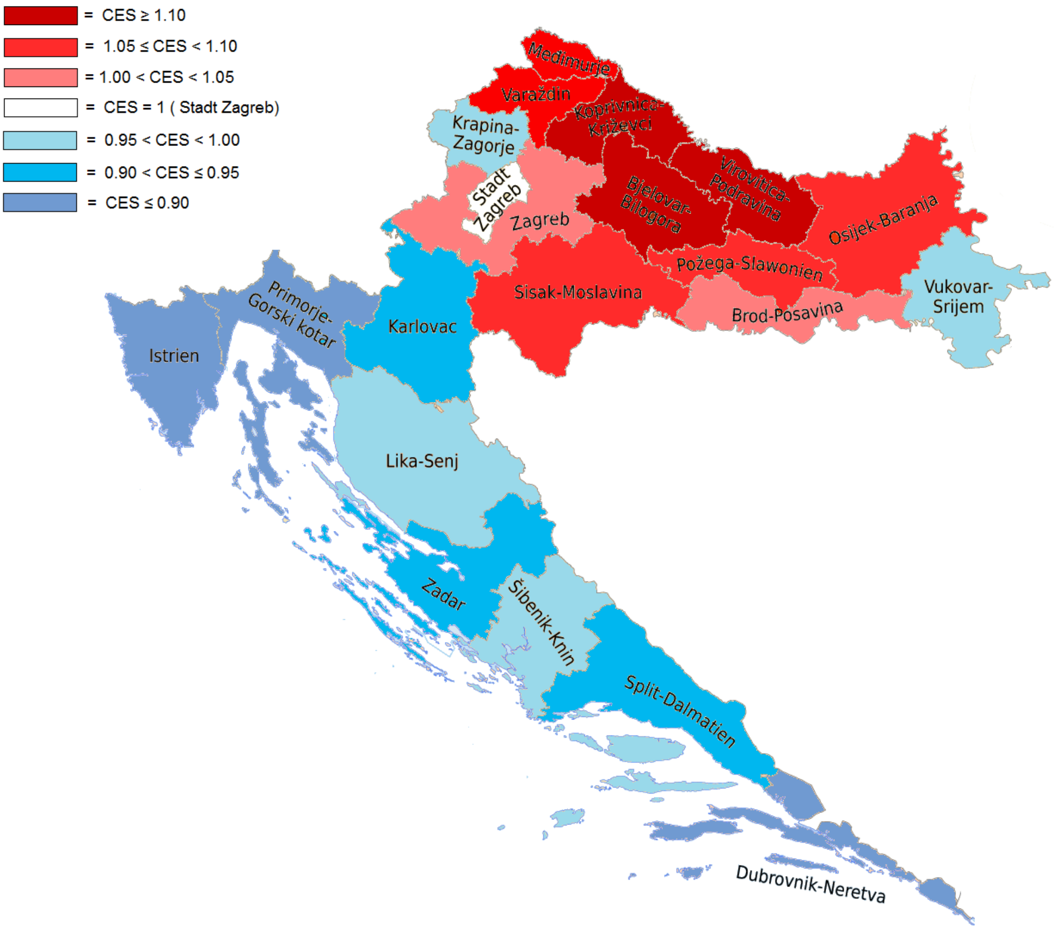
Appendix C.1 Topographic map of Croatia

Source: GRID-Arendal *http://maps.grida.no/go/graphic/croatia_topographic_map*.

Credit: Philippe Rekacewicz, Emmanuelle Bournay

Appendix C.2 Map of Croatia by geographic region

Appendix C.3 Climate equivalence scale map of Croatia by administrative region



CHAPTER 5

INCOME ELASTICITY OF MARGINAL UTILITY- WHAT CAN LIFE SATISFACTION TELL US?

5.1 Introduction

It is often claimed in public policy that marginal utility in income is diminishing. In this respect a poor individual will obtain a greater increase in welfare from an additional unit of income than a richer counterpart. Utility is therefore positive but strictly decreasing in income. The elasticity of marginal utility with respect to income represents the percentage rate at which utility changes for every percentage change in income.

Pearce and Ulph (1995), for example, derive the elasticity of marginal utility algebraically. The marginal utility of income is simply the first derivative of utility (U) with respect to income (Y)

$$\frac{dU}{dY} \qquad \textbf{(5.1)}$$

Diminishing marginal utility requires

$$U'(Y) = \frac{dU}{dY} > 0 \text{ and } U''(Y) = \frac{d^2U}{dY^2} < 0 \qquad \textbf{(5.2)}$$

The elasticity of marginal utility with respect to income, ρ, is therefore the specific rate at which marginal utility diminishes as income rises and is dependent on the level of Y.

$$\rho = -\frac{Y.U''(Y)}{U'(Y)} > 0 \qquad \textbf{(5.3)}$$

The value of ρ can be interpreted across three different dimensions that relate to risk aversion and inequality across consumption. The first dimension is 'risk aversion'. This reflects an individual's (or household's) own attitude to risk. It is often referred to as the coefficient of relative risk aversion. [102] The second dimension is 'inequality aversion'. This is inequality across space and reflects distribution of consumption in a single time period. The third dimension is 'intertemporal substitution'. This is inequality in consumption over time (i.e. across generations). It is often assumed that the value of ρ is transferable across all three (Atkinson et al, 2009). This is because if individuals are behave like a veil of ignorance, it should not matter whether redistribution then spatial inequality should not differ from one's attitudes to risk (Harsanyi, 1955).[103]

It is necessary to estimate ρ in order to redistribute income through setting efficient levels of taxation, to weight appropriately different income households in social cost benefit analysis and social discounting (Atkinson, 1970). The latter follows the intertemporal substitution

[102] In this sense, an individual is said to be risk averse if their elasticity of marginal utility, or relative risk aversion is greater than zero. The utility gained from a one pound increase in income will always be outweighed by the disutility of a one pound fall in income. See Arrow (1965) for the theory of risk aversion.

[103] Atkinson et al (2009), however, use a stated preference survey estimate ρ for each of the three dimensions and find there to be little correlation between respondent risk aversion, inequality aversion and intertemporal substitution. See Section 5.2.2 for further details and other stated preference surveys.

dimension identified above, whilst the other two reflects inequality aversion. The coefficient of relative risk aversion is uusually referred to in the financial economics literature A more risk averse individual exhibits a higher elasticity of marginal utility and subsequently marginal utility diminishes faster as income increases (Stiglitz, 1988).

The elasticity of marginal utility is a key parameter for redistribution in social cost-benefit analysis. If the aim of public policy is to redistribute wealth then weighting the poor by their relatively higher elasticity of marginal utility with respect to income will result in inequality aversion (Stiglitz, 1988; Atkinson, 1970). The size of a welfare weight determines the amount of income that needs be redistributed from one individual to another. Corresponding welfare weights are decreased monotonically as income increases (Cowell and Gardner, 1999).[104]

The redistribution welfare weight (a) to individual i is a function of ρ with respect to Y:

$$a_i = Y_i^{-\rho} \tag{5.4}$$

The size of the redistribution is dependent on the value taken for ρ.[105] Compared to the average income ($\overline{Y}$), the relative weight for individual i is

[104] Atkinson and Stiglitz (1980) identify that, for a proportional tax, only workers whose elasticity of marginal utility is greater than unity will decide to work an additional unit of labour. A lower than unity elasticity will deter workers from working. However, the greater the proportion of the tax the lower marginal utility each individual will receive net of taxes.

[105] Transferring income through taxation will incur transaction costs and requires the weight for the rich and the poor to be different to account for inefficiency (Brent, 1997). 'Leaky bucket' experiments seek to trade-off equity through redistribution and the level of inefficiency in redistributing. See Okun (1975) for a full discussion of leaky bucket experiments.

$$\frac{a_i}{\bar{a}} = \frac{Y_i^{-\rho}}{\bar{Y}^{-\rho}} \qquad \textbf{(5.5)}$$

From a public policy perspective it is critical to apply an appropriate social discount rate to estimate the present value attached to possible Government public expenditure choices. It is inappropriate to take the market rate of interest as the social discount rate in public policy because of the existence of constraints such as taxation on capital (e.g. see Brent, 1997). A Ramsey (1928) social time preference rate (STPR) framework has been adopted by the UK government requires the direct estimation of the elasticity of marginal utility (HM Treasury, 2003). The STPR therefore reflects the intertemporal substitution dimension for ρ.

Brent (1997) explains that the STPR for the welfare (W) of all future generations alive at time t is a function of only Y. The function which transforms Y into W in time period t is isoelastic and therefore dependent on the elasticity of marginal utility with respect to income. The impact of additional income on welfare is given by ρ in equation 5.6. Now, the greater the value of ρ, the lower the influence Y has on the level of W.

$$W(t) = \left[\frac{1}{1-\rho}\right] Y^{1-\rho} \qquad \textbf{(5.6)}$$

Equation 5.6 is a static model and can be expanded to cover multiple time periods. The intertemporal welfare function gives the present value of all generational welfare functions

W(t) and is discounted at a intergenerational discount rate, or rate of time preference (δ). The larger the value of ρ, the lower the welfare weight placed on future generations.

$$W = \int e^{-\delta t} W(t) \qquad \textbf{(5.7)}$$

To obtain the STPR it is necessary to estimate the value of an extra unit of income on welfare. Differentiating with respect to Y gives us the rate at which a change in income leads to a change in welfare. Let us call this W_y. Equation 5.8 solves the derivation.

$$W_y = e^{-\delta t} \frac{(1-\rho)Y^{1-\rho-1}}{1-\rho} = e^{-\delta t} Y^{-\rho} \qquad \textbf{(5.8)}$$

The STPR is the rate at which W_y falls over time.

$$STPR = -\frac{dW_Y / dt}{W_Y} = \frac{e^{-\delta t} Y^{-\rho-1} dy / dt + e^{-\delta t} \delta Y^{-\rho}}{e^{-\delta t} Y^{-\rho}} \qquad \textbf{(5.9)}$$

This simplifies to

$$STPR = \rho \frac{dY / dt}{Y} + \delta \qquad \textbf{(5.10)}$$

The function *(dY/dt)/Y* is the growth rate in income per capita which we simplify to *g*. This gives the standard STPR formula (e.g. see HM Treasury, 2003)

$$STPR = \delta + \rho g \quad \textbf{(5.11)}$$

The aim of this chapter is to provide evidence on the appropriate value of ρ using survey data from Croatian households. It is important to note that the cross-sectional nature of this study means that the value of ρ estimated in this Chapter is one of inequality aversion as opposed to one of intertemporal substitution outlined in the STPR. Croatia represents an interesting study to research because it is a middle income country which was until recently a war-torn state. They key question is whether the value of ρ differs substantially enough for value transfer to be applicable from other countries. Four approaches are reviewed to estimate ρ. The life-cycle behaviour model seeks to observe the intertemporal elasticity of substitution for consumption over time and corresponding optimal savings behaviour. The equal absolute sacrifice model assumes that the income tax rate reduces utility at a constant rate across all income levels. The preference independent goods approach assumes additive separability of two or more goods. Finally the SWB approach assumes utility can be measured directly through self-reporting.[106] We adopt the latter approach and compare our findings to previous empirical estimate of ρ using the alternative methodologies.

Following Layard et al (2008) we use self-reported LS scales to measure utility directly. A member of each household is required to rate their overall level of LS on a bounded integer scale between 1 and 10. However we make a number of important contributions to the literature. Firstly, we control for differences in household composition and house size and find them to be statistically significant determinant of LS. This allows us to examine, using a

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[106] The theory that LS measures utility is given in Section 5.2.4 of this chapter

demographic scaling technique, whether demographic features of households influence the value of ρ directly. Secondly, we consider the problem of measurement error for income reported in household surveys. This is a common issue in SWB studies where income ranges (e.g. deciles) are often the only information available to the analyst. We develop an IVs approach to account for this data limitation.

To anticipate our results we find that the marginal utility of income is diminishing for Croatian households. However, our estimation for ρ is lower than the multi-country findings of Layard et al (2008).

The remainder of the chapter is structured as follows. Section two reviews the empirical literature on the estimation of ρ using a number of techniques including the use of SWB. Section three introduces the dataset and provides a summary of the relevant variables. Section four presents the empirical analysis. We consider both a cardinal approach to LS, using an ordinary least squares estimation, and an ordinal approach, using an ordered probit technique. Cardinality assumes that the magnitude of life satisfaction responses is comparable across individuals. Ordinality only assumes individuals who report their life satisfaction to be, for example, 8 out of 10 are more satisfied than those who report it to be 7, ignoring what the magnitude of this difference might be. Section five discusses the meaning of the empirical findings and the final section concludes.

5.2 Literature review

The majority of empirical literature has focused on estimating a social discount rate with which the costs and benefits of projects funded by public expenditure are discounted over time. The most recent publication of the Treasury's Green Book (HM Treasury, 2003) adopts the STPR framework, making it necessary to determine appropriate values for δ, g and ρ.

The striking feature of the Green Book, on which UK government departments take the appropriate social discount rate, is the antiquated evidence base of the three elements making up the STPR.[107] This is apparent, for example, with ρ where a best estimate of unity is taken from Blundell et al (1994) and a review of social discounting (Pearce and Ulph, 1995; 1999). Blundell et al (1994) use a dataset covering an period of extreme economic turbulence (1970-1986). Pearce and Ulph (1995) only review a subset of possible techniques available.

Pearce and Ulph (1995) explain δ to be dependent on the sum of two factors. The first is a pure time preference effect. This is the discounting value that individuals place on future utility from consumption purely because it occurs later. The second is the rate of growth of life chances. Future consumption will only bring utility if one is alive to enjoy it. From a policy perspective, this could be the occurrence of an event of catastrophic risk which would eliminate or unpredictably alter any future returns (HM Treasury, 2003). The value of δ as taken by the HM Treasury (2003) is currently estimated at 1.5. OXERA (2002) suggest a sensible value for pure time preference lies between 0 and 0.5 whereas changing life chances may account for about 1.1%.

[107] Current government policy is to use a social discount rate of 3.5% (HM Treasury, 2003)

The expected rate of growth of consumption, *g*, is generally estimated in a straightforward fashion by averaging past annual growth data (A. Maddison, 2001). Taking very long past rates of growth in per capita consumption should smooth out any temporary fluctuations (Pearce and Ulph, 1995).

The appropriate value for ρ has attracted much academic attention, especially since the Stern debate (e.g. see Nordhaus, 2007; Weitzman, 2007). Pearce and Ulph (1995) describe two approaches that can be taken to estimate the value of ρ. The first is to obtain evidence on the savings behaviour of individual households. This involves a life-cycle behaviour model, where the reciprocal of the inter-temporal elasticity of substitution of consumption of households can be interpreted as the coefficient of relative risk aversion. The second is to observe society's redistribution of income from rich to poor. For example, a government's aversion to income equality should be observable from the progressiveness of its income tax (Evans, 2005). Pearce and Ulph (1995) ignore an approach that analyses consumer demand when goods are preference independent. Furthermore, it predates empirical research on ρ that utilises SWB data.[108]

An exploration of these techniques forms the remainder of this literature review. Five empirical techniques are considered: the life-cycle behaviour model, stated preference surveys, consumer demand for preference independent goods, equal absolute sacrifice models and the SWB approach. A summary of the empirical estimates of ρ are summarised in Table 5.1 at the end of Section 2.

[108] Financial economics literature use survey techniques to estimate relative risk aversion of respondents, however a review of this literature is beyond the scope this chapter. See, for example, Filbeck et al (2005) who analyse whether personality traits are important in determining risk aversion to financial investments.

5.2.1 Life-cycle behaviour model

The way in which individuals behave in consumption decisions over time has been tested empirically using a multi-period life-cycle model as a basis. It is possible to estimate the value of ρ by observing the savings behaviour of individual households. The choice a household makes on how much to consume in each time period, in the pretence of maximising life-time consumption, is dependent on the rate of interest that affects the level of saving. This is the relative price of consumption in different periods.

The way in which individuals behave in consumption decisions over time has been tested empirically using a multi-period life-cycle model as a basis. Standard practice in the literature however (e.g. see Kuglar, 1988; Campbell and Mankiw, 1991) is to aggregate consumption data of households and to estimate the intertemporal elasticity of substitution for consumption.

Bliss (2004) outlines the present value of all future time period in equation 5.12. The weight at which the utility from future consumption periods is discounted to the present is given by *1-δ*. Under the assumption that a unit of consumption today is preferred than in the future then $0 < \delta < 1$. The closer $1-\delta$ is to 1 (and therefore δ is to zero), the greater the weight of future consumption in the present value utility function.

$$U(C_1,\ldots,C_t,\ldots)=\sum_{t=1}^{\infty}(1-\delta)^{t-1}U(C_t) \qquad \textbf{(5.12)}$$

The consumer is constrained in the consumption function. The intertemporal budget constraint is given by the present value of all consumption ($(1/1+r)^t$) multiplied by C_t. This must be no greater than the present value of infinite lifetime income (*I*).

$$\sum_{t=1}^{\infty}\left(\frac{1}{1+r}\right)^t C_t \leq I \quad \textbf{(5.13)}$$

The rate of return to saving (*r*) between time periods *t* and *t+1* is given by

$$\frac{\left(\frac{1}{1+r}\right)^t}{\left(\frac{1}{1+r}\right)^{t+1}} - 1 = \frac{(1+r)^{t+1}}{(1+r)^t} - 1 = r \quad \textbf{(5.14)}$$

If $(1/1+r)^{t+1}$ were to rise, with $(1/1+r)^t$ remaining constant, this would lead to a fall in the rate of return to saving. This is because it has now become more attractive to consume in time *t* as opposed to waiting until *t+1*. We now maximise equation 5.12 subject to equation 5.13 which gives (for both *t* and *t+1*)

$$(1-\delta)^{t-1}\frac{dU(C_t)}{dC_t} - \lambda\left(\frac{1}{1+r}\right)^t = 0 \text{ and } (1-\delta)^{t+1-1}\frac{dU(C_{t+1})}{dC_{t+1}} - \lambda\left(\frac{1}{1+r}\right)^{t+1} = 0 \quad \textbf{(5.15)}$$

We now rearrange with respect to λ and substitute

$$\frac{(1-\delta)^{t-1}\dfrac{dU(C_t)}{dC_t}}{\left(\dfrac{1}{1+r}\right)^{t}}=\lambda=\frac{(1-\delta)^{t}\dfrac{dU(C_{t+1})}{dC_{t+1}}}{\left(\dfrac{1}{1+r}\right)^{t+1}} \qquad \textbf{(5.16)}$$

It is then possible to rearrange equation 5.16 and simplify as follows

$$\frac{(1-\delta)^{t-1}\dfrac{dU(C_{t+1})}{dC_{t+1}}}{(1-\delta)^{t}\dfrac{dU(C_t)}{dC_t}}=\frac{\left(\dfrac{1}{1+r}\right)^{t+1}}{\left(\dfrac{1}{1+r}\right)^{t}}\Rightarrow\frac{1}{1-\delta}\frac{\dfrac{dU(C_{t+1})}{dC_{t+1}}}{\dfrac{dU(C_t)}{dC_t}}=\frac{1}{(1+r)} \qquad \textbf{(5.17)}$$

To derive the Euler equation, we assume that the utility derived from consumption in time period t be iso-elastic:

$$U(C_t)=\frac{C_t^{1-\rho}-1}{1-\rho} \qquad \textbf{(5.18)}$$

And $\dfrac{dU(C_t)}{dC_t}=\dfrac{(1-\rho)C_t^{1-\rho-1}}{1-\rho}=C_t^{-\rho}$ **(5.19)**

