Beyond Montesquieu

Developing a new framework for climate and growth

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Mankind are influenced by various causes: by the climate, by the religion, by the laws, by the maxims of government, by precedents, morals, and customs; whence is formed a general spirit of nations. (Montesquieu 1990, 135)

Abstract

The thesis sets out to study the correlation between long-run economic growth and climate, through testing two hypotheses. In the first hypothesis Montesquieu's climate theory is compared to a modern approach, while in the second hypothesis, natural disaster and disease ecology variables are suggested and tested as growth determinants. In the application of multiple regression analysis two significant growth determinants related to climate were found. First, drought decreases productivity in the agricultural sector. Secondly, malaria risk negatively affects the productivity of human capital and disincentivises investment in education.

Key words: climate, economic growth, malaria ecology, Montesquieu, natural disasters

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1. Introduction

1.1. Preamble

A look at the distribution of wealth in the world reveals that most of the world's annual GDP is generated in countries with cold to temperate climates. Hence, there seems to be a correlation between climate and wealth. In several empirical studies the distance from the equator and being situated in Africa or Latin America seem to matter for growth, but the mechanisms behind this pattern has yet to be fully explained. Since the beginning of the 1920s scientists have been reluctant to admit this connection and have turned their focus away from the then prevailing paradigm of environmental determinism, and instead concentrated on human culture as the determinant variable for economic development (Judkins, Smith, and Keys 2008, 20). Still, almost a hundred years later, the same pattern of income distribution lingers. Therefore, if we are serious in our attempts to answer the question of why some people are rich while others are poor, it is logical for economists studying economic growth to look with fresh eyes upon the economy-climate connection.

The aim of this thesis is just this: to analyse the role of climate in determining economic growth. Climate theory has been of interest to scientists and philosophers for a long time; inspired by thinkers such as Plato, Aristotle, Hippocrates, Khaldûn and Montesquieu. Many of these earlier climate theorists made the assumption that climate affects the human character; assumptions that today do not find any support in the scientific community. This thesis sets out to analyse and operationalize Montesquieu's climate theory in comparison to modern approaches, and to develop a framework alternative to those of the old climate theorists'. There are undeniably differences in the climatic circumstances around the world, and the interesting question that arises is how they affect the incentives people face in economic decisions. In particular, the effects of climate related natural disasters and disease ecology are studied.

Studies conducted, mainly by Jeffery Sachs and John Gallup, during the last decade points out that there are several possible ways through which geography, of which the climate is a part, can adversely affect societies. In their work Sachs and Gallup have studied how tropical climate zones increases the risk of malaria infection. The thesis at hand expands on the finding of Gallup and Sachs by further testing and theorizing on the economy-climate connection.

1.2. The Question at Issue

The aim of this thesis is to establish whether there is a causal relationship between temperature and economic growth, and, if so, explain an underlying principle governing this causality.

To establish a position with regards to the first issue, data from 123 countries between the years 1970 and 2009 is examined. In the spirit of Montesquieu the thesis will also test the theory underlying *The Spirit of Laws*, namely that France constitute the perfect climate for human and, in turn, economic development. To operationalize the term climate the mean temperature of a country will be used. This is in line with the discussion of Montesquieu, who distinguishes between warm, cold and temperate countries in terms of the effect they have on the character of people living there. Montesquieu's argument is interpreted as meaning that temperatures deviating from the mean temperature of France will have adverse effects on economic growth. This leads to the first hypothesis of the thesis: the temperature in France is optimal for economic growth. Meaning that both mean temperatures higher and lower than that of France will result in lower economic growth, ceteris paribus. This hypothesis is expected to be rejected since a quick look at the global distribution of wealth reveals that there are several high growth countries north of France.

The second issue pondered is to what extent the relationship between climate and economic development can be explained through the causal mechanism of natural disasters and malaria ecology correlated with climate.

The second step of the second question is more intellectually challenging and employs results obtained from a multiple regression analysis in conjunction with the existing literature on the subject. In this part an analysis of the variables that has a significant correlation with economic growth is made. By reviewing the empirical results together with literature from different disciplines, an explanation to the causal mechanisms and underlying principles is provided. Given this methodology the thesis ends up with two hypotheses to test.

- The climate of France is optimal for economic growth.
- Climate affects economic growth mainly by the causal link of natural disasters and malaria risk.

Furthermore, the analysis will touch upon possible policy implications stemming from the results found. These are not tangible policy recommendations, but rather a brief overview of where to look for the solutions to the problem climate can pose for economic growth.

2. Theory and Methodology

The objective of this chapter is twofold. First, the chapter will provide an overview and definition of causality and determinism together with a discussion of how the concepts will be treated in this thesis. Secondly, the theoretical background to the hypotheses will be discussed, in relation to both old and modern theories of how climate affects human nature and economic development.

2.1. Causality and Determinism

Environmental determinism had its glory days in the beginning of the 20^{th} century. The concept is of an arbitrary nature and needs to be defined. In this thesis it reflects what could be thought of as the physical environment such as geography, topography, climate and biological properties, concepts that are entangled and distinct simultaneously. The thesis will mainly consider climate determinism from which the broader concept of environmental determinism emanated.

The paradigm of climate determinism had to endure growing criticism for completely disregarding human intentionality, and for failing to prove that comparable climates resulted in similar human responses. Hence, the climate determinism paradigm was replaced with structural and behavioural paradigms during the 1920s (Judkins, Smith, and Keys 2008, 19ff). The publication of *Guns, Germs and Steel* by Jared Diamond (1999) once again brought the relationship between humans and the physical environment back on the agenda. However, determinism has recently been downplayed and scientists instead focus on how the environment alters peoples' opportunities.

Early climate determinism was brought forward by scientists wanting to explain the greatness of their country compared to others (see for example Khaldûn 2005; Montesquieu 1990). Also, more contemporary North European scientist has fostered this idea. Arguing that the cold climate of the north makes people more prone to work, ceteris paribus. In common for almost all climate determinists was the belief that the physical environment, and mainly the climate, affects the psyche of people. The theories have often had racist connotations, arguing that people living in warm climates lack creativity, intelligence and energy while having uncontrollable passions and desires leading to social disorder.

