How much are countries willing to pay for global warming not to take place?

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This thesis attempts to examine how much a representative consumer per each country is willing to pay to avoid global warming by analysing their welfare gains from having a smoother consumption path. Temperature variations affect economic activity, and consumption is subject to shocks related to global warming. I start by reviewing the economic literature that studied the relationship between temperatures and economic activity. I highlight which are the main effects on the economy that are correlated to rising temperatures and I review the methods that are usually employed by economists to assess environmental damages. I then take a sample of 163 countries and compute the welfare gains for each country for having a smoother consumption path, following the method used by Lucas (2003). To do this, I use country-level household consumption data and I set values for the risk aversion coefficient following the suggestions of the previous economic literature. I repeat the experiment with a smaller sample of 72 countries, this time using country-specific risk aversion coefficients retrieved from Gandelman and Hernández-Murillo (2015). In both cases, I obtain that most of the countries have welfare gains lying in the order of 10^{-2} and 10^{-3}. Using annual temperature data, I test the Spearman correlation coefficient between welfare gains and average temperatures. Although the previous literature stressed the adverse effects of global warming on the economy, I find no significant correlation between these two variables. Countries that are more at risk do not display higher welfare gains than countries with a lower risk of imminent climate damages. To explain my results, I then consider determinants of risk aversion other than temperature and conclude that risk aversion, and consequently the value of welfare gains, can depend on several other factors.

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1 Introduction and Research Question

This thesis draws on the current topic of global warming. After discussing the previous literature to prove that there exists a correlation between temperatures and economic activity, I will analyse how much countries are willing to pay for global warming not to take place. The question that I am going to investigate is how much a representative consumer from each of the 163 sampled countries would give up of their consumption to eliminate their consumption variability. To do this, I am going to base my analysis on the conclusion derived by Burke et al. (2015) in the paper *Global non-linear Relationship of Temperatures on Economic Production* published on the scientific journal *Nature* and on other articles of the climate economics literature. Burke et al. (2015) found that there is a correlation between an increase in global average temperatures and economic production and that this correlation is, generally, negative. Economic production obviously affects household consumption and negative effects on production will be reflected by the consumers' side. Relying on Burke et al.'s (2015) result, I will analyse consumption data and calculate how much consumers would be willing to pay to have a smooth consumption path. The empirical approach is widely based on Lucas (2003), who examines a similar question in a policy-making context. Lucas (2003) determines the welfare effects of a stabilization policy. He identifies the welfare gains, denoted by λ, of a policy that would eliminate all consumption variability. In the same way, I will take country-level household final consumption data over a 58-year period and examine the welfare gains of removing their variability. After doing this, I will compare the country-level results to country-level average annual temperature. If the correlation between consumption and temperatures holds, then countries with higher average temperature should also display higher consumption variability and consequently, higher welfare gains from a smoother consumption path.

This thesis aims at bringing another perspective to the literature on climate economics. Most of the previous work had focused mainly on the quantification of the damages that could arise in the future because of climate change. Moreover, the existing studies about willingness to pay for environmental issues tend to focus only on a single or a few countries. These studies are usually performed by surveying people directly and for this reason, they need to be limited to a certain spatial area. However, with this thesis, I intend to expand the study of willingness to pay to a broader set of countries so that between-country comparisons will be easier.

This thesis is structured as follows. I will open with an extensive and detailed review of significant papers from the field of climate and environmental economics. The problem of climate change is very wide, but I will mainly focus on why it is important for economics and why economic research about this issue is needed. I will present and compare some of the most relevant results on the correlation between increasing temperatures and economic activity. Part of the papers is discussed in detail, whereas other papers are briefly discussed to highlight their main conclusions. Once the major results are presented, I will discuss the tools that economists usually employ to enforce policies to confront climate change, highlighting their strengths and weaknesses. Then, I will discuss the principal assumptions that are usually made when modelling for climate change.
The third section will describe the data that I will use for the thesis and their sources.
The fourth section will analyze in detail the method used by Lucas (2003) and explain how it will be applied to the issue that I intend to study. It will also describe the assumptions that I have made concerning the parameters of the model.
The fifth section will present the results of my estimation and a primary discussion of the outcomes.
The sixth section will include a wider discussion of the results and contains comparisons with other papers in the economic and social science literature, giving guidance for further research.
The seventh section will conclude.
Most of the tables reporting the estimates are to be found in the *Appendix*, which is the last section of this thesis.

Since climate change is a topic that scopes beyond the sole field of economics, the papers discussed in the literature review have been retrieved from both economic and scientific journals. The papers have been selected according to their relevance for the thesis, by searching for keywords, such as “climate change”, ”global warming”, “willingness to pay”, “integrated assessment models”, etc. The review is built to first prove that climate change does have impacts on global economic activity. Once this correlation is verified, I will examine the tools that researchers have been using to assess the damages related to climate change, highlighting their advantages and drawbacks.
The discussion at the end of the thesis comments on the results and tries to find explanations for what I have obtained. In this section, in addition to environmental economics papers, I discuss

papers coming from other fields of economics, such as behavioural economics, as well as from the wider area of social sciences. Most of the references used in this review are journal articles, and most of them are publicly available on *JSTOR*, *Springer* and *Elsevier* websites. The computational part of this thesis has been performed with the programme *R*.

2 Literature Review

Nowadays, climate change occupies a central place in the news and many scientists have been warning political leaders about the necessity to act soon to prevent disastrous scenarios from occurring in the relatively near future. Stern (2008) reports that growing greenhouse emissions increase the probability of the occurrence of natural disasters, such as floods, droughts and storms, and that the consequences of the above-mentioned appear to be tragic. The IPCC reports (2012a, 2014a) add that increasing temperatures threaten biodiversity and are the main drivers of sea-level rise. The rise in the temperature is referred to as global warming. Although the terms ”global warming” and ”climate change” are often used interchangeably, they are not synonyms. Global warming is only one aspect of the climate change process that the world is undergoing. The NASA website explains the difference between the two in the following way: ”“Global warming” refers to the long-term warming of the planet. “Climate change” encompasses global warming, but refers to the broader range of changes that are happening to our planet, including rising sea levels; shrinking mountain glaciers; accelerating ice melt in Greenland, Antarctica and the Arctic; and shifts in flower/plant blooming times”. Although I will often use the broader term ”climate change”, my thesis will mainly focus on global warming, investigating the relation between temperature and consumption.

Even if the effects of global warming may affect and be perceived heterogeneously in different areas of the world, every country will be impacted in the long term. Human activity is undoubtedly one of the principal drivers of climate change. As Hsiang and Kopp (2018) report, the correlation between human activity and climate change has been hypothesized at least two centuries ago, and the scientific community is now able to confirm this conjecture. One of the pieces of evidence supporting this hypothesis, reported in Hsiang and Kopp (2018) and the IPCC report (2012a), is that warming has been registered to be considerably slower over the ocean than over the land, where most of the economic and human activity is concentrated. This implies that the nature of global warming is mainly anthropogenic.

The main concern about climate change is the magnitude of its effects. Indeed, Tol (2009) defines climate change as the *mother of all externalities*, because of its huge and uncertain outcomes relative to other environmental issues. The same idea is supported by Hsiang and Kopp (2018), who recognize that climate change stands on a much wider scale than other past natural transformations, such as the agricultural revolution, or the introduction of dams and reservoirs.

2.1 *The significance of climate change for economics*

In a recent paper, Hsiang and Kopp (2018) argue that, although there is massive research on the scientific and physical aspect of climate change, the cooperation between scientists and economists is still not sufficiently developed. This cooperation would be necessary to answer to economically and socially relevant questions. As a matter of fact, climate change is an important issue that touches several areas of interest, and economics is undeniably one of them. One of the reasons why climate change is important for economics is rigorously pointed out in Burke et al. (2015). Burke et al. (2015) find that average temperature presents a non-linear relationship with economic production. The changes in temperature affect productivity, which indicates the ability of societies to turn labour, capital, energy and additional natural resources into goods or services. Therefore, the reason why productivity matters is that it has a direct influence on the well-being of all societies. Through an empirical analysis, Burke et al. (2015) find that the optimal level of production is reached at an average annual temperature of 13°C. To do so, they estimate a function $h(.)$, representing the alleged non-linear relationship between annual temperatures and income growth. $h(.)$ is assumed to be of the form:

$$h(T_{it}) = \beta_1 T_{it} + \beta_2 T_{it}^2 \, ^1,$$

and appears in the model as follows:

$$\Delta Y_{it} = h(T_{it}) + \lambda_1 P_{it} + \lambda_2 P_{it}^2 + \mu_i + \nu_t + \theta_{i1} t + \theta_{i2} t^2 + \epsilon_{it}.^2$$

Therefore, we can think about this relationship as a concave curve hitting its maximum at 13°C and decreasing after this threshold. A straightforward consequence coming from this result is that countries that already have higher average temperatures will be badly hit by increasing temperatures in the following decades, in terms of economic production. As a matter of fact, according to Burke et al. (2015), the probability that the marginal effect of warming is negative for countries with high average annual temperatures is close to 80%. An important conclusion arising from Burke et al. (2015) is that if our strategies to fight against climate change do not evolve

[1] T_{it} is annual temperature, where i is the country and t is the year. β_1 and β_2 are the parameters to be estimated

[2] P_{it} is precipitation, μ_i are country-specific fixed effects, ν_t are year-specific fixed effects, the term $\theta_{i1}t + \theta_{i2}t^2$ refers to flexible country-specific fixed trends

from the ones that we followed in the past, average global incomes will decrease by roughly 23% by 2100 and global income inequality will substantially increase. Thus, increasing temperatures will not only have implications for production, but they will also affect poverty levels.

A negative correlation between temperature and economic variables is also highlighted by further economic literature. For example, Dell et al. (2012) find significant and negative effects of higher temperature on economic growth. However, this result only holds for poorer countries, which seems to be in contradiction with the fact that climate change will have negative impacts on the *global* economy, as highlighted by Burke et al. (2015). Another discrepancy between Burke et al. (2015) and Dell et al. (2012) is that while the former find that the relationship between temperature and economic production is non-linear, the latter obtain a linear relationship between temperature and GDP. However, Burke et al. (2015) explain that the inconsistencies between their findings and those of Dell et al. (2012) are probably due to differences in the specified functional form of the temperature-growth relationship, in the sample used, and in the controls for time-varying omitted variables.
Moreover, Dell et al. (2012) add that temperature changes will not only impact the rate of economic growth, but also economic productivity and political stability. Indeed, as Dell et al. (2012) point out, their result shed awareness on the fact that global warming may affect the economy also through other channels than those usually considered by the common climate literature. Both Burke et al. (2015) and Dell et al. (2012) use the *World Development Indicators Database* and the *Terrestrial Air and Precipitation Gridded Monthly Series by Matsuura and Willmott* as their sources of data on economic indicators and temperature variables.
Another interesting study on the effects of temperature changes on economic activity is the one by Jones et al. (2010), who examine the effects of temperature shocks on exports, by using export data to the United States and the broader world. The results identify a negative correlation between temperature and exports, but again, this relationship only holds for poor countries. According to Jones et al. (2010), a poor country is a country that lies in the bottom half of the world per capita purchasing power parity income distribution. The authors find that this negative relation is significant for the agricultural and light manufacturing sector. As a matter of fact, higher temperatures in factories have proven to be noxious to workers' productivity. However, even if rich countries' exports have proven not to react to temperature shocks, high-income countries economies can still be indirectly affected by increasing temperatures. Indeed, if poor

countries' exports decrease, then the prices of goods imported to rich countries will increase and their quantities will be reduced, affecting both demand and supply of high-income countries.

The table below reports the estimated reactions to an increase in 1°C of some economic indicators *for poor countries*, reported in Burke et al. (2015), Dell et al. (2012) and Jones et al. (2010):

Affected Variable	**Loss in Percentage Points**	**Paper**
Growth rate	>-1	Burke et al. (2015)
Industrial output growth	-2,04	Dell et al. (2012)
Agricultural output growth	-2,66	Dell et al. (2012)
Exports to the world growth rate	-2,00/-2,04	Jones et al. (2010)
Exports to the US growth rate	-3,80/-5,70	Jones et al. (2010)

Table 1: Effects of temperature on economic variables

From the table above, it is clear that upward variations in temperature have a negative impact on all the economic variables (of poor countries) considered by the authors.
As previously argued, only Burke et. al (2015) find a correlation between temperature and high-income countries economies. However, this applies only to a zero-lag model. As a matter of fact, by adding more temperature lags to the model, both Burke et al. (2015) and Dell et al. (2012) find a negative relationship between temperatures and growth for both rich and poor countries. This suggests that even if, in the beginning, high-income countries may have some productivity gains from increasing temperatures, in the long run, both rich and poor countries will be negatively impacted.

In addition to the variables that have previously been cited, global warming has undoubtedly an effect on consumption as well. Changes in economic production will inevitably alter consumption trends. This is easy to see if we consider the influence of climate change on agriculture. Adams et al. (1998) analyse how rising temperatures and precipitations affect agriculture in North and South America. A consequence of the higher temperatures is that many crop yields will decrease leading to a reduction of the supply of these crops. From basic economic theory, we know that when the supply of a certain good decreases, its price increases. In turn, increased prices affect consumers and their welfare, which will decrease. Nevertheless, Adams et al. (1998) stress that consumers and producers can adopt adaptation strategies to face the modifications of agricultural production. For instance, consumers can shift their consumption to cheaper products, whenever they are replaceable with the more expensive ones. However, the demand for certain kinds of products is quite inelastic and if consumers have to face higher prices, they may renounce to the purchase of other goods. Thus, consumption is also vulnerable to global warming and climate change in general.

Following the conclusions discussed above, it is evident that studying the effects of global warming is a task not to be limited to the scientific field only, but it is an issue that should be analysed by other experts in several other fields.

A consistent part of climate economics examined the welfare impact of climate change, and more precisely, global warming. Tol (2009) finds that several methods have been used to identify this impact. While some authors have used measures of physical effects of climate change, other authors have adopted a statistical approach. However, both methods reach similar results about the extent of global warming impacts on welfare. The common conclusions highlight initial *global* gains resulting from higher temperatures, which are counterbalanced and overcome by substantial losses as the temperature keeps on increasing. This result may appear to contradict the negative effects on economic activity found by Burke et al. (2015) that have been noted earlier, but there is a clear reason behind this. Tol (2009) explains that, even if most of the world population is concentrated in countries lying between the tropics, the size of the economies of these countries is quite irrelevant compared to the size of the economies of richer countries. Since high-income countries are generally colder, an initial increase in temperatures will bring some gains to the economies of richer countries, which will counterbalance the negative effects perceived by poorer countries, as the size of richer countries' economies "matters" more on a global level. Therefore, the global economy will initially register positive effects. This would also explain why Dell et al. (2012) found a negative correlation between temperatures and economic growth only for low-income countries in a zero-lag model. Tol (2009) measures the threshold after which the gains caused by global warming start to decrease on a global scale. He defines 1.1°C as the brink in the rise in global annual average temperature after which the gains of richer countries will no longer compensate the losses of poorer countries.