Therefore:

$$\frac{1}{(1-\delta)}\frac{C_{t+1}^{-\rho}}{C_t^{-\rho}}=\frac{1}{(1+r)}\Rightarrow\frac{(1+r)}{(1-\delta)}=\frac{C_t^{-\rho}}{C_{t+1}^{-\rho}}\Rightarrow\frac{(1+r)}{(1-\delta)}^{-\frac{1}{\rho}}=\frac{C_t}{C_{t+1}}\Rightarrow C_t\frac{(1+r)}{(1-\delta)}^{\frac{1}{\rho}}=C_{t+1} \qquad \textbf{(5.20)}$$

Taking logs gives the Euler equation

$$\ln C_t + \frac{1}{\rho}(1+r) + \ln\frac{1}{\rho}(1-\delta) = \ln C_{t+1} \qquad \textbf{(5.21)}$$

In order to demonstrate how the intertemporal elasticity of substitution, and therefore the elasticity of marginal utility, can be derived, we return to equation 5.17. Firstly, let us simplify by letting $\varepsilon = C_{t+1}/C_t$, $\pi_t = (1/1+r)^t$ and taking logs.

$$\ln\frac{dU(\varepsilon C_t)}{dC} - \ln\frac{dU(C_t)}{dC} = \ln\pi_t - \ln\pi_{t+1} - \ln(1-\delta) \qquad \textbf{(5.22)}$$

It is now possible to differentiate to the second order with respect to ε giving

$$\frac{C_t}{dU(\varepsilon C_t)/dC} \cdot \frac{dU^2(C_{t+1})}{dC^2} \cdot \frac{d\varepsilon}{d\pi_{t+1}} = \frac{1}{\pi_{t+1}} \qquad \textbf{(5.23)}$$

This can be simplified to

$$\frac{d\varepsilon}{d\pi_{t+1}} = -\frac{\sigma(C_t)}{\pi_{t+1}} \qquad \textbf{(5.24)}$$

Where σ is the intertemporal elasticity of substitution and is equal to equation 5.25 when consumption is generalised for all time periods

$$\sigma(C) = -\frac{\frac{dU(C)}{dC}}{\frac{dU^2(C)}{dC^2}} \quad \textbf{(5.25)}$$

The derivation of σ comes from the elasticity of marginal utility with respect to consumption which is simply the reciprocal. Hence following from Equation 5.23

$$-\frac{1}{\sigma(C_t)} \cdot \frac{d\varepsilon}{d\pi_{t+1}} = \frac{1}{\pi_{t+1}} \, where \, -\frac{1}{\sigma(C)} = \frac{C_t}{dU(\varepsilon C_t)/dC} \cdot \frac{dU^2(C_{t+1})}{dC^2} \quad \textbf{(5.26)}$$

Converting $\varepsilon C_t = C_{t+1}$ and then generalising consumption for all time periods now gives

$$\frac{1}{\sigma(C)} = -\frac{C}{dU(C)/dC} \cdot \frac{dU^2(C)}{dC^2} \quad \textbf{(5.27)}$$

Hence

$$\rho = \frac{1}{\sigma(C)} \quad \textbf{(5.28)}$$

A body of work has sought to establish the key determinants of consumption over the life-cycle by applying demand analysis for within period preferences (e.g. Blundell et al, 1994; Attansio and Browning, 1995). Within period preferences are determined by demographic composition and the division of general consumption into specific categories. This overcomes the issue of consumption being excessively sensitive to income and allows demographic features to influence consumption. The result is that the marginal utility of consumption is smoothed to a far greater extent than the distribution of income over the life-cycle.

The within-period demand analysis is then repeated across time-periods to estimate an inter-temporal consumption function. Optimal inter-temporal behaviour is specified by an Euler equation specifying the marginal utility of one extra unit of consumption in the current time period is equal to the marginal cost given by the rate of interest.

Blundell et al (1994) derive a value for the inter-temporal elasticity of substitution using micro-economic data by making certain assumptions about the within-period preferences of individuals over time (also see Cowell and Gardner (1999) for a summary).

For the purposes of this literature review we use Blundell et al (1994) and Attansio and Browning (1995) as exemplars of empirical evidence. For an extensive review of empirical estimations of the intertemporal elasticity of substitution, in both developed and developing countries, see Besley and Meghir (1998).

Blundell et al (1994) empirically test this methodology using 17 years of time series data between 1970 and 1986 from the UK Family Expenditure Survey for a vector of seven broad consumption goods. Consumption allocations are allowed to vary by household's demographic composition. Attansio and Browning (1995) make use of the same dataset.

An obvious limitation of time series, compared to panel data, in considering lifecycle behaviour is that different individuals are analysed over time. They attempt to overcome this by grouping individuals by date of birth cohorts and averaging. Household characteristics, such as family composition, are included to allow the possibility that it may affect inter-temporal elasticity of substitution. Furthermore, a dummy variable is included in a second model for pre-1981 responses to account for a possible structural break effect caused by a change from negative to a positive real interest rate in 1981.

The results indicate that the elasticity of marginal utility is just above unity. Blundell et al (1994) estimate lowest income decile households return a value of ρ equal to 1.17 and the top income decile a value of 1.39. However, the inclusion of the dummy variable has a dramatic downward effect on the elasticity of the low income group reducing it round 0.35 whereas the high income group falls to just over 1. Attansio and Browning (1995) also find evidence that higher levels of consumption increase the inter-temporal elasticity of substitution. Wealthier households are more able to substitute their consumption inter-temporally.

A clear limitation of the Blundell et al (1994) is with respect to the economically turbulent time for which the time-series data is set. Whilst Pearce and Ulph (1995) note the inclusion of the aforementioned dummy variable as an important feature, Evans (2005) voices concerns such as oil price shocks, high inflation rates, UK membership of the EU and the rise in monetarism will not be captured by this relatively crude technique. Heeding the concerns of Evans (2005) would suggest that the life-cycle behaviour model needs to be modernised in order to obtain more reliable estimates for the value of ρ. However, the present day deregulated and highly competitive financial markets make specifying a single, reliable rate of saving and borrowing over time very difficult (Evans, 2008).

5.2.2 Stated preference and experimental surveys

A small number of studies use stated preference surveys use measure respondents' attitudes towards risk and inequality. Stated preferences surveys have the ability to capture the risk aversion, inequality aversion and intertemporal substitution dimensions of ρ. Atkinson et al (2009) is the only study to estimate all three dimensions and is in the context of climate change. Therefore we use this as a baseline. We then compare other relevant studies (Barsky et al, 2002; Carlsson et al, 2005 and Johansson-Stenson et al, 2002) which estimate one or two of the dimensions.

Atkinson et al (2007) analyse survey data for over 3000 respondents in the United Kingdom, the United States, Australia, Canada and Mexico. Given the volume of respondents they group estimates of the three dimensions of ρ into ranges between less than 0.5 and greater than 7.5 (in steps of different sizes). Median and modal ranges are reported. Carlsson et al (2005) estimate risk aversion and inequality aversion for a survey of just 324 Swedish university students. The students are asked to make choices on behalf of pretend grandchildren. This follows on from a similar study by Johansson-Stenman et al (2002) using the same data source. Barsky et al (1997) conduct an experimental survey using over 11,000 middle aged and old US respondents in the first wave of the Health and Retirement Study. They estimate the value of ρ for risk aversion and intertemporal substitution.[109]

The first dimension that Atkinson et al (2009) test is risk aversion. Atkinson et al (2009) estimate both the median and modal value of ρ to be between 3 and 5. Carlsson et al (2005) estimate a lower median range of between 2 and 3. The other study to estimate a risk aversion value of ρ is Barsky et al (1997) who find a median of greater than 3.76.[110]

For inequality aversion, Atkinson et al (2009) estimate a lower median value of between 2 and 3. This is higher than the range of between 1and 2 estimated by Carlsson et al (2005) but same as Johansson-Stenman et al (2002). Surprisingly, the estimated modal value for ρ in Atkinson et al (2009) is in the upper range of over 7.5. In terms of distributive justice this finding would suggest a very high level of income redistribution from rich to poor is needed.[111]

For intertemporal substitution Atkinson et al (2009) estimate the intertemporal elasticity of substitution and find it to be very inelastic. This translates to a very high value of ρ given it is simply the reciprocal of the intertemporal elasticity of substitution. Atkinson et al (2009) estimate ρ to be 8.8 for the median respondent.[112] This corresponds closely with Barsky et al (1997) who estimate a modal value of 8.8 (they do not report a median value for direct comparison).

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[109] A detailed investigation of individual experimental survey questions for the three dimensions of ρ is beyond the scope of this thesis. See Atkinson et al (2009) for further discussion.
[110] The value of 3.76 reflects the lower bound of the threshold. The upper bound was infinite.
[111] See Section 5.2.4 for a discussion on distributive justice through the theory of equal absolute sacrifice.
[112] The nature of the experiment for intertemporal substitution doesn't allow for ranges of ρ to be reported.

The main limitation of this approach is the reliance on stated preferences which can suffer from many limitations and sources of bias that can undermine the subsequent economic analysis. For instance, one key limitation that Atkinson et al (2009) and Carlsson et al (2005) both identify is hypothetical bias. This occurs when respondents fail to answer survey questions as if they reflected real life decisions.

Notwithstanding the limitations of stated preference approaches, the empirical evidence points towards a failure for the assumption that the value of ρ remains constant across different dimensions. Indeed Atkinson et al (2009) finds only very weak evidence that their estimates of ρ are correlated with each other. This raises important questions about the appropriate use of ρ and whether spatial estimation can appropriately be translated into temporal estimation.

5.2.3 Consumer demand for preference independent goods

The key assumption underlying preference independence goods is that an individual's utility function should consist of at least two additively separable goods. Let us say that Y for a representative consumer is spent on the consumption of two goods (x_1,x_2) and their respective prices (p)

$$p_1 x_1 + p_2 x_2 = Y \qquad \textbf{(5.29)}$$

Where consumers maximise U as follows

$$\max U(x_1, x_2) = U_1(x_1) + U_2(x_2) \qquad \textbf{(5.30)}$$

Consumers allocate their budget to meet tangency conditions to maximise utility, hence marginal utility (*u*) for both goods are given as

$$u_1 = \frac{\delta U(x_{1,} x_2)}{\delta x_1}; \; u_2 = \frac{\delta U(x_{1,} x_2)}{\delta x_2} \qquad \textbf{(5.31)}$$

And

$$\frac{u_1}{p_1} = \frac{u_2}{p_2} = y \qquad \textbf{(5.32)}$$

where y *(=dY/dt)* is the marginal utility of income. This satisfies the assumption that, if there are two consumption goods, the quantity consumed of the first good remains constant and the second changes, then the marginal utility of the first good must remain the same (Fellner, 1967). Thus preferences between the two goods are independent. The standard, very broad, aggregate goods which tend to be considered in the empirical estimates tend to be 'food' and 'non-food' (Evans and Sezer, 2002).

Let us say that p_1 is the price of food and p_2 the price of non-food. For a given percentage change in p_1 will require a corresponding increase in Y to keep x_1 unchanged and maintain a constant y.[113] Hence, even though prices have increased, so has income to compensate the household and ensure they are consuming exactly the same amount of food as before. Income must increase until the marginal utility of income equates to the change in price. Algebraically, preference independence leads to a percentage change in p_1 to be equal to the

[113] Hence a Hicksian demand function is assumed where changes in prices can be *compensated* by an equivalent change in income to maintain a constant level of utility.

negative of the percentage change in y. This is because y is necessarily falling as absolute income increases.

$$\%\Delta p_1 = -\%\Delta y \quad \textbf{(5.33)}$$

The value of ρ can then be calculated by dividing through by the percentage change in absolute income

$$\rho = \frac{-\%\Delta y}{\%\Delta Y} = \frac{\%\Delta p_1}{\%\Delta Y} \quad \textbf{(5.34)}$$

The assumption of demand preference means there is the same demand response (D) from the changes in p_1 and y given above. A consumer will respond to a change in income or a change in the price of food by changing their demand in exactly the same way. Dividing the right hand side of equation 5.34 by the percentage change in D gives

$$\rho = \frac{\%\Delta p_1 / \%\Delta D}{\%\Delta Y / \%\Delta D} \quad \textbf{(5.35)}$$

The numerator here is the reciprocal of the compensated price elasticity of demand. The demand function is compensated because only a change in income can restore demand to its original level. The denominator is the reciprocal of the income elasticity of demand. Rearranging, the value of ρ is the ratio of the income elasticity of the demand for food (i) to the compensated price elasticity of demand (e) (Kula, 1984; Evans, 2005; Evans et al, 2005).

$$\rho = i / e \quad \textbf{(5.36)}$$

Empirical estimates of the values of the elasticity of marginal utility tend to be higher than studies using the lifetime consumption method. Kula (1984) follows this procedure to calculate ρ for time series data for the United States and Canada between 1954 and 1976. Regression results indicate a value of ρ for the United States being 1.89 and 1.56 for Canada.

If the budget for food, however, has a large weighting of total expenditure then it may not be accurate to assume the above formula (Fellner, 1967). Instead the income elasticity of demand for food should be weighted as follows (Frisch, 1959):

$$\rho = i(1 - wi)/e \qquad \textbf{(5.37)}$$

where w is the share of the budget spent on food. Evans and Sezer (2002) suggest that this formula should be adopted if the budget for food comprises at least 5% of total expenditure. The value of ρ is therefore influenced by the proportion of budget a household spends on food.

Evans and Sezer (2002) use annual time-series data for the UK between 1967 and 1997 obtained from the Office for National Statistics. A dependent variable of logged per capita household expenditure on food is regressed against log income, the logged price index of food and logged price index of all other consumer goods. Income elasticity of demand is given by the coefficient of log income and compensated own-price elasticity by the coefficient on logged price index of food. The mean annual budget share of expenditure on food is calculated as 13.1%. This gives a value of ρ at 1.60.[114] Evans (2004) include a similar methodology but for French time series data between 1970 and 2001. The value of ρ is found to be slightly higher than then UK estimate at 1.78.

5.2.4 Equal absolute sacrifice model

For equal absolute sacrifice to hold it requires that equality in taxation is met through equality in sacrifice. Equal absolute sacrifice means that every member of society forgoes the same amount of utility when paying their taxes (Young, 1987). The underlying theory of the equal absolute sacrifice model is that ρ can be derived by examining Government taxation. It gives the curvature of the utility function with respect to income and whether current taxation reflects an equal sacrifice of income (Young, 1987). The more progressive a tax, leading to a greater redistribution, will reflect in a larger value for ρ (Evans and Sezer, 2004).

Equal absolute sacrifice can be derived as follows. The utility one derives from their gross income *U(Y)* minus their net income inclusive of a tax rate *t(Y)* implies that the utility lost through income taxation should be remain constant regardless of the initial value of *Y*.

$$U(Y) - U(Y-t(Y)) = Constant \qquad \textbf{(5.38)}$$

[114] Evans et al (2005) re-test this using a wider time series (1963-2002) for the same UK dataset and find ρ to remain at 1.60.

Usually an iso-elastic utility function is assumed for the shape of *U(y)* (e.g. see Cowell and Gardner, 1999; Evans and Sezer, 2004; Evans, 2005) to derive the ρ:

$$U(Y) = \frac{Y^{1-\rho} - 1}{1-\rho} \quad \textbf{(5.39)}$$

Substituting the iso-elasticity function into the equal absolute sacrifice model gives

$$\frac{Y^{1-\rho} - 1}{1-\rho} - \frac{(Y - t(Y)^{1-\rho}) - 1}{1-\rho} = Constant \quad \textbf{(5.40)}$$

Differentiating with respect to *Y* gives the following first order condition

$$Y^{-\rho} - (Y - t(Y))^{-\rho}(1 - t') = 0 \quad \textbf{(5.41)}$$

where *t'* is the marginal income tax rate. Taking logs to simplify the expression leads to

$$\ln(1 - t') = \rho \ln\left(1 - \frac{t(Y)}{Y}\right) \quad \textbf{(5.42)}$$

where *t(Y)/Y* is the average rate of income tax. Rearranging with respect to ρ gives

$$\rho = \frac{\ln(1 - t')}{\ln\left(1 - \frac{t(Y)}{Y}\right)} \quad \textbf{(5.43)}$$

Cowell and Gardner (1999) adopt this methodology to obtain a value of 1.41 using 1999/2000 data on UK personal income tax data. The further inclusion of national insurance contributions reduces this to 1.28. An early study by Stern (1977) estimated ρ to be 1.97. Evans and Sezer (2004) estimate the value of ρ for six developed countries. Similarly to Cowell and Gardiner (1999) they use income tax data for their UK estimation but for the years 2001-2002. (they ignore national insurance contributions). An elasticity of 1.50 for the UK is comparable to the Cowell and Gardiner (1999) estimation of 1.41. The value of ρ for all six countries falls in the range of 1.30-1.70. Evans (2005) follows a similar process for 20 different OECD countries. The elasticity of marginal utility estimations are split into low and high income bands across all countries. Interestingly, the United Kingdom appears to have a relatively low elasticity of 1.08 for low income levels which increases to 1.40 for high incomes. This compares with the 20 country averages of 1.34 and 1.42 respectively.[115]

Young (1990) follows the equal absolute sacrifice approach to analyse US federal tax data in four cross-sections in for 10 year intervals between 1957 and 1987. Mean income and tax paid is taken for two tax schedules. The value of ρ is estimated to be between 1.37 and 1.79. The lowest estimate of 1.37 is for 1987 and may be caused by a simplification of tax system in the 1986 Tax Reform Act.

A key limitation of this approach is the assumption that the only objective of income taxation is to raise government revenue subject to equal sacrifice from tax payers. Government may also use income taxation as a supply-side incentive in the market for labour (Spackman, 2004). There also lies uncertainty over which forms of taxation should be included. Cowell

[115] The estimated values of ρ are based on wages of the average tax payer. This is potentially problematic because it masks the rate at which ρ changes for different levels of income.

and Gardner (1999) include one model with national insurance contributions though Evans (2008) believes this can be ignored as ‘the rationale’ for national insurance is different as it funds specific social schemes such as healthcare, state pension and other social security benefits.[116]

5.2.5 The SWB approach

The economics of SWB measures directly the utility of household survey respondents. Respondents are required to self-report their ‘happiness’ or ‘life satisfaction’, typically on a discrete scale of 1-10 where 10 represents the maximum possible level of satisfaction and 1 the lowest. This provides a set of ex-post utility values.

A key assumption of the life satisfaction approach is that survey respondents’ are able to map accurately their true utility onto a discrete integer scale

$$LS_i = g_i(U_i) \qquad \textbf{(5.44)}$$

Where LS_i is the reported satisfaction of individual *i* and g_i describes a monotonic function used by individual *i* to convert utility U_i to reported LS. It is further necessary to assume all survey respondents use a common function *g* to convert utility to reported LS[117]

$$g_i = g \forall i \qquad \textbf{(5.45)}$$

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[116] Evans (2005) also subtracts tax-free personal allowances from income tax under the assumption that diminishing marginal utility only occurs past the subsistence level

[117] This assumption cannot be validated and reflects a limitation of the SWB approach.

The functional relationship g between LS and U determines the appropriate estimation model in our empirical analysis. Function g is unknown and therefore the less restrictive approach is to assume only an ordinal association between reported satisfaction and utility. If an individual reports a value of 8 we should merely assume that they are more satisfied than if they had reported a value of 7. Employing OLS requires us to assume a linear and hence cardinal association between true utility of each respondent and their self-reported happiness. Ferrer-i-Carbonell and Frijters (2004) find some evidence that that assuming a cardinal or ordinal relationship does not make any significant difference to their empirical findings.