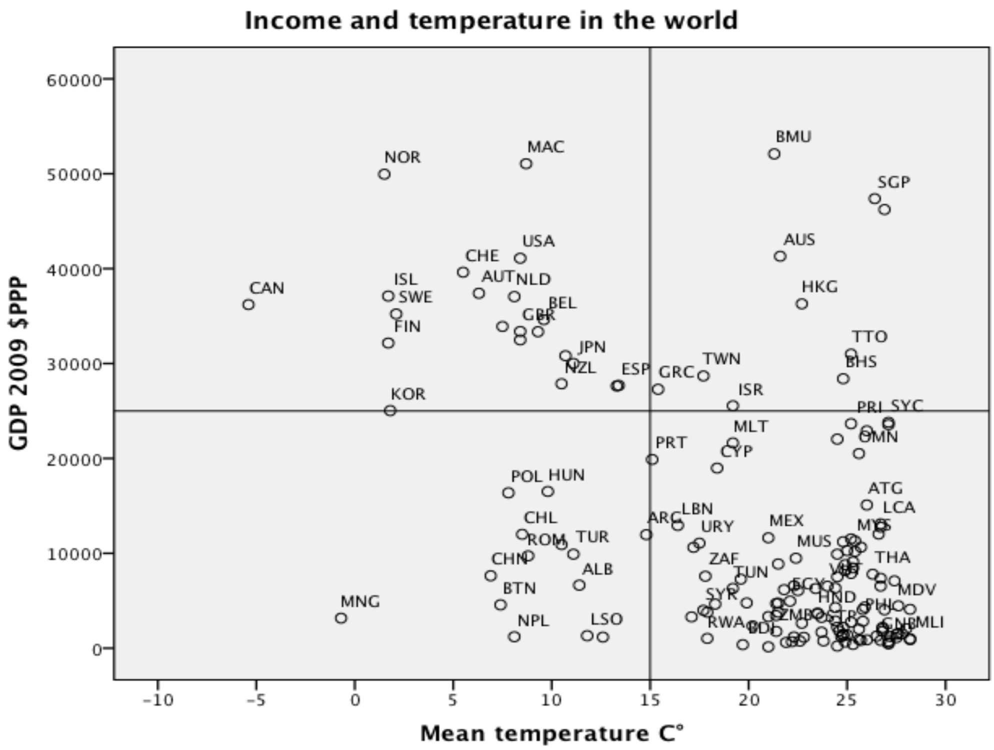
> *If we draw near the south, we fancy ourselves entirely removed from the verge of morality; here the strongest passions are productive of all manner of crimes, each man endeavouring, let the means be what they will, to indulge his inordinate desires. (Montesquieu 1990, 103)*

Khaldûn puts it even more bluntly when describing the climate's effect on people living in warm climates: "Their qualities of character, moreover, are close to those of dumb animals." (Khaldûn 2005, 58f). Both Montesquieu and Khaldûn base much of their findings on religious beliefs and scientific methods that would not be accepted in today's modern science. This can be exemplified with his study of a sheep's frozen tongue, in order to determine the effects a cold climate has on the character of human beings.

> *I caused the half of this tongue to be frozen, and, observing it with the naked eye, I found the papillae considerably diminished [...] The outermost part I examined with the microscope, and perceived no pyramids. In proportion as the frost went off, the papillae seemed to the naked eye to rise, [...]. (Montesquieu 1990, 103)*

However, neither Montesquieu nor Khaldûn's theory about the human psyche is the focus of this thesis. Instead the effects climate has on societies' economic development are analysed and explained. Even though many historians today refute this idea as deterministic (Judkins, Smith, and Keys 2008; Peet 1985; Rodrik, Subramanian, and Trebbi 2002), the fact remains that almost all low-income countries are located in warmer climates. A quick look at Figure 1 reveals that only small Caribbean islands, Asian city-states, Australia and Taiwan are located in the upper right quadrant of rich and warm countries. The other contradiction to the general principle of cold countries being rich and warm countries being poor is the lower left quadrant where mainly former communist countries are situated.

Figure 1



Determinism and causality are two controversial concepts that are constantly discussed in the academic community. The next part of this chapter presents an overview of the two concepts, and provides a definition for the purpose of this thesis.

In modern social science a narrow definition of cause is often adopted. Jochen Runde defines cause as “anything that contributes to, or makes a difference, to the realisation of an event in one or more of its aspects.” (Runde 1998, 154). The objection towards causality is often based on the fear of accepting determinism and not allowing for human intentions in the study of society. “If determinism is rejected by physics, then it is surely implausible to suggest that the paradigm could be rehabilitated by successfully underpinning theories in economics.”

(Drakopoulos and Torrance 1994, 191). However, rejecting determinism only leads to the question of what caused human intentions. If not explained with a causal process human intentions have to be considered a result of chance. Accepting chance, or properly expressed; stochasticity, is not the only option to explain the mysteries of physics. Einstein famously expressed "that he could not believe 'in a God who plays dice'"(Hodgson 2004, 178). Instead he argued that hidden laws and variables that we have not yet discovered, or are unable to discover, govern the process called chance. It is possible, then, to accept causality without making the claim that all human actions, and quantum mechanics for that matter, can be predicted, which leads to the discussion of epistemological determinism, ontological determinism and stochastic behaviour.

Ontological determinism assume that "for every event there is some set of antecedent circumstances that completely caused it", while epistemological determinism refers to the claim that "we can know, or it is possible for us to discover, the determining causes of every event in the universe." (Drakopoulos and Torrance 1994, 177). The acceptance of true knowledge about causal relations builds on the assumption that the world is governed by causality. However, a deterministic view of the world does not imply that causality can be understood. Hence, it is important to note that epistemological determinism presupposes ontological determinism, but not vice versa, i.e. it is possible to accept the notion that everything has a cause while rejecting that science will discover, less fully understand, these causal relationships.

The distinction between ontological and epistemological determinism is of methodological importance because reflects the problem of what can be said about the correlation between climate and economic growth, as well as other economic and social phenomena. The idea that every event has a cause does not imply that every event is predictable, that one cannot take into account human intentions or that one set of events will always lead to the same outcome. The principle of universal causation only states "everything is determined in accordance with laws by something else." (Hodgson 2004, 189). Accepting ontological determinism, it is not certain, however, that it is possible to obtain knowledge about all antecedent causes to an event. This unknown variable problem may make determined events seem stochastic, which makes a statistical approach necessary. By studying the distribution and correlation of known variables and acknowledging the presence of a random error term that reflects the unknown variables, it is possible to estimate probabilities for the correlations found between known variables. This approach is called stochastic determinacy.

Hence, stochastic determinacy, which will be used in this thesis, is fully compatible with the principle of universal causation. "Apparent statistical determinacy may be an aggregate outcome of stricter causal processes operating at lower, micro levels." (Hodgson 2004, 178). For example, even though there is a causal correlation between the mean temperature and economic growth, science will not be able to fully grasp this relationship since it does not understand all the causal process working at the micro levels. The best science can do is to offer an explanation based on a stochastic approach.

Also, by accepting a stochastic approach to determinism, acknowledging unknown variables, is a rejection of climate determinism in an absolute sense. This is to say that other factors independent from climate is of importance as well, i.e. countries with a certain climate are not doomed to poverty. Hence, despite the fact that climate matters, ceteris paribus, good policies and institutions that take climate into account can spur economic growth.

The thesis argues that it is important to be well aware of the difficulties in explaining causal relationships and that, in social sciences, it is impossible to be aware of all the causal factors determining an outcome. Statistical methods and interpretation of the data collected will only provide one possible interpretation of the causality behind the events. Hence, ontological determinism is accepted whereas epistemological determinism is rejected for the purpose of the thesis.