2.2 *Who will be impacted the most by climate change?*

From the discussion in the previous subsection it is evident that low-income countries are found to be the ones that display the largest negative responses from higher temperatures. Moreover, a significant part of the economy of low-income countries is based on agriculture, an activity whose outcome closely depends on weather and climate. Tol (2009) states that agriculture in poorer countries is already bearing the effects of higher temperatures and that low-income countries are often not able to adapt properly to climate change, because of their limited resources and inadequate institutions. Following these allegations, Tol (2009) claims that low-income countries are suffering the most from the impacts of higher temperatures, although their contribution to global warming is rather limited. Indeed, most of the greenhouse gas emissions seem to originate from high-income countries. Moreover, Burke et al. (2016) argue that much of the research about damages and policies to mitigate climate change is concentrated in high-income countries, neglecting the impact on poorer countries.
Furthermore, according to the previous literature, poorer hot countries will also be more affected by increasing temperature in the future. This is also because, as Berrang-Ford et al. (2011) point out, poorer countries are less likely to adopt strategies of adaptation to climate change than richer countries. Berrang-Ford et al. (2011) also find that environmental and climate change literature has mainly focused on normative analysis on how to adapt to climate change, but there is a lack of literature arguing whether adaptation is actually taking place or not.

However, as previously mentioned, in the long-run all countries will be negatively affected by temperature shocks. Given the results coming from some of the most influential papers on the topic presented above, it is evident that there is wide agreement in the economic literature about the negative impacts of climate change and temperature shocks on the economy. If it is obvious that the global economy will experience a loss, it would also be interesting to quantify such a loss numerically. As a matter of fact, these articles only prove the existence of a correlation between temperature and economic activity, but they do not provide any quantitative analysis of the potential damages resulting from this correlation. In this sense, these articles form the background and starting point for my thesis, as they provide strong evidence of the fact that global warming does have negative implications for the economy, and that these negative effects will

be perceived all around the globe.
Therefore, the rest of this literature review will focus on how environmental damages are usually assessed in the economic literature. Notice that I will use a different empirical approach than the ones that are about to be introduced. The following methods are discussed because of their wide usage in the climate economics literature and because of the common elements they present with the procedure that I intend to use for my project. In environmental and climate economics, one of the most common strategies to give a quantitative measure to environmental losses is the estimation of the so-called Integrated Assessment Models (IAMs). The following paragraph will review the advantages and drawbacks of this technique.

2.3 *Measuring the damages: the Integrated Assessment Models (IAMs)*

Being aware of the fact that human activity triggers climate change and that the latter may have disastrous consequences, is not enough to mitigate the problem. Once the possibility of the occurrence of damages has been confirmed, it is also necessary to compute the size of these potential damages. However, Diaz and Moore (2017) argue that quantification is quite complex, because of uncertainty, long-term horizon, heterogeneity of effects and normative ethical issues, which are all characteristics related to climate change. Heal and Kriström (2002) point out that economists are concerned with the way climate change translates into effects on human societies. This implies that the concern of economists is divided into two steps. The first step is the actual variation in the climate, and the second step is the way this change directly affects humans. Consequently, there is uncertainty both about how the climate will evolve in the coming decades and about how these changes translate into economic terms. Moreover, this inevitably leads to uncertainties about the economic policies that should be applied to mitigate emissions. Heal and Kriström (2002) specify that time lags are also very long. In other words, climate and economics tend to react extremely slowly to mitigation policies.

Despite the obstacles to the quantification of climate change damages, many economists have tried to estimate them numerically. One of the measures of climate damages is the so-called Social Cost of Carbon (SCC). Pearce (2003) defines the SCC as the monetary measure of global damage due to CO_2 emissions caused by humans. Also, Pearce (2003) points out that the tonnes of CO_2 emitted in the future will cause a higher damage than the tonnes of CO_2 emitted at the present moment, because of the cumulative character of the damage functions. This suggests that the impacts of CO_2 emissions will worsen year by year. The SCC has often been measured thanks to Integrated Assessment Models (IAMs). Ackerman et al. (2009) compiled a review of the limitations of the IAMs, where they also explain the main features of these models. Even if there is not a unique IAM, all IAMs present a basic similar structure. Following the description provided by Ackerman et al. (2009), IAMs usually include a social welfare function, characterized by a utility function and a parameter ρ. Thus, the IAMs usually have the following general form (as reported in Ackerman et al. (2009)):

$$W = \int_0^\infty e^{-\rho t} U[c(t)]dt,$$

where ρ is defined as the rate of time preference, i.e. the weight that agents put on today's consumption and tomorrow's consumption, and $U[c(t)]$ is the utility of consumption. Ackerman et. al (2009) argue that the value of the parameter ρ has been widely debated, especially due to ethical-related issues. As a matter of fact, a positive value of ρ would imply that the current generation cares more about its well-being than about the well-being of future generations. Therefore, the correct solution in ethical terms would be to set ρ=0. This would mean that the current generation values its well-being and future well-being equally. However, Ackerman et al. (2009) point out that this is often not the case, as in economic literature the value of ρ is usually higher than 0, mainly because of mathematical reasons. Kelly and Kolstad (1999) are also in line with this result, reporting that even if models setting ρ=0 do exist, it is quite hard for them to be accepted in high-income countries, as they would imply that developed nations are supposed to give up a lot for the sake of low-income countries' future. In other words, establishing the value of ρ may clash with ethics, and therefore, this discussion may result to be quite sensitive. Moreover, Kelly and Kolstad (1999) argue that the pure rate of time preference, ρ, is not the only parameter that characterizes IAMs models. Two other parameters also need to be set, i.e. the weight assigned to future generations (even if the rate of time preference has also implications on the importance given to future generations) and the economic growth rate. Kelly and Kolstad (1999) also state that future generations are usually believed to be better-off than current generations, as the continuous advances in technology necessarily result in higher per-capita economic growth. Even if most of the authors relatively agree on the values of these parameters, it is important to mention that even slight differences in their estimation may lead to consistently different results, because of the long-term application of the models.

Despite the IAMs technique and the evaluation of the SCC dominate climate economics, Burke et al. (2016) describe the limits of the SCC measures, pointing out that researchers are in wide disagreement about the values of the SCC, mainly because of the discrepancies in the use of the IAMs. Moreover, Ackerman et al. (2009) assert that one of the limits of the IAMs is that the monetary estimates of the benefits of climate relief they provide often depend on partial information and therefore, these models may present upward biased mitigation costs. Kelly and Kolstad (1999) also point out that IAMs model economic responses to control policy in different ways and that these responses tend to be exogenous to the model rather than endogenous. However, they agree that making the response endogenous will lead to more complex IAMs, and that complexity may bring to quite imprecise outcomes.

To conclude, IAMs are extremely used in climate economics, but they require many assumptions on certain parameters. Different assumptions lead to different results, and even if the consensus on IAMs outcomes is quite consistent, these models also present several limits. For this reason, IAMs may not be the best choice for modelling climate change damages and therefore, for assessing how much consumers would need to pay for avoiding these losses.

2.4 *The uncertainty related to climate change: the coefficient of relative risk aversion*

In climate economics, the modelling of policy questions addressing climate change is closely related to the modelling of uncertainty and risk. In the previous subsection, I showed how uncertainty makes it troublesome to get precise estimations out of IAMs. As a matter of fact, apart from having massive effects on a global scale, climate change is also widely discussed because of its highly uncertain character. Stern (2008) links this uncertainty to the specific characteristics of greenhouse emissions as an externality.

Given the uncertain nature of climate change, economic modelling of this phenomenon needs to unavoidably take into account risk aversion. Anthoff et al. (2009) examine costs and benefits from potential future climate change policies. To do so, they use a special type of IAM, the IAM FUND, where the rate of time preference, ρ, that has been widely discussed in the previous section, appears again. However, they also introduce a new parameter, risk aversion. The link between the rate of time preference and the parameter of risk aversion is given by the so-called Ramsey discount rate. The Ramsey discount rate (as reported in Anthoff et. al (2009)) runs as follow:

$$r = \rho + \eta g$$

In the equation above, the rate of pure time preference is captured by ρ, the elasticity of marginal utility with respect to consumption by η, and the growth rate of per capita consumption is defined by g. Since η measures the curvature of the utility function, it is also defined to be the parameter of risk aversion. Notice that this parameter measures what is referred to as *relative* risk aversion. Relative risk aversion is a unit-free measure consisting of the product of absolute risk aversion and the outcome variable taken into consideration. As Meyer and Meyer (2005) explain, wealth and consumption are the two outcome variables that are mostly used for computing the risk aversion coefficient. In the case of income, the coefficient η also raises an issue that will also reappear in the next section, i.e. income heterogeneity. This means that richer individuals - or countries - generally display lower risk aversion than poorer ones, as η also depends on income. In their paper, Anthoff et al. (2009) intend to show that η has a bigger weight than ρ in the assessment of the SCC and eventually find that this hypothesis holds.
The same strategy used by Anthoff et al. (2009) has been used by several other authors in the context of climate economics. One example is Arrow (2007), who states that individuals are generally assumed to dislike risk, i.e. they are risk-averse towards uncertain outcomes. The assumption of risk aversion raises another crucial question, namely what is the correct value that should be assigned to the parameter of risk aversion η. It seems that there is no real agreement among the economic community about the value to assign to this parameter, and sometimes the values used in the literature vary a lot. Lucas (1987) states that agents are generally very risk-averse and therefore, in the economic literature, it is possible to find values of η larger than 10. However, Lucas (2003) adds that η is generally chosen between 1 and 4. Arrow (2007) suggests a value of 2 or 3 for this parameter with consumption as the outcome variable. Ha-Duong and Treich (2004) also apply the same model using recursive preferences, and they set the value of the parameter of risk aversion between $0,5$ and 4, mainly focusing on the values $1,5$ and 2. Running estimates for different values of this parameter, Ha-Duong and Treich (2004) also find that increasing the value of risk aversion will decrease the number of emissions in the

short term. Meyer and Meyer (2005) find that the coefficient of risk aversion for consumption is approximately five times larger than the coefficient of risk aversion for wealth at the mean. However, Anthoff et al. (2009) run their estimates using values of η for wealth between 0 and 3. Moreover, there is a strand of economic literature that attempted to measure the risk aversion coefficient for income at a country-level. Szpiro and Outreville (1988) estimate the coefficients of risk aversion for a sample of 31 countries, including 11 developing countries. They find values ranging from 1 to 5, with an average value of $2,89$. Layard et al. (2008) find rather homogeneous values ranging from $1,19$ to $1,30$. Finally, Gandelman and Hernández-Murillo (2015), whose estimates will be used for this thesis, find that the coefficient of risk aversion oscillates between 0 and 3, with an average value of $1,00$ for developing countries and an average value of $0,92$ for developed countries. These values do not seem to confirm the conclusion reached by Meyer and Meyer (2005), as there is much homogeneity in the values of the risk aversion coefficient for consumption and the risk aversion coefficient for income in the economic literature.

2.5 *Willingness to pay and willingness to accept*

Another way to give a price to environmental-related damages is to assess how much individuals or countries would be willing to pay to prevent these events from happening. This approach widely differs from the use of IAMs that has been previously presented. First of all, IAMs are proper to the assessment of damages resulting from environmental shocks, whereas WTP and WTA are tools that can be applied to other economic questions as well. Moreover, Pearce (2003) defines WTP a *cost-effectiveness* analysis rather than a *cost-benefit* analysis (as in the case of IAMs). Nevertheless, the economic literature presents many studies on willingness to pay (WTP) and/or willingness to accept (WTA) in the context of environmental economics and climate-related issues. In this context, WTP refers to the maximum monetary amount that an individual is willing to give up for avoiding an unpleasant event. Conversely, WTA is the minimum monetary amount that an individual is willing to accept for bearing something negative. These analyses are defined as contingent valuation (CV) studies, and they usually include a survey to a sample group of respondents. For example, the inhabitants of a village subject to a high risk of flooding can be asked how much they would be willing to pay for the creation of more effective flood barriers. On the other hand, the same villagers could be asked how much they would be willing to accept for the construction of a new factory that will pollute the waters of their river. Arrow et al. (1993) thoroughly explain the concept of CV and suggest that, in the case of direct surveys, it is preferable to use WTP over WTA, since respondents are more likely to exaggerate the amount of compensation that they would like to accept for a disservice than the monetary amount that they would be willing to pay for a service. Tol (2009) confirms this result, by demonstrating that empirical research comparing WTP and WTA often shows that the WTP for enhanced environmental protection is consistently lower than WTA compensation for lower quality services. This is the reason why, generally, estimates of WTA are substantially higher than estimates of WTP. Furthermore, Arrow et al. (1993) point out that the CV approach has been widely criticized because the respondents of the surveys may not give reasonable or rational answers and it is, therefore, hard to assess the credibility of the received feedback. Indeed, respondents may violate the basic assumptions of rationality and they may not be able to take into account budget and resource constraints, often suggesting compensation amounts that are not realizable in practice. Another bias of CV is that it often refers to hypothetical scenarios. Arrow et al. (1993) report that CV is very likely to overestimate the actual WTP since respondents tend to give different answers in a hypothetical setting than they would do in a real-life scenario, where their actual money is directly concerned.

The difference in the values of WTP and WTA may also be related to the very nature of the good in question. As a matter of fact, Horowitz et al. (2002) find that the largest inconsistency between the two measures occurs in the case of public and non-market goods.

Moreover, Pearce (2003) highlights another limit of WTP, i.e. income heterogeneity. WTP is correlated with income, which implies that richer people, who have more monetary resources, may be willing to pay more than poorer people.