Layard et al (2008) outline a methodology to estimate ρ using a SWB approach. Each survey respondent is required to self-report their happiness or LS which amounts to a numerical representation of their true utility. The LS of each individual is then regressed against respondent's Y_i and number of socio-economic variables (x_i).[118] Income is assumed to take the form of an iso-elastic utility function. The general model is given by:

$$h_i = \alpha + \beta \frac{y_i^{1-\rho} - 1}{1-\rho} + \sum_k \gamma_k x_{ik} + \varepsilon_i \qquad \textbf{(5.46)}$$

where α, β and $\sum_k \gamma_k$ are parameters to be estimated via maximum likelihood estimation. A value of $\rho > 0$ implies diminishing marginal utility of income.

Layard et al (2008) empirically test for evidence of the diminishing marginal utility of income by estimating ρ for six separate surveys including questions on self-reported happiness and

[118] This includes employment status, sex, age, level of education and marital status.

life satisfaction[119]. Different surveys ask these questions on different numerical discrete integer scales and are consequently all normalised to a single 1-10 scale, the most common format. Questions on happiness and life satisfaction data are used interchangeably. Respondents in surveys including both a happiness and life satisfaction question were given a single value based on their average.

Diminishing marginal utility of income is estimated and ρ remains consistent across the different datasets with a combined value of 1.26 (see Table 5.1 for a breakdown by survey). This is then retested by means of an ordered logit approach which ranks happiness by order but not the difference between scores. Furthermore, Layard et al (2008) test the socio-economic stability of the value of ρ by splitting observations into various population subgroups. This includes gender, splitting age into two cohorts and three categories for education and marital status. The maximum likelihood estimates of ρ are found to remain consistent in each of these cases.

Layard et al (2008) acknowledge that using survey responses for income may lead to measurement error. This is especially the case when respondents are required only to provide an income range rather than an exact value. They try to overcome this problem by restricting their analysis to respondents aged 30-55 "for whom annual income tends to be highly correlated with permanent income". We add to the current literature by providing a systematic method for dealing with measurement error in a cross-sectional dataset using instrumental variables (IVs).

[119] Four of the surveys are cross-sectional (three of which contain multiple waves). The other two are panel studies.

A second contribution we make is to investigate the importance of household demographics in determining the value of ρ. Layard et al (2008) finds little variation in ρ when disaggregating the data by socio-economic characteristics of the respondent. They ignore that demographic composition of households (such as family size) may be important in determining the value of ρ. We incorporate these characteristics into the income iso-elasticity function to capture variation in the financial cost of household members. Accounting for demographic characteristics as a function of income has not been tested before in the SWB literature.

Table 5.1 Summary of elasticity of marginal utility estimates

Source	Data	ρ
Lifetime Consumer Behaviour		
Blundell et al (1994)	UK Family Expenditure Survey 1970-1986	**1.20-1.40**
	No Dummy Variables	**0.35-1.05**
	High interest dummy included	
Besley and Meghir (1998)[a]	Developed Countries	**0.51-4.24**
	Mid-point	**1.63**
	UK Only	**0.51-1.59**
Stated Preference Surveys		
Atkinson et al (2009)	UK, US, Aus, Can, Mex survey (median values reported)	
	Risk Aversion	**3.0-5.0**
	Inequality Aversion	**2.0-3.0**
	Intertemporal Substitution	**8.8**
Carlsson et al (2005)	Swedish student survey (median values reported)	
	Risk Aversion	**2.0-3.0**
	Inequality Aversion	**1.0-2.0**
Johansson-Stenman et al (2002)	Swedish student survey (median values reported)	
	Inequality Aversion	**2.0-3.0**
Barsky et al (1997)	US Health and Retirement Study (1992)	
	Risk Aversion (median)	**>3.76**
	Intertemporal Subtitution (modal)	**8.7**
Consumer Demand for Preference Independent Goods		
Kula (1984)	US data on demand for Food 1957-1976	**1.89**
	Canadian data on demand for Food 1955-1976	**1.56**
Evans and Sezer (2002)	UK data on Food demand 1967-1997	**1.60**
Evans, Sezer and Kula (2005)	UK data on Food demand 1963-2002	**1.60**
Evans (2004)	French data on Food demand 1970-2001	**1.78**
Equal Absolute Sacrifice		
Cowell and Gardiner (1999)	UK Income Tax Data 1999-2000	**1.41**
	Income Tax estimates	**1.28**
	Including National Insurance	
Evans and Sezer (2004)	Data on 6 OECD Countries (2001)	
	UK only	**1.50**
	All 6 OECD	**1.30-1.70**
Evans (2005)	Data on 20 OECD Countries	
	UK only	**1.08-1.40**
	OECD Average	**1.34-1.42**

Young (1990)	US Federal Tax data	
	1957	1.61-1.63
	1967	1.52-1.52
	1977	1.72-1.79
	1987	1.37
Subjective Well-Being		
Layard et al (2008)	German Socio-Economic Panel 1984-2005	**1.26 (1.16)**[b]
	British Household Panel Survey 1996-2004	**1.30 (1.32)**
	General Social Survey (US) 1972-2004	**1.20 (1.26)**
	European Social Survey 2002 and 2004	**1.34 (1.25)**
	European Quality of Life Survey 2003	**1.19 (1.05)**
	World Values Survey 1981 – 2003	**1.25 (1.26)**

[a] Besley and Meghir (1998) is a review of many empirical estimates of the intertemporal elasticity of substitution. Developed countries included the UK, US, Canada, Japan, Italy, West Germany, France, Singapore, Switzerland and Ireland.
***[b]** Brackets after elasticity estimates in Layard et al (2008) denotes ordered logit methodology as opposed to maximum likelihood estimation.*

5.3 Data

Data is from an unpublished UNDP survey in 2008. Its primary purpose was to survey attitudes to climate change and collect data for a WTP survey for projects intended to reduce energy use in Croatia. The survey was administered through telephone interview to a stratified random sample of 1000 households in Croatia. Also included was a question asking respondents to self-report their life satisfaction on a discrete integer scale.

> *"On a scale of 1 to 10 where 10 means perfectly satisfied and 1 means completely dissatisfied, how would you rate your satisfaction with your life over the last 12 months?"*

This is an important difference to the standard life satisfaction question used in the economics literature because it requires respondents to consider their well-being in a specific time period. Some surveys include indistinct words such as 'nowadays' (e.g. European Social Survey) or 'these days' (e.g. World Values Survey) as an acknowledgement that respondents' are reporting present LS. There is a belief that individuals may be affected by their momentary mood when responding to the question. For example Schwarz and Clore (1983) and more recently Tsutsui (2011) find evidence that the weather conditions at the time of questioning can significantly affect SWB responses. Encouraging respondents to consider a specific time period may help reduce these momentary mood fluctuations.

Summary statistics are provided in Table 5.2. The survey requires respondents to provide the number of household members who fall into specific age and gender categories. Three age categories were available; 0-15, 16-64 and 65+. Along with gender this provides six numerical variables on the demographic composition of the household.

To our knowledge these variables have not been used in the SWB literature. This could reflect an important omission if we find them to determine LS. A small body of literature (e.g. Rojas, 2007) adopt a SWB approach to estimating equivalence scales but only account for the number of additional income dependents relative to a childless two adult household.[120] Demographic information such as age and gender are typically only available for the member of the household who is the survey respondent.

The survey also asks respondents to provide standard socio-economic information. These include an indicator on net household income (divided into 12 ranges). We acknowledge that the use of income range as opposed to actual household income, will lead to measurement error. We use IVs to overcome this in Section 5.4.5. Further socio-economic variables include age, gender, education (from not finished elementary school to finished university

[120] This approach is reviewed in Section 4.4.2.3

degree), employment status (full-time working, part-time working, unemployed, retired, student, and housewife), and health (from very bad to very good).

The literature on SWB leads us to have some a priori expectations about the direction of the explanatory variables. It is anticipated that income should be exhibit a strong positive and significant relationship with happiness. This should resemble the cross-sectional findings of Easterlin (1974). Another typical finding is that LS decreases with age. However, further investigation tends to find a U-shaped curve with the inclusion of a squared term. Thus LS falls up to middle age and then rises into old age (Frey and Stutzer, 2000; Blanchflower and Oswald, 2004).

Gender and education level are sometimes included as a time-invariant individual characteristic (e.g. Clark et al 2005). Females are sometimes found to respond more positively to happiness questions. Employment status primarily accounts for the usual finding that those who are unemployed are less happy (Clark and Oswald, 1994). We have no particular expectations on the signs of the other employment variables.

Household demographic composition and size of house are not usually included in SWB studies, presumably due to data limitations and so we include them to consider their effect on LS. We expect family size to be negative as larger families constitute larger household costs. House size is measured by the metre-squared area of floor space. We have no prior expectation about its direction. A positive relationship could demonstrate a wealth effect of those living in larger houses. Furthermore, if wealth is important in the definition of income then omitting it could lead to a biased income coefficient.[121] A negative coefficient, however, could reflect the higher household costs of maintaining a larger house.

Finally, we might expect higher levels of self-reported health to have a positive effect on LS. For example, Blanchflower and Oswald (2008) find evidence that self-reported happiness is higher in countries reporting lower levels of hypertension.

[121] This reflects a further limitation of Layard et al (2008)

Table 5.2 Summary statistics
Number of Observations: 787

Variable	Mean	Std. Dev.	Min	Max
Life Satisfaction	6.205845	2.274052	1	10
Net Income	6750.318	4015.505	1000	16000
Male 0-14	0.242694	0.562444	0	5
Male 15-64	1.072427	0.809354	0	4
Male 65+	0.200762	0.410237	0	3
Female 0-14	0.241423	0.56186	0	4
Female 15-64	1.100381	0.814211	0	4
Female 65+	0.256671	0.437074	0	1
Age	48.66836	16.62215	15	88
Floor Space	99.97078	54.31979	18	400
Female	1.570521	0.495317	0	1
In Fulltime Employment	0.4459975	0.4973913	0	1
Unemployed	0.07878	0.269567	0	1
Retired	0.312579	0.463839	0	1
Student	0.07751	0.267568	0	1
Housewife	0.062262	0.241784	0	1
Health Very Good	0.260483	0.439177	0	1
Health Good	0.257942	0.43778	0	1
Health Satisfactory	0.3506989	0.4774923	0	1
Health Bad	0.092757	0.290277	0	1
Health Very Bad	0.038119	0.191606	0	1

5.4 Empirical analysis

5.4.1 Basic life satisfaction model

We begin the empirical analysis by restricting ρ to unity by assuming a logarithmic functional form for net household income, Y. A set of standard socioeconomic variables (x), such as respondent age, gender, self-reported health and employment status are included in the regression. Also included are a set of household demographic characteristics (d).[122] .

$$LS_i = \alpha + \beta \ln(Y_i) + \sum_k \gamma_k x_{ik} + \sum_j \delta_j d_{ik} + \varepsilon_i \qquad \textbf{(5.47)}$$

where α, β, γ_k and δ_j are coefficients to be determined and ε_i is an idiosyncratic error term.

The purpose of estimating this model is predominantly for comparative reasons. Firstly it is to compare alternative estimation methods.

We regress, initially, a set of additive models including individual and household characteristics introduced in the data section. We run parallel regressions for OLS (Model 1) and ordered logit (Model 2). The results are presented in Table 5.3 below. Robust standard errors are estimated in both Models.

[122] Some studies account for certain household characteristics such as the number of children (Ferrer-i-Carbonell and Frijters, 2004)

Beginning with Model 1, the adjusted R^2 is 0.2655. Logged net household income is positive and statistically significant at the one per cent level of confidence confirming that a higher income increase life satisfaction.

With respect to household demographic characteristics, we find the number of males aged 15 to 64 and 65+ to be negative and statistically significant at the one per cent level. An additional male aged 15 to 64 in a household reduces LS by 0.317 and an additional male over 65 reduces life satisfaction by 0.816. Males over 65 reduce LS by more than twice as much as those aged 15 to 65. Additional females in the under 15 and over 65 age categories are statistically insignificant but there is weak statistical significance at the ten per cent level for those aged 15 to 65. We confirm the importance of including the demographic variables by finding a test of joint significance statistically significant at the one per cent level of confidence in both Models. Furthermore, floor space is statistically significant at the one per cent level of confidence. A larger house size increase LS. These results demonstrate that household composition and the size of house are important determinants of LS and should be included in the model. Failure to control for them, like Layard et al (2008) risks estimating a biased coefficient for income and therefore ρ.

The dummy variable for survey respondents being female is statistically significant at the five per cent level. Female respondents have higher LS than males in the sample. The coefficients on the health dummy variables are statistically significant and signed as expected. The omitted dummy is a satisfactory level of health. They are all statistically significant at the one per cent level. Having very good or good health increases LS relative to satisfactory health. Bad and very bad health reduces LS. The very large magnitudes of the coefficients show that being of poor health is associated with large decreases in LS.

All of the employment dummies are statistically insignificant including those who are unemployed. This is an unusual finding as unemployment is commonly found to be a key determinant of lowering LS. Another typical finding in the literature is to find age and its quadratic to exhibit a U-shaped relationship with LS. Whilst the signs of our coefficients resemble this, they are imprecisely determined and so we cannot make any firm conclusions on the effect of age.

Moving onto the ordered logit specification of Model 2 the R^2 is 0.0771 and logged net household income is also statistically significant at the one per cent level. The coefficient 0.85 is slightly smaller than the OLS regression results.

The household demographics characteristics are the same sign and significance as Model 1 except females aged 15 to 64 which is now statistically significant at the five per cent level. The coefficients are comparable but slightly smaller in Model 2. Males aged 15 to 65 are now more burdensome on LS relative to similarly aged women with coefficients of -0.274 and -0.225 respectively. Males aged over 65 continue to have the largest effect on LS, with a coefficient of -0.742 in Model 2. Once again the household demographics are group statistically significant at the one per cent level.

Floor space and the self-reported health dummy variables all remain statistically significant at the one per cent level in Model 2. Females are now statistically significantly more satisfied with their lives at the one per cent level, although the size of the coefficient remains largely the same as Model 1.

Table 5.3 Logged net household income

	Model 1 OLS	Model 2 OLOGIT
Log Net Household Income	0.918*** (6.84)	0.852*** (6.57)
Male 0-14	0.026 (0.18)	0.061 (0.42)
Male 15-64	-0.317*** (-2.94)	-0.274*** (-2.67)
Male 65+	-0.816*** (-3.39)	-0.742*** (-3.08)
Female 0-14	-0.135 (-1.06)	-0.132 (-1.09)
Female 15-64	-0.194* (-1.73)	-0.225** (-2.09)
Female 65+	0.317 (1.46)	0.238 (1.17)
Age	-0.028 (-0.95)	-0.019 (-0.71)
Age^2	0.0002 (0.69)	0.001 (0.43)
Floor Space	0.005*** (3.24)	0.004*** (3.13)
Female	0.351** (2.26)	0.365** (2.52)
Part-time Working	-0.636 (-1.24)	-0.497 (-0.92)
Unemployed	-0.181 (-0.68)	-0.241 (-1.02)
Retired	-0.021 (-0.08)	0.060 (0.25)
Student	0.494* (1.70)	0.367 (1.43)
Housewife	0.485 (1.30)	0.512 (1.42)
Health Very Good	0.948*** (5.05)	0.975*** (5.41)
Health Good	0.482** (2.58)	0.478*** (2.85)

Health Bad	-1.154*** (-4.07)	-0.965*** (-3.59)
Health Very Bad	-2.019*** (-6.46)	-1.700*** (-5.82)
Constant	-1.466 (-1.07)	
N	796	796
R^2	0.2839	-
Adjusted R^2	0.2655	-
Pseudo R^2	-	0.0771
Household Characteristics Joint Significant Test	F(6,775) =3.63***	$Chi^2(6)$ =21.85

T-statistics in parentheses
* p<.10, ** p<.05, *** p<.01

5.4.2 Including net household income squared

Next we allow net household income to be a non-linear determinant of life satisfaction by including a quadratic income term:

$$LS_i = \alpha + \beta_1 \ln(Y_i) + \beta_2 \ln(Y_i)^2 + \sum_k \gamma_k x_{ik} + \sum_j \delta_j d_{ik} + \varepsilon_i \qquad \textbf{(5.48)}$$

The quadratic term means ρ is no longer constrained to unity. Whether ρ is greater or less than unity will be dependent on the sign and statistical significance of the quadratic term. Algebraically the elasticity of marginal utility is given as:

$$\frac{d^2LS}{dY^2} \bullet \frac{Y}{dLS/dY} = \frac{2\beta_2 \ln(Y) - 2\beta_2 + \beta_1}{2\beta_2 \ln(Y) + \beta_1} \qquad \textbf{(5.49)}$$

Table 5.4 presents the quadratic logged income results for both the OLS (Model 3) and ordered logit (Model 4) specifications. Beginning with Model 3 the coefficient on logged net household net income now becomes negative and statistically insignificant whilst the quadratic is positive and statistically insignificant. However, a test of joint significance clearly shows income's continued importance. Furthermore the adjusted R^2 rises slightly to 0.2665. This is a surprising finding as it suggests that logged income is U-shaped in life satisfaction. The turning point, however, is very low at 221Kuna for Model 3 and 294 Kuna and so we do not read too much into these signs. It is possible that this could be related to perverse incentives caused by high unemployment rates and benefit payments. Section 4.2 reviews Croatia's recent history including unemployment rates.

We note that ρ is non-constant as it is dependent on the income level. The estimated value of ρ is 0.71 based on mean income of the dataset. This is somewhat lower than the unity assumed in Model 1. All other explanatory variables remain unchanged after the addition of the quadratic logged income term.

For Model 4 there is little change in the magnitudes of the statistically significant coefficients on the non-income explanatory variables. The addition of logged net household income squared has the same effect as the OLS model, with both income terms being individually insignificant but together are joint significant. The pseudo R^2 is 0.0778 and the estimated value of ρ is 0.68. There is little evidence of any differences between the OLS and ordered logit specifications.

Table 5.4 Log net household income squared

	Model 3 OLS	Model 4 OLOGIT
Log Net Household Income	-1.690246 (-0.88)	-1.82 (-1.01)
Log Net Household Income^2	0.1565 (0.137)	0.1601 (1.50)
Male 0-14	0.03331 (0.23)	0.0709 (0.49)
Male 15-64	-0.3233*** (-2.99)	-0.2796*** (-2.72)
Male 65+	-0.8022*** (-3.36)	-0.7287*** (-3.08)
Female 0-14	-0.1220 (-0.96)	-0.1232 (-1.02)
Female 15-64	-0.1884* (-1.68)	-0.2219** (-2.06)
Female 65+	0.3269 (1.52)	0.2504 (1.25)
Age	-0.0269 (-0.65)	-0.0187 (-0.70)
Age^2	0.0020 (0.65)	0.00012 (0.41)
Floor Space	0.0043*** (3.03)	0.0042*** (2.93)
Female	0.3417** (2.21)	0.3613** (2.50)
Part-time Working	-0.6431 (-1.24)	-0.4839 (-0.89)
Unemployed	-0.1571 (-0.59)	-0.2151 (-0.90)
Retired	-0.0184 (-0.07)	0.0534 (0.22)
Student	0.5082* (1.75)	0.3797 (1.47)
Housewife	0.4818 (1.27)	0.5093 (1.39)
Health Very Good	0.9240*** (4.88)	0.9530*** (5.26)
Health Good	0.4778** (2.56)	0.4725*** (2.83)
Health Bad	-1.1624*** (-4.09)	-0.9721*** (-3.59)

Health Very Bad	-2.048*** (-6.45)	-1.7344*** (-5.84)
Constant	9.3201 (1.15)	-
P	0.71	0.68
N	796	796
R^2	0.2858	-
Adjusted R^2	0.2665	
Pseudo R^2	-	0.0778
Household Characteristics Joint Significant Test	F(6,774) =3.66***	Chi^2 (6) =22.32***
Income Joint Significant Test	F(2,774) =25.97***	Chi^2 (2) =48.76***

T-statistics in parentheses
* p<.10, ** p<.05, *** p<.01

5.4.3 Further techniques to estimating the elasticity of marginal utility

The assumption of a logarithmic specification for net household income is now relaxed and replaced with an iso-elasticity function. This allows the estimation of a point value for *ρ*. All other explanatory variables remain unchanged. The algebraic model now becomes:

$$LS_i = \alpha + \beta \frac{Y_i^{1-\rho} - 1}{1-\rho} + \sum_k \gamma_k x_{ik} + \sum_j \delta_j d_{ik} + \varepsilon_i \qquad \textbf{(5.50)}$$

The difference in using this approach, as opposed to the logarithmic specification, is that it provides a constant estimation of *ρ* across the income spectrum. The value of *ρ* in the logarithmic specification with a quadratic term is dependent on income level. The iso-elasticity assumption therefore simplifies the interpretation of *ρ*.