To be able to distinguish coincidence from cause and avoid a *post hoc ergo procter hoc* logical fallacy, a hypothesis-testing approach is adopted in line with the scientific methodology proposed by Hume (Drakopoulos and Torrance 1994, 179). Only by explaining the mechanisms and principles that are assumed to govern the causality it can be established that the correlation found is causal. That is not to say that any reasonable hypothesis with statistical evidence supporting it is per definition true; for every observed phenomenon a multitude of explanations can be thought of. Therefore, no single thesis or paper in social science will give the complete answer to a research question; it is the re-visitation and questioning of old theories and debate over new ones that enriches the knowledge of social phenomena.

2.2. Hypothesis 1 - Climate and Economic Growth

The first hypothesis is that France has the optimal climate for economic growth, which is the implicit implication from Montesquieu's climate theory. Hence the aim is to study, on both a theoretical an empirical level, the correlation between climate and economic growth.

For the purpose of this thesis, the part of *The Spirit of the Laws* that is dedicated to the discussion on climate is of interest; Montesquieu argues that the climate affects the temper of the mind and passions of the heart (Montesquieu 1990, 102). The idea that Montesquieu presents is that climates colder and warmer than France will adversely affect the character of the people and thus the organization of society and, in effect, the potential for economic growth. People in cold climates are, according to Montesquieu, likely to be bold, phlegmatic and lack cunning. Conversely, people in warm climates are, following the same reasoning, more prone to temporary pleasures and lack the ability to adequately plan for the future (Bok 2010). In the temperate zones, where Montesquieu lived, the climate does not have any of the adverse effects from cold and hot climate. This implicitly means that temperate climates like that in France are best suited for economic growth, since neither phlegm nor spendthrift can reasonably be expected to promote growth.

Even though Montesquieu does not write about economic growth in particular, but rather on how the climate affects political and social institutions, it is reasonable to assume that if Montesquieu is right the same climatic factors that leads to social order, and a well functioning political system also facilitates economic growth. In this thesis Montesquieu's theory will be interpreted as meaning that any absolute difference in mean temperature from France will adversely affect economic growth. The thesis puts this interpretation of Montesquieu's theory against a modern theory that claims that an increase in the mean temperature has unfavourable effects on economic growth. If the modern approach is correct, the mean temperature variable will show a stronger correlation than the absolute temperature difference from France, rendering the rejection of the first hypothesis. If a significant correlation between mean temperature and growth is prevalent other factors have to be thought of. The next subsection will present an alternative view of how climate can affect the society and its economic growth.

Figure 2

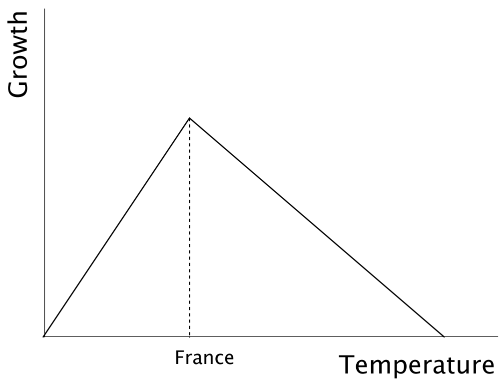
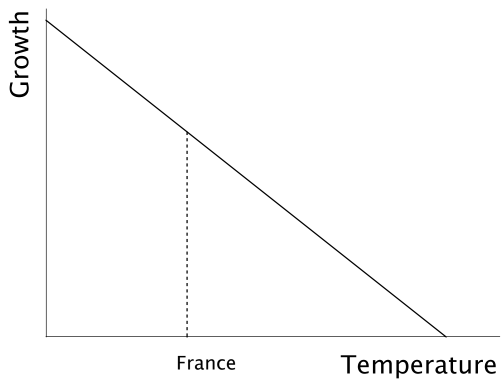


Figure 3



To illustrate the theory behind the hypothesis two figures are provided. Figure 2 shows the implication of Montesquieu's theory, namely that temperatures like that in France will provide the highest economic growth rates, and a higher temperature difference from France implies lower growth. Figure 3 shows the alternative to this hypothesis where there is a constant negative linear correlation between temperature and growth.

It is worth noting that the orientalist view is very pertinent in Montesquieu's ideas on climate. This thesis aims to empirically test and critically review the arguments of this theory. Hence, even though the empirical results would confirm Montesquieu's thesis linking economic growth to temperature difference from France, the theory explaining the causal relationship is still flawed and need to be remodelled. The theory, as originally proposed, is based on assumptions and dubious scientific methodology as mentioned in the previous subsection of this chapter.

2.3. Hypothesis 2 - Disasters and Disease as Growth Determinants

The second hypothesis is that climate related natural disasters and diseases are important causal mechanisms through which climate affects economic growth. The analysis is based on the empirical results of the statistical analysis conducted in the thesis and the literature on the subject. Two types of variables will be tested statistically. First, natural disaster variables such as droughts, floods, wild fires and epidemics are tested. Secondly, a variable for malaria ecology is applied.

The choice to use natural disaster variables and malaria ecology is based on the idea that certain types of natural disaster will negatively affect factors such as human capital, fixed capital and productivity in a country. Early growth theories, such as the augmented Solow model, have traditionally focused on the accumulation of human and physical capital and productivity. The second hypothesis takes the Solow model as given, but expands the scope of the study to propose explanations to why some countries have succeeded to accumulate more capital and increase the total factor productivity more than others. Total factor productivity is referring to the efficiency by which an economy utilises the factors of production, such as physical capital, human capital and labour.

Epidemics and malaria risk may have negative effects on a country's productivity. If the population of a country is repeatedly hit by epidemics and/or is subject to widespread malaria it has negative consequences on their productivity. Furthermore, high rates of mortality and morbidity lead to fewer productive work hours in the labour force. Also it is possible that disease have adverse effects on the incentives to invest in human capital. If large parts of the population cannot use their full productivity potential because of early death or illness, the benefits of human capital investment are likely to be lower, thus generating less investment. However, there are several pitfalls when studying the impact of epidemics on economic growth. The spread of several diseases is caused by poverty rather than being a cause of it. Therefore it is important to be cautious about reverse causation when studying the correlation between these two variables.

Floods, droughts, and other natural disasters are here assumed have a negative impact on the agriculture production in a country. The occurrence of natural disasters can in some cases ruin a year's harvest. In economies that are dependent on agriculture this have serious consequences on economic growth. Hence, a correlation between economic growth and natural disasters channelled through agricultural productivity decreases are expected to be found, particularly in economies that are dependent on agriculture. If returns on agricultural investments are uncertain, incentives to invest in fixed capital will be limited. The depreciation rate of fixed capital in country that is constantly over-flooded or exposed to droughts can therefore be assumed to be higher than normal. According to the augmented Solow model this means that a country exposed to this type of natural disasters will need a higher savings rate to keep the fixed capital constant.

3. The Model

To test the hypotheses put forward in the previous chapter a statistical approach will be used in combination with an analysis of the results obtained in relation to the literature on the subject. The main statistical tools used will be the simple Pearson correlation analysis combined with multiple regression analysis applied on cross country data of growth, and a set of explanatory variables. This chapter describes the method used and assumptions made in the regression analysis as well as explaining the choice and computation of variables used in the statistical analysis.