Despite the significant number of previous studies on WTP and WTA, it is quite hard to find papers whose results can be compared with each other and with the results of my thesis. The reason is, as pointed out by Carlsson et al. (2012), that most of the studies on WTP tend to focus on a single country and that the questions of the surveys have been designed in various ways, making comparisons quite hard. In other words, the question asked to the respondents is usually very specific and tends to focus on different aspects of climate change mitigation. However, Carlsson et al. (2012) try to partially solve the problem by studying WTP for reducing CO_2 emissions in three countries: Sweden, China, and the United States. Their main finding is that each country reacts differently to the issue, and the authors find that WTP is correlated to many variables, such as sex, age, religious beliefs, political orientation and income. Another determinant of WTP for CO_2 reduction is the acknowledgement of the existence of climate change. For instance, respondents from the United States declared to be more sceptical about climate change and they do not necessarily believe that climate change is fueled by human activity. For this reason, Americans are willing to pay less than Swedish citizens. Numerically, Carlsson et al. (2012) find that Swedes, Americans, and Chinese are willing to pay 1.6%, 1.1%, and 0.9% of their income, respectively, to prevent a temperature increase of more than 2°F.

However, studies that use CV present a big drawback: they are both time and resource consuming. They include the preparation and collection of surveys from a large sample of individuals, which goes far beyond the scope of this thesis. Because of the aforementioned reasons and the complexity of the research design, this thesis will follow another procedure to estimate willingness to pay. I will exploit existing consumption data and apply the method of welfare gains used by Lucas (2003), that doesn't involve direct surveys to individual consumers. The fourth section of this thesis will provide a detailed presentation of this method.

2.6 *Conclusion and contribution*

This literature review intended to examine previous works in the context of climate change economics that will support my thesis. As a matter of fact, since the approach I will use in my thesis is very specific and the economic literature on the same topic is not well developed yet, the literature review focused more on papers that will theoretically support my thesis rather than on papers that provide a comparison of similar studies.

The review started from the very necessity of studying climate change, i.e. because it highly affects various economic variables. I argued about what countries are likely to be impacted the most by temperature shocks and I concluded that most of the damages will be born by hot low-income countries. After confirming that temperature shocks affect the economy, I focused on how these kinds of damages have been computed by previous literature and I found that the most common way to assess them is by making a cost-benefit analysis through IAMs. Contingent valuation studies are also often used to assess climate-related damages and give a measure of the amount that individuals would be willing to invest to avoid a certain outcome to occur in the future.

I also went through the limits of these strategies and highlighted the points of agreement and disagreement in the literature about how to estimate environmental damages. I focused on the discussion of how to set the value of some parameters that would be used in my thesis as well, namely the coefficient of risk aversion, arguing the implications that follow from using different values.

Based on the previous discussion, my thesis will estimate the amount that countries would be willing to pay for global warming not to happen. This will be done by analyzing how much of their consumption economic agents would be willing to give up for having a smooth consumption path. Global warming affects the trend of temperatures, that will anomalously oscillate. Temperature fluctuations affect economic activity, and consumption is inevitably impacted by these changes. Therefore, under temperature variations, the consumption path is more volatile and subject to shocks. In this case, the consumption path which is vulnerable to temperature variations is the outcome that individuals would like to avoid, because of the averse and uncertain consequences on their consumption.

Most of the economic literature written on this topic focused on the analysis of the areas of the world that would be primarily and strongly affected by an increase in average temperatures. The main empirical techniques used in this literature are IAMs and CV. However, there is still little research on the measures that could be taken to limit the dramatic effects of global warming on the economy. This thesis aims at giving more insights into this area that is still not highly developed. By studying how much countries would be willing to pay for avoiding global warming, it is also possible to compute the optimal amounts of taxes or subsidies that could be introduced to mitigate the problem. It would then be possible to think about actual policy measures that could be applied in certain countries to fight against global warming. This would mean to contribute to the solution of one of the main problems of the last decades, which is also expected to be a central issue for many years to follow. Moreover, most of the literature on climate change has been assessing the potential damages resulting from global warming. However, this is only the first step to find a solution to the increasing threat of global warming. Once the potential damages have been assessed, it would be necessary to find a way to avoid these damages from occurring. This thesis intends to build a connection between the two.

The motivation for this thesis comes from the very importance of the topic of global warming. The impacts caused by climate change are having and will have huge consequences in terms of space and time, as they will affect the whole globe for many years. Hsiang and Kopp (2018) argue that the contribution of economists is fundamental to the progress of research in the field of climate change since economists can bring to science an evaluation of the outcomes from a socio-economic point of view. However, this contribution is still quite restricted. Stern (2008) points out that, although climate change plays a central role in the scientific talk, it has not been much researched in the field of economics yet. However, the research in climate economics should develop quite quickly, since policy action appears to be rather urgent.

3 Data Management

This section describes the data that I will use in my thesis and where they have been retrieved from. The data sets have been created with data coming from different sources. The most extensive data set that I will use contains country-level household consumption data for 163 countries. This data set is used for computing the welfare gains keeping the risk aversion coefficient fixed for all countries. The smaller data set contains 72 countries and their household consumption levels, average annual temperature, and coefficient of risk aversion. This data set is used for estimating the welfare gains using country-level risk aversion data. It is then used for examining the correlation between risk aversion, temperature and welfare gains. The following sections describe the sources of the data.

3.1 *Consumption data*

To apply the method of Lucas (2003) to the issue that I intend to study, I will use consumption data. The data set that I will use comes from the World Bank Open Data website. I use data on Households and NPISHs Final consumption expenditure per capita (constant 2010 US$). The data set comprises households final consumption data for all the countries of the world from 1960 to 2018. The time frame that I chose is the largest time frame available on the World Bank Open Data website. A multi-decade time frame is very suitable for the purposes of my thesis because it describes well the evolution of consumption over time. However, the data set needed to be slightly modified, as some countries had no or insufficient data for the whole 1960-2018 period. The countries that I had to delete due to a lack of observations are *Andorra, Antigua and Barbuda, Channel Islands, Curacao, Cayman Islands, Djibouti, Dominica, Ethiopia, Fiji, Federate States of Micronesia, Gibraltar, Grenada, Isle of Man, Kiribati, St. Kitts and Nevis, Libya, Liechtenstein, St. Martin (French part), Monaco, Maldives, New Caledonia, Nauru, Papua New Guinea, North Korea, French Polynesia, Senegal, Solomon Islands, San Marino, Somalia, Sao Tome and Principe, Sint Maarten, Syria, Turks and Caicos, Trinidad and Tobago, Tuvalu, Saint Vincent and the Grenadines, British Virgin Islands, Samoa, Yemen Republic*. Moreover, some countries had only one observation available. Since the analysis accounts for the evolution of consumption over time, one observation is not enough. Therefore, in addition to the above-mentioned countries, I had to discard the following: *Afghanistan, Aruba, Bermuda, Barbados, Faroe Islands, Iraq, St. Lucia, Myanmar, Suriname, Seychelles, Turkmenistan, Tonga, Zambia*.

Furthermore, I deleted *Namibia* and *Cuba*, because of inappropriate data. After these modifications, the data set counts 163 countries and includes the years (1960 to 2018), the values of consumption and the country names and codes. I added the time from 1 to 59.

3.2 *Temperature data*

I retrieved the data on temperature from Burke et al. (2015). The data had been deposited at the *Stanford Digital Repository* and they originally come from the *Terrestrial Air Temperature Gridded Monthly Series by Matsuura and Willmott*. The data set used by Burke et al. (2015) contains annual average temperature data for most countries of the world, when available. The temperatures are measured in degrees Celsius. The data was originally created by gathering information coming from multiple up-to-date sources. I created a new data set by computing the annual averages of these temperature data for each country over the available period (1960-2010). This data will be used to investigate the relationship between temperatures, risk aversion, and welfare gains. However, some countries that had consumption data did not have available temperature data. These countries are *Bahrain, Guam, Hong Kong, Kosovo, Macao, Malta, Marshall Islands, Montenegro, Northern Mariana Islands, Palau, Singapore, South Sudan, Timor-Leste, Virgin Islands, West Bank and Gaza* and they have been ruled out from the correlation test and from graphical representations of the relationship between welfare gains, risk aversion and temperature.

3.3 *Risk aversion coefficients*

Initially, the value of the risk aversion coefficient is set according to the suggestions coming from the previous literature. Most of the economic literature agrees that the value of the risk aversion coefficient is comprised between 0 and 4. Following these guidelines, I run experiments with different values of risk aversion spanning between these two numbers. I set these values to be 0.5, 0.8, 1, 2, and 4. Realizing that it would be more precise and realistic to use different risk aversion coeffcients for each country, I then take country-individual risk aversion coefficients for a smaller sample of 75 countries. These risk aversion coefficients come from Gandelman and Hernández-Murillo (2015). They have been computed using income in the CRRA utility function, but under the assumption that income is a proxy for consumption. The motivation for choosing the estimates from this paper comes from the fact that it is one of the few papers that extensively accounts for measures of risk aversion for developing countries. Most of the economic literature has estimated risk aversion coefficients mainly for developed countries. Therefore, these coefficients are suitable to represent heterogeneous countries of the world. The coefficients estimated by Gandelman and Hernández-Murillo (2015) are country-specific and have been computed thanks to the results of the *2006 Gallup World Poll*, which includes self-reported satisfaction about life and income. The sample includes 23 developed countries and 52 developing countries, defined according to the World Bank guidelines. Developing countries are defined as such if their gross national income per capita is less than 12000$ (2010 US dollars). The risk aversion coefficients are calculated using a CRRA (Constant Relative Risk Aversion) utility function. Despite Gandelman and Hernández-Murillo (2015) calculated a total of 75 risk aversion coefficients, the final data set with country-level risk aversion coefficients that I will use contains 72 countries. The reason for this is that three countries had previously been discarded because of incomplete or non-existing consumption data.

4 Econometric Method

This section presents the empirical method of my thesis. I will first explain the intuition behind the welfare gains method of Lucas (2003) and I will then show how it applies to household consumption data for the purposes of my thesis. This section also includes a discussion on how I chose the values of the parameter of risk aversion and on how I tested the relation between welfare gains temperature.

4.1 ***Welfare gains method, Lucas (2003)***

Contingent valuation analyses are usually based on surveys taken by the desired sample of respondents. For this reason, this type of studies is rather limited to a specific area or type of respondents. However, in the context of this thesis, I intend to explore willingness to pay on a global level. Applying a contingent valuation strategy would mean surveying an enormous number of individuals coming from all over the world. Such a method would be extremely resource-consuming and would also go far beyond the scope of this thesis. Moreover, classical studies on willingness to pay and willingness to accept are often biased and tend to abstract from the rationality assumptions, because they directly involve respondents (see *Section 2.5* for more details on these two methods). This led me to use an alternative approach that doesn't involve surveys. The method I will use draws from Lucas (2003) and is described in the paper *Macroeconomic Priorities*. Lucas examines how much a representative consumer is willing to pay for having a different consumption path than the one they are endowed with. More precisely, he considers a consumer, whose consumption path is very variable throughout time, and wonders how much this representative agent would be willing to pay to eliminate all the variability related to his consumption. To do this, Lucas estimates the so-called welfare gains, i.e. a measure of how much the consumer would be willing to give to reach the same utility that he would obtain with a smooth consumption path. More precisely, he wonders what is the value of the welfare gain, denoted by λ, for which the following equality holds:

$$U((1+\lambda)c_A) = U(c_B), \tag{1}$$

where $U(c_A) < U(c_B)$.

In the equation above, c_A is the consumption level under the variable and uncertain path, whereas

c_B is the consumption level under the certain and linear path. $U(c_A)$ and $U(c_B)$ are the respective utilities.
Lucas then sets the utility function to be of the form

$$U(c_t) = \frac{c_t^{1-\gamma}}{1-\gamma}, \quad (2)$$

where $c_t = Ae^{\mu t}e^{-\frac{1}{2}\sigma^2}\epsilon_t$ and γ is the Arrow-Pratt coefficient of relative risk aversion. Notice that, although I have previously denoted the coefficient of relative risk aversion as η, I will from now on use γ to follow Lucas' notation. The particular utility function reported in (2) is referred to as CRRA (Constant Relative Risk Aversion) utility function. In the CRRA utility function, positive values of γ indicate risk aversion, whereas $\gamma = 0$ expresses risk neutrality. Lucas assumes that $log(\epsilon_t) \sim N(0, \sigma^2)$ and that $E(e^{-\frac{1}{2}\sigma^2}\epsilon_t) = 1$. This implies that the mean of consumption is $Ae^{\mu t}$. Given these assumptions and the form of the utility function depicted in (2), the preferences of the consumer follow the path

$$E\{\sum_{t=0}^{\infty}(\beta^t \frac{c_t^{1-\gamma}}{1-\gamma})\},$$

where $\beta = \frac{1}{1+\rho}$ is the discount factor, with $0 < \rho < 1$. This implies that β is always positive and smaller than 1.
By considering that the mean of consumption is $Ae^{\mu t}$ and equation (1), we can conclude that, given the CRRA utility function, the following equality must hold:

$$E\{\sum_{t=0}^{\infty}\beta^t \frac{((1+\lambda)c_t)^{1-\gamma}}{1-\gamma}\} = \sum_{t=0}^{\infty}\beta^t \frac{(Ae^{\mu t})^{1-\gamma}}{1-\gamma}$$

This equation means that there must a value of λ for which the two consumption streams are equal. By simplifying the equality above, Lucas finds that the welfare gain λ depends on the amount of risk σ^2 and the parameter of relative risk aversion γ. σ^2 is the variance of consumption and it will result from running a regression on the equation of consumption. γ is a parameter that is determined outside of the model. I will rely on the previous literature to set its value. The parameters σ^2 and γ are related by the following equality (full derivation in the *Appendix*):

$$\lambda \cong \frac{1}{2}\gamma\sigma^2$$

4.2 *Application to consumption data*

Lucas (2003) measures the gains in terms of welfare of an improved stabilization policy. He considers a representative consumer endowed with the following stochastic consumption stream:

$$c_t = Ae^{\mu t}e^{-\frac{1}{2}\sigma^2}\epsilon_t, \tag{3}$$

and wonders to what extent welfare would be affected if all consumption variability would be removed. This relies on the assumption that consumers always prefer a smooth consumption path to a stochastic one. Consumption smoothing, together with income smoothing, is a way of insurance against risk. In the case of global warming, where temperatures and weather highly impact consumption and other economic variables, consumption smoothing is a way to self-insure against adverse shocks. Consumption smoothing grants the consumer an even level of consumption over time.