We begin by employing a grid search methodology to estimate the value of *ρ* for both OLS and ordered logit specifications. This requires inputting values of ρ into the model and finding the value which maximises the log-likelihood. Following Layard et al (2008) we calculate the maximum likelihood estimate by computing the log-likelihood for values of ρ in 0.1 intervals between 0 and 3. We then locate the vicinity of the maximum by identifying the value of ρ which the highest log-likelihood. We increase the number of decimal places to two around this maximum and re-estimate ρ. This gives us a point estimate for ρ in both models. We use the grid search method to compare the coefficients and statistical significance of net household income in the OLS and ordered logit models and determine the appropriate specification. We also compare the goodness of fit relative to the logarithmic net household income models.

The results of the grid search are presented in Table 5.5**.** Model 5 gives the OLS results and Model 6 the ordered logit results. Once again there is very little change in the non-income explanatory variables in either model. The large fall in the coefficient for net household income in both models simply corresponds to the fact that it is no longer logarithmically specified. In Model 5 the value of ρ that maximises the log-likelihood is 0.64. This increases the adjusted R^2 to 0.2675, improving the fit of the model.

For Model 6 the value of ρ which maximises the log-likelihood is 0.60 which is a small degree lower than Model 5. The fit of the model improves relative to Model 2, evident from the pseudo-R^2 increasing to 0.0779.

Once again, there appears little difference in employing either an OLS or ordered logit specification. We therefore conclude that the interpersonal monotonic transformation of true utility to reported life satisfaction is sufficiently linear and OLS is a suitable estimator.

Table 5.5 Grid search method for estimating *ρ*

	Model 5 OLS	Model 6 OLOGIT
Log Net Household Income (ρ = 0.64)	0.0442948*** (7.19)	-
Log Net Household Income (ρ= 0.60)	-	0.02907*** (6.98)
Male 0-14	0.03424 (0.24)	0.07253 (0.51)
Male 15-64	-0.3222*** (-2.99)	-0.2781*** (-2.71)
Male 65+	-0.7994*** (-3.37)	-0.7241*** (-3.08)
Female 0-14	-0.1195 (-0.94)	-0.1210 (-1.00)
Female 15-64	-0.1868* (1.67)	-0.22012** (-2.04)
Female 65+	0.3277 (1.53)	0.2516 (1.26)
Age	-0.02692 (-0.92)	-0.01856 (-0.69)
Age^2	0.00020 (0.66)	0.0001172 (0.40)
Floor Space	0.0043*** (3.04)	0.0042*** (2.93)
Female	0.3411** (2.21)	0.3612** (2.50)
Part-time Working	-0.6494 (-1.25)	-0.4879 (-0.89)
Unemployed	-0.1599 (-0.60)	-0.2188 (-0.92)
Retired	-0.0205 (-0.08)	0.0504 (0.21)
Student	0.5068* (1.74)	0.3786 (1.46)
Housewife	0.4791 (1.27)	0.5050 (1.38)
Health Very Good	0.9216*** (4.90)	0.9508*** (5.25)
Health Good	0.4775** (2.56)	0.4720*** (2.83)
Health Bad	-1.1639*** (-4.10)	-0.9746*** (-3.61)
Health Very Bad	-2.0497*** (-6.55)	-1.7362*** (-5.94)

Constant	3.7581*** (4.44)	-
N	796	796
R^2	0.2859	-
Adjusted R^2	0.2675	
Pseudo R^2	-	0.0779
Log Likelihood	-1649.1051	-1575.3749

T-statistics in parentheses
* p<.10, ** p<.05, *** p<.01

5.4.4 Household demographics and the elasticity of marginal utility

It is possible estimate equation 5.50 without relying on manually imputing ρ using the grid search method by employing non-linear least squares (NLS) where ρ is now a coefficient to be determined. If the grid search has been estimated successfully then re-estimating the same model as equation 5.50 using NLS should provide exactly the same value of ρ.

The implementation of NLS allows net household income to be iso-elastic whilst keeping the control variables additive. Incorporating household composition characteristics in additive form to the model will capture the impact of additional types of family member on LS. However, net household income may only act as a partial representation of the relative affluence of each household. A further key attribute may also be the demographic composition of households and if this impacts directly on the value of ρ.

By means of an example, two households identical in all ways (including income) but differing only in the number of members may not exhibit the same marginal utility of income. Family size and composition determines consumption patterns and the quantity of disposable income a household has. Family size and composition may play a role in determining the value of ρ.

Pollak and Wales (1981) incorporate household demographic characteristics into the allocation of expenditure in consumption. It is possible to incorporate these into our non-linear least squares framework. This allows the estimation of ρ for net household income accounting for household composition in the iso-elasticity function

We follow their approach of demographic scaling which scales net household income by household composition. Net household income is divided by a set of composition variables multiplied by their estimated coefficients. The purpose of rearranging the model as follows is to make ρ dependent not only on household income but also the financial cost of particular family members. The value of ρ is no longer determined by absolute income but income accounting for the cost of each household member. This gives the following model to be estimated:

$$LS_i = \alpha + \beta \frac{\left(\frac{Y_i}{1 + \sum_j \delta_j d_{ik}} \right)^{1-\rho} - 1}{1 - \rho} + \sum_k \gamma_k x_{ik} + + \varepsilon_i \qquad \textbf{(5.51)}$$

The set of household composition variables now represent equivalence scale for each 'type' of person in the household. This demonstrates a new approach in which household equivalence scales can be estimated using the LS approach. Note that their additive forms are dropped from the model. The estimated coefficients of household demographic composition represent their relative magnitudes on the financial cost they have on the household. A positive coefficient infers a positive financial cost and makes the household relatively poorer. The larger the coefficient the more absolute net household income is scaled downwards. Having demographically scaled for income, a new parameter for ρ is then estimated. [123]

We now investigate the impact of scaled household demographic characteristics on the value of ρ. Layard et al (2008) estimate the value of ρ for different socioeconomic groups and find that there exists little variation when disaggregating the data by age, education level, marital status and gender. Our main contribution to the literature is that we incorporate the demographic characteristics of the household directly into the income elasticity function. This allows for absolute net household income to capture the financial cost of their demographic characteristics.

Table 5.6 presents a set of Models that are estimated using NLS. Model 7 includes the set of socio-economic characteristics as additive terms and net income is non-linear accounting for ρ which is a coefficient to be determined. Demographic characteristics are ignored in Model 7 but are included in additive form in Model 8.

Beginning with Model 7, being female continues to be statistically significant and increase LS as does having very good or good self-reported health as opposed to a satisfactory level. Bad and very bad health continues to impact negatively on LS. Furthermore, floor space is positive and statistically significant at the five per cent level. This closely resembles the relationships estimated in Models 1 and 3. However the non-linear estimation of net

[123] Pollak and Wales (1981) also introduce a framework demographic translating in which household characteristics are subtracted from net household income. A Gorman framework incorporates both translating and scaling, giving translating order preferences, whilst a reverse-Gorman gives scaling order preference. We ran regressions of all these models but found there to be no difference to the scaling approach (results not shown).

household income is imprecisely estimated. No conclusions can be drawn from the estimated coefficient on ρ of 0.49.

Model 8 includes the demographic variables. A likelihood ratio test is statistically significant at the one per cent level confirming their importance in the regression. The inclusion of additive demographic variables makes the coefficient of ρ statistically significant at the five per cent level. A value of 0.64 provides very similar estimates to the grid search results in Model 5 as anticipated.

Model 9 removes the additive demographic terms and incorporates them directly into the non-linear estimation of net household income following the demographic scaling approach of Pollak and Wales (1981). All statistically significant socioeconomic variables remain unchanged as well as floor space. The demographic variables are all individually insignificant apart from males over 65 at the ten per cent level of confidence. This means that household equivalence scales cannot be estimated with any degree of precision. However a likelihood ratio test confirms that Model 9 is still statistically significant at the one per cent level confirming it is not nested in Model 7. They also have the opposite signs than their additive form. This is unsurprising as it confirms that the groups that reduce LS also serve to decrease scaled income by increasing the demographic denominator. The scaling of income by the demographic composition has had the effect of increasing the value of ρ to 0.83 which is statistically significant at the one per cent level. Household income, once scaled by demographic characteristics, has a higher ρ. By means of an example, having a male over 65 in the household imposes a substantial financial burden equivalent to reducing income by 182%.[124]

Table 5.6 Non-linear Least Squares Estimations

	Model 7 NLS No demographics	Model 8 NLS Additive Demographics	Model 9 NLS Demographic Scaling
Log Net Household Income	0.0103771 (0.36)	0.0460758 (0.46)	0.2589851 (0.54)
Male 0-14	-	0.3413 (0.26)	-
Male 15-64	-	-0.3222*** (-2.87)	-
Male 65+	-	-0.7998*** (-3.77)	-
Female 0-14	-	-0.1197 (-0.91)	-
Female 15-64	-	-0.1870* (-1.70)	-
Female 65+	-	0.3276 (1.60)	-
Male 0-14 (Scaled)	-	-	-0.1425 (-0.51)
Male 15-64 (Scaled)	-	-	0.7862 (1.58)
Male 65+ (Scaled)	-	-	1.8275* (1.74)
Female 0-14 (Scaled)	-	-	0.3682 (0.85)
Female 15-64 (Scaled)	-	-	0.4422 (1.04)
Female 65+ (Scaled)	-	-	-0.1900 (-0.51)
Age	-0.0390 (-1.30)	-0.2693 (-0.87)	-0.2958 (-0.93)
Age^2	0.00038 (1.27)	0.00020 (0.64)	0.00025 (0.77)
Floor Space	0.0033** (2.42)	0.0431*** (3.11)	0.00429*** (3.13)

[124] Clearly, number of males over 65 is only statistically significant at the ten per cent level of confidence and so we this figure for illustrative purposes only..

Female	0.4349*** (2.97)	0.3412** (2.24)	0.3287** (2.12)
Part-time Working	-0.6801 (-1.41)	-0.6491 (-1.36)	-0.6586 (-1.38)
Unemployed	-0.3427 (-1.20)	-0.1598 (-0.56)	-0.1550 (-0.54)
Retired	-0.0662 (-0.27)	-0.0203 (-0.08)	-0.0162 (-0.07)
Student	0.4009 (1.10)	0.5068 (1.38)	0.5094 (1.38)
Housewife	0.2500 (0.74)	0.4795 (1.42)	0.5246 (1.54)
Health Very Good	0.9712*** (4.91)	0.9219*** (4.66)	0.9431*** (4.76)
Health Good	0.4724** (2.55)	0.4775** (2.59)	0.4787** (2.60)
Health Bad	-1.1493*** (-4.32)	-1.1637*** (-4.41)	-1.1489*** (-4.35)
Health Very Bad	-1.964*** (-5.15)	-2.0492*** (-5.40)	-1.9931*** (-5.26)
Constant	4.258*** (3.28)	3.7305** (2.10)	1.578 (0.51)
ρ	0.49 (1.54)	0.64** (2.56)	0.83*** (3.44)
N	796	796	796
R^2	0.2630	0.2859	0.2846
Adjusted R^2	0.2488	0.2665	0.2652
Likelihood Ratio test nested in Model 7	-	$Chi^2(6)$ =25.16***	$Chi^2(6)$ =23.75***

T-statistics in parentheses
* p<.10, ** p<.05, *** p<.01

5.4.5 Instrumental variables

A common limitation of employing household survey data is that respondents are only required to choose a range in which their household income falls. Standard practice in the LS literature has inadequately been to simply take the mid-point of the reported range as a point estimate for household income. However, this inevitably leads to measurement error and may cause household income to be correlated with the residual error term. Furthermore, observing income in only a single time period may suffer measurement error caused from transitory movements away from permanent household income level.

'Permanent' income of household *i* in a specific time period (Y^A) is therefore a function of reported income (Y^R) and unobserved measurement error (v) and transitory changes in income (w).

$$Y_i^A = Y_i^R + v_i + w_i \tag{5.52}$$

Cross-sectional studies in the life satisfaction literature tend to ignore measurement error and assume the mean and variances of these errors are zero and lead to no bias in the estimation results (Cameron and Trivedi, 2005).

However, there is little explanation of why. It is clear from the reliance on income ranges in many studies that measurement error does exist. And the transitory component of income can never be dismissed in a cross-sectional study. Not accounting for these will lead to Y^A assumed in the regression model being correlated to the error term and biased coefficients (Cameron and Trivedi, 2005). The precise estimation of the income coefficients is crucial to our analysis which determines the value of ρ. Therefore we should be estimating a model as follows

$$LS_i = \alpha + \beta_1 \ln(Y_i^R) + \beta_2 \ln(Y_i^R)^2 + \sum_k \gamma_k x_{ik} + \sum_j \delta_j d_{ik} + v_i + w_i + \varepsilon_i \tag{5.53}$$

The implementation of an appropriate set of IVs overcomes this by removing the unobserved error and ensures Y^A is being estimated correctly

$$LS_i = \alpha + \beta_1 \ln(Y_i^R - v_i - w_i) + \beta_2 \ln(Y_i^R - v_i - w_i)^2 + \sum_k \gamma_k x_{ik} + \sum_j \delta_j d_{ik} + \varepsilon_i \qquad \textbf{(5.54)}$$

Layard et al (2008) attempt to overcome the transitory income problem by restricting their analysis to respondents aged 30-55 "for whom annual income tends to be highly correlated with permanent income". Given the small sample size of our dataset we cannot take such measures.[125] Layard et al (2008) use a number of datasets in their analysis of which the panels ask for actual household income variables (the German Socio-Economic Panel, British Household Panel Survey). However, the other surveys do not (General Social Survey, World Values Survey, European Social Survey, European Quality of Life Survey). Measurement errors in these datasets are simply assumed away with no discussion.

Measurement error is the most likely cause of bias in our model. For example, the second lowest income category is those who earn between 2000 and 3000 Kuna per month. We are restricted to taking the midpoint of 2,500 Kuna as our actual income estimate. This risks overestimating or underestimating actual income by up to 500 Kuna per month. Transitory movements away from actual household income could be caused by an atypical windfall of income for any reason which isn't indicative of normal household income.

[125] Doing so results in income and ρ becoming statistically insignificant and prevents us from obtaining any meaningful results.

There is surprisingly little empirical literature on the appropriate specification of IVs to deal with measurement error in household surveys. Murthi (1994) identifies that instruments to deal with measurement error in expenditure surveys should account for the medium to long-term wealth of respondents. This might include the age and gender of the household head and the number of adults. Given age and gender are typically included as additive determinants in LS regressions one might have reason to believe these are unsuitable as IVs. Ettner (1996) empirically tests the importance of income in determining a number of health measures and instrument household for direct impacts on wage rates (state unemployment rates and level of work experience) as well as non-earnings income proxies (the education of parents and spouse characteristics). The latter captures the possible importance of transitory income

We therefore contrive to create a set of IVs which are sufficiently correlated to reported income yet are uncorrelated with the idiosyncratic error term.

The first IV we create is based on the comparison of respondents with a similar set of individual and household characteristics which may be important in determining household income. These characteristics include the number of household members aged 15 and over (which is from 1 up to 6), whether the survey respondent is in poor health (dummy variable) and the education level of the respondent (low, medium, high).

The number of adults gives a proxy to the number of household members who may be working and will determine overall household income. Whilst retired members of a household may not contribute in terms of earned income, they may redistribute wealth towards the household and capture transitory income. We argue that whilst precise household composition itself is an important determinant in LS, the number of adults better describes the incoming wages. Poor health is a dummy variable capturing whether the respondent has reported their health as either poor or very poor. Whilst self-reported health is often a key determinant in LS, as estimated in our earlier regressions, poor health is more likely to determine LS through its impact on the ability to work. This effect may vary dependent on the total number of working adults in the household. Education is a proxy for a respondent's ability to earn a higher income. Helliwell (2003) believes that higher education leads to wider benefits in terms of higher income, and better health rather than having a direct impact on LS. It is possible that cross-sectional studies that do find education to be a statistically significant determinant of LS only do so because of the measurement error of income. Whilst many studies, including Chapter 2 of this thesis, control for education level and find it statistically significant in explaining life satisfaction, we do not in this Chapter. A regression controlling for all education dummies was found to be individually statistically insignificant as well as jointly insignificant (results not shown).[126]

The next step is to calculate the average income of households according to the above characteristics. All three characteristics are combined to create 36 categories. For example, one group would be a household with 1 adult, a respondent in poor health and a high level of education. The average income of each category is then calculated as follows:

$$\overline{Y}_{HS} = \frac{\sum_{1}^{k} Y_k\,(Adults_k, Education_k, Health_k)}{k}\;\forall k \qquad \textbf{(5.55)}$$

[126] This finding was consistent for all models regressed in this Chapter.

This approach smoothes over the measurement error of reported household income of a single household as well as any transitory changes that might exist.

The second IV we create is the average income of each respondent's five nearest neighbours. This is created by utilising the spatial nature of the data sets given by decimalised coordinates for latitude and longitude. These spatially weighted average income variables were created in the statistical package SpaceStat. There is little reason to suspect this should have any effect on LS directly. Although the importance of relative income has been discussed intensely in the literature (e.g. Clark et al, 2008), households living in close proximity do not necessarily fall in to each others' reference group. This comparison of individuals by geographical proximity should again help to smooth measurement error and transitory changes.

$$\overline{Y}_{HS} = \frac{\sum_{1}^{n} Y_n(Neighbour_{1,\ldots,5})}{n} \forall n \quad \textbf{(5.56)}$$

The third IV is a more general approximation for geographic proximity of survey respondents. We calculate average income for the administrative region in which each respondent lives. The benefit of such an approach over the five nearest neighbours is that it should capture better any regional income disparities that exist across Croatia.

$$\overline{Y}_{REGION} = \frac{\sum_{1}^{m} Y_m(\mathrm{Re}\,gion_m)}{m} \forall m \quad \textbf{(5.57)}$$

Table 5.7 provides the regression results for our instrumental analysis. Again we include logged net household income and its square to allow ρ to deviate from unity. Model 3 presented in Table 5.4 provide the 'base' regression which we instrument here.

Before discussing the results we outline four methods in which we test the effectiveness of our IVs. An underidentification test informs us whether the instrumental variables are sufficiently correlated with household income. We estimate an Anderson canonical correction Lagrange multiplier statistic to test this. A rejection of the null hypothesis of underidentification will confirm the IVs are suitable in this respect. Even if the instruments pass the underidentification test then it is still possible that they are only weakly correlated with net household income. Stock and Yogo (2002) develop a methodology using a Wald test to test for weak instruments through relative bias and size. Relative bias exists if the IV estimator bias relative to the OLS estimator exceeds a defined threshold. Weak instruments through size occur if the Wald test has a size which exceeds a pre-defined threshold. Stock and Yogo (2002) set critical values for different thresholds of relative bias. If IVs require a high threshold then they are weakly determined. A rejection of the null of relative bias and size confirm instruments are not weak and are suitable estimators.