3.1. Regression Model

In the 1980s the cross-country growth regression became a popular tool for operationalizing economic growth theory. Even though a vast literature has emerged since the 80s there are still a lot of uncertainty regarding the admissibility of the results, and certainly no consensus on specification and methodology. One problem is the constraints posed by the lack of data, especially evident in the 80s and 90s (Durlauf, Johnsson, and Temple 2009, 1120). The sample is limited to the number of countries in the world and, although new countries have emerged in the post-world war II era, this will most certainly pose a constraint in the foreseeable future. A large number of variables have been suggested to affect growth and, even though many of them are proxies for the same underlying phenomena, there are still a vast number of factors suggested to be significantly affecting growth. A good summary of empirical growth studies can be found in Durlauf, Johnsson and Temple (2005, Appendix B).

The model have since the 80s been of the same basic form with the long run average growth rate as the dependent variable and a set of explanatory variables, assumed to linearly affect growth, on the right hand side (Kalaitzidakis, Mamuneas, and Stengos 2002; Levine and Renelt 1992) Most papers include a set of variables that are used in all regressions, since they are predicted by the Solow model to have a significant correlation with growth. One problem, though, is that all empirical papers do not include the same control variables. A survey done by Levine and Renelt show that out of 41 empirical studies only 29 include population growth and 33 include the investment share (1992, 945).

The failure of influential studies such as Barro (1991) and Sala-i-Martín (1997) to argue for why variables such as population growth are excluded, is limiting their reliability, since growth regressions are sensitive to specification (Kalaitzidakis, Mamuneas, and Stengos 2002; Levine and Renelt 1992). From the regressions conducted for the purpose of this thesis it can be concluded that the significance of the other explanatory variables are affected by the inclusion or exclusion of, for example, population growth.

In this thesis, a neoclassical approach will be used. The model is based on the method explained in Durlauf, Johnsson and Temple (2009, 1125-1128) where convergence is assumed at a constant rate giving an expression for growth that reads:

Equation 1

$$\gamma_i = g + \beta \log \tilde{y}_{i,\infty} + \beta \log A_{i,0} + \beta \log y_{i,0} + \nu_i$$

Where g is the growth rate in worldwide technology, $\tilde{y}_{i,\infty}$is the steady state value of output per effective worker, $A_{i,0}$ is the initial level of factor productivity and $y_{i,0}$ is the initial level of per capita income. The error term is denoted as ν_i.

The Solow model augmented with human capital will serve as an indication of the steady state level of income, as used in Mankiw, Romer and Weil (1992). This steady state level can be represented as:

Equation 2

$$\tilde{y}_{i,\infty} = \left(\frac{s_{K,i}^{\alpha} s_{H,i}^{\phi}}{(n_i + g + d)^{\alpha+\phi}} \right)^{\frac{1}{1-\alpha-\phi}}$$

Where $s_{K,i}$ is the investment flow into real capital, $s_{H,i}$ is the investment in human capital, n_i is the population growth, g is the total factor productivity growth and d is the depreciation rate of capital. The sum of g+d is assumed to be constant across countries in accordance with the Solow model, and is estimated to equal 0.05 based on data from the US (Mankiw, Romer, and Weil 1992, 413f).

Assuming that the particular variables of interest, excluding the Solow steady state variables, affect growth through influencing the initial level of factor productivity or the steady state growth of productivity, the model can be expressed as:

Equation 3

$$\gamma_i = \beta_1 + \beta_2 \log y_{i,0} + \beta_3 \log(n_i + g + d) + \beta_4 \log s_{K,i} + \beta_5 \log s_{H,i} + \beta_6 X_i + \varepsilon_i$$

X_i is a vector of variables that are believed to affect growth. For a further development of this model please refer to Durlauf, Johnsson and Temple (2009, 1125-1128). The model is estimated using Ordinary Least Squares (OLS) and heteroscedasticity robust standard errors are used where the null hypothesis of homoscedasticity can be rejected, using the regular White's test.

The reason for choosing an augmented Solow model for the regressions in this thesis is because it has been able to explain much of the difference in income levels across countries, in the influential paper by Mankiw, Romer and Weil (1992, 432). It has also been widely used in the growth literature, making comparisons between results easier, although problems arise when some fundamental variables such as population growth have been excluded in various studies.

By clearly stating a model to follow, the ambiguity that arises when different researchers use different control variables is avoided. The model is certainly not perfect, especially since a problem of endogenity arises. In order to establish a causal relationship from, for example, population growth to economic growth there must be good cause to regard the population growth as exogenous to economic growth, which is a very strong assumption. Furthermore, there might exist significant co-linearity between variables such as investment in human capital, most easily approximated by education, and population growth, or between the initial level of income and the investment share of GDP.

The problem is accentuated by the fact that there is cause to assume that the specific vector of X-variables used is affecting growth not only through total factor productivity, but also by determining, for example, the investment in human capital. A high risk of Malaria might not only reduce the productivity of the human capital stock of the economy, but also reduce incentives to accumulate human capital through education since it lowers the expected financial return to education.

It is worth pointing out that a high statistical significance for a relationship only tells the researcher that there exists statistical significance. To make claims of causality, a plausible mechanism needs to be put forward to explain why a statistical relationship is causal.

3.2. Choice of Variables and Sample

3.2.1. Sample

The sample consists of 123 countries from which GDP and education data is available since 1970 in the Penn World Tables and the Barro-Lee data on education. This criterion is based on the necessity to use long-term growth rates in order to approximate a steady state rate. Using the average economic growth over the 39 years between 1970 and 2009 reduces the risk of capturing short-term fluctuations in the growth rate in a systematic way. Arguably, it would be preferred to average an even longer period, but that would reduce the sample size and the data quality significantly, making it harder to draw general conclusions from the regression model. Using a sample size of 123 countries with growth data averaged over 39 years is thus a workable compromise. A list of all countries included is presented in appendix 1.

3.2.2. Dependent Variable

The main dependent variable is the rate of economic growth between 1970 and 2009. It is computed using values for Real GDP per capita (Constant Prices: Chain Series) (Heston, Summers, and Aten 2011) according to the following formula:

Equation 4

$$grwth7009 = \left(\frac{GDP_{2009}}{GDP_{1970}}\right)^{\frac{1}{2009-1970}} - 1$$

In the equation above the growth rate is expressed as a yearly average over the whole period, making comparisons with other data possible.

3.2.3. Control Variables

The control variables used are based on the above model and thus include the log of initial GDP, the log of the investment rate, the log of human capital investment and the log of the sum of population growth, depreciation rate and technological progress.