Before moving on with the method, it is important to spend some words on consumption smoothing and why it is important. The notion of consumption smoothing comes from the Permanent Income Hypothesis (PIH), which states that households' consumption can be smoothed over time by saving before the occurrence of adverse economic shocks and dissaving when they occur. Meng (2003) specifies that saving takes place when expected income is lower than realized income, and dissaving occurs in the opposite case. This type of saving is referred to as *precautionary savings*. Current consumption is largely influenced by the present discounted value of future income. Carroll (1994) explains that it is especially the extent of uncertainty in future income that affects current consumption. The higher the uncertainty related to income, the lower the current consumption. This effect is found to be quite large and it is estimated that the decrease in consumption associated with a one-standard-deviation increase in income uncertainty ranges from 3 to 5 per cent. Older people usually tend to have lower coefficients of income uncertainty compared to younger people because by the time they get old, they have enough spared funds and they do not need to reduce their consumption any further to save for their future. Dynan (1993) adds that agents displaying higher income uncertainty will face higher consumption growth in the future. The reduction in consumption triggered by greater uncertainty will increase precautionary savings in the beginning and cause a steeper increase in consumption in the long run. On the other hand, Carroll (1994) also finds that current consumption is not related to unpredictable income variations and concludes that agents behave in a rational and forward-looking way. The possibility of consumption smoothing plays a crucial role namely in developing countries. Meng (2003) notes that developing countries are often hit by economic shocks that cause hardship to the households of these countries. In developing countries, not only are households generally poorer, but the government is frequently unable to provide its citizens with financial aid and economic support during negative economic shocks. Therefore, the actual capability of smoothing consumption plays a central role in the household's survival and has major implications for support policy design. Carter and Lybbert (2012) point out that the ability of households in poorer countries to deal with uninsured income shocks is what determines interventions aimed at strengthening insurance markets and designing new insurance instruments. On the other hand, Skinner (1988) acknowledges that policies addressing the reduction of income risk can entail a fall in aggregate savings. The enforcement of support policies wouldn't make it necessary anymore to save for precautionary motives. However, Carter and Lybbert (2012) stress that the lack of insurance in poorer areas of the world can entail significant welfare losses and consequently, slow down economic development. Moreover, empirical evidence seems to invalidate the presence of consumption smoothing in poorer countries. In fact, the attitude of poorer households towards consumption smoothing has proven to be very heterogeneous.

For my analysis, I follow the same approach as Lucas (2003), which I will apply to country-level household consumption data. This will highlight how much countries would be willing to pay for having a smooth consumption path. To do this, I rewrite equation (3) in the form of a linear regression equation. The procedure is illustrated below. I start by taking logarithms on both sides of the equation. I then rename the terms to simplify the notation.

$$c_t = Ae^{\mu t}e^{-\frac{1}{2}\sigma^2}\epsilon_t,$$
$$\Leftrightarrow log(c_t) = log(A) + log(e^{\mu t}) - log(e^{\frac{1}{2}\sigma^2}) + log(\epsilon_t)$$
$$\Leftrightarrow log(c_t) = log(A) + \mu t - \tfrac{1}{2}\sigma^2 + log(\epsilon_t)$$
$$\Leftrightarrow log(c_t) = log(A) - \tfrac{1}{2}\sigma^2 + \mu t + log(\epsilon_t)$$

$$\Leftrightarrow log(c_t) = \beta_0 + \mu t + u_t,$$

where $\beta_0 = log(A) - \frac{1}{2}\sigma^2$ and $u_t = log(\epsilon_t)$. I first take the data on household level consumption and I calculate the logarithms of consumption, as reported in the equation above. This enables me to run the regression and estimate the coefficients β_0 and μ of the equation as well as the variance σ^2. The estimation is performed thanks to the programme *R*. Since Lucas (2003) finds that $\lambda = \frac{1}{2}\gamma\sigma^2$, I am mostly interested in the estimated value of σ^2. To get estimates of σ^2, I use the Newey-West estimator. On the other hand, γ is a parameter, and its value needs to be set. Once I find the values of σ^2 and set γ, I use Lucas' formula to compute the welfare gains for all the countries of the data set. This procedure is applied both to the larger dataset of 163 countries and to the smaller one of 72 countries. The results are reported in *Table 6* and *Table 7* in the *Appendix*. The next subsection contains the details of how I set the value of γ.

4.3 *Setting the value of* γ

4.3.1 *Fixed* γ *for all countries*

Meyer and Meyer (2005) explain that relative risk aversion for a certain outcome variable is obtained by dividing the percentage change in the marginal utility from that variable by the percentage change in the variable itself. In the model that I am going to use, relative risk aversion is represented by the coefficient γ. Much discussion is present in the economic community on which value of γ is most realistic. *Section 2.4* of this thesis already introduced the discrepancies about the value of this parameter in economic research.

From the formula of welfare gains suggested by Lucas (2003), we can infer that higher values of γ lead to higher welfare gains. This conclusion is quite intuitive. If a consumer is more risk-averse, they will also be willing to pay more for having a smoother consumption path, as they will be more worried about the effects of their consumption variability. When applying the above-mentioned method to my data, I calculate the σ^2 for each country and set a value for the risk aversion coefficient. I initially apply the same value of γ to the whole sample of 163 countries. I then vary the value of the risk aversion parameter to verify what happens to the welfare gains when risk aversion increases or decreases. In this exercise, I keep the value of γ between 0 and 4, as it is suggested by most of the economic literature. Because of the form of the utility function, all these values represent more or less risk averse agents. I will run estimates of welfare gains for $\gamma = 0.5$, $\gamma = 0.8$, $\gamma = 1$, $\gamma = 2$, and $\gamma = 4$. Notice that $\gamma = 1$ is the special case of log-utility. For this reason, it would be more appropriate to rewrite (2) as:

$$\mathrm{U}(\mathrm{c}_t) = \begin{cases} \frac{c_t^{1-\gamma}}{1-\gamma} & \text{if } \gamma > 0, \gamma \neq 1 \\ ln(c_t) & \text{if } \gamma = 1 \end{cases}$$

4.3.2 *Applying country-specific values of* γ

In reality, it is very unlikely that all the countries have the same coefficient of risk aversion. Risk aversion depends on several variables and it seems that culture itself influences the attitude of people towards risk. *Section 6* of this thesis will discuss the determinants of risk aversion in more detail. Therefore, applying the same values of γ for all countries is an interesting exercise to see how the other variables vary when γ increases or decreases, but it is not very representative of reality. A more truthful way to set the value of γ would be to assign a different coefficient to each country.

Gandelman and Hernández-Murillo (2015) estimated the coefficients of relative risk aversion for 75 countries. Their sample includes 23 developed countries and 52 developing countries, and their estimates are based on the results of self-reported personal well-being from the *2006 Gallup World Poll* and using a CRRA utility function. Despite the authors agree with Lucas (2003) that the values of risk aversion used in economics usually oscillate between 1 and 3, they find that the value of the coefficient γ rather fluctuates around 1. This finding holds for both developed and developing countries. More precisely, the average coefficient for developed countries is $0,92$, whereas the average coefficient for developing countries is $1,00$. As it is more realistic to apply these estimated coefficients rather than setting a single γ for the whole sample of countries, I then take the estimates by Gandelman and Hernández-Murillo (2015) and I use them to estimate the welfare gains. However, in doing so I had to restrict the sample of countries, as Gandelman and Hernández-Murillo (2015) calculated the coefficient of risk aversion for 75 countries only. Moreover, I left out *Myanmar, Senegal* and *Taiwan*, because they were absent or had already been deleted from the original World Bank Open Data database due to a lack of observations for consumption. Consequently, I calculate the welfare gains using individual risk aversion coefficients for 72 countries. This sample contains less than half of the countries of the full sample that I used for calculating welfare gains using the same risk aversion coefficients for all countries. Unfortunately, there are not many studies that attempted at computing risk aversion coefficients on a country-level and those who did found estimates for a quite limited number of countries. The estimates of the risk aversion coefficients by Gandelman and Hernández-Murillo (2015) are one of the, if not the study that presents the coefficients of risk aversion for a larger sample of countries. Despite this sample is still restricted compared to the total number of countries of the world, it contains a wide set of both developed and developing countries and includes countries belonging to every continent. Thus, this sample is quite representative of the whole world.

4.4 *Consumption and temperature*

The application of the method of Lucas (2003) reveals how much consumers are willing to pay to eliminate any kind of fluctuation from their consumption. To see if and how this relates to temperature, I test the correlation between welfare gains and temperature. Since the results from the sample of 72 countries are more representative of reality, I test the correlation between temperature and welfare gains only for this sample. I calculate the average temperature over a 50-year period for every country in the sample and I then test its correlation with the value of the corresponding welfare gains.

Usually, the Pearson correlation test is the most common method to investigate the correlation between two variables. However, the data that I am using violate some of the assumptions on which the Pearson test relies. In this case, the Spearman correlation test is a good alternative when the requirements for performing the Pearson correlation test are not fully satisfied. The Spearman correlation test is used to examine whether two variables are correlated and by how much. The Spearman test delivers a coefficient that ranges from -1 to 1. A value of 0 indicates the absence of correlation. If the coefficient is positive, the two variables evolve in the same direction, i.e. they both increase or decrease at the same time. If the coefficient is negative, the variables are inversely correlated. In other words, when one increases, the other decreases, and vice versa. According to the p-value, the correlation between the variables can be more or less significant.

In addition to the relationship between average temperature and welfare gains, I apply the test to investigate whether there exists a relationship between average temperature and risk aversion.

Once again, I use the smaller sample of 72 countries, since this test would only make sense if the values the risk aversion coefficient are heterogeneous. In this case, the test is performed on the average temperature over the period 1960-2010 and the value of the corresponding risk aversion coefficient. The test is performed with *R*.

5 Results

This section presents a summary of the results that I found. The full results are reported in the *Appendix*. The following tables show the main statistical indicators of the results. I report the mean, median, minimum and maximum values of λ for each value of γ that I set. They all increase with the increase of the risk aversion coefficient.

5.1 *Fixed γ, 163 countries*

Risk aversion	**Mean**	**Median**	**Min**	**Max**
0,5	0,00392	0,00162	0,00014	0,11601
0,8	0,00627	0,00259	0,00022	0,18562
1	0,00784	0,00324	0,00028	0,23202
2	0,01568	0,00648	0,00055	0,46404
4	0,03136	0,01296	0,00111	0,92808

Table 2: Estimates for all countries

For values of γ smaller than or equal to 1, the welfare gains that a representative consumer would obtain for having a smooth consumption path amount to values in the order of 10^{-3}, on average. If instead γ has higher values, they would rather be willing to renounce to a part of their consumption that lies in the order of 10^{-2}, on average. In percentage terms, this means that if the risk aversion coefficient is assumed to be $0,5$, consumers are, on average, willing to renounce to $0,0039\%$ of their consumption for having a smooth consumption path rather than a variable one. In the opposite case, with $\gamma = 4$, consumers would be willing to pay around $0,03\%$ of their consumption for having a smoother consumption path, on average. In all five cases, the country with the lowest welfare gains is Niger and the country with the highest welfare gains is Pakistan. The median values show that more than half of the sampled households would be willing to give up $0,0016\%$ and $0,013\%$ of their consumption for values of γ of $0,5$ and 4, respectively. The median and minimum values do not change significantly with the increase of the coefficient of risk aversion. The difference between the highest and lowest values of these two categories is approximately $0,011$ and $0,00097$, respectively. Therefore, the minimum values are very close to each other, although the coefficient of risk aversion varies quite significantly. On the other hand, the maximum value ranges from $0,1$ to $0,9$, which is a difference of about $0,8$ percentage points.

5.2 *Country-specific γ, 72 countries*

The table below reports the descriptive statistics of the results obtained when applying the individual coefficients of risk aversion taken by Gandelman and Hernández-Murillo (2015), for a sample of 72 countries. The second column reports the descriptive statistics for the coefficient of risk aversion, γ, whereas the third columns describes the estimated welfare gains, λ.

Indicator	Risk aversion	Welfare gains
Mean	0,9417	0,00482
Median	0,915	0,00215
Min	0,04	0,00033
Max	2,96	0,77940

Table 3: Welfare gains estimates for 72 countries

The risk aversion coefficients reported in Gandelman and Hernández-Murillo (2015) are all between $0,04$ and $2,96$ and more than half of the sampled households displays a risk aversion coefficient smaller than 1. The median coefficient is $0,915$. The welfare gains oscillate between the order of 10^{-4} and 10^{-1}, with an average value lying in the order of 10^{-3}. The mean value is in the same order as the previous results for values of γ smaller or equal than 1, and the result is consistent since most of the countries in this sample also display such a low risk aversion coefficient. On average, a representative consumer from the sampled countries would be willing to renounce to approximately $0,00482\%$ of their consumption for having a smoother consumption path. In this sample, the country displaying the lowest welfare gains in Panama $(0,00008)$ and the country with the highest welfare gains is Moldova $(0,03251)$.

5.3 *Relation with temperature*

Once I find the values of the welfare gains, I compare them with the average temperature of each country to investigate whether there is a relationship between the two. I first calculate the average annual temperature for each country in the sample over the period 1960-2010. I initially plot the relationship between average temperature and risk aversion for the smaller sample of the 72 countries. This sample is more reliable because it is based on country-specific risk aversion coefficients. The data for temperatures are the ones used by Burke et al. (2015) and cover the period 1960-2010. They come from the *Indicators Database and the Terrestrial Air and Precipitation Gridded Monthly Series by Matsuura and Willmott (2012)*. For a clearer representation, I divide the sample of countries into cold and hot countries. Taking into account that the optimal temperature for productivity presented by Burke et al. (2015) is 13°C, I define cold countries those countries with annual average temperatures below this threshold. Similarly, the countries that have an annual average temperature higher than 13°C are referred to as hot countries. I obtain a sample of 32 cold countries and a sample of 38 hot countries.

The figures suggest that risk aversion is not related to temperature. As a matter of fact, there is no evident trend in the distribution of points over the plots and both cold and hot countries have heterogeneous values of γ. The average value of γ for cold countries is $0,87$, while the average value of γ for hot countries is $0,97$.

Secondly, I plot the relation between average temperatures and welfare gains. Once again, I plot two figures distinguishing between cold and hot countries. Most cold countries have welfare gains lower than $0,01$. However, there is an isolated cluster of four cold countries (Moldova, Chile, Bulgaria, Armenia) that displays relatively higher welfare gains than the rest of the countries in the sample, ranging from $0,01$ to $0,04$. As for the warm countries, the welfare gains are more scattered over the figure. However, all the values are lower than $0,025$, and, apart from Uzbekistan, all other countries have welfare gains of less than $0,015$. On the whole, cold countries have slightly higher welfare gains than hot countries. The average welfare gains for cold countries is $0,0058$, whereas the average λ for hot countries is $0,0038$. This initial observation is not consistent with the conclusions coming from the previous economic literature. As a matter of fact, Burke et al. (2015) proved a negative correlation between temperature and production, meaning that higher average temperatures have bad effects for a country's economy. Therefore, we would expect to see the values of the welfare gains increasing with the average temperatures of countries. However, this is not evident from the figures. This behaviour is only reflected by the fact that the warmer countries in the sample have a higher risk aversion coefficient, on average, but it is not reflected by the value of the welfare gains.