The problem of overidentification leads to IVs being correlated with the error term. A Sargan statistic tests a null of no overidentification. A rejection of the null would confirm overidentification rendering the IVs unsuitable. Finally we perform a redundancy test on a subset of instruments to test whether the asymptotic efficiency of the model is improved by their inclusion. A rejection of the null confirms that the instruments are not redundant. We note that both the Sargan test and weak identification test for relative bias require the number of instruments to exceed the number of endogenous variables.

Table 5.7 below provides the results for the IV regressions. Model 10 instruments net household income using average income according to household characteristics and spatially weighted average income of the five nearest neighbours. Both instruments are logged. Quadratic terms are also included to make the total number of instruments equal to four. 16 observations are lost due to omitted geographical coordinates. It is immediately clear the inclusion of IVs has a large impact on net income. The coefficient on logged net income is over 5 times larger than in Model 3 whilst its quadratic is almost 4 times larger.[127] This leads to a point estimate of ρ which is now 0.21. This result implies that the ρ is only just less than linear. The instruments pass underidentification and overidentification tests. With respect to the weak instrument test, they also pass the relative bias and the size test at the highest level of significance. However, the spatial five nearest neighbour instrument does not pass the redundancy test informing us it is not improving the asymptotic efficiency of the regression.

We therefore replace the spatial instrument with the average income by region instrument, given in Model 11. Once again it is logged and a quadratic term is included. This specification of the instruments seemingly performs better, passing underidentification, overidentification and both weak identification tests at the highest level of significance as well as the redundancy tests. There is little difference in the estimated coefficients of the Model however and ρ changes only marginally to a value of 0.22.

[127] The turning points of net household income increases markedly in Models 10 and 11 than Models 3 and 4 above. Model 10's turning point is 1900 wihlst Model 11 is 1863. This, however, is still less than 30% of sample mean income in both cases.

Table 5.7 Instrumental variables

	Model 10 Instruments: **Household Characteristics, 5 Nearest Neighbours**	**Model 11** Instruments: **Household Characteristics Mean Regional Income**
Log Net Household Income	-9.187638 (-1.55)	-9.078 (-1.64)
Log Net Household Income^2	0.6085* (1.73)	0.6028* (1.82)
Male 0-14	0.0508 (0.37)	0.0632 (0.47)
Male 15-64	-0.3473*** (-2.80)	-0.3488*** (-2.87)
Male 65+	-0.7804*** (-3.40)	-0.7734*** (-3.44)
Female 0-14	-0.1065 (-0.76)	-0.1167 (-0.84)
Female 15-64	-0.1869 (-1.60)	-0.1778 (-1.56)
Female 65+	0.2849 (1.36)	0.3467* (1.68)
Age	-0.0192 (-0.60)	-0.0221 (-0.70)
Age^2	0.00012 (0.37)	0.00015 (0.47)
Floor Space	0.0035** (2.33)	0.0035** (2.35)
Female	0.3529** (2.25)	0.3384** (2.19)
Part-time Working	-0.6836 (-1.42)	-0.6542 (-1.37)
Unemployed	-0.1081 (-0.33)	-0.1127 (-0.35)
Retired	-0.0208 (-0.08)	-0.02469 (-0.09)
Student	0.5553 (1.46)	0.5582 (1.48)
Housewife	0.4225 (1.09)	0.4712 (1.26)
Health Very Good	0.8085*** (3.84)	0.8131*** (3.94)
Health Good	0.3915** (2.08)	0.4257** (2.29)
Health Bad	-1.205***	-1.185***

	(-4.44)	(-4.43)
Health Very Bad	-2.027*** (-4.94)	-2.0824*** (-5.26)
Constant	40.1442 (1.63)	39.65* (23.10)
P	0.21	0.22
N	771	787
R^2	0.2637	0.2673
Anderson canonical correlations test LM Statistic (underidentification)	76.581***	85.225***
Sargan Statistics (overidentification)	1.059	0.192
Cragg-Donald Wald F-stat (Weak identification)	20.595	23.165
Critical values:		
5% maximal IV relative bias	11.04	11.04
10% maximal IV size	16.87	16.87
15% maximal IV size	9.93	9.93
IV redundancy tests:		
Household Characteristics	238.617***	239.293***
5 Nearest Neighbours	5.437	
Mean Regional Income		29.420***

T-statistics in parentheses
** p<.10, ** p<.05, *** p<.01*

5.6 Discussion

The primary objective of this chapter has been to estimate ρ for Croatian households using self-reported data on LS. From our results it is clear that marginal utility is diminishing as incomes rise but that this rate is lower than unity. There also appears little difference whether we employ and OLS or ordered logit estimation technique. We henceforth focus on only the OLS regression results. A summary of the findings are provided in Table 5.8 below. The 95% confidence intervals are calculated using bootstrapped standard errors for 1000 replications of each model. Overall, it is clear that the point estimates all indicate that the value of ρ is less than unity. However, in four of the five models the wide 95% confidence intervals make it impossible to rule out unity. Demographic scaling by household composition increases the value of ρ whilst the incorporation of IVs markedly reduces ρ.

Table 5.8 Summary of ρ estimates including 95% confidence intervals

Model	*point estimate of ρ*	*Bootstrapped (95% confidence interval)*
OLS LnY LnY^2	0.71	0.32 to 1.09
NLS No family variables	0.49	-0.30 to 1.29
NLS family additive	0.64	0.03 to 1.25
NLS demographic scaling	0.85	0.17 to 1.48
OLS IV LnY LnY^2	0.22	-0.50 to 0.95

Our initial modelling found the estimated value of ρ to be 0.71 with the addition of a quadratic income term. Despite logged net household income and its quadratic being individually insignificant, they were jointly significant at the one per cent level in both models confirming their importance. It is clear to observe that the 95% confidence interval is large, however we can conclude that the elasticity of marginal utility is diminishing.

It is clear to see that the 95% confidence intervals of the three NLS models remain wide. For the NLS model with no family demographic variables it is inappropriate to conclude that ρ is diminishing as the lower bound is negative. However, we also cannot rule out that ρ diminishes at a rate of unity or even higher. The inclusion of family demographic variables in additive form rules out negative values in the 95% confidence interval. This reflects the higher point estimate of 0.64 and its statistical significance at the five per cent level of confidence.

The demographic scaling approach provides a higher point estimate of ρ than including family demographics additively. Income is scaled according the cost of additional household members by age and by sex. It stands to reason that households of varying demographic compositions may have vastly different attitudes to changes in income. The empirical analysis identified additional males aged 15-65 and over 65 have the largest financial cost on households. The point estimate of ρ is 0.85. The upper bound of the 95% confidence interval is the highest of all models at 1.48. This provides evidence that scaling income by household demographics may determine the marginal utility of income and therefore the appropriate point estimate for ρ

This is potentially an important finding. The empirical literature on household equivalence scales, reviewed in Chapter 4, finds clear evidence that additional family members increase household costs. A larger household therefore requires a greater income to reach a given level of utility. Yet there exists no evidence on the direct effect household composition has on the rate at which marginal utility declines. Our estimates suggest that accounting for household composition is important in controlling for its level of disposable income.

The addition of IVs on the OLS model with net household income and its quadratic has a visible downward effect on the estimation of ρ. This highlights that the presence of measurement error and transitory income effects is contributing to a large degree of bias in the estimation of the income coefficient. We find that taking the average income of households with similar characteristics and the average income of households living in the same region are suitable IVs. Whilst average income variables could themselves determine LS directly due to relative income effects, an overidentification test demonstrates it is not statistically significantly correlated with the error term. The IVs pass three further statistical tests to demonstrate their suitability in this model. The new estimate for ρ is 0.22, implying the elasticity of marginal utility diminishes very slowly for income. It is the only model specification for which the 95% confidence interval is able to rule out unity, however it is only by a small margin with the upper bound being 0.95.

Comparing these findings with earlier estimates, they generally fall into the range of the elasticity of marginal utility estimated from the life-cycle behaviour model of Blundell et al (1994) but are noticeably lower than the consumer demand for preference independence goods and equal absolute sacrifice techniques. Most notably, our findings are also lower than the similar subjective well-being approach of Layard et al (2008). We note that in all the aforementioned models excepting the IVs, it is impossible to rule out a value of unity which consistently falls within estimated 95% confidence intervals. The range of ρ estimates for each technique is provided in Table 5.9.

Table 5.9 Range of estimates for ρ

Technique	Range[a]
Life Cycle Behaviour model (Blundell et al, 1994)	0.35-1.40
Consumer Demand for Preference Independent Goods	1.56-1.89
Stated Preference Surveys	
Risk Aversion	2.0-5.0
Inequality Aversion	1.0-3.0
Intertemporal Substitution	8.7-8.8
Equal Absolute Sacrifice	1.08-1.79
Subjective Well-being (Layard et al, 2008)	1.05-1.34
Subjective Well-being (our results)	0.04-0.83

[a] *based on empirical evidence provided in Table 5.1*

Our lowest point estimate is found when we include IVs for net household income. This suggests the higher estimates in other models in the empirical analysis are being caused by measurement error and the existence of transient income. The cross-sectional datasets in Layard et al (2008) do not account for measurement error and only crudely control for transient income by restricting respondents to those aged 30-55. This risks overestimating the true value of ρ. However, Layard et al (2008) obtain similar estimates for ρ using panel data for which they have access to actual household income levels rather than deciles.

A possible reason is that the Croatian data considered in this chapter is more at risk from measurement error and transient income due to the smaller size of the dataset. There is no way to test the likelihood although there is anecdotal evidence from our findings in Chapter 3 that instrumenting income appeared to have no significant effect on our estimates using a similar average income technique.

Similar to Layard et al (2008) we find little observable difference between using OLS and ordered logit estimation techniques. This suggests that the assumption of a cardinal transformation of true utility to reported life satisfaction is not an excessively restrictive one in the case of our Croatian dataset.

5.7 Conclusion

This chapter has applied a new technique to estimate ρ using a cross-sectional study of Croatia. Our point estimates of ρ indicate that marginal utility diminishes at a rate less than unity across all models. Their 95% confidence intervals, however, cannot conclude vehemently that ρ is statistically different from one.

We make a number of original contributions to the literature. Firstly we find that controlling for household demographic compositions has the effect of increasing the elasticity of marginal utility. Absolute household income ignores the cost of living differences across Croatia. This is only partially accounted for by incorporating demographics as a set of additive terms. Scaling income by household compositions raises the value of ρ.

Given the importance of the parameters estimated for the income variables we also provide a rigorous analysis of IVs to deal with the measurement error associated with relying on midpoint data for income ranges. This is a significant limitation of many household surveys. A further problem of cross-sectional analysis is the possibility transient income effect. We find that taking average income of those residing in the same Croatian region and similar socioeconomic characteristics provide suitable IVs. An overidentification test confirms that these instruments are not significant in determining LS itself through any relative income effects. Instrumenting income leads to a significant reduction the in estimated elasticity of marginal utility and cannot unequivocally conclude that ρ is diminishing at all.

Researchers employing the SWB approach need to acknowledge more widely that assuming a value of unity for ρ is potentially restrictive. It is not satisfactory to assume simply that household income should be logarithmic because it appears to fit quite well or relatively better than a linear alternative. This is particularly the case when the willingness to pay for goods are dependent on the estimated coefficient if household income. Our research finds this is exacerbated when information on exact actual household income is not available.

Whilst SWB offers an original technique to estimate ρ much further research is required to learn whether there exists consistency in international comparisons. The relative simplicity of collecting socio-economic, income and demographic information from households might make it an attractive choice for government objectives in social discounting, appropriate taxation and inequality aversion.

CHAPTER 6

CONCLUSIONS

The purpose of the thesis has been to investigate current omissions to climate change modeling which are potentially important factors in the benefits and costs of avoiding climate change. Households reveal their implicit value of climate in a wide number of ways. This could be through migration and where households choose to relocate. Alternatively, it is possible to identify the extent to which climate impacts on the income necessary to reach a particular level of well-being. Climate could instead have a direct effect on well-being itself.

The amenity value of climate needs to be estimated as part of a rigorous investigation into the benefits and costs of climate change. Preferences will be affected by climate change either positively or negatively and impacts on households' production of service flows. Climate directly determines household costs in the form of heating and cooling requirements and expenditure on commodities such as clothing and food. It can also promote a sense of psychological well-being and other health benefits. Climate also determines the quality of local amenities such as flora and fauna.

Projected climate change will require humans to adapt to a different bundle of climate variables. 'Physical' adaptation such as the cost of constructing sea defences and changing production techniques are relatively simple to monetise. But little is known on the ability of households to adapt to climate change and measuring their climate preferences. Extensive spatial variation in climate across the planet indicates that humans are capable of adapting to different types of climate. The common found statistical significance of climate variables imply residual costs and benefits exist after all cost efficient adaptation has taken place.

6.1. Climate and IRM

The first approach investigates if climate is able to explain patterns IRM of UK pensioners. Individuals who are entitled to receive a UK state pension may draw it from any country in the world.[128] Pensioners are no longer tied by working commitments and can geographically redistribute themselves according to their personal preferences which may include climate.

Chapter 2 estimated the importance of climate in determining the migration destination of UK pensioners and predicted how climate change will affect retired migration patterns. The results show that pensioners exhibit a number of traits. They prefer migrating to countries that are not too far from the UK, such as within the EU. However, a country whose first language is English plays an important role in attracting retired migrants as do historical colonial links. Environmental amenities such as the length of coastline and more mountainous countries increase UK pensioner migration.

With respect to the climate we acknowledge that preferences are, to some extent, dependent on the estimation model adopted. The Poisson estimation results show preferences for higher average temperatures and a U-shaped relationship for cloud cover. However, the negative binomial estimation identifies an aversion to very high temperature, higher average

[128] There may exist barriers which make it more difficult to migrate to certain countries e.g. set criteria for obtaining a retirement visa in Australia. See footnote 40 for further details.

precipitation, too little cloud cover and an inverted U-shaped relationship for vapour pressure. Evidence of overdispersion implies the negative binomial model is the preferred estimation method.

The model with the lowest mean square error is then employed to predict changes to retirement migration caused by estimated climate change using four IPCC emissions scenarios (A1fi, A2, B1, B2). We find that climate change leads to noticeable changes in predicted proportion of UK retired migrants in each country but limited change in the overall ranking of countries by migrant popularity.

The implication of these findings is that climate is undoubtedly an important quality when UK pensioners choose to migrate internationally. However, climate change may not play an important role in altering future migration patterns when compared to more traditional economic indicators. This finding potentially has important policy implications. Across all climate change scenarios the share of UK pensioners in destination countries is unlikely to change substantially. These countries can expect a steady of UK pensioners in the future. This could avoid the unnecessary allocation of resources to deal with an anticipated influx/exodus of UK pensioners and any associated costs and benefits (e.g. increased/decreased demand on social and healthcare services).

6.2 Climate and well-being

The second investigation into the implicit value of the climate was to identify the direct effect of climate on well-being. A self-reported life satisfaction question was employed to provide a direct measure of well-being for an international household survey of European countries.

We also controlled for a number of individual and household characteristics (e.g. age, gender, employment status, marital status) that are often found to be important determinants of well-being in the literature.

We find the common U-shaped relationship between age and life satisfaction and estimate a turning point of 53 years. Logged net household income increases life satisfaction but a statistically significant quadratic term implies this relationship is diminishing. Other controls such as marriage (compared to being single) and unemployment (compared to being fully employed) correspond to empirical findings in the literature.

The climate variables reveal a fall in life satisfaction caused by wide variations in annual temperature and the number of rain days. Furthermore, higher annual relative humidity decreases life satisfaction and a greater annual percentage of sunshine increases life satisfaction.

From these findings we estimated the marginal willingness to pay for climate, non-marginal changes between large European cities and construct climate cost of living indices by country and region. The willingness to pay estimates for the climate variables are large. This is indicated by the wide ranging 95% confidence intervals indicating the coefficients are imprecisely estimated. It is therefore difficult to make any inference on the price value of the climate variables.. This culminates in households requiring huge financial compensation to migrate to cities with less preferable climates.

However, the climate cost of living indices, based on the entire suite of climate variables, provide an insightful look into household preferences for the climate. The most amenable climates are typically Mediterranean whilst the least amenable are Scandinavian and Baltic regions. There also appears to be a 'ski' effect with well-known ski resorts performing well in the ranking index. This is an unexpected but fascinating result which may lead to positive amenity values for extreme climatic conditions. Finally, disaggregating our results by gender and age appears to lead to large changes in climatic preferences. Women find the Mediterranean climate most amenable whilst men are more sympathetic towards the climate of northern Europe. There is less variation in by age categories. The most distinctive feature is that those who are middle aged (38 to 55) appear to benefit most greatly from the amenity value of the climate.

6.3 Household and climate equivalence scales

The third approach was also based on a household survey and required survey respondents to provide the minimum income necessary to reach a verbally defined level of welfare. This verbally defined level of welfare was to live 'comfortably and without problems'. It is then possible to calculate the additional income a household requires to compensate for changes in household composition and the climate.

Our study improves on the previous studies of climate equivalence scales of Van Praag (1988) and Frijters and Van Praag (1998) by examining a higher spatial resolution and controlling for the demographic composition of the household. Furthermore, we control for elevation as an additive determinant of cost of living as well as accounting for the adiabatic lapse rate in weather station observations. Furthermore we investigated household equivalence scales and explore the possible link between the impact of climate on cost of living and specific household attributes. This allows us to investigate whether it is possible for households to adapt to changes in climate by altering the size of the household and the size of house inhabited. This can also help to identify particular household which may be more sensitive to climate change

We find that household costs increase with a higher number of January frost days. This corresponds with the negative correlation found between cold January's and life satisfaction. Specific household composition is also very important in determining cost of living. However, we find little correlation between the cost of climate and household composition. This could be due to the limited number of observations in the dataset. Alternatively, it may be because there simply isn't a link.

Climate is important in determining how much a household requires to reach a specified level of utility. Climate change will alter the cost of living requirements to maintain a constant level of utility. If the quality of climate improves (deteriorates) for a household then, assuming income remains constant, they will be relatively better (worse) off than before climate change. Climate equivalence scales are able to inform policymakers how much households need to be compensated through higher incomes to inhabit harsh climates.

The hypothetical nature of the approach allows climate to enter the utility function both directly and indirectly. It avoids having to make the assumption of demand dependency. However, it does require making alternative assumptions which cannot be tested with our dataset, such as utility being independent of base and that all households interpret the IEQ in the same manner.

6.4 Social discounting the costs and benefits of climate change

This thesis also contributes to the social discounting literature by estimating the elasticity of marginal utility with respect to income (ρ) using the subjective well-being approach. The socio-time preference rate has often been used in estimating the present value of the costs and benefits of climate change (e.g. Stern et al, 2007; HM Treasury, 2003) and why it is analysed within this thesis. The value of ρ is usually assumed to be equal to unity based on early research contributions (Blundell et al, 1994; Pearce and Ulph, 1995). This implies that utility diminishes at a constant rate as income rises. However, a number of approaches to estimate the value of ρ empirically conclude that unity may be too conservative. If true this risks significantly overestimating the costs (and benefits) of future climate change.

Layard et al (2008) is the only existing empirical study to estimate ρ using data on self-reported happiness and life satisfaction. They find ρ to be equal to 1.26 and conclude this to be consistent over multiple datasets and across different socio-economic groups.

However, there are two reasons why this work should be considered exploratory in nature. Firstly, they ignore for the possible importance of controlling for household demographic composition in determining the extent to which a household's income is stretched. Secondly, the existence of measurement error is insufficiently dealt with and risks creating biased coefficients on which ρ is estimated.