The variable log_GDP70 is computed from the real GDP per capita level in 1970 from the same Penn World Tables chain series (Heston, Summers, and Aten 2011) that is used to compute the growth variable.

log_INV7009 is the logarithm of the average investment share. The share is computed as the average of the values for investment share of GDP in Penn World Tables (Heston, Summers, and Aten 2011), over the entire period. It can be expressed as:

Equation 5

$$\text{log\_}INV7009 = \log \frac{1}{2009-1970} \sum_{t=1970}^{2009} ci_t$$

The variable log_NGD is computed using the average population growth derived from Penn World Tables (Heston, Summers, and Aten 2011) for the period 1970-

2009 and the assumption explained above that depreciation and technological progress equals 0.05. This gives the following expression:

Equation 6

$$\log\_NGD = \left(\left(\frac{POP_{2009}}{POP_{1970}}\right)^{\frac{1}{2009-1970}} - 1\right) + 0.05$$

Measuring the investment in human capital is a difficult endeavour, the term is very broad and there is no consensus on how to limit it. Human capital can include skills, attributes, experience, values, and health etcetera. Everything that is specific to one individual and improves the productivity can be considered human capital. It is thus hard to measure human capital accumulation; everything from travelling abroad to discover new cultures, to having a hip replacement is an investment in human capital. The need to limit the definition for the practical purposes of statistical inquiries is obvious. The proxy that will be used here is the average years of schooling of a country's population. This is an imperfect proxy of one aspect of human capital investment, but has the benefits of measurability and comparability across countries. The variable used is *average years of total schooling, age 15+* from the widely referred to Barro-Lee dataset (Barro and Lee 2010). It is computed as the logarithm of the average over the period 1970-2009.

Equation 7

$$log\_EDU7009 = \log \frac{1}{n} \sum_{t=0}^{n} TYR_t$$

3.2.4. Temperature Variables

The measure used for climatic circumstances is the mean temperature, which is a plausible proxy for climate. The advantages over using variables for climate zones are the fact that it is one continuous variable capturing a large part of the variation in climate. Using climate zones directly would require several variables leading to a loss in degrees of freedom. The climate zones are also subject to some arbitrariness in their definition leading to problems when it comes to drawing the boundaries, therefore a continuous variable such as temperature has clear advantages since it reflects differences within climate zones as well.

The mean temperature data is retrieved from the Tyndall Centre and refers to an average annual mean temperature computed over the period 1961-1990 (Mitchell et al. 2003). This temperature measure covers the entire geographic area of the country, and it might, therefore, exist large variations within a specific country. It is possible to think of cases such as Canada, where the mean temperature of the entire area is not representative of the mean temperature where people live, but generally countries do not have large variations within them and this is, therefore, a plausible proxy that can be used to operationalize climate differences.

Another variable computed from the mean temperature variable is called absolute difference from France. This variable measures the absolute mean temperature difference from France, which is a specific way to operationalize Montesquieu's climate theory used in the first hypothesis.

3.2.5. Natural Disaster and Disease Ecology Variables

The data on natural disasters is retrieved from the International Disaster Database (EM-DAT). The variables are divided in to four main categories, all with several sub-categories. The main categories are meteorological, hydrological, climatological, and biological disasters. Geophysical disasters are excluded from the set of variables studied because they do not have a connection to climate factors. The different sub-categories are defined as storm, flood, extreme temperature, drought, wild fire, and epidemic. The different sub-categories in turn can be defined even more precisely. For a more exact definition of the variables, please refer to the database (EM-DAT).

The impact of natural disasters is calculated in three different ways. First, total affected refers to the number of people that requires immediate assistance during the crisis. This includes people who need basic necessities such as food, water, shelter, sanitation, and medical assistance in order to survive. Secondly, total deaths are a measurement of the number people that has died directly or indirectly, as a consequence of the disaster. Thirdly, total cost defines the economic impact of the disaster. All variables are measured as a total between the year 1970 and 2009.

To make the data comparable across countries the variables have been divided by the population in the case of deaths and total number of affected and are expressed as a per thousand number, i.e. a value of 200 in the variable *Total affected per 1000 drought (TApMDrought)* implies that 200 people per thousand (20%) was affected by drought between 1970 and 2009. This number might well have a value over 1000 (100%) since a single individual might be affected by drought on several occasions during this period. The total cost variables are divided by the GDP in the end of the period in the same fashion to create cross-country comparability.

These variables are not perfect in the sense that they are completely exogenous to the income level; a rich country will have a lower death toll for a given natural disaster because of better precautions, such as flood barriers and emergency healthcare. However, since the income level is used as a control variable in all regressions, the coefficients and standard errors for these disaster variables will be reflecting the difference in the variance of growth that the disaster variables account for holding the income level constant.

The malaria ecology variable, called ME, is sourced from (Sachs 2003, 7) and is calculated using the conditions that determine the risk of malaria, such as climatological characteristics and species abundance. It is calculated on a disaggregated level and then averaged for the whole country. It reflects the underlying risk of malaria rather than the number of people affected which makes it exogenous to income level and amount of protection.

A list of all the variables used is presented in appendix 2.

4. Empirical Results

This part empirically test the theoretical framework outlined previously. The aim of the testing is twofold. First, the correlation between economic growth and temperature is established. Secondly, using a method of multiple regression analysis the mechanisms through which temperature is affecting economic growth are established.

4.1. Climate and Economic Growth

The first part of the hypothesis is a correlation analysis of economic growth and income level on the one hand, and the absolute temperature difference from France and mean temperature on the other hand. This simpler form of analysis helps to establish the relationship between the variables of interest.

Table 1

Correlation matrix

Meantemp	Absdiff.france	grwth7009	log_GDP70	
1	0.7641	-0.2727	-0.4673	**Meantemp**
	1	-0.2417	-0.3914	**Absdiff.france**
		1	0.0565	**grwth7009**
			1	**log_GDP70**

Correlation Coefficients, using the observations 1 - 123
5% critical value(two-tailed) = 0.1771 for n = 123

Note: This matrix shows the Pearson correlation between income, growth, mean temperature and absolute temperature difference from France.

In the correlation matrix (Table 1) both the mean temperature and the absolute temperature difference from France are studied against the average annual growth rate and log_GDP70. The matrix shows a negative correlation between both mean temperature and absolute temperature difference from France on the one hand, and grwth7009 and log_GDP70 on the other hand. However, the negative correlation between mean temperature and the two income variables is more significant. Hence, the correlation between absolute temperature difference from France and the income and growth variables capture part of the correlation that is derived from mean temperature. Conclusively it can be inferred that temperatures lower than in France do not adversely affect growth in the same way as temperatures higher than in France. This contradicts the predictions of Montesquieu's climate theory.

In the next step the test is expanded from the simple correlation analysis to a multiple regression analysis. In this model average growth is the dependent variable, and log_GDP70, log_INV7009, log_NGD and log_EDU7009 represents the independent variables. In addition to these growth determinants suggested by the augmented Solow framework, the absolute temperature difference from France and mean temperature are brought in as the X_i vector.

Montesquieu's theory, and the first hypothesis of the thesis, is accepted if absolute temperature difference from France has a higher significance than mean temperature.