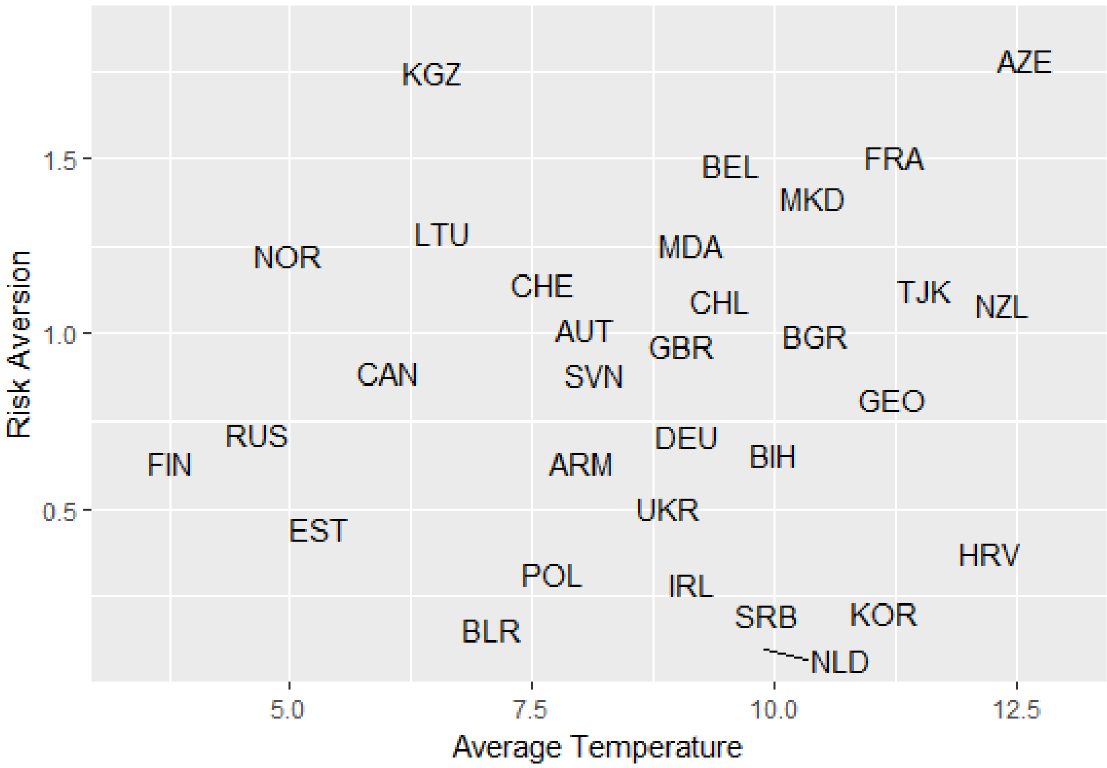

Figure 1: Relation between average temperature and risk aversion, cold countries

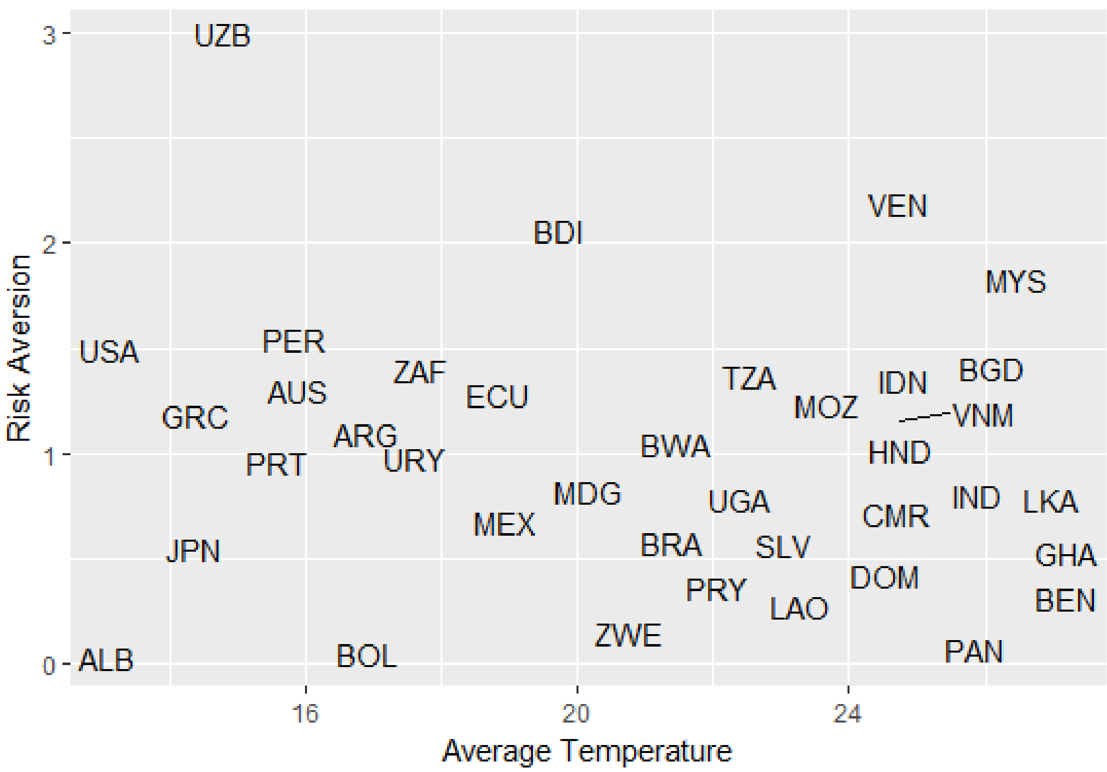

Figure 2: Relation between average temperature and risk aversion, hot countries

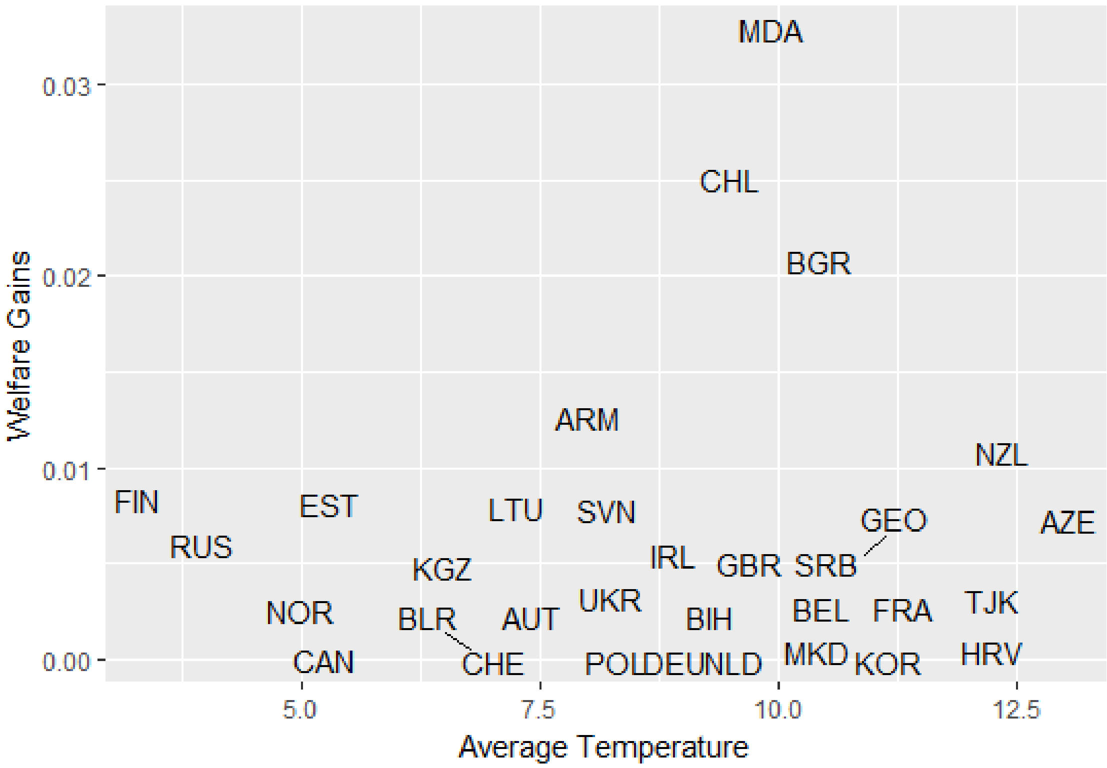

Figure 3: Relation between average temperature and welfare gains, cold countries

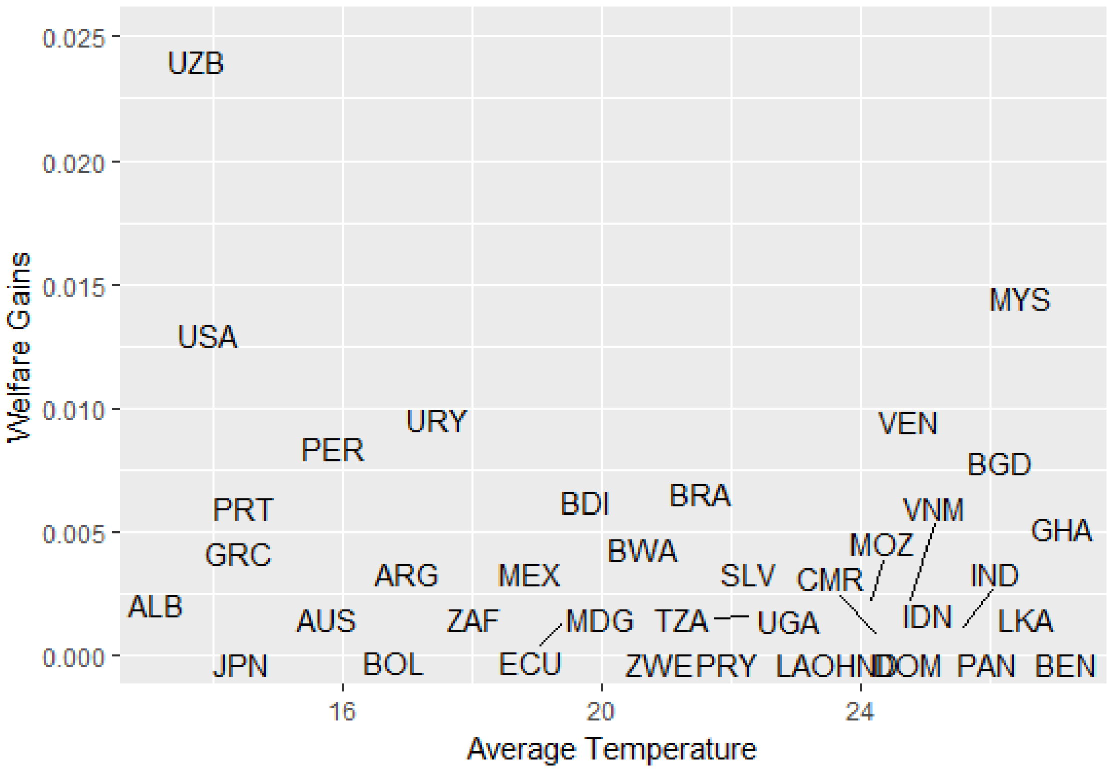

Figure 4: Relation between average temperature and welfare gains, hot countries

To examine whether and how much risk aversion, temperature, and welfare gains are related, I run the Spearman correlation test.

	Correlation coefficient	p-value
Risk aversion and temperature	0,04678915	0,7005
Welfare gains and temperature	-0,1941212	0,1073

Table 4: Spearman correlation test

The table reported above presents the results from the Spearman correlation test. It investigates whether the variables above reported are correlated and by how much. The table confirms what was already expected from the graphical representation of the relations between these variables. Risk aversion is positively correlated with temperature, but this correlation is very low. The coefficient correlation is very close to 0 ($\cong 0,047$), indicating poor correlation. Interestingly, welfare gains result to be negatively correlated with temperature.
However, neither correlation is particularly significant. The significance of the results is suggested by the p-value. Two variables are usually said to be significantly correlated if the p-value is smaller than or equal to $0,05$. In both cases, the p-value exceeds the threshold value, and in the case of risk aversion and temperature, this value is extremely high. Therefore, we can conclude that neither risk aversion nor welfare gains are correlated with average temperature.

5.4 *Welfare gains* λ

In both of the procedures I used, when setting the same value of γ for all the 163 countries in the full database, I get values of λ that range from 10^{-4} to 10^{-1}. Changing the value of γ does not affect significantly the estimates of welfare gains, which increase accordingly with the increase of the coefficient of risk aversion. This makes sense because the formula of welfare gains itself positively relates these two variables. When using the values of γ of individual countries computed by Gandelman and Hernández-Murillo (2015), the values of λ, still lie in the order of 10^{-4} to 10^{-1}. These values are in line with what Lucas (2003) estimated in his paper. However, Lucas (2003) found a welfare gain of $\lambda = 0,0005$ to eliminate consumption variability over the period 1947-2001 in the sole United States. I get $\lambda \cong 0,01$ for the same country over the period

1960-2018. This difference can be due to two reasons. First of all, the period over which I run my analysis different. Although the time range is quite the same, the period that I considered could have been subject to different shocks that hit consumption. Moreover, the values of the coefficient of risk aversion that I used differ from what Lucas (2003) used.

Unfortunately, the previous economic literature doesn't have many studies of this kind. Therefore, I can't verify and compare my results with other previous research on welfare gains. The only study that adopts a similar strategy is the one carried out by NBER researchers Bansal and Ochoa (2011). They apply the procedure of Lucas (1987) to find welfare gains for smoothing consumption in a temperature change scenario. They wonder how much consumers are willing to pay to eliminate the variability of consumption attributable to global warming. To do this, they use a utility function with Epstein-Zin preferences. They find that, globally, the welfare gains amount to $0,78$. However, they do not provide estimates for individual countries. This result is much higher compared to what I find. Again, there are two possible reasons for this. First of all, Bansal and Ochoa (2011) use an extremely high coefficient of risk aversion, $\gamma = 10$. Moreover, they use a different type of utility function, which inevitably influences the result.

5.5 *Welfare gains per continent*

I now present the estimates for the welfare gains performed by using the risk aversion coefficients from Gandelman and Hernández-Murillo (2015) and I calculate the average risk aversion coefficient, welfare gains, and average annual temperature per continent. This presentation makes it easier to understand how developed and developing countries behave in terms of welfare gains. The results are reported in the table below.