We attempt to overcome these limitations in our own exploratory investigation. Beginning with uninstrumented income, we find ρ to be between 0.49 and 0.85. 95% confidence intervals, however, are large and incorporate a value a unity in all models.

The introduction of instrumental variables has a marked effect on the estimation of ρ. Adopting an instrument that passes overidentification, underidentification, weak identification and redundancy tests leads to a noticeable fall in the elasticity to 0.22. This has important ramifications for setting appropriate tax rates in Croatia, social discounting and cost benefits analysis.

6.5 Original contribution

This thesis provides a number of original contributions to the economics literature on climate change. Firstly, it investigates the amenity value of the climate which currently lacks sufficient attention in the academic literature and subsequently ignored in prominent reports into the impacts of climate change. It is important to understand the amenity values of climate. It offers insight into the residual value of climate even if humans have made cost effective climatic adaptation. Ignoring these effects could result in inappropriate estimation of the benefits and costs of climate change.

Secondly, it offers the first quantitative analysis of the impact of estimated climate change on international migration flows of UK retirees. This builds on the predominantly qualitative evidence that currently exists on IRM. One cost of climate change is the economic costs of forced migration. However, climate change also determines the pattern of amenity seeking migration. The economic benefit or cost of amenity seeking migration to a country is therefore dependent on whether its climate becomes more or less amenable.

Thirdly, this thesis brings together a variety of alternative valuation techniques which are not common in the climate change literature. The vast majority of academic literature employs the hedonic technique to estimate the amenity value of the climate. Yet this approach is only able to measure marginal values climate in observable marketed such as wage rates and housing rents. This can be overcome by utilising the subjective well-being and hypothetical equivalence scales approaches.

Finally, the subjective well-being and hypothetical equivalence scales literature presently fails to deal adequately with the problems of income measurement error and transient income for cross-sectional studies. This is exacerbated by the common limitation that household surveys require respondents to provide only the income range they fall into. This can have serious consequences when the magnitudes of the estimated coefficients for income are of interest. Clearly this is of importance in the monetisation of the costs and benefits of climate change in monetary terms as well as estimating the elasticity of marginal utility. This thesis has investigated econometric methods to overcome bias caused by measurement error and transient income using instrumental variables. Previous cross-sectional studies in the relevant literature fail to account for this bias.

6.6 Future directions

Further research is needed investigating the importance of household preferences for climate. A growing volume of literature observes climate amenity values to be an important factor using a variety of techniques. Presently, however, monetary valuations of studies vary greatly and there is a lack of standardisation of which climate variables to regress in the literature. This needs to be addressed to make a convincing argument that climate amenity values can reliably be incorporated into the overall costs and benefits of climate change.

We have also identified the need to be extremely careful with the use of income ranges as a proxy for income. Measurement error and the existence of transient income in cross-sectional survey data may lead to biased estimates of the income coefficients. For cross-sectional studies estimating the willingness to pay of climate or the elasticity of marginal utility with respect to income, ignoring this could vastly overestimate or underestimate true values. This thesis acknowledges these errors exist and analyses conventional methods in which it can be combated. Future work should seek to standardise the implementation of instrumental variables to overcome measurement error in cross-sectional household survey datasets.

Our finding that the elasticity of marginal utility with respect to income is lower in Croatia than Layard et al's (2008) multi-country estimates also imply that different countries may need to employ different social discounting rates when estimating the costs of climate change. A one size fits all policy could risk underestimating the future costs and benefits of climate change in some regions whilst overestimating it in others.

Bibliography

Ackerman, F., DeCanio, S.J., Howarth, R.B. and Sheeran, K. (2009) 'Limitations of Integrated Assessment Models of Climate Change' *Climatic Change* **95**, 297-315.

Albouy, D. (2008) 'Are Big Cities Really Bad Places to Live? Improving Quality of Life Estimates across Cities' *NBER Working Paper No. 14472*. Cambridge, MA.

Albouy, D., and Leibovici, F. (2009) 'Quality of Life, Firm Productivity, and the Value of Amenities across Canadian Cities' Mimeo, University of Michigan.

Alcázar, L. and Andrade, R. (2010) 'Influence of Individual, Urban and Civil Society Spheres on Quality of Life in Metropolitan Lima, Peru' in Lora, E., Powell, A., Van Praag, B.M.S. and Sanguinetti, P. 'The Quality of Life in Latin American Cities: Markets and Perceptions' *Inter-American Development Bank and World Bank*, Washington DC.

Arrow, K.J. (1965) 'The Theory of Risk Aversion' in Saatio, Y.J. (1971) 'Essays in the Thoery of Risk Bearing' *Markham Publishing Company* Chicago.

Atkinson, A.B. (1970) 'On the Measurement of Inequality' *Journal of Economic Theory* 2, 244-263.

Atkinson, G., Dietz, S., Helgeson, J. Hepburn, C. and Sælen, H. (2009) 'Siblings, not Triplets: Social Preferences for Risk, Inequality and Time Discounting in Climate Change' *Economics: The Open-Access, Open-Assessment E-Journal*, Vol. 3, 2009-26. Available online at: http://www.economics-ejournal.org/economics/journalarticles/2009-26

Atkinson, A.B. and Stiglitz, J. (1980) 'Lectures in Public Economics' *Mc-Graw Hill*.

Atkinson, G. and Mourato, S. (2008) 'Environmental Cost-Benefit Analysis' *Annual Review of Environment and Resources* **33,** 317-344

Attansio, O.P. and Browning, M. (1995) 'Consumption over the Life Cycle and over the Business Cycle' *The American Economic Review* 85, 1118-1137.

Attias-Donfut, C. (2004), '*New Patterns of Migration and Transmigration A Life Course Perspective*', Document Presented at the European Regional Meeting Migrants and Social Protection, Oslo, April 2004.

Bahar, H. I., Laçiner, S., Bal, İ. and Özcan, M. (2009), 'Older Migrants to the Mediterranean: The Turkish Example', *Population, Space and Place*, Vol. 15, pp. 509 – 522.

Balkir, C. and Kýrkulak, B. (2009), Antalya, the New Destination for International Retirement Migration', *Migration in Europe – Threat or Chance?* Co-editors Heinze Fassmann, Max Haler, David Lane, Edward Elgar.

Barsky, R.B., Juster, F.T., Kimball, M.S. and Shapiro, M.D. (1997) 'Preference Parameters and Behavioral Heterogeneity: An Experimental Approach in the Health and Retirement Study' *Quarterly Journal of Economics* 112, 537-579.

Barten, A.P. (1964) 'Family Composition, Prices and Expenditure Patterns' in Hart, P.E., Mills, G. and Whitaker, J.K. (eds.), *Econometric Analysis for National Economic Planning*, Butterworths, London,

Bartlet, J.E.

Bauer, T., and Zimmermann, K. F. (1995), 'Modelling International Migration: Economic and Econometric Issues', in R. Van der Erf and L. Heering (eds), *Causes of International Migration*, pp. 95 – 115. Luxemburg: Office for Official Publications of the European Communities.

Baumol, W.J. and Oates W.E. (1988) 'The Theory of Environmental Policy' Cambridge University Press, UK.

Becker, G. (1965) 'A theory of the allocation of time' *Economic Journal* 75, 493–517.

Besley, T. And Meghir, C. (1998) 'Tax Based Savings Incentives' LSE Working paper. Available online at: http://darp.lse.ac.uk/PapersDB/Besley-Meghir_(99).pdf

Bell, M. and Ward, G. (2000), 'Comparing Temporary Mobility with Permanent Migration', *Tourism Geographies*, Vol. 2, No. 1.

Benedetti, F., Colombo, C., Barbini, B., Campori, E., and Smeraldi, E. (2001) 'Morning Sunlight Reduces Length of Hospitalization in Bipolar Depression' Journal of Affective Disorder 62, 221-223.

Bie Lilleør, H. Amd Van den Broeck, K. (2011) 'Economic Drivers of Migration and Climate Change in LDCs' Global Environmental Change 21 (S1), S70-S81.

Biggar, J. C. (1980), 'Reassessing elderly Sunbelt Migration', *Research on Aging*, Vol. 2, pp. 177 – 190.

Black, R.W., Adger, N., Arnell, N.W., Dercon, S., Geddes, A. and Thomas, D. (2011) 'The Effect of Environmental Change on Human Migration' *Global Environmental Change* 21 (S.1), S3-S11.

Blanchflower, D. and Oswald, A.J. (2004) 'Well-Being Over Time in Britain and the USA' *Journal of Public Economics* 88, 1359-1386.

Blanchflower, D.G. and Oswald, A.J. (2008) 'Hypertension and Happiness across Nations' *Journal of Health Economics* 27, 218-233.

Bliss, C. (2004) 'Some Implications of a Variable EIS' Nuffield College Economics Working Paper 2004-W26' available online at http://www.economics.ox.ac.uk/index.php/papers/details/some_implications_of_a_variable_eis/

Blomquist, G.C., Berger, M.C. and Hoehn. J.P. (1988) 'New Estimates of Quality of Life in Urban Areas' *The American Economic Review* 78, 89-107.

Blundell, R., Browning, M. and Meghir, C. (1994), 'Consumer demand and the life-cycle allocation of household expenditures', *Review of Economic Studies*, 61, 57–80.

Bockstael, N.E. and McConnell, K.E. (1981) 'Theory and Estimation of the Household Production Function for Wildlife Recreation' *Journal of Environment Economics and Management* 8, 199-214.

Böhringer, C. (2003) 'The Kyoto Protocol: A Review and Perspectives' *Oxford Review of Economic Policy* 19, 451-466.

Bolzman, C., Fibbi, R. and Vial, M. (2006), 'What to do After Retirement? Elderly Migrants and the Question of Return', *Journal of Ethnic and Migration Studies*, Vol. 32, No. 8.

Borjas, G. J. (1989), 'Economic Theory and International Migration', *International Migration Review*, Vol. 23, No. 3.

Borjas, G. J. (1994) 'The economics of immigration', *Journal of Economic Literature,* Vol. 32 No. 4.

Bosello, F., Roson, R. and Tol, R.S.J (2007) 'Economy-wide Estimates of the Implications of Climate Change: Sea Level Rise' *Environmental and Resource Economics* 37, 549-71.

Botrić, V. (2004) 'Hedonic Regressions and Price Indices – Application to the Personal Computer Price Index in Croatia' *Economic Trends and Economic Policy* 98, 30-61.

Bradford, D. and Hildebrand, G. (1977) Observable public good preferences *Journal of Public Economics* 8: 111-131.

Brent, R.J. (1997) 'Applied Cost-Benefit Analysis' Edward Elgar Publishing Limited, Cheltenham, UK.

Breuer, T. (2003), 'Deutsche Rentnerresidenten auf den Kanarischen Inseln', *Geographische Rundschau*, Vol. 55, No. 5.

Brereton, F., Clinch, J.P. and Ferreira, S. (2008) 'Happiness, Geography and the Environment' *Ecological Economics* 65, 386–396.

Brown, J.A.C. (1954) The Consumption of Food in Relation to Household Composition and Income, *Econometrica* 22, 444-60

Brown, J.A.C. and Deaton, A.S. (1972) Models of Consumer Behaviour: A Survey, *Economic Journal* 82, 1145-236

Brown, O. (2008) 'Migration and Climate Change' *IOM Migration Research Series*, No. 31, Geneva: International Organization for Migration.

Buck, A.L. (1981) 'New Equations for Computing Vapor Pressure and Enhancement Factor' *Journal of Applied Meteorology* 20, 1527-1532.

Butler, A. and Nicholson, R. (2000). 'The Effects of Sunlight are both Beneficial and Detrimental to Human Health. *Chemistry in Britain*, *36*(12), 34-36.

Calow, P.P (1998) *Encyclopedia of Ecology and Environmental Management*, Blacwell Science Ltd, Oxford

Cameron, C. and Trivedi, P. K. (1998), *Regression Analysis of Count Data*, Econometric Society Monograph No. 30, Cambridge University Press.

Cameron, C. And Trivedi,P.K. (2005), *Microeconometrics: Methods and Applications*, Cambridge University Press

Campbell, J.Y. and Mankiw, N.G. (1991) 'The Response of Consumption to income: A Cross-country Investigation' *European Economic Review* 35, 723-756.

Carlsson, F., Daruvala, D. and Johansson-Stenman, O. (2005). 'Are People Inequality Averse, or Just Risk-Averse?' *Economica* 72, 375–396.

Casado-Díaz, M. A. (2006), 'Retiring to Spain: An Analysis of Differences among North European Nationals', *Journal of Ethic and Migration Studies*, Vol. 32, No. 8.

Casado-Díaz, M. A., Kaiser, C. and Warnes, A.M. (2004), 'Northern European Retired Residents in Nine Southern European Areas: Characteristics, Motivations and Adjustment', *Ageing and Society,* Vol. 24, pp. 353 – 381.

Cavailhes, J., Joly, D., Hilal, M., Brossard, T., Cardot, H. and Wavresky, P. (2009) 'The Price of Climate: Revealed preferences of French consumers' *The 5th Urban Research Symposium "Cities and Climate Change".*

CIA World Factbook – Croatia. Available online at:
https://www.cia.gov/library/publications/the-world-factbook/geos/hr.html
Accessed 01/11/11

Clark, A.E. and Oswald, A.J. (1994) 'Unhappiness and Unemployment' *The Economic Journal* 8, 89-107.

Clark, A.E. and Oswald, A.J. (1996) 'Satisfaction and Comparison Income' Journal of Political Economy 61, 359-381.

Clark, A., Etilé, F., Postel-Vinay, F., Senik, C. And Straeten, K. (2005) 'Heterogeneity in Reported Well-Being: Evidence from Twelve European Countries' *The Economic Journal* 115, C118-C132.

Clark, A.E.; Frijters, P. and Shields, M.A. (2008) 'Relative Income, Happiness, and Utility: An Explanation for the Easterlin Paradox and Other Puzzles' *Journal of Economic Literature* 46, 95-144.

Clark, D. and Cosgrove, J. (1990) 'Hedonic prices, identification and the demand for public safety' *Journal of Regional Science* 30, 105–121

Clark, D. and Cosgrove, J. (1991) 'Amenities versus labor market opportunities: choosing the optimal distance to move' *Journal of Regional Science* 31, 311–328.

Clark, D. and Hunter, W. (1992), 'The impact of economic opportunity, amenities and fiscal factors on age-specific migration rates', Journal of Regional Science, Vol. 32, No. 3.

Clark, D., Knapp, T.A. and White, N.E. (1996), 'Personal and location-specific characteristics and elderly interstate migration', *Growth and Change*, Vol. 27, No. 3.

Cohen, R. (1996), *Theories of Migration*, Cheltenham: Edward Elgar.

Cohen, J., Cohen P., West, S.G. and Aiken, L.S. (2003), 'Applied Multiple Regression/Correlation Analysis for the Behavioral Sciences' Third Edition, Mahwah, NJ: Erlbaum.

Coldron, K. and Ackers, L. (2009), 'European Citizenship, Individual Agency and the Challenge to Social Welfare Systems: A case Study of Retirement Migration in the European Union', *Policy and Politics*, Vol. 37, No. 4.

Copenhagen Accord (2009) 'Conference of the Parties on its Fifteenth Session: Draft Decision -/CP.15. Available online at:http://unfccc.int/resource/docs/2009/cop15/eng/l07.pdf

Cowell, F. A. and Gardiner, K. (1999) 'Welfare weights' *London School of Economics, STICERD, Economics Research Paper no. 20*.

Costanza, R., Wilson, M., Troy, A., Voinov, A., Liu, S., and D'Agostino, J. (2007). 'The Value of New Jersey's Ecosystem Services and Natural Capital' *The Gund Institute of Ecological Economics*, Burlington, VT and The New Jersey Department of Environmental Protection, Trenton, New Jersey.

Coulon, A., and Wolff, F-C. (2005), 'Immigrants at Retirement: Stay/Return or 'Va-et-Vient'?', CEP Discussion Paper No. 691, *Center for Economic Performance*, London School of Economics, London.

Cragg, M. and Kahn, M. (1997) 'New Estimates of Climate Demand: Evidence from Location Choice' *Journal of Urban Economics* 42, 261-284.

Cragg, M. and Kahn, M. (1999), ‘Climate consumption and climate pricing from 1940 to 1990’, *Regional Science and Urban Economics*, Elsevier, Vol. 29, No. 4.

Cruces, G., Ham, A. and Tetaz, M. (2010) ‘Well-being at the Subcity Level: The Buenos Aires Neighbourhood Quality of Life Survey, in Lora, E., Powell, A., Van Praag, B.M.S. and Sanguinetti, P. ‘The Quality of Life in Latin American Cities: Markets and Perceptions’ *Inter-American Development Bank and World Bank*, Washington DC.

Cuba, L. (1989), ‘Retiring to Vacationland: from Visitor to Resident’, *Generations*, Vol. 13, pp. 63 – 7.

Cuba, L. and Longino, C. (1991), ‘Regional Retirement Migration: The Case of Cape Cod’, *Journal of Gerontology*, Vol. 46, No. 1.

Cushing, B. J. (1987) A note on specification of climate variables in models of population migration *Journal of Regional Science* 27: 641-649.

Danziger, S., Van der Gaag, J., Taussig, M. K. and Smolensky, E. (1984) The Direct Measurement of Welfare Levels. How much does it cost to make ends meet? *Review of Economics and Statistics* 66, 500-505.

Darwin, R.F. and Tol, R.S.J. (2001) ‘Estimates of the Economic Effects of Sea Level Rise’ *Environmental and Resource Economics* 19, 113-129.

Davidson, R. and MacKinnon, J. G. (1993) ‘Estimation and Inference in Econometrics’ *Oxford University Press: Oxford.*

Day, F. and Barlett, J. (2000), ‘Economic impact of retirement, migration on the Texas hill country’, *Journal of Applied Gerontology*, Vol. 19, No. 1.

Deaton, A.S and Muellbauer, J. (1980) *Economics and Consumer Behaviour,* Cambridge University Press, Cambridge.

Deaton, A.S and Muellbauer, J. (1986) On Measuring Child Costs: With Applications to Poor Countries, *Journal of Political Economy* 94, 720-744

Deaton, A.S., Ruiz-Castillo, J. and Thomas, D. (1989) ‘The Influence of Household Composition on Household Expenditure Patterns: Theory and Spanish Evidence’ *Journal of Political Economy* 97, 179-200.

De Bruin, K.C. Dellink, R.B. and Tol, R.S.J. (2009) ‘AD-DICE: An Implementation of Adaptation in the DICE model’ *Climatic Change* 96, 63-81.

De Coulon, A. and Wolff, F. (2006), ‘The Location of Immigrants at Retirement: Stay/Return or ‘Va-et-Vient’?, *IZA Discussion Papers 2224*, Institute for the Study of Labor (IZA).

Department for Energy and Climate Change (2011) Annual Report on Fuel Poverty Statistics 2011. Available online at:

http://www.decc.gov.uk/en/content/cms/statistics/fuelpov_stats/fuelpov_stats.aspx

Deyak, T.A. and Smith, K.V. (1978) 'Congestions and Participation in Outdoor Recreation: A Household Production Function Approach' *Journal of Environmental Economics and Management* 5, 63-80.

Di Tella, R. and MacCulloch, R. (2008) 'Gross national happiness as an answer to the Easterlin Paradox?' *Journal of Development Economics*. 86, 22-42.

Di Tella, R., MacCulloch, R.J. and Oswald A.J (2001) 'Preferences over Inflation and Unemployment: Evidence from Surveys of Happiness' *The American Economic Review* 91, 335-341.

Di Tella, R., MacCulloch, R.J. and Oswald A.J (2003) 'The Macroeconomics of Happiness' *Review of Economics and Statistics* 85, 809-827.