The results of the multiple regression analysis are shown in Table 2. All of the variables predicted to affect growth by the augmented Solow model show significance at a five per cent level. Although, none of the temperature variables are significant, the mean temperature is more significant than the absolute temperature difference from France, implying that the same conclusion drawn from the simple correlation matrix seems to hold even in an OLS multiple regression estimation.

To illustrate the sensitivity of the specification, regression 3 and 4 have been estimated without the variable log_NGD, which includes population growth. Then mean temperature shows significance at a five per cent level, whereas the absolute temperature difference from France only shows significance at a ten per cent level. This indicates that there is reason to suppose that a large part of the true correlation between mean temperature and economic growth is reflected by the partial correlation between temperature and population growth. In regressions 5 and 6 (Table 3), where log_NGD is the dependent variable and log_GDP60, log_EDU7009 and the two temperature variables are used as independent variables, it is clear that population growth can be predicted to a large extent by the mean temperature. The income variable used, log_GDP70, is not significant in regressions 5 and 6 and thus it is more likely that the possible causality goes from temperature through population growth to income rather than income affecting population growth. Mean temperature or absolute difference from France shall therefore not be regarded as insignificant determinants of growth. Since mean temperature showed the strongest significance in its correlation with growth the variable will be used in the next section, where the possible disaster variables by which mean temperature may affect growth are tested.

Table 2

Dependent variable:	**grwth7009**			
Regression number:	**(1)**	**(2)**	**(3)**	**(4)**
	OLS	OLS	OLS	OLS
const	-0.07887**	-0.08567**	0.01245	0.006992
	[0.0337]	[0.0185]	[0.4573]	[0.6616]
log_GDP70	-0.006382**	-0.006263**	-0.006124**	-0.005909**
	[0.0001]	[0.0002]	[0.0004]	[0.0005]
log_EDU7009	0.01053**	0.01067**	0.01442**	0.01486**
	[0.0078]	[0.0071]	[0.0002]	[0.0001]
log_INV7009	0.01432**	0.01446**	0.01259**	0.01275**
	[0.0001]	[0.0001]	[0.0006]	[0.0006]
log_NGD	-0.03334**	-0.03464**		
	[0.0064]	[0.0050]		
Meantemp	-0.0001849		-0.0004235**	
	[0.3758]		[0.0316]	
Absdiff.france		-0.0001817		-0.000545*
		[0.5447]		[0.0534]
n	123	123	123	123
Adj. R-squared	0.3321	0.3297	0.2941	0.2888

p-values in brackets
* indicates significance at the 10 percent level
** indicates significance at the 5 percent level

Note: This table shows the result of 4 regressions with GDP growth as the dependent variable and the Solow control variables along with temperature variables as independent variables.

Table 3

Dependent variable:	**log_NGD**	
Regression number:	**(5)**	**(6)**
	OLS	OLS
const	-2.580**	-2.525**
	[0.0000]	[0.0000]
log_EDU7009	-0.09872**	-0.1039**
	[0.0008]	[0.0001]
log_GDP70	-0.01117	-0.01336
	[0.4553]	[0.2777]
Meantemp	0.007074**	
	[0.0001]	
Absdiff.france		0.01043**
		[0.0000]
n	123	123
R-squared	0.4829	0.4896

p-values in brackets
* indicates significance at the 10 percent level
** indicates significance at the 5 percent level

Note: This table shows the results of two regressions with log_NGD as the dependent variable and is used to test how population growth is affected by income, education and temperature.

4.2. Disasters and Disease as Growth Determinants

The second hypothesis test, establish the processes through which the climate affects economic growth. As before, the model used will be the augmented Solow model plus mean temperature. In addition to these variables various natural disaster variables correlated with growth are also included, along with the ME variable. The theory behind this hypothesis is based on research that shows that climate influences the risk for natural disasters, particularly floods, droughts, epidemics, and malaria risk (see theory chapter for a full account of the subject).

First, a correlation analysis of temperature and the different disaster variables is made. The reason for this is to establish the correlation between the different independent variables. Secondly, the independent variables are tested against average economic growth in a multiple regression analysis. By adding the natural disaster variables to the growth model suggested by Solow it is possible to se how they, ceteris paribus, correlate with growth. If these variables in turn are correlated with mean temperature, and have the same sign in the regression model it is possible to assume that mean temperature affect growth through the variable at hand.

Table 4 shows which variables are significantly, at a five per cent confidence level, correlated with mean temperature. Disease, flood and drought are positively correlated, whereas costs for wildfires and deaths from extreme temperature are negatively correlated. To determine how these variables affect growth all variables with significant Pearson correlation were entered into a multiple regression model as the X_i vector together with mean temperature. The results are shown in Table 5 regression 7, where none of the variables entered showed significance. By stepwise elimination of the least significant variables, a p-value over 0.2, regression 8 was estimated. In this model, both total affected by drought and malaria ecology showed significance, although the malaria ecology is just outside the 5 per cent significance level with a p-value of 0.0588.

Table 4

Pearson Correlation Table - Meantemp

5% critical value = 0.1786
Red fill= Significant negative correlation
Green fill = Significant positive correlation

0.1071	**DpMDrought**
0.345	**DpMEpidemic**
-0.2959	**DpMExtremetempe**
0.1367	**DpMFlood**
0.0187	**DpMMassmovement**
0.1237	**DpMStorm**
-0.129	**DpMWildfire**
0.2168	**DpMTotal**
0.2586	**TApMDrought**
0.1293	**TApMEpidemic**
-0.0821	**TApMExtremetemp**
0.2105	**TApMFlood**
-0.0353	**TApMMassmovemen**
0.1662	**TApMStorm**
0.0586	**TApMWildfire**
0.3316	**TApMTotal**
0.0267	**TCGDPDrought**
-0.0255	**TCGDPExtremetem**
0.0745	**TCGDPFlood**
0.0005	**TCGDPMassmoveme**
0.167	**TCGDPStorm**
-0.2325	**TCGDPWildfire**
0.0433	**TCGDPTotal**
0.4791	**ME**

The high significance of the TApMDrought variable indicates that there is a negative relationship between drought and economic growth, a correlation that is channelled through mean temperature, which is shown in the correlation between drought and mean temperature in the simple Pearson correlation table (Table 4). As argued in the analysis chapter below, drought affects growth negatively mainly by reducing agricultural productivity.

It is also worth noticing that the education variable is rendered insignificant at a 10 per cent level in the final regression (8) from being significant at a 1 per cent level in the first four regressions. This can signify the negative effect that malaria is assumed to have on human capital accumulation.