Continent	**Risk aversion**	**Welfare gains**	**Average temperature**
Africa	0,896	0,0021	22,37
America	0,897	0,0052	18,84
Asia	1,19	0,0048	19,65
Europe	0,823	0,0054	9,21
Oceania	1,16	0,0056	14,62

Table 5: Average welfare gains per continent

From the table above, we can infer once again that the coefficient of risk aversion is not significantly related to average temperature. This is particularly evident in the case of Africa. Given the discussion provided in *Section 2* and supported by previous literature, we would expect that African consumers are more worried about global warming. The average temperature in Africa is already quite high and a further increase will be threatening for the agricultural production of the continent. As a matter of fact, much of the temperature fluctuation is due to climate activity and it is expected to get worse if global warming will worsen in the future. Bansal and Ochoa (2011) suggest that an increase in temperature entails lower long-run growth and that the higher the temperature, the higher the negative effects. In other words, global warming is a source of very high risk, especially for warm and developing countries. However, this claim is not reflected in the results I found. Although Africa hosts many of the warmest and poorest countries of the world, it displays the second-lowest average coefficient of risk aversion. The same happens with welfare gains and temperature. For instance, Africa has the lowest welfare gains even though it has the highest average temperature among all the continents. The representative African consumer would be willing to renounce to approximately $0,0021\%$ of their consumption to have a smoother consumption path. On the other hand, the representative consumer of Oceania has the highest welfare gains, being willing to renounce to about $0,0056\%$ of their consumption. Although these results seem to be in contradiction with the conclusions coming from the previous literature, they are in line with the results from the Spearman correlation test. Since the test didn't highlight any significant relation between welfare gains, risk aversion and average temperatures, it is not surprising that a higher average temperature doesn't imply higher welfare gains or higher risk aversion. Each continent displays different values for the welfare gains, but these values do not vary much between them and they all lie the order of 10^{-3}. All continents but Africa exhibit very close values of λ. It is interesting to see that although the average temperature of the American continent is twice the average temperature of Europe, they both have very similar welfare gains. This clearly shows that the determinants of welfare gains are to be found outside risk aversion and temperature.

The two figures plotted below give a graphical representation of the absence of correlation between welfare gains and temperature according to the continent. The first picture provides a graphical representation of the relationship between welfare gains and temperatures for the smaller sample of 72 countries. The points are coloured according to the continent to which the country belongs. The second picture depicts the same relationship, but for the larger sample of 163 countries. Notice that for this representation I used $\gamma = 2$, but the overall distribution of the points wouldn't change if I used other values of γ. In both cases, the figures confirm that a positive correlation between welfare gains and temperature doesn't hold. Warmer countries have similar welfare gains as colder countries. The warmer countries belong to Africa, South America and Southeast Asia. These countries coincide with developing countries. In this sense, seeing that they do not have higher welfare gains is surprising in two ways. First, countries with already high average temperatures will be hit sooner by adverse global warming effects. Secondly, these countries have significantly fewer resources than colder countries (e.g. European and North American) to cope with global warming losses and plan mitigation strategies.

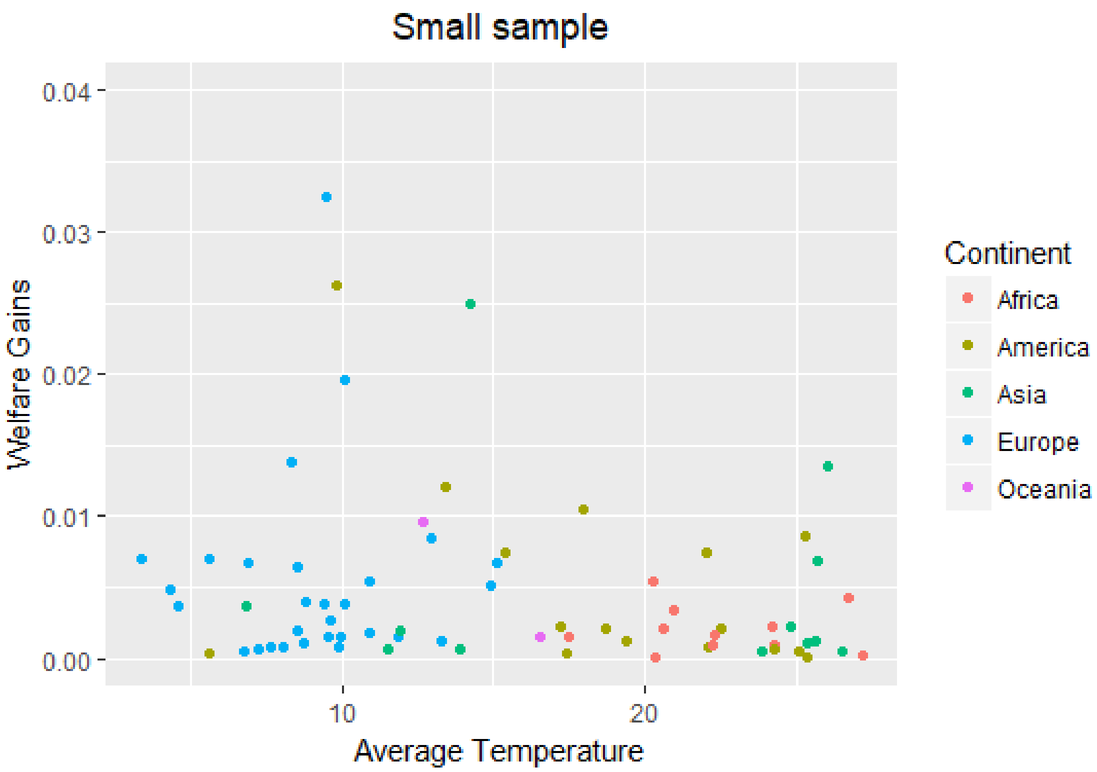

Figure 5: Relation between average temperature and welfare gains, 72 countries

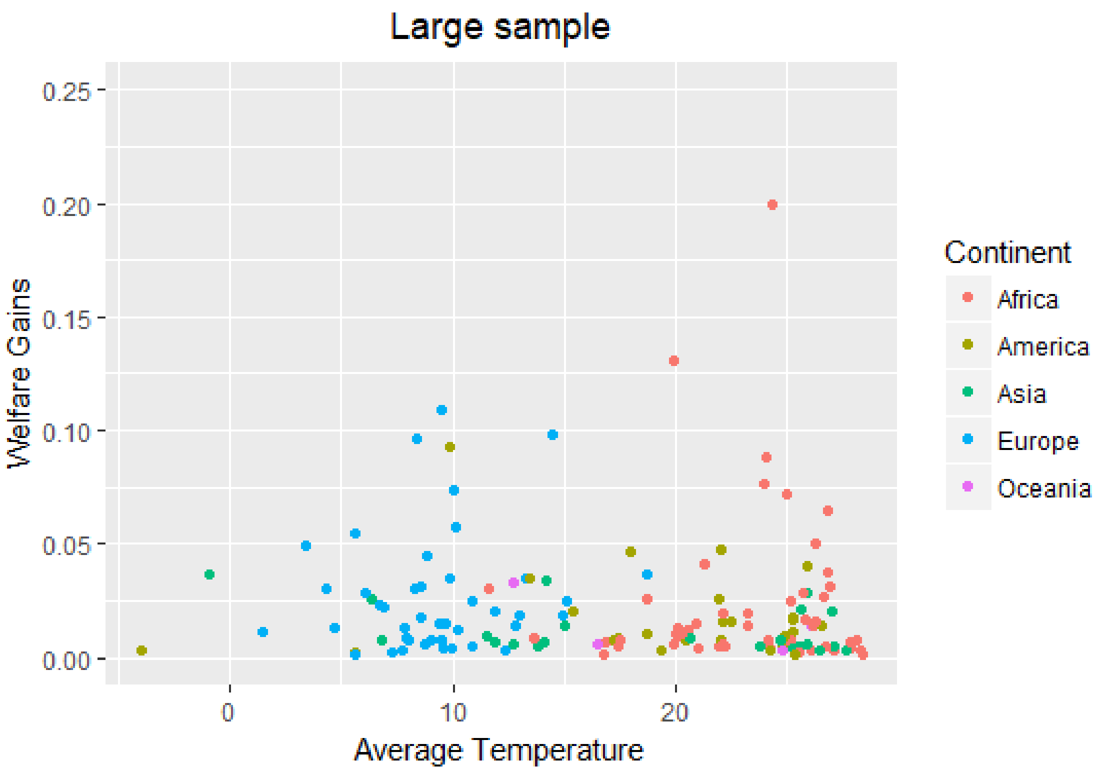

Figure 6: Relation between average temperature and welfare gains, 163 countries

6 Discussion

The results of this thesis presented an estimation of the welfare gains for having a smoother consumption path for representative agents of most countries of the world. The values of the welfare gains appear to be very small, but they need to be put in a context to understand their practical meaning. For instance, take the household final consumption level for Austria in 2010, which amounted to $25.069, 95$\$ (2010 constant US\$). Saying that a representative Austrian consumer would be willing to pay $0, 0862\%$ of their consumption for having a smoother consumption path means that they would renounce to approximately $21, 6$\$ (2010 constant US\$) of their consumption to grant themselves a smooth consumption path over time. This amount is indeed quite small. Lucas (2003) also finds very low values of λ and therefore, points out that a stabilization policy wouldn't lead to any significant increase in welfare. The formula for welfare gains theorized by Lucas (2003) assumes that welfare gains depend on risk aversion. The more agents are risk-averse, the more they fear consumption variability. Therefore, the more they will be willing to pay for insuring themselves against this scenario. Indeed, in the first part of the results, I saw that increasing the value of the coefficient of risk aversion leads to higher welfare gains. Moreover, Heal and Kriström (2002) point out that if agents are risk-averse, they may be willing to pay a lot even if an event is very unlikely to happen. On the other hand, the results didn't highlight a significant relationship between welfare gains and temperature. The Spearman correlation coefficient wasn't significant and pointed to a surprising negative correlation between the two variables. Even though higher temperatures will primarily have adverse effects on the economies of warmer countries, the latter do not appear to be willing to pay more than colder countries for having a smoother consumption path. The formula of welfare gains illustrated by Lucas (2003) and that I have also used for my estimates, depicts welfare gains as depending on risk aversion and the variance of consumption. However, relying only on these two variables may be quite limiting and may ignore some other crucial determinants. In fact, it is possible that when agents make their willingness to pay decisions, they take into account other factors as well. For example, as discussed in *Section 2.5*, willingness to pay studies often encounter the issue of income heterogeneity. Richer individuals may be willing to pay more than poorer agents as a result of their higher available income. The same could be applied in this context; richer countries may be willing to pay more than poorer countries because they indeed possess more resources. Further research in this topic could then try to measure willingness to pay by accounting for more variables and using different utility functions.

Furthermore, the country-level coefficients of risk aversion used in the computation of the second part of the results concern 72 countries. Even if I stressed that this sample is representative for the whole world, there are still many countries that haven't been taken into account. Therefore, further research in this field should try to estimate the coefficients of risk aversion for a larger sample of countries so that the relationship between temperature and willingness to pay can be further and more precisely analyzed. Finding how much representative agents would be willing to pay, in this case for eliminating their consumption uncertainty, could be useful in designing optimal taxation in the context of climate policies. Further research on the topic can also go in this direction, trying to assess the optimal taxes given the welfare gains values.

Moreover, this thesis focused only on how much countries would be willing to pay for smoothing consumption to improve their welfare. However, it ignores international dynamics and the willingness of each country to pay for other countries' welfare. Are poorer countries left alone in the fight against climate change? A direction for further research could be to explore these dynamics based on international relations and solidarity. A few decades ago, Walter and Ugelow (1979) already realized that developing countries are already struggling with several socioeconomic issues, and therefore environmental problems are left in the background. Furthermore, coping with environmental threats is costly and lower-income countries have consistently lower resources to implement stricter environmental policies. Consequently, poorer countries are usually likely to enforce more lenient climate change measures. However, as global warming is a phenomenon that concerns the whole world, it should be taken seriously by each country. As highlighted in the first part of this thesis, even if colder countries will initially register gains from higher average temperatures, in the long run, the threshold of 13°C will be overcome and each country will experience unfortunate consequences.

6.1 *Possible determinants of risk aversion*

The value of welfare gains highly depends on the coefficient of risk aversion. The results showed that risk aversion is not significantly related to average temperatures. It seems that the two variables evolve in the same direction, but the p-value of the test was too high to draw conclusions. The result of the correlation test only highlighted the absence of correlation between temperature and risk aversion, but didn't hint at other factors to which risk aversion may be connected. In reality, several factors can shape risk aversion. For instance, cultural differences seem to play a major role in the individuals' attitude towards risk. Heal and Kriström (2002) explain that perceptions of risk towards future outcomes can be culture-specific. For example, the US seems to be a country with a high-risk tolerance. On the other hand, Europe usually displays low-risk tolerance. Wang et al. (2017) published a study on how loss aversion varies through different cultures. Notice that loss aversion is related to but is not a synonym of risk aversion. Wang et al. (2017) find that loss aversion is influenced by multiple factors and is framed by culture and environment. Their main findings highlight that loss aversion is larger in individualistic and masculine societies, in cultures with higher distance to power, and cultures displaying a higher uncertainty avoidance index. Additional factors, such as wealth and religion, may shape individuals' attitudes towards loss. For instance, in their sample, African individuals manifest the lowest loss aversion, whereas Eastern Europeans exhibit the highest values of loss aversion. They conclude that it appears that loss aversion results more from cultural factors than from economic circumstances. The results I found seem to be in line with these conclusions. Africa exhibits lower risk aversion compared to other continents and of the four cold countries that presented higher welfare gains, two belong to Eastern Europe. Bontempo et al. (1997) found that Western people are more risk-averse towards small losses that have a higher probability of occurring, whereas Chinese people are more risk-averse towards large losses that have a small probability of taking place. Dake (1992) adds that governments, institutions, and other public and private actors shape the perceptions of risk even further. For example, the media can present the risk in a way that it appears weaker or stronger than what it actually is. Moreover, the language used to describe the risk can be used strategically to guide the population towards one particular political orientation. O'Connor et al. (1999) state that individuals are usually in the middle ground when it comes to making efforts for fighting climate change. On one hand, they do not deny the need to take measures to mitigate global warming. On the other, they wouldn't engage fully in personal and political terms to adopt environmental-friendly behaviours. A crucial element in how environmental risk is perceived is environmental knowledge. Leiserowitz (2005) finds that most Americans are not fully aware of the risks posed by climate change, especially to human health and wellbeing. Overall, he finds that Americans perceive global warming as a "moderate risk" and think the effects of global warming will be visible only in distant time and space dimensions. Moreover, he stresses the importance of the perception of environmental risks of American citizens, because the US is accounted responsible for about 25% of global CO_2 emissions, despite they host only 5% of the global population. All these factors indicate that aversion to risk is a very complex process which is sensitive to a myriad of external elements. Beliefs and perceptions appear to matter a lot in this context and if the general public is not convinced of the danger of climate change, their aversion to risk will not be affected by the prospect of higher temperatures.