Dustmann, C. (1996), 'Return Migration: The European Experience', *Economic Policy*, No. 22, pp. 215 – 250.

Dwyer, P. (2000), 'Movements to Some Purpose? An Exploration of International Retirement Migration in the European Union', *Education and Ageing*, Vol. 15.

Dwyer, P. and Papadimitriou, D. (2006), 'The Social Security Rights of Older International Migrants in the European Union', *Journal of Ethnic and Migration Studies*, Vol. 32, No. 8.

Easterlin, R.A. (1974) 'Does Economic Growth Improve the Human Lot? Some Empirical Evidence' In: David P.A and Reder. M.W. (Eds.), '*Nations and Households in Economic Growth: Essays in Honor of Moses Abramovitz'*. Academic Press, 89-125.

Easterlin, R.A. (1995) 'Will Raising the Income of All Increase the Happiness of All?' *Journal of Economic Behavior and Organization* 27, 35-47.

Easterling, D.R., Horton, B., Jones, P.D., Peterson, T.C., Karl, T.R., Parker, D.E., Salinger, M.J., Razuvayev, V., Plummer, N., Jamason, P. and Folland, C.K. (1997) 'Maximum and Minimum Temperature Trends for the Globe' *Science* 277, 364-367.

Edin, P-A., LaLonde, R.J. and Åslund, O. (2000), 'Emigration of Immigrants and Measures of Immigrant Assimilation: Evidence from Sweden', *Swedish Economic Policy Review*, Vol. 7, pp. 163 – 204.

Ekerdt, D. J. (2009), 'Population Retirement Patterns' in Uhlenberg, P. (2009), *International Handbook of Population Aging*, Springer Science.

Engel, E. (1895) Die Lebenskosten Belgischer Arbeiter-Familen Früher and Jetzt, *International Statistical Institute Bulletin* 9, 1-74.

Engelbrecht, H-J. (2009) 'Natural Capital, Subjective Well-Being, and the New Welfare Economics of Sustainability: Some Evidence from Cross-country Regressions' *Ecological Economics* 69, 380-388.

Englin, J. (1996) 'Estimating the amenity value of rainfall' *Annals of Regional Science* 30, 273–283

Ettner, S.L. (1996) 'New Evidence on the Relationship between Income and Health' *Journal of Health Economics* 15, 67-85.

European Commission (2009) 'EU Action against Climate Change: Leading action to 2020 and beyond. Available online at:
http://www.ab.gov.tr/files/ardb/evt/1_avrupa_birligi/1_6_raporlar/1_3_diger/environment/eu_emmissions_trading_scheme.pdf

EUROSTAT (2007) 'Regions in the European Union: Nomenclature of Territorial Units for Statistics' EUROSTAT methodologies and working papers
Available online at: http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-RA-07-020/EN/KS-RA-07-020-EN.PDF

EUROSTAT (2011) Regional Statistics. Available online at:
http://epp.eurostat.ec.europa.eu/portal/page/portal/region_cities/regional_statistics/data/main_tables
Accessed 01/11/2011

Evans, D.J. (2004) 'A Social Discount Rate for France' *Applied Economic Letters* 11, 803-808

Evans, D.J. (2005) 'The Elasticity of Marginal Utility of Consumption: Estimates for 20 OECD Countries', *Fiscal Studies* 26, 197-224.

Evans, D.J. and Sezer, H. (2002) 'A time preference measure of the social discount rate for the UK' *Applied Economics* 34, 1925–34.

Evans, D.J. and Sezer, H. (2004) 'Social discount rates for six major countries' *Applied Economics Letters* 11, 557–60.

Fankhauser, S. (1995) 'Valuing climate change: the economics of the greenhouse' Earthscan, London

Fellner, W. (1967), 'Operational Utility: the Theoretical Background and a Measurement', in W. Fellner (ed.), *Ten Economic Studies in the Tradition of Irving Fisher*, New York: John Wiley and Sons.

Ferre, Z., Gandelman, N. and Piani, G. (2010) 'Housing and Neighbourhood Satisfaction in Montevideo, Uruguay' in Lora, E., Powell, A., Van Praag, B.M.S. and Sanguinetti, P. 'The

Quality of Life in Latin American Cities: Markets and Perceptions' *Inter-American Development Bank and World Bank*, Washington DC.

Ferreira, M.L., Buse, R.C. and Chavas, J-P. (1998) 'Is there bias in computing Household Equivalence Scale?' *Review of Income and Wealth* **44**, 183-198.

Ferreira, S. and Moro, M. (2010) 'On the Use of Subjective Well-being Data for Environmental Valuation', *Environmental and Resource Economics*, 46, 249 – 273.

Ferreira, S., Moro, M. and Clinch, P.J. (2006) 'Transaction Costs and Hedonic Valuation: The Case for a Life Satisfaction Approach. Working Paper, Planning and Environmental Policy Series. University College Dublin.

Ferrer-i-Carbonell, A. and Frijters, P. (2004) 'How Important Is Methodology for the Estimates of the Determinant of Happiness?' *The Economic Journal* 114, 641-659.

Ferrer-i-Carbonell, A and Gowdy, J.M. (2007) 'Environmental Degradation and Happiness' *Ecological Economics* 60, 509-516

Ferrer-i-Carbonell, A. and Van Praag, B.M.S (2001) Poverty in Russia, *Journal of Happiness Studies* 2, 147-72

Filbeck, G., Hatfield, P. And Horvath, P. (2005) 'Risk Aversion and Personality Type' *The Journal of Behavioral Finance* 6, 170-180

Freeman, A.M. (1999) 'The Measurement of Environmental and Resource Values: Theory and Methods' Third Edition, *Resources for the Future*, Washington D.C.

Frey, B.S. and Stutzer, A. (2000) 'Happiness, Economy and Institutions' *The Economic Journal* 110, 918-938.

Frey, B.S. and Stutzer, A. (2002) 'Happiness & Economics' *Princeton University Press*, Princeton, New Jersey.

Frey, B.S. and Stutzer, A. (2005) 'Happiness Research: State and Prospects' *Review of Social Economy* 57, 207-228.

Friedrich, K. and Kaiser, C. (2002), 'Rentnersiedlungen auf Mallorca?Möglichkeiten und Grenzen der Übertragbarkeit des NordamerikanischenKonzepts auf den Europäischen Sunbelt', Europa Regional, Vol. 9, No. 4.

Frijters, P. and Van Praag, B.M.S. (1998) 'The Effects of Climate on Welfare and Well-being in Russia' *Climatic Change* 39, 61-81.

Gibler, K. M., Casado-Diaz, J., Casado-Diaz, M., Rodriquez, V. and Taltavull, P. (2009), 'Late Life Second Move Housing Choices of International Retiree Migrants', *International Journal of Housing Markets and Analysis*, Vol. 2, No. 2.

Goedhart, T., Halberstadt, V., Kapteyn, A. and Van Praag, B. (1977) The Poverty Line: Concept and Measurement, *The Journal of Human Resources* 12, 503-520.

Gorman, W.M. (1976) 'Tricks with Utility Functions' in Artis, M. and Nobay, R. (eds.) Essays in Economic Analysis, Cambridge University Press, Cambridge

Graham, C., Higuera, L. and Lora, E. (2009) 'Valuing Health Conditions: Insights from Happiness Surveys across Countries and Cultures' *Inter-American Development Bank Working Paper Series No. 100*.

Graves, P. (1980), 'Migration and climate', Journal of Regional Science, Vol. 20, No. 2.

Graves, P. and Waldman, D. (1991), 'Multimarket Amenity Compensation and the Behavior of the Elderly', *American Economic Review* 81, pp. 1374 – 81.

Grote, U. and Warner, K. (2010), 'Environmental Change and Forced Migration: Evidence from Sub-Saharan Africa', Submitted to the *International Journal of Global Warming* 2, 17-47.

Greenwood, M. J. (1975) 'Research on Internal Migration in the United States: A Survey' Journal of Economic Literature 13, 397-433.

Grossman, M. (1999) 'The Human Capital Model of the Demand for Health' *NBER Working Paper 7078.*

Gustafson, P. (2002), 'Tourism and Seasonal Retirement Migration', *Annals of Tourism Research*, Vol. 29, No. 4.

Gyourko, J. and Tracy, J. (1991) 'The Structure of Local Public Finance and the Quality of Life' *Journal of Political Economy*. 99, 774-806.

Hagenaars, A.J.M. (1986) *The Perception of Poverty*. Amsterdam: North-Holland Publishing Company.

Hagenaars, A.J.M. and Van Praag, B.M.S. (1985) A Synthesis of Poverty Line Definitions, *Review of Income and Wealth* 23, 243-266.

Hall, L.J., Robalino, J. and Madrigal, R. (2010) 'Pricing Amenities in Urban Neighbourhoods of Costa Rica' in Lora, E., Powell, A., Van Praag, B.M.S. and Sanguinetti, P. 'The Quality of Life in Latin American Cities: Markets and Perceptions' *Inter-American Development Bank and World Bank*, Washington DC.

Hansen, L. R. (1982) 'Large Sample Properties of Generalized Method of Moment Estimators' *Econometrica* 50, 1029-1054.

Hardill, I., Spradbery, J., Arnold-Boakes, J. and Marrugat, M.L. (2005), 'Severe Health and Social Care Issues among British Migrants who retire to Spain', *Ageing and Society*, Vol. 25, 769 – 783.

Hartog, J. (1988) Poverty and the Measurement of Individual Welfare. A Review of A.J.M Hagenaars' The Perception of Poverty, The Journal of Human Resources 23, 243-266.

Hass, W. and Serow, W. (1993), 'Amenity migration process: A model and preliminary evidence', *The Gerontologist* 33, No. 2.

Haug, W., Compton, P. and Courbage, Y. (ed) (2002), The Demographic Characteristics of Immigrant Populations, *Population Studies*, No. 38. Council of Europe Publishing.

Helliwell, J.F. (2003) 'How's Life? Combining Individual and National Variables to explain Subjective Well-being' *Economic Modelling* 20, 331-260.

Helset, A., Lauvli, M. and Sandlie, H.C. (2005), 'Jubilados Noruegos en España', in Rodríguez, V., Casado Díasz, M. and Huber, A. (eds) *La Migración de Europeos Retirados en España*, Madrid: CSIC.

Hoch, I. and Drake, J. (1974) 'Wages, climate and the quality of life' *Journal of Environmental Economics and Management* 1, 268–275.

Hoehn, J. P., Berger, M. C., and Blomquist, G. C. (1987) 'A Hedonic Model of Interregional Wages, Rents and Amenity Values' *Journal of Regional Science* 27, 605-620.

Hope, C. (2006) 'The Marginal Impact of CO_2 from PAGE2002: An Integrated Assessment Model Incorporating the IPCC's Five Reasons for Concern' *The Integrated Assessment Journal* **6**, 19-56.

Hooren, F. (2008), 'Welfare Provision Beyond National Boundaries: The Politics of Migration and Long Term Elderly Care in Italy', *Paper Presented at the ESPAnet Doctoral Researches Workshop*: 'The Politics of Recalibration: Welfare Reforms in the Wider Europe', Forli, 5 – 7 June.

HM Treasury (2003) 'Appraisal and Evaluation in Central Government' *The Green Book*. London: HMSO.

Huber, A. and O'Reilly (2004), 'The Construction of Heimat under Conditions of individualised Modernity: Swiss and British Elderly Migrants in Spain', *Ageing and Society*, Vol, 24, No. 3.

Hugo, G. (1987), 'Using Census Data to Study Elderly Migration: Problems and Possibilities', *International Migration Review*, Vol. 21, No 4.

Intergovernmental Panel on Climate Change (2007), Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on climate Change: Impacts, Adaptation and Vulnerability, Cambridge University Press, UK.

Jennissen, R. (2007), 'Causality Chains in the International Migration Systems Approach', *Population Research Policy Review,* Vol. 26, pp. 411 – 436.

Johansson-Stenman, O., Carlsson, F. and Daruvala, D. (2002) 'Measuring Future Grandparents' Preferences for Equality and Relative Standing' *Economic Journal* 112, 362-383.

Kahn, M.E. (2008) 'Urban Growth and Climate Change' On-Line Working Paper Series, California Center for Population Research.

Kahn, M. (2009), 'Urban Growth and Climate Change', *The Annual Review of Resource Economics*, Vol. 1, No.16.

Kahneman, D., Kruger, A. B., Schkade, D. A., Schwartz, N., & Stone, A.A. (2004) 'A Survey Method for Characterizing Daily Life Experience: The Day Reconstruction Method' *Science* 306, 1776-1780.

Kapteyn, A. and Van Praag, B. (1976) A New Approach to the Construction of Family Equivalence Scales, *European Economic Review* 7, 313-335.

Karl, T.R., Jones, P.D., Knight, R.W., Kukla, G., Plummer, N., Razuvayev, V., Gallo, K.P., Lindseay, J., Charlson, R.J. and Peterson, T.C. (1993) 'Asymmetric Trends of Daily Maximum and Minimum Temperature' *Bulletin of the American Meteorological Society* 74, 1007-1023.

Kasof, J. (2009), 'Cultural Variation in Seasonal Depression: Cross-national Differences in Winter Versus Summer Patterns of Seasonal Affective Disorder', *Journal of Affective Disorders*, Vol. 115, pp. 79 – 86.

Kelly, D.L. and Kolstad, C.D. (1999) 'Integrated Assessment Models for Climate Change Control in Folmer, H. and Tietenberg, T. (eds), *International Yearbook of Environmental and Resource Economics 1999/2000: A Survey of Current Issues*, Cheltenham, Edward Elgar.

King, R.,. Warnes, A.M. and Williams, A.M.(1998), 'International Retirement Migration in Europe', *International Journal of Population Geography*, Vol. 4, pp. 91 – 111.

King, R. and Patterson, G. (1998), 'Diverse paths: the elderly British in Tuscany', *International Journal of Population Geography*, Vol. 4, No. 2.

King, R., Warnes, A. and Williams, A.M. (2000), Sunset Lives: British Retirement Migration to the Mediterranean. Oxford: Berg.

Kleibergen, F. And Paap, R. (2006) 'Generalized Reduced Rank Tests using the Singular Value Decomposition' *Journal of Econometrics* 133, 97-126.

Klinthäll, M. (2003), *Return Migration from Sweden 1968 – 1996: A Longitudinal Analysis*, Almqvist and Wiksell International, Stockholm.

Klinthäll, M. (2006), 'Retirement Return Migration from Sweden', *International Migration*, Vol. 44, No. 2.

Koch-Schulte, J. (2008), Planning for International Retirement Migration and Expats: a Case Study of UdonThani, Thailand, The University of Manitoba, Winnipeg.

Kugler, P. (1988) ‘Intertemporal Substitution, Taste Shocks and Cointegration’ *Economic Letters* 26, 235-239.

Kula, E. (1984) ‘Derivation of Social Time Preference Rates for the United States and Canada’ The Quarterly Journal of Economics 89 , 873-882.

Lam, R.W., Tam, E.M. Yatham, L.N. Shiah, I.S. and Zis, A.P.. (2001), ‘Seasonal Depression: The Dual Vulnerability Hypothesis Revisited’, *Journal of Affective Disorders*, Vol. 63, pp. 123 – 132.

Lancaster, G. and Ray, R. (1998) ‘Comparison of Alternative Models of Household Equivalence Scales: The Australian Evidence on Unit Record Data’ *The Economic Record* 74, 1-14.

Lardiés, R. (1999), ‘Migration and Tourism Entrepreneurship: North-European Immigrants in Cataluña and Languedoc’, *International Journal of Population Geography*, Vol. 5.

Layard., R, Mayraz. G. and Nickell. S. (2008) ‘The Marginal Utility of Income’ *Journal of Public Economics* 92, 1846-1857.

Layard, R., Mayraz, G. and Nickell, S. (2009) ‘Does Relative Income Matter? Are the Critics Right? *CEP Discussion Paper No. 918*.

Lazaridis, G., Poyago-Theotoky, J. and King, R. (1999), ‘Islands as havens for retirement migration: finding a place in sunny Corfu’, in *Small Worlds, Global Lives. Islands and Migration*, R. King and J. Connell (eds), Pinter, London, UK.

Levinson, A. (2009) ‘Valuing Public Goods using Happiness Data: The Case of Air Quality’ *NBER Working Paper 15156*.

Lewbel, A. (1989) ‘Household Equivalence Scales and Welfare Comparisons’ *Journal of Public Economics* 39, 377-391.

Longino, C. F. and Biggar, J. C. (1981), ‘The Impact of Retirement Migration on the South’, *The Gerontologist*, Vol. 21, pp. 283-290.

Luechinger, S. (2009) ‘Valuing Air Quality Using the Life Satisfaction Approach’ *The Economic Journal* 119, 482-515.

Mackerron, G. (2011) ‘Happiness Economics from 35,000 Feet’ *Journal of Economic Surveys* 26, 705-735.

Mackerron, G. (2012) ‘Happiness and Environmental Quality, PhD thesis, London School of Economics.

Mackerron, G. and Mourato, S. (2009) 'Life Satisfaction and Air Quality in London' *Ecological Economics* 68, 1441-1453.

Maddison, A. (2001) 'The World Economy: A Millennial Perspective, Paris, OECD.

Maddison, D. (2001) The Amenity Value of the Climate: The Household Production Function Approach, in Maddison, D. (ed) *The Amenity Value of the Global Climate*, Earthscan, London.

Maddison, D. (2003) 'The Amenity Value of the Climate: the Household Production Function Approach' *Resource and Energy Economics* 25, 155-175.

Maddison, D. and Bigano, T. (2003) 'The Amenity Value of the Climate' *Journal of Environmental and Management* 45, 319-332.

Marchiori, L. and Schumacher, I. (2011) 'When Nature Rebels: International Migration, Climate Change and Inequality' *Journal of Population Economics* 24, 569-600.

Massey, D. S., Arango, J., Hugo, G., Kouaouci, A., Pellegrino, A. and Taylor, J.E. (1993), 'Theories of International Migration: A Review and Appraisal', *Population and Development Review*, Vol. 19, No. 3.

Massey, D. S., Arango, J., Hugo, G., Kouaouci, A., Pellegrino, A. and Taylor, J.E. (1998), Worlds in Motion: Understanding International Migration at the End of the Millennium, Oxford, England: Clarendon Press.

McHugh, K. E. (1990), 'Seasonal migration as a Substitute for, or Precursor to, Permanent Migration', *Research on Aging*, Vol. 12, No. 2.

Mcleman, R. and Smit, B. (2006) 'Migration as an Adaptation to Climate Change' *Climatic Change* 76, 31–53.

Medina, C., Morales, L. and Núñez, J (2010 'Quality of Life in Urban Neighbourhoods of Bogotá and Medellín, Colombia' in Lora, E., Powell, A., Van Praag, B.M.S. and Sanguinetti, P. 'The Quality of Life in Latin American Cities: Markets and Perceptions' *Inter-American Development Bank and World Bank*, Washington DC.

Mendelsohn, R. (2001) A Hedonic Study of the Non-Market Impacts of Global Warming in the US, in Maddison, D. (ed) *The Amenity Value of the Global Climate*. Earthscan: London.

Mirza, M. M. Q. (2003) 'Climate Change and Extreme Weather Events: Can Developing Countries Adapt?' Climate Policy 3, 233-248.

Mitchell, T.D., T.R. Carter, P.D. Jones, M. Hulme and M. New (2003) 'A comprehensive set of high-resolution grids of monthly climate for Europe and the globe: The observed record (1901-2000) and 16 scenarios (2001-2100)', *mimeo, Tyndall Centre: University of East Anglia.*

Molin, J., Mellerup, E., Bolwig, T., Scheike, T. and Dam, H. (1996), 'The Influence of Climate on Development of Winter Depression', *Journal of Affective Disorders,* Vol. 37, pp. 151 – 155.