Table 5 – Continued on next page

Dependent variable:	grwth7009	
Regression number:	(7)	(8)
	OLS	OLS
const	-0.04715	-0.06971**
	[0.2546]	[0.0298]
Meantemp	-0.0002087	
	[0.3801]	
log_GDP70	-0.007436**	-0.006956**
	[0.0003]	[0.0000]
log_EDU7009	0.008363*	0.006635
	[0.0776]	[0.1119]
log_INV7009	0.01524**	0.01481**
	[0.0001]	[0.0000]
log_NGD	-0.02620**	-0.03343**
	[0.0449]	[0.0029]
TCGDPWildfire	-0.09057	
	[0.3130]	
TApMTotal	-1.03E-06	
	[0.7489]	
TApMFlood	2.97E-06	
	[0.5024]	
TApMDrought	-2.38E-06	-3.247e-06**
	[0.5074]	[0.0393]
DpMTotal	0.0006953	
	[0.4130]	
DpMExtremetempe	0.002931	
	[0.8586]	

DpMEpidemic	-0.001867	
	[0.7114]	
ME	-0.0004093	-0.0004975*
	[0.1522]	[0.0588]
n	121	121
Adj. R-squared	0.3422	0.3603

p-values in brackets
* indicates significance at the 10 percent level
** indicates significance at the 5 percent level

Note: This table shows the results from two regressions with GDP growth as the dependent variable along with the control variables and natural disaster variables as independent variables.

5. Analysis

The analysis brings the theoretical framework and the empirical results together, and aims to answer the research questions of the thesis. In doing so, it provides an analysis of the causal links between mean temperature and economic growth.

5.1. Does France have the Perfect Climate?

The first hypothesis emanated from Montesquieu's theory of France constituting the perfect environment for human and, in turn, economic development. As expected, this theory has little support in the empirical data. Instead, a stronger correlation between mean temperature and economic growth was found. A quick look on the distribution of wealth also supports these findings. The Nordic countries in both Europe and North America are among the richest countries in the world, even though their climate should promote 'phlegm' according to Montesquieu (Bok 2010).

5.2. A Note on Population Growth

Other mechanisms than those described by Montesquieu must be established to explain the correlation between temperature and growth present in the data. The multiple regression models show no significant result when population growth is used as a control variable, but omitting this control variable a large significance was found. Thus, it is possible that population growth, which theoretically affects growth and income in a multitude of ways in all neoclassical growth models, is one of the mechanisms that needs to be studied. A formal theoretical treatment of what determines population growth is not included in this thesis and should be studied more thoroughly in future research. What is clear, though, is that population growth changes over time and this can lead to further rejection of climate determinism in an absolute sense; accepting that other factors independent from climate contribute to determine both population and GDP growth.

Another possibility in this case is that an unknown variable affects both economic growth and population growth. A possible candidate is the quality of institutions, which is argued by Rodrik, Subramanian and Trebbi (2002). This argument assert that geography, i.e not climate specifically, affects institutions that in turn affect growth. Institutions may affect population growth in several different ways, the extreme example here being China; where the law is limiting the number of children allowed per woman.

A possible link is also the effect climate, and specifically natural disasters and disease ecology, have on mortality. High child mortality may incentivise parents to have more children to the extent that it actually over-compensates for the high mortality. If this is proven to be true, the growth determinants discussed below, namely droughts and malaria ecology have an even stronger negative effect on growth than is shown in the final regression.

5.3. Causal Mechanisms

In the results from the second hypothesis test it can be found that particularly two climate related variables are significantly correlated with growth; drought and malaria. Arguably this correlation is of a causal rather than coincidental nature and possible explanation mechanisms will be explored below.

5.3.1. Climate and Agriculture

Kamarck points out that a tropical climate affects the soil, which in turn adversely influences agricultural productivity (Kamarck 1976). Building on these findings this thesis proposes mainly two channels through which mean temperature affects agricultural productivity: drought and frost, although, frost is not tested in the empirical section.

The connection between drought and high mean temperatures is obvious, and even though high mean temperature is not the only factor causing drought it is an important one. The relationship between drought and economic growth is more complex. In the first instance, droughts lower the productivity of the agricultural sector, weakening the economy as a whole, through multiplier effects discussed in the end of this subsection. Thus, developing countries, more often dependent on agriculture, are more vulnerable to droughts than industrial economies. This view is supported by studies in biology, arguing that a combination of high temperatures and lack of rainfall leads to droughts, which can be seen as one of the major threats to crop yields in the world (Ashraf 2010, 169).

The threat that droughts pose to the agricultural sector in many warm developing countries has increased due to a sustained period of bad land management, which has severely reduced the capacity for the land to resist natural chocks, such as floods and droughts (Rockström 2003, 1997). This underscores the importance of understanding the environment in connection to human action. If bad land management increases the damages to crops from droughts, good land management would reverse this effect.

The green revolution in the 1940s solved many of the problems connected to agriculture and increased the productivity in the sector. However, despite the technical advances since the 1940s crops' resistance to drought has barely improved, and it therefore remains one of the biggest problems for the agricultural sector in warm countries (Ashraf 2010, 170).

In addition to higher exposure to droughts, countries with high temperatures also lack a natural protection against pests and diseases. In warmer countries "[t]he great executioner of nature, winter, is absent." (Kamarck 1976, 17). The absence of frost in many African, South American and South Asian countries, results in a great variety of species. However, this is not all good, a diversity of species also mean more weeds, parasitic fungi, and viruses that attack crops with smaller harvests as a result (Kamarck 1976, 17; Masters and McMillan 2001). The advances of the green revolution solved many of these problems, which significantly increased output. However, most of the African countries never experienced a green revolution, instead the increase in output on the continent has been due to new land exploration rather than a productivity increase (Breisinger et al. 2011, 82).

The argument is supported by the theory developed by William Masters and Margaret McMillan of how frost protects the agricultural sector from pests and diseases. The study concludes that the frequency of frost during the winter months is positively correlated with economic growth and that a major channel for this "could be that seasonal frosts kill exposed organisms, raising the productivity of investment in human capital and in agriculture by selectively reducing competition from pests, parasites and disease vectors." (Masters and McMillan 2001, 182). If their theory is correct it means that northern countries with a colder climate had an economic advantage in the beginning of the industrialization, something that helped the Europe and North America to accumulate human capital and savings (Masters and McMillan 2001, 182).

It is not only the absence of cold temperatures that adversely affect economic growth. Also, high temperatures in combination with humid climate causes organic matter in the soil to break down quickly, depriving it of important nutrients as well as the structure needed to absorb fertilizers and slow erosion (Gallup and Sachs 2000, 734). The need for a new green revolution addressing the problems of the high temperature countries is therefore pertinent.

High mean temperature in combination with unevenly distributed rainfalls reduces the soil fertility and formation. Hence, the low soil-water ratio in large parts of Africa is highly unfavourable for agriculture (Bloom et al. 1998, 221f). The scarce frequency and high intensity of the rainfalls in large parts of the tropics often cause ruined crops (Weischet and Caviedes 1993, 13). Rainfalls are also connected to the frequency of droughts. Lower yearly rainfall together with higher temperatures causes disturbances in the water to soil ratio, and increases the risk for droughts (Bloom et al. 1998, 222). This makes warm countries dependent on irrigation systems to increase crop yields (Gallup and Sachs 2000, 734). Irrigation systems in countries that need them the most are often difficult to put in place and requires big investments.