6.2 *Shaping risk and environmental policies*

Understanding the determinants of risk aversion is crucial, because responses to risk matter when designing policies and especially climate change policies. The economic literature reports that the policy actions taken to face climate change can take the form of mitigation or adaption. Mitigation means that action is taken before the damage occurs and aims at preventing or at least reducing the damages that may be caused by climate change. Conversely, adaptation refers to the strategies that are taken to cope with existing or expected losses. Klein et al. (2005) report that mitigation and adaptation differ on three fronts: spatial and temporal scales, the measure of benefits, and actors that are responsible to implement them. Mitigation is implemented by a limited number of actors but has a global target and its effects may be perceived only after several years. The benefits of mitigation are easily calculated and compared between different mitigation strategies. On the contrary, adaptation is more localized and its effects are quite immediate. Adaptation involves actors coming from many different sectors and it is hard to express its benefits universally, making it hard to compare different adaptation strategies with each other.
However, the perceptions of risk are very heterogeneous between countries. Chichilnisky and Heal (1993) report that disparities in the understanding of risk create the basis for risk trading. International risk markets would show the extent to which each country is concerned with climate change-related risks. The fact that climate change has global impacts suggests that environmental and abatement policies are effective only if they are internationally coordinated and if the same measures are implemented worldwide. However, Chichilnisky and Heal (1993) argue that diverse understandings of scientific evidence lead to country-level differences regarding perspectives over future risks. Moreover, Chichilnisky and Heal (1994) report that there is no universal agreement on who is to blame for the growing amount of CO_2 emissions. On one hand, developed countries attribute the problem to the rapid population growth in developing countries. On the other, the latter believe that CO_2 emissions have been proper to industrialized countries for several decades and developed countries are still the main source of carbon emissions. Although the world is divided on who is most responsible for carbon emissions, no country will be spared from their adverse effects. CO_2 emissions travel throughout the globe,

regardless of where they originate and in the long run they will affect every country.

6.3 *Willingness to pay in policy decisions*

The degree of risk aversion is only one aspect to take into account when designing environmental policies. Willingness to pay is also a crucial element to consider in this process. Thanks to insights about how much individuals are willing to pay for avoiding a certain event, governments could be able to plan taxation for environmental purposes. This thesis presented estimates of willingness to pay that could be serve as a starting point for policy design. As *Section 2.5* described, willingness to pay coexists with its complementary measure – willingness to accept. The latter usually displays higher values than the former, because people tend to exaggerate the amount of compensation that they would like to receive to allow an adverse event to take place. Consequently, it would be natural to think that willingness to pay should be preferred over willingness to accept when devising environmental policies. However, there are some authors that do not agree with this claim. For instance, Knetsch (1990) explains that basing policy decisions on willingness to pay could lead to underestimation of costs. The reason for this is that the difference between the two measures – which, ideally, should be equal – is too large. If willingness to accept overestimates compensations for environmental damages, willingness to pay tends to underestimate the magnitude of these losses. Although environmental policies are certainly not only based on estimates of willingness to pay, information on this measure may enable policymakers to make better choices. Yet, Knetsch (1990) fears that relying on willingness to pay estimates will result in poor mitigation efforts and incentives for environmentally degrading plans. Therefore, it appears that further research is needed also in studies on willingness to pay and especially on how to make this measure more reliable and efficient.

7 Conclusion

This thesis examined the welfare gains for global warming mitigation for a sample of countries. This work distances itself from the previous literature, as previous attempts of calculating welfare gains are made under a global perspective, rather than under a country-level perspective. I opened this work with an extensive literature review on the existing studies about the economic impacts of climate change. I started by presenting the evidence of a relationship between global warming and economic activity. I then discussed the methods that are usually employed by economists to assess the damages caused by climate change.
In the third section, I presented the data sets that I used for computation and the sources from where they have been retrieved. The fourth section described the empirical strategy. After taking data on household final consumption, I applied Lucas' (2003) method of computing welfare gains and I obtained estimates for different values of risk aversion. I initially used values of the risk aversion coefficient that range between $0,5$ and 4 and I applied them to the whole set of 163 countries. I then reduced the data set to 72 countries and I applied country-specific values of the coefficient of risk aversion. These values have been retrieved from Gandelman and Hernández-Murillo (2015). The results reported in the fifth section highlighted the expected correlation between risk aversion and welfare gains. Applying the same risk aversion coefficient to the full set of countries and increasing its value has confirmed that the value of the welfare gains evolves in the same direction as the risk aversion coefficient. However, no other significant relationship emerged from the results. The Spearman correlation test showed that risk aversion and temperature seem to be positively correlated, but this relationship is far from being significant. Similarly, I didn't find a significant relationship between welfare gains and temperature.

These results are quite surprising when compared to the conclusions that arose from the previous climate literature. Many authors found a negative relation between temperatures and economic activity. Moreover, poorer and warmer countries are believed to be the most vulnerable to the damages coming from climate change. However, they display the lowest welfare gains and relatively low risk aversion coefficients. There can be many reasons for these results. In the discussion, I considered explanations coming from economics and other areas of social sciences. A pure economic reason may be related to income; poorer countries would be willing to pay less because they have more limited resources than richer countries. However, other possibilities include non-economical factors. Risk aversion seems to be related to culture and it is significantly influenced by the way the risk is framed by governments and the media. The way risk is perceived influences consumers' willingness to pay decisions. Understanding the dynamics that are behind the willingness to pay is important to model policy actions that could be taken against climate change.

Climate change is a threat with an extremely high level of uncertainty. Although economists have attempted to measure the potential damages, there is no certainty about what will happen and when. Researchers in other fields share these issues related to the unpredictability of climate change. Unfortunately, the uncertainty in scientific and economic research is reflected in the attitude of the general public. Alongside people concerned with climate change, there is a lot of scepticism and denialism. Many people still believe that climate change is not real or are not aware of the magnitude of its consequences. The scientific community needs to make its best to give more answers to a problem whose resolution is rather urgent.

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9 Appendix

Derivation of the equation for welfare gains of Lucas (2003)

According to Lucas (2003), the value of the welfare gains is the value of λ for which the following equality holds:

$$U((1+\lambda)c_A) = U(c_B) \tag{1}$$

Consumption is defined by the equation $c_t = Ae^{\mu t}e^{-\frac{1}{2}\sigma^2}\epsilon_t$. This equation refers to a stochastic consumption path and it represents c_A in the formula above. The definition of consumption is plugged into the CRRA utility function $u(c_t) = \frac{c_t^{1-\gamma}}{1-\gamma}$ and indicates the utility that the consumer gains from a stochastic consumption path. Therefore, the left handside of equation (1) becomes:

$$E\{\sum_{t=0}^{\infty}\beta^t\frac{((1+\lambda)c_t)^{1-\gamma}}{1-\gamma}\} = E\{\sum_{t=0}^{\infty}\beta^t\frac{((1+\lambda)Ae^{\mu t}e^{-\frac{1}{2}\sigma^2}\epsilon_t)^{1-\gamma}}{1-\gamma}\}$$

On the other side of equation (1), the utility of consumption measures the utility from the average of consumption, which is not subject to variability and follows a smooth path. Because $E(e^{-\frac{1}{2}\sigma^2}\epsilon_t) = 1$, the mean of consumption is $Ae^{\mu t}$. Thus, the right handside of equation (1) can be rewritten as:

$$\sum_{t=0}^{\infty}\beta_t\frac{(Ae^{\mu t})^{1-\gamma}}{1-\gamma}$$

and equation (1) becomes:

$$E\{\sum_{t=0}^{\infty}\beta^t\frac{((1+\lambda)Ae^{\mu t}e^{-\frac{1}{2}\sigma^2}\epsilon_t)^{1-\gamma}}{1-\gamma}\} = \sum_{t=0}^{\infty}\beta_t\frac{(Ae^{\mu t})^{1-\gamma}}{1-\gamma}$$

$$\Leftrightarrow (1+\lambda)^{1-\gamma}\sum_{t=0}^{\infty}\beta_t\frac{(Ae^{\mu t})^{1-\gamma}}{1-\gamma}E[(e^{-\frac{1}{2}\sigma^2}\epsilon_t)^{1-\gamma}] = \sum_{t=0}^{\infty}\beta_t\frac{(Ae^{\mu t})^{1-\gamma}}{1-\gamma}$$

By simplifying the same terms on both side of the equality, we are left with the condition:

$$(1+\lambda)^{1-\gamma}E[(e^{-\frac{1}{2}\sigma^2}\epsilon_t)^{1-\gamma}] = 1$$

$$\Leftrightarrow E[(e^{-\frac{1}{2}\sigma^2}\epsilon_t)^{1-\gamma}] = (\frac{1}{1+\lambda})^{1-\gamma} \tag{2}$$

Denote $Y_t = log\epsilon_t$. Then, $\epsilon_t = e^{log_t} = e^{Y_t}$. Develop the left handside of (2).

$$E[(e^{\frac{1}{2}\sigma^2} e^{Y_t})^{1-\gamma}]$$

$$= E[(e^{-\frac{1}{2}\sigma^2})^{1-\gamma}(e^{Y_t})^{1-\gamma}]$$

$$= e^{-\frac{1}{2}\sigma^2(1-\gamma)} E[e^{Y_t(1-\gamma)}] \tag{3}$$

Plugging (3) into (2), we obtain:

$$e^{-\frac{1}{2}\sigma^2(1-\gamma)} E[e^{Y_t(1-\gamma)}] = (\tfrac{1}{1+\lambda})^{1-\gamma}$$

Now, denote $Z_t = (1-\gamma)Y_t$. Suppose that $Z_t \sim N(0, (1-\gamma)^2\sigma^2)$.

$$E[e^{Z_t}] = (\tfrac{1}{1+\lambda})^{1-\gamma} e^{\frac{1}{2}\sigma^2(1-\gamma)}$$

$$e^{\frac{1}{2}\sigma^2(1-\gamma)^2} = (\tfrac{1}{1+\lambda})^{1-\gamma} e^{\frac{1}{2}\sigma^2(1-\gamma)}$$

$$\Leftrightarrow e^{\frac{1}{2}\sigma^2(1-\gamma)(1-\gamma-1)} = (\tfrac{1}{1+\lambda})^{1-\gamma}$$

$$\Leftrightarrow \tfrac{1}{2}\sigma^2(1-\gamma)(-\gamma) = (1-\gamma)log(\tfrac{1}{1+\lambda})$$

$$\Leftrightarrow \tfrac{1}{2}\sigma^2(-\gamma) = log(1) - log(1+\lambda)$$

$$\Leftrightarrow log(1+\lambda) = \tfrac{1}{2}\gamma\sigma^2$$

By applying the Taylor expansion formula of the logarithm and stopping at the first order, we get

$$\lambda \cong \tfrac{1}{2}\gamma\sigma^2$$

Tables

Country	γ=0,5	γ=0,8	γ=1	γ=2	γ=4
Albania	0,00441	0,00706	0,00883	0,01765	0,03531
Algeria	0,00083	0,00133	0,00166	0,00331	0,00663
American Samoa	0,00171	0,00274	0,00343	0,00685	0,01370
Angola	0,00065	0,00105	0,00131	0,00262	0,00523
Argentina	0,00095	0,00152	0,00190	0,00380	0,00761
Armenia	0,01207	0,01932	0,02415	0,04829	0,09658
Australia	0,00068	0,00109	0,00136	0,00272	0,00545
Austria	0,00040	0,00064	0,00080	0,00160	0,00319
Azerbaijan	0,00228	0,00365	0,00456	0,00913	0,01826
Bahamas, The	0,00145	0,00233	0,00291	0,00582	0,01164
Bahrain	0,00192	0,00307	0,00383	0,00766	0,01533
Bangladesh	0,00265	0,00424	0,00530	0,01060	0,02120
Belarus	0,00290	0,00464	0,00580	0,01159	0,02319
Belgium	0,00051	0,00082	0,00103	0,00205	0,00411
Belize	0,00352	0,00563	0,00703	0,01406	0,02813
Benin	0,00036	0,00057	0,00071	0,00143	0,00286
Bhutan	0,00076	0,00121	0,00152	0,00303	0,00606
Bolivia	0,00103	0,00165	0,00206	0,00411	0,00823
Bosnia and Herzegovina	0,00184	0,00294	0,00368	0,00735	0,01470
Botswana	0,00182	0,00290	0,00363	0,00726	0,01452
Brazil	0,00595	0,00952	0,01189	0,02379	0,04758
Brunei Darussalam	0,00066	0,00105	0,00132	0,00263	0,00527
Bulgaria	0,00926	0,01482	0,01853	0,03705	0,07410
Burkina Faso	0,00048	0,00077	0,00097	0,00193	0,00387
Burundi	0,00124	0,00198	0,00248	0,00496	0,00991
Cabo Verde	0,00053	0,00084	0,00105	0,00210	0,00420
Cambodia	0,00039	0,00063	0,00079	0,00158	0,00316
Cameroon	0,00057	0,00091	0,00113	0,00227	0,00453
Canada	0,00023	0,00037	0,00046	0,00092	0,00185