Moro, D. (2006), 'International Retirement Migration: Legal Framework in European Union', Warwick University, Dept of Economics.

Moro, D. (2007), '*Modeling Economic Effects of International Retirement Migration within The European Union*', A Thesis submitted for the Degree of PhD at the University of Warwick.

Moro, M., Brereton, F., Clinch, J.P. and Ferreira, S. (2008) 'Ranking Quality of Life Using Subjective Well-being Data' *Ecological Economics* 65, 448-460.

Muellbauer, J. (1977) Testing the Barten Model of Household Composition Effects and the Cost of Children, *Economic Journal* 87, 460-87.

Mueller, V., and Sheriff, G. (2010) 'On Hedonic Valuation of Urban Amenities Using Unbalanced Data' *Land Economics* 86. 545 – 551.

Murthi, M. (1994) 'Engel Equivalence Scales in Sri Lanka: Exactness, Specification and Measurement Error in Blundell, R., Preston, I. and Walker, I. (eds) *'The Measurement of Household Welfare'* Cambridge University Press.

Myers, D.G. (2000) 'The Funds, Friends and Faith of Happy People' *American Psychologist* 55, 56-67.

Nelson, J. A. (1992) Methods of Estimating Household Equivalence Scales: An Empirical Investigation, *Review of Income and Wealth* 38, 295-310.

New, M., Lister, D., Hulme, M. and Makin, I. (2002) A High-resolution Data Set of Surface Climate over Global Land Areas, *Climate Research* 21, 1-25.

Newbold, K. B. (1996), 'Determinants of Elderly Interstate Migration in the United States, 1985-1990', *Research on Aging,* Vol. 18, No. 4.

Ng, Y-K. (1997) 'A Case for Happiness, Cardinalism and Interpersonal Comparability' *The Economic Journal* 107, 1848-1858.

Nordhaus, W.D. (1993) 'An Optimal Transition Path for Controlling Greenhouse Gases' *Science* 258, 1315-1319.

Nordhaus, W.D. (1993a) 'Rolling the 'DICE': An Optimal Transition Path for Controlling Greenhouse Gases' *Resource and Energy Economics* 15, 27-50.

Nordhaus, W. (1996) 'Climate amenities and global warming' in: Nakicenovic, N., Nordhaus, W., Richels, R. and Toth, F. (eds.) 'Climate change: Integrating science, economics and policy' IIASA, Laxenburg.

Nordhaus, W.D. (2007) 'A Review of the Stern Review on the Economics of Climate Change' *Journal of Economic Literature* 45, 686-702.

Nordhaus, W. (2007) 'The Challenge of Global Warming: Economic Models and Environmental Policy' available online at:
http://nordhaus.econ.yale.edu/dice_mss_072407_all.pdf

Öberg, S. (1997) 'Theories on Inter-regional Migration: An Overview' in H. H. Blotevogel and A. J. Fielding (eds) (1997), *People, Jobs and Mobility in the New Europe*, pp. 3 – 22. Chichester, England: Wiley.

Okun, A.M. (1975) *Equality and Efficiency, the Big Trade-off*, Brookings Institution Press

Olders, H. (2003) 'Average Sunrise Time Predicts Depression Prevalence' *Journal of Psychosomatic Research* **55**, 99-105.

Omann, I., Stocker, A. and Jäger, J. (2009) 'Climate change as a threat to biodiversity: An application of the DPSIR approach' *Ecological Economics* 69, 24-31.

Oswald, A.J. (1997) 'Happiness and Economic Performance' *Economic Journal* 107, 1815-1831.

Oswald, A.J. and Powdthavee, N. (2008) 'Death and the Calculation of Hedonic Damages' *Journal of Legal Studies* 37, S2: pp. S217-S251.

OXERA (2002), 'A Social Time Preference Rate for Use in Long-Term Discounting: A Report' *for ODPM, DfT and DEFRA*, Oxford.

Pearce, D. and Ulph, D. (1995) 'A Social Discount Rate for the UK' CSERGE, paper no. 95-01.

Pearce, D. and Ulph, D. (1999) 'A social discount rate for the UK', in Pearce D W (ed) *Economics and the Environment: Essays on Ecological Economics and Sustainable Development*, Edward Elgar Publishing, Cheltenham UK.

Plourde, C. G. (1972) 'A Model of Waste and Accumulation' *Canadian Journal of Economics* 5, 119-125.

Pollak, R. J. and Wales, T.J. (1979) Welfare Comparisons and Equivalence Scales, *American Economics Review* 69, 216-221.

Pollak, R. J. and Wales, T.J. (1981) 'Demographic Variables in Demand Analysis' *Econometrica* 49, 1533-51.

Poulain, M. and Perrin, N. (2002), 'The Demographic Characteristics of Immigrant Populations in Belgium', in Haug, W. et al. (ed) (2002), *The Demographic Characteristics of Immigrant Populations,* Population Studies, No. 38. Council of Europe Publishing.

Radua, J., Pertusa, A. and Cardoner, N. (2010), 'Climatic Relationship with Specific Clinical Subtypes of Depression', *Psychiatry Research,* Vol. 175, pp. 217 – 220.

Ramsey, F. P. (1928), 'A Mathematical Theory of Saving', *Economic Journal* 38, 543–59.

Rappaport, J. (2005), 'Why are Some Cities So Crowded?', *2005 Meeting Papers 131*, Society for Economic Dynamics.

Rehdanz, K. and Maddison, D. (2005) 'Climate and Happiness' *Ecological Economics* 52, 111-125.

Rehdanz, K. and Maddison, D. (2008). 'Local environmental quality and life-satisfaction in Germany', *Ecological Economics* 64, 787-797

Rehdanz, K. and Maddison, D. (2009) The amenity value of climate to households in Germany *Oxford Economic Papers* 61: 150-167.

Reuveny, R., and Moore, W. (2009), 'Does Environmental Degradation Influence Migration? Emigration to Developed Countries in the Late 1980s and 1990s', *Social Science Quarterly,* Vol. 90, No. 3.

Roback, J. (1982), 'Wages, Rents and the Quality of Life', *Journal of Political Economy,* pp. 1257 – 78.

Rodríguez, V. (2001), 'Tourism as a Recruiting Post', *Tourism Geographies*, Vol. 3.

Rodríguez, V. and Egea, C. (2006), 'Return and the Social Environment of Andalusian Emigrants in Europe', *Journal of Ethnic and Migration Studies,* Vol. 32, No. 8.

Rodríguez, V., Fernández, G.F., Pérez, F.R. and García, A.A. (1999), *Los Inmigrantes Europeos Jubilados en Andalucía*. Madrid: Instituto de Economía y Geografía, Consejo Superior de Investigaciones Científicas.

Rojas, M. (2007) A Subjective Well-being Equivalence Scale for Mexico: Estimation and Poverty and Income-distribution Implications, *Oxford Development Studies* 35, 274-293.

Rosen, S. (1974), 'Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition' *Journal of Political Economy* 82, 34-55.

Rosenzweigh, C., Iglesias, A., Yang, X.B., Epstein, P.R. and Chivian, E. (2001) 'Climate Change and Extreme Weather Events: Implications for Food Production, Plant Diseases and Pests' Global Change and Human Health 2, 90-104.

Rothbarth, E. (1943) Note on a Method of Determining Equivalent Income For Families of Different Composition, *in War-Time Pattern of Saving and Spending* by Madge, C. Cambridge University Press, Cambridge.

Rowthorn, R. (2009). 'The Economic and Demographic Impact of Immigration on Western Europe' in *Migration and the Movement of People in Europe: Threat or Benefit?* Ed. M. Halle and D. Lane.

Samuelson, P. A. (1954) The Pure Theory of Public Expenditure, *Review of Economics and Statistics* 36, 387-389.

Schwarz, N. and Clore, G.L. (1983) 'Mood, Misattribution and Judgements of Well-Being: Informative and Directive Functions of Affective States' *Journal of Personality and Social Pyschology* 45, 513-523.

Seidl, C. (1994) How Sensible is the Leyden Individual Welfare Function of Income? *European Economic Review* 38, 1633-1659.

Seo, S.N., Mendelsohn, R., Dinar, A., Hassan, R. and Kurukulasuriya, P. (2009) 'A Ricardian Analysis of the Distribution of Climate Change Impacts on Agriculture across Agro-Ecological Zones in Africa' *Environmental and Resource Economics* 43, 313-332.

Serow, W. (2003), 'Economic Consequences of Retiree Concentrations: A Review of North American Studies', *Gerontologist*, Vol. 43, pp. 897 – 903.

Sjaastad, L. (1962), 'The costs and returns of human migration', *Journal of Political Economy*, Vol. 70 No. 5.

Smith, V. K. (1991) Household Production Function and Environmental Benefit Estimation, in *Measuring the Demand for Environmental Quality* edited by Braden, J. B. and Kolstad, C. D. Elsevier Science Publishers: North Holland.

Smith, K.V., Liu, J.L. and Palmquist, R.B. (1993) 'Marine Pollution and Sport Fishing Quality' *Economics Letters* 42, 111-116

Snow Jones, A., Miller, D.J. and Salveker, D.S. (1999) 'Parental Use of Alcohol and Children's Behavioural Health: A Household Production Analysis' *Health Economics* 8, 661-683

The Social Fund Winter Fuel Payment Regulations (1998). Available online at: http://www.legislation.gov.uk/uksi/1998/19/made

Spackman, M. (2004) 'Time Discounting and of the Cost of Capital in Government' *Fiscal Studies* 25, 467-518.

Srinivasan, S. and Stewart, G. (2004) 'The quality of life in England and Wales', *Oxford Bulletin of Economics and Statistics*, **66**, 1 – 22

Sriskandarajah, D. and Drew, C. (2006), Brits Abroad: Mapping the Scale and Nature of British Emigration, IPPR: London.

Stavins, R.N. (1997) ‘Policy Instruments for Climate Change: How can National governments address a Global Problem’ *Resources for the Future Discussion paper 97-11*.

Stern, N., S. Peters, V. Bakhshi, A. Bowen, C. Cameron, S. Catovsky, D. Crane, S. Cruickshank, S. Dietz, N. Edmonson, S.-L. Garbett, L. Hamid, G. Hoffman, D. Ingram, B. Jones, N. Patmore, H. Radcliffe, R. Sathiyarajah, M. Stock, C. Taylor, T. Vernon, H. Wanjie, and D. Zenghelis (2006) *Stern Review: The Economics of Climate Change*, HM Treasury: London.

Stevenson, B., and Wolfers, J. (2008), ‘Economic Growth and Subjective Well-Being: Reassessing the Easterlin Paradox’, *Brookings Papers on Economic Activity*.

Stiglitz, J. (1988) ‘Economics of the Public Sector’ *Second Edition, W.W. Norton & Company,* New York.

Stock, J.H. and Yogo, M, (2002) ‘Testing for Weak Instruments in Linear IV Regression’ *NBER Technical Working Papers 0284.*

Straszheim, M. (1974) ‘Hedonic Estimation of Housing Market Prices: A Further Comment’ *Review of Economics and Statistics* 56: 404-406.

Sullivan, D. A. and Stephens, S. A. (1982), ‘Snowbirds: Seasonal Migrants to the Sunbelt’, Paper presented at the Annual Meeting of the Population Association of America, San Diego.

Todaro, M. (1969), ‘A model of labor migration and urban unemployment in less developed countries’, *American Economic Review*, Vol. 59, No. 1.

Tol, R.S.J (2002a) ‘Estimates of the Damage Costs of Climate Change. Part 1: Benchmark Estimates’ *Environmental and Resource Economics* 21, 47–73.

Tol, R.S.J (2002b) ‘Estimates of the Damage Costs of Climate Change. Part 1: Dynamic Estimates’ *Environmental and Resource Economics* 21, 135-160.

Tol, R.S.J. (2009) ‘The Economic Effects of Climate Change’ Journal of Economic Perspectives 23, 29–51.

Tol, R.S.J., van der Burg, T., Jansen, H.M.A. and Verbruggen, H. (1995) ‘The Climate Fund – Some Notions on the Socio-economic Impacts of Greenhouse Gas Emissions and Emission Reduction in an International Context’ *Institute for Environmental Studies , R95/03*, Vrije Universiteit, Amsterdam.

Tsutsui, Y. (2012) ‘Weather and Individual Happiness’ Osaka University, Graduate School of Economics and Osaka School of International Public Policy (OSIPP).

Tuunainen A., Kripke D. and Endo T. (2004) Light Therapy for Non-Seasonal Depression. Cochrane Database Syst Rev. CD004050.

UNDP Human Development Report: Croatia (2006) 'Faces of Social Exclusion in Croatia'. Available online at:
http://hdr.undp.org/en/reports/nationalreports/europethecis/croatia/CROATIA_2006_en.pdf

UNDP (2007) 'Quality of Life in Croatia: Regional Disparities'. Available online at:
http://www.undp.hr/upload/file/242/121418/FILENAME/Regional_Disparities_final.pdf

UNFCCC (2008) 'Report of the Conference of the Parties on its Thirteenth Session, held in Durban from 28 November to 11th December 2007, Part One: Proceedings. Available online at:
http://unfccc.int/resource/docs/2007/cop13/eng/06.pdf

UNFCCC (2012) 'Report of the Conference of the Parties on its Thirteenth Session, held in Bali from 3 to 15th December 2007, Part One: Proceedings. Available online at:
http://unfccc.int/resource/docs/2011/cop17/eng/09.pdf

Van de Vliert, E., Schwartz, S.H., Huismans, S.E., Hofstede, G. and Daan, S. (1999) 'Temperature, cultural masculinity, and domestic political violence: A cross-national study' *Journal of Cross-Cultural Psychology* 30, 295–318.

Van der Vliert E, Huang X, Parker P (2004) Do Hotter and Colder Climates Make Societies More, But Poorer Societies Less, Happy and Altruistic? *Journal of Environmental Psychology* 24, 17-30.

Van Praag, B.M.S (1968) Individual Welfare Functions and Consumer Behaviour, *North-Holland, Amsterdam.*

Van Praag, B.M.S (1971) The Welfare Function of Income in Belgium: An Empirical Investigation, *European Economic Review* 2, 337-369

Van Praag, B.M.S (1988) Climate Equivalence Scales: An Application of a General Method, *European Economic Review* 32, 1019-1024.

Van Praag B.M.S. and Baarsma, B.E. (2005) 'Using Happiness Surveys to Value Intangibles: The Case of Airport Noise' *The Economic Journal* 115, 224-246.

Van Praag, B.M.S and Ferrer-i-Carbonell, A (2008) *Happiness Quantified. A Satisfaction Calculus Approach*, Oxford University Press, Oxford.

Van Praag, B.M.S and Ferrer-i-Carbonell, A (2008) 'Toward an Urban Quality of Life Index: Basic Theory and Econometric Methods' in Lora, E., Powell, A., Van Praag, B.M.S. and Sanguinetti, P. 'The Quality of Life in Latin American Cities: Markets and Perceptions' *Inter-American Development Bank and World Bank*, Washington DC.

Van Praag, B.M.S and Kapteyn, A. (1973) Further Evidence of the Individual Welfare Function of Income: An Empirical Investigation in the Netherlands, *European Economic Review* 4, 33-62.

Van Praag, B.M.S and Kapteyn, A. (1994) How Sensible is the Leyden Individual Welfare Function of Income? A Reply, *European Economic Review* 38, 1817-1825.

Van Praag, B.M.S and Van der Sar, N. (1988) Household Cost Functions and Equivalence Scales, *Journal of Human Resources* **23**, 193-210.

Van Praag, B., Kapteyn, A. and Van Herwaarden, F.G. (1978) The Individual Welfare Function of Income: A Log-Normal Distribution Function! A Rejoinder, *European Economic Review* 11, 395-402.

Van Praag, B.M.S, Goedhart, T. and Kapteyn, A. (1980) The Poverty Line – A Pilot Survey in Europe, *The Review of Economics and Statistics* 62, 461-465.

Van Praag, B.M.S., Hagenaars, A.J.M. and Kapteyn, A. (1982_a) Poverty in Europe, *Review of Income and Wealth* 28, 345-359.

Van Praag, B.M.S., Spit, J.S. and Van de Stadt, H. (1982_b) A Comparison Between the Food Ratio Poverty Line and Leyden Poverty Line, *The Review of Economics and Statistics* 64, 691-694.

Waldorf, B. S. (1994), 'Assimilation and Attachment in the Context of International Migration: The Case of Guest-workers in Germany', *Papers in Regional Science*, Vol. 73, No. 3.

Waldorf, B. S. (1996), 'The Internal Dynamic of International Migration Systems', *Environment and Planning*, Vol. 28, No. 4.

Walters, W. (2002), 'Later-Life Migration in the United States: A Review of Recent Research', *Journal of Planning Literature*, Vol. 17, No. 37.

Wang, L., Kanji, S. and Bandyopadhyay, S. (2009) 'The Health Impact of Extreme Weather Events in Sub-Saharan Africa' *World Bank Policy Research Working Paper 4979.*

Warnes, T.A.M. (2009) International Retirement Migration. In Poston Jr. D.L. (ed): International Handbooks of Population, Springer Netherlands

Warnes, A. and Williams, A. (2006), 'Older migrants in Europe: a new focus for migration studies', *Journal of Ethnic and Migration Studies*, Vol. 32, No. 8.

Weitzman, M.L. (2007) 'A Review of the Stern Review on the Economics of Climate Change' *Journal of Economic Literature* 45, 703-724.

Welsch, H. (2002) 'Preferences over Prosperity and Pollution: Environmental Valuation Based on Happiness Surveys' *Kyklos*. 55, 473-495.

Welsch, H. (2006) 'Environment and Happiness: Valuation of Air Pollution Using Life Satisfaction Data' *Ecological Economics* 58, 801-813.

Welsch, H. (2007) 'Environmental Welfare Analysis: A Life Satisfaction Approach' *Ecological Economics* 62, 544-551

Wierenga, B. (1978) The Individual Welfare Function of Income. A Log-Normal Distribution Function? *European Econtlm4634omic Review* 11, 387-393.

Winkelmann, L. and Winkelmann, R. (1998) 'Why Are the Unemployed So Unhappy? Evidence from Panel Data' *Economica* 65, 1-15.

Williams, A. M., King, R. and Warnes, A. (1997), 'A Place in the Sun: International Retirement Migration from Northern to Southern Europe', *European Urban and Regional Studies*, Vol. 4.

Williams, A. M., and Hall, C.M. (2000), 'Tourism and International Retirement Migration: New Forms of an Old Relationship in Southern Europe', *Tourism Geographies*, Vol. 2.

Winkelmann, R. and Zimmermann, K.F. (1995) 'Recent Developments in Count Data Modelling: Theory and Application' *Journal of Economics Surveys* 9, 1-24.

Wiseman, R. F. and Roseman, C. C. (1979), 'A Typology of elderly Migration Based on the Decision Making Process', *Economic Geography*, Vol. 55, No. 4.

Wiseman, R.F. (1980), 'Why Older People Move: Theoretical Issues', *Research on Aging*, Vol. 2, No. 2.

World Bank (2011) *Data and Statistics for Croatia*. Available online at:
http://go.worldbank.org/PA8DYK9N90
Accessed 01/11/2011

World Meteorological Organization (2006) 'Guide to Meteorological Instruments and Methods of Observation' available online at: http://www.inamhi.gov.ec/educativa/wmo8final.pdf

Young, H.P. (1987) 'Progressive Taxation and the Equal Sacrifice Principle' *Journal of Public Economics* 32, 203-214.

Young, H.P. (1990) 'Progressive taxation and Equal Sacrifice' *American Economic Review* 80, 253-266.