The mean temperature's effect on the agricultural output in developing countries has adverse consequences on the economy as a whole. The agricultural sector is a crucial part of the economy in many less developed countries, and it is therefore possible that droughts, the absence of frost and poor soil fertility have severe effects not only on agriculture, but on the economy as a whole. The agricultural share of GDP in Sub-Saharan Africa has fluctuated between 15 and 20 per cent between 1970 and 2009, whereas the agricultural share of GDP in the U.S. and the EU has been falling steadily, from around five per cent in the 1970 to less than 2 per cent in 2009 (World Bank 2011).

There are also suggestions that the agricultural sector plays a more important role for the overall economy than the agricultural share of GDP reveals. Recent research on agriculture and economic growth has shown that the agricultural sector can cause multiplier effects and, therefore, has a higher significance on economic growth than its share suggests (Valdes and Foster 2010, 1364). High productivity growth in the agricultural sector can spur overall growth by reducing the number of workers in the agriculture sector, allowing for further urbanisation and industrialisation of a poor country. The effect of droughts on agricultural productivity can reduce the opportunity for overall economic growth, giving rise to a low-income equilibrium where low productivity does not allow for excess income that can be used for investment in agriculture and other sectors.

5.3.2. Disease Ecology

The other finding of the empirical study was a correlation between malaria ecology and economic growth. Malaria is one of the most widely spread diseases in the world with over 225 million cases reported in 2009, and around 800 000 deaths the same year. Around 91 per cent of all cases reported to the World Health Organization have been reported in Africa (WHO 2010, 60). The spread of malaria is to a large extent determined by the ecology of the disease vector and the inherited endemicity of the disease (Gallup, Sachs, and Mellinger 1999, 196).

The failure to contain malaria in particularly Africa is not only due to corrupt regimes and the lack of functioning health care institutions; equally important is the climate of these countries. Other diseases that are distressing poor countries are direct consequences of poverty; malaria, however, does not follow the same pattern (Bloom et al. 1998, 232). In Saudi Arabia, with GDP per capita in 2009 of 14 799 USD, 54 per cent of the population is at risk to be contaminated by Malaria. On the contrary, South Africa, with GDP per capita in 2009 of 5 786 USD, has been highly successful in limiting the spread of malaria (WHO 2010, 46, 114), something that indicates the significance of the government's priorities and international help.

The findings of the empirical analysis conducted in the chapter above have been present in other studies. In their analysis of malaria's effect on economic growth Gallup and Sachs finds that the average growth rate between 1965 and 1990 in countries with severe malaria problems has only been 0.4%, whereas average growth rate in the remaining countries has been 2.3%, more than five times higher (Gallup and Sachs 2000, 1).

Malaria is caused by one-celled parasites belonging to the plasmodium genus often spread through one of the 60 species of the anopheles mosquito. Just as agricultural pests and diseases malaria is easier to control in temperate zones, in winter climates most of the mosquito vectors are killed. In fact, the most efficient malaria vector known, *anopheles gambiae*, only live in sub-Saharan Africa and on the Arabian peninsula (WRBU 2011).

Malaria affects economic growth by reducing the productivity of existing human capital and disincentivising investment in human capital. A high infection rate in a population has negative consequences for a country's overall productivity. If people are infected by malaria for long periods of their lifetime and die early their overall contribution to the economy will be smaller than would have otherwise been the case. The symptoms are a typical example of how total factor productivity is decreased. Out of two workers with the same education, skills and real capital available, a worker infected by malaria will utilise this human and physical capital in a less efficient way, ceteris paribus.

Research has shown that secondary and higher education has significant impact on economic growth. The results indicate that an additional year of schooling increases the annual average growth rate with 0.44 per cent (Lazear and Barro 2002, 17f). If parts of the population are not able to use their education in an equally productive way due to malaria, both the government and the individual will have less of a reason to invest in education than would have been the case if the economy was not beset by malaria.

In economic theory, human capital can be thought of as an investment with benefits and costs. To invest in an extra unit of capital the individual will calculate the cost of that unit of human capital against the value of the future wage stream, i.e. the extra money that will be earned until retirement due to the extra unit of human capital (Polachek and Siebert 1993, 25). In most of the developed countries the retirement age is around sixty-five years of age and people often live longer than that, giving them an extended flow of benefits from educational investment.

In countries where the risk of dying early from malaria is high, the retirement age can be substituted with expected lifetime. For example, if individuals are only expected to work until forty, due to early death and sickness, they will calculate the expected value of future wages and other less tangible benefits from education on a shorter period, not justifying as large an education investment as in countries with high life expectancy. Hence, for individuals to invest in human capital the extra wage for every unit of education must be higher in countries with low low life expectancy, which is rarely the case.

The reasoning at the societal level is similar to that of individuals. Governments will provide an education if the expected returns from having an educated population, through, for example, increased tax revenues, exceeds the costs of schooling. It is worth noting that it is difficult to raise money for human capital through the private market, since education is not a good collateral security for bank loans, as human capital can not be liquidated instantly in the majority of the world's countries that prohibit slave trading (Polachek and Siebert 1993, 47).

Therefore the government must play an active part in providing funding for education, but if malaria decreases the expected return of education it creates a disincentive to invest.

The results from the multiple regression analysis presented in the previous chapter also indicate that malaria affects the significance of the relationship between education and economic growth. The education variable is rendered insignificant at a 10 per cent level in the final regression (8), where ME is included, from being significant at a 1 per cent level in the first four regressions. It is important to note that this result only can be seen as an indication of the causality outlined in previous paragraphs, and more research on the area is needed.

5.4. Policy Implications

The findings of this thesis suggest that climate, although not alone, determines economic development. Hence, it is relevant to ask what policy can do to mitigate the adverse effects that are present in the data. Since the climate of a country is a variable exogenous to the government policy of that particular country, except for the possibility of acquiring land through warfare, it is not possible to do anything on a state level to affect the climate. Wanting to expand the territory for economic growth reasons is not a just cause for war according to international law, which is why this option is disregarded from in this thesis.

Having concluded that the mean temperature is exogenous to a single country the question is not about how to counter high mean temperature, but rather it's adverse effects. To counter the effects of droughts policy makers have to focus on agriculture, an industry particularly vulnerable. Investments have to be made in new drought-resistant crops as well as irrigation systems. It is unlikely that a single sub-Saharan country can make a difference by investing in the development of new crops. However, international private companies and research institutes make investments in drought-resistant crops today. (Ashraf 2010, 170).

Irrigation and water management though is something that can be handled effectively on a national level. It is very hard to establish an efficient market for water, and it is generally plagued by the archetypical tragedy of the commons market failure; *use it or lose it* (Tietenberg and Lewis 2008, 222-229). This means that there will be no incentive for private actors to conserve water in rainy periods and build efficient irrigation systems. Farmers upstream have an impact on those downstream in their decision on how much water to use, if they do not have to pay for their water-usage they will use inefficiently much, provided that the marginal cost, i.e. the marginal benefit to users downstream, is not zero. It is therefore unlikely that upstream farmers will