Central African Republic	0,00902	0,01443	0,01803	0,03607	0,07213
Chad	0,07157	0,11451	0,14314	0,28629	0,57257
Chile	0,01164	0,01862	0,02327	0,04655	0,09309
China	0,00080	0,00129	0,00161	0,00322	0,00643
Colombia	0,00091	0,00145	0,00181	0,00363	0,00725
Comoros	0,00306	0,00489	0,00612	0,01223	0,02447
Congo, Dem. Rep.	0,00239	0,00383	0,00479	0,00958	0,01916
Congo, Rep.	0,00093	0,00149	0,00186	0,00373	0,00745
Costa Rica	0,00197	0,00316	0,00395	0,00789	0,01578
Cote d'Ivoire	0,00178	0,00285	0,00356	0,00712	0,01424
Croatia	0,00254	0,00406	0,00508	0,01016	0,02032
Cyprus	0,00462	0,00739	0,00924	0,01848	0,03696
Czech Republic	0,00112	0,00180	0,00224	0,00449	0,00898
Denmark	0,00166	0,00266	0,00333	0,00665	0,01331
Dominican Republic	0,00075	0,00120	0,00150	0,00300	0,00601
Ecuador	0,00045	0,00072	0,00090	0,00180	0,00360
Egypt, Arab Rep.	0,00512	0,00820	0,01025	0,02049	0,04098
El Salvador	0,00197	0,00316	0,00394	0,00789	0,01578
Equatorial Guinea	0,02496	0,03993	0,04991	0,09982	0,19964
Eritrea	0,00176	0,00282	0,00352	0,00704	0,01408
Estonia	0,00685	0,01096	0,01370	0,02741	0,05482
Eswatini	0,00126	0,00202	0,00253	0,00505	0,01010
Finland	0,00616	0,00985	0,01232	0,02463	0,04926
France	0,00061	0,00097	0,00122	0,00243	0,00487
Gabon	0,00061	0,00097	0,00122	0,00244	0,00487
Gambia, The	0,00045	0,00072	0,00090	0,00181	0,00361
Georgia	0,00309	0,00494	0,00617	0,01234	0,02468
Germany	0,00075	0,00119	0,00149	0,00298	0,00596
Ghana	0,00335	0,00535	0,00669	0,01339	0,02677
Greece	0,00235	0,00376	0,00471	0,00941	0,01882
Greenland	0,00044	0,00071	0,00089	0,00177	0,00355
Guam	0,00015	0,00024	0,00030	0,00059	0,00118

Guatemala	0,00326	0,00522	0,00653	0,01306	0,02611
Guinea	0,00101	0,00162	0,00203	0,00405	0,00811
Guinea-Bissau	0,00466	0,00746	0,00932	0,01864	0,03728
Guyana	0,00171	0,00273	0,00341	0,00682	0,01364
Haiti	0,00221	0,00354	0,00443	0,00885	0,01771
Honduras	0,00038	0,00061	0,00076	0,00152	0,00303
Hong Kong SAR, China	0,00602	0,00963	0,01204	0,02407	0,04815
Hungary	0,00155	0,00248	0,00309	0,00619	0,01238
Iceland	0,00146	0,00234	0,00292	0,00584	0,01168
India	0,00064	0,00102	0,00127	0,00255	0,00510
Indonesia	0,00047	0,00075	0,00094	0,00187	0,00374
Iran, Islamic Rep.	0,00173	0,00277	0,00347	0,00694	0,01387
Ireland	0,00561	0,00898	0,01123	0,02245	0,04491
Israel	0,00161	0,00258	0,00322	0,00645	0,01289
Italy	0,00179	0,00287	0,00359	0,00718	0,01436
Jamaica	0,00120	0,00191	0,00239	0,00479	0,00957
Japan	0,00067	0,00108	0,00135	0,00269	0,00538
Jordan	0,00100	0,00159	0,00199	0,00399	0,00797
Kazakhstan	0,00318	0,00509	0,00637	0,01273	0,02546
Kenya	0,00078	0,00125	0,00157	0,00314	0,00627
Korea, Rep.	0,00118	0,00188	0,00235	0,00471	0,00942
Kosovo	0,00073	0,00117	0,00146	0,00292	0,00583
Kuwait	0,00029	0,00047	0,00058	0,00116	0,00233
Kyrgyz Republic	0,00101	0,00162	0,00202	0,00405	0,00810
Lao PDR	0,00064	0,00103	0,00129	0,00257	0,00514
Latvia	0,00352	0,00563	0,00704	0,01408	0,02817
Lebanon	0,00112	0,00179	0,00224	0,00447	0,00895
Lesotho	0,00380	0,00608	0,00760	0,01521	0,03041
Liberia	0,00206	0,00330	0,00413	0,00825	0,01651
Lithuania	0,00274	0,00438	0,00548	0,01096	0,02191
Luxembourg	0,00093	0,00149	0,00187	0,00373	0,00747
Macao SAR, China	0,00060	0,00095	0,00119	0,00238	0,00477

Madagascar	0.00151	0.00241	0.00301	0.00602	0.01205
Malawi	0.00247	0.00395	0.00494	0.00989	0.01977
Malaysia	0.00352	0.00564	0.00704	0.01409	0.02818
Mali	0.00094	0.00150	0.00188	0.00375	0.00751
Malta	0.00019	0.00030	0.00037	0.00075	0.00150
Marshall Islands	0.00218	0.00349	0.00436	0.00872	0.01743
Mauritania	0.00042	0.00068	0.00084	0.00169	0.00338
Mauritius	0.00951	0.01522	0.01902	0.03805	0.07609
Mexico	0.00132	0.00212	0.00265	0.00530	0.01059
Moldova	0.01366	0.02186	0.02732	0.05464	0.10928
Mongolia	0.00456	0.00730	0.00913	0.01825	0.03651
Montenegro	0.00353	0.00565	0.00706	0.01412	0.02824
Morocco	0.00018	0.00028	0.00035	0.00070	0.00140
Mozambique	0.00101	0.00161	0.00201	0.00403	0.00805
Nepal	0.00111	0.00178	0.00223	0.00446	0.00891
Netherlands	0.00435	0.00696	0.00870	0.01740	0.03479
New Zealand	0.00418	0.00669	0.00837	0.01673	0.03346
Nicaragua	0.00499	0.00798	0.00998	0.01995	0.03991
Niger	0.00014	0.00022	0.00028	0.00055	0.00111
Nigeria	0.00062	0.00099	0.00124	0.00249	0.00497
North Macedonia	0.00056	0.00090	0.00113	0.00225	0.00450
Northern Mariana Islands	0.02155	0.03449	0.04311	0.08622	0.17244
Norway	0.00162	0.00259	0.00324	0.00648	0.01296
Oman	0.01104	0.01766	0.02208	0.04416	0.08832
Pakistan	0.11601	0.18562	0.23202	0.46404	0.92808
Palau	0.00079	0.00126	0.00157	0.00315	0.00629
Panama	0.00022	0.00035	0.00043	0.00087	0.00173
Paraguay	0.00091	0.00146	0.00183	0.00366	0.00731
Peru	0.00260	0.00416	0.00520	0.01040	0.02080
Philippines	0.00068	0.00109	0.00136	0.00273	0.00546
Poland	0.00100	0.00159	0.00199	0.00399	0.00797
Portugal	0.00312	0.00499	0.00624	0.01248	0.02496

Puerto Rico	0.00050	0.00079	0.00099	0.00198	0.00396
Qatar	0.00805	0.01288	0.01610	0.03221	0.06441
Romania	0.00091	0.00146	0.00182	0.00364	0.00728
Russian Federation	0.00374	0.00598	0.00747	0.01495	0.02989
Rwanda	0.01640	0.02623	0.03279	0.06558	0.13116
Saudi Arabia	0.00360	0.00577	0.00721	0.01441	0.02883
Serbia	0.00722	0.01155	0.01443	0.02887	0.05774
Sierra Leone	0.00628	0.01005	0.01256	0.02512	0.05023
Singapore	0.00220	0.00352	0.00440	0.00880	0.01761
Slovak Republic	0.00375	0.00600	0.00750	0.01499	0.02998
Slovenia	0.00392	0.00626	0.00783	0.01566	0.03132
South Africa	0.00059	0.00095	0.00119	0.00237	0.00474
South Sudan	0.00279	0.00446	0.00557	0.01115	0.02229
Spain	0.01233	0.01973	0.02466	0.04932	0.09863
Sri Lanka	0.00042	0.00067	0.00084	0.00167	0.00334
Sudan	0.00082	0.00131	0.00164	0.00327	0.00655
Sweden	0.00016	0.00026	0.00033	0.00066	0.00131
Switzerland	0.00026	0.00041	0.00052	0.00103	0.00206
Tajikistan	0.00080	0.00128	0.00160	0.00320	0.00639
Tanzania	0.00063	0.00102	0.00127	0.00254	0.00508
Thailand	0.00252	0.00403	0.00504	0.01007	0.02014
Timor-Leste	0.00854	0.01367	0.01709	0.03417	0.06835
Togo	0.00197	0.00316	0.00394	0.00789	0.01578
Tunisia	0.00324	0.00518	0.00648	0.01296	0.02592
Turkey	0.00039	0.00063	0.00079	0.00158	0.00316
Uganda	0.00071	0.00114	0.00142	0.00284	0.00569
Ukraine	0.00226	0.00362	0.00452	0.00904	0.01808
United Arab Emirates	0.00388	0.00620	0.00775	0.01551	0.03101
United Kingdom	0.00189	0.00303	0.00379	0.00758	0.01515
United States	0.00434	0.00694	0.00868	0.01735	0.03471
Uruguay	0.00584	0.00934	0.01168	0.02336	0.04672
Uzbekistan	0.00422	0.00675	0.00843	0.01687	0.03374

Vanuatu	0.00036	0.00058	0.00073	0.00146	0.00292
Venezuela, RB	0.00207	0.00331	0.00414	0.00827	0.01655
Vietnam	0.00098	0.00157	0.00196	0.00393	0.00785
Virgin Islands (U.S.)	0.00100	0.00160	0.00200	0.00400	0.00799
West Bank and Gaza	0.00075	0.00121	0.00151	0.00301	0.00603
Zimbabwe	0.00134	0.00215	0.00268	0.00537	0.01073

Table 6: Welfare gains with fixed risk aversion coefficients

Country	Risk aversion	Welfare gains	Average temperature
Albania	0,14	0,00124	13,25
Argentina	1,2	0,00228	17,23
Armenia	0,57	0,01376	8,37
Australia	1,17	0,00159	16,54
Austria	1,08	0,00086	7,70
Azerbaijan	1,85	0,00844	12,97
Bangladesh	1,3	0,00689	25,63
Belarus	0,09	0,00052	6,76
Belgium	1,55	0,00159	9,95
Benin	0,21	0,00015	27,11
Bolivia	0,16	0,00033	17,41
Bosnia and Herzegovina	0,72	0,00265	9,65
Botswana	0,94	0,00341	20,95
Brazil	0,63	0,00749	22,02
Bulgaria	1,06	0,01964	10,08
Burundi	2,17	0,00538	20,23
Cameroon	0,82	0,00093	24,22
Canada	0,83	0,00038	5,65
Chile	1,13	0,02630	9,86
Croatia	0,31	0,00157	11,89
Dominican Republic	0,32	0,00048	25,04
Ecuador	1,39	0,00125	19,34
El Salvador	0,54	0,00213	22,49
Estonia	0,51	0,00699	5,65
Finland	0,57	0,00702	3,42
France	1,43	0,00174	10,90
Georgia	0,88	0,00543	10,90
Germany	0,77	0,00115	8,76

Ghana	0,63	0,00422	26,66
Greece	1,08	0,00508	14,92
Honduras	0,91	0,00069	24,25
India	0,92	0,00117	25,58
Indonesia	1,24	0,00116	25,32
Ireland	0,35	0,00393	8,82
Japan	0,44	0,00059	13,86
Korea, Rep.	0,27	0,00064	11,51
Kosovo	1,03	0,00150	NaN
Kyrgyz Republic	1,81	0,00366	6,83
Lao PDR	0,39	0,00050	23,80
Lithuania	1,23	0,00674	6,93
Madagascar	0,72	0,00217	20,56
Malaysia	1,93	0,01360	25,96
Mexico	0,78	0,00207	18,71
Moldova	1,19	0,03251	9,49
Montenegro	2,1	0,01483	NaN
Mozambique	1,11	0,00223	24,15
Netherlands	0,1	0,00087	9,90
New Zealand	1,15	0,00962	12,70
North Macedonia	1,34	0,00151	9,96
Norway	1,16	0,00376	4,65
Panama	0,18	0,00008	25,34
Paraguay	0,47	0,00086	22,09
Peru	1,44	0,00749	15,36
Poland	0,38	0,00076	8,05
Portugal	1,07	0,00668	15,10
Russian Federation	0,65	0,00486	4,32

Serbia	0,27	0,00390	10,13
Slovenia	0,83	0,00650	8,56
South Africa	1,29	0,00153	17,44
Sri Lanka	0,68	0,00057	26,46
Switzerland	1,21	0,00062	7,29
Tajikistan	1,19	0,00190	11,90
Tanzania	1,26	0,00160	22,26
Uganda	0,67	0,00095	22,18
Ukraine	0,44	0,00199	8,57
United Kingdom	1,03	0,00390	9,40
United States	1,39	0,01206	13,43
Uruguay	0,9	0,01051	17,96
Uzbekistan	2,96	0,02496	14,24
Venezuela, RB	2,08	0,00860	25,25
Vietnam	1,15	0,00226	24,76
Zimbabwe	0,04	0,00011	20,30

Table 7: Welfare gains with country-level risk aversion coefficients

Country code	Country name
ALB	Albania
ARG	Argentina
ARM	Armenia
AUS	Australia
AUT	Austria
AZE	Azerbaijan
BGD	Bangladesh
BLR	Belarus
BEL	Belgium
BEN	Benin
BOL	Bolivia
BIH	Bosnia and Herzegovina
BWA	Botswana
BRA	Brazil
BGR	Bulgaria
BDI	Burundi
CMR	Cameroon
CAN	Canada
CHL	Chile
HRV	Croatia
DOM	Dominican Republic
ECU	Ecuador
SLV	El Salvador
EST	Estonia
FIN	Finland
FRA	France
GEO	Georgia
DEU	Germany
GHA	Ghana
GRC	Greece

HND	Honduras
IND	India
IDN	Indonesia
IRL	Ireland
JPN	Japan
KOR	Korea, Rep.
KGZ	Kyrgyz Republic
LAO	Lao PDR
LTU	Lithuania
MDG	Madagascar
MYS	Malaysia
MEX	Mexico
MDA	Moldova
MOZ	Mozambique
NLD	Netherlands
NZL	New Zealand
MKD	North Macedonia
NOR	Norway
PAN	Panama
PRY	Paraguay
PER	Peru
POL	Poland
PRT	Portugal
RUS	Russian Federation
SRB	Serbia
SVN	Slovenia
ZAF	South Africa
LKA	Sri Lanka
CHE	Switzerland
TJK	Tajikistan
TZA	Tanzania

UGA	Uganda
UKR	Ukraine
GBR	United Kingdom
USA	United States
URY	Uruguay
UZB	Uzbekistan
VEN	Venezuela, RB
VNM	Vietnam
ZWE	Zimbabwe

Table 8: Country codes and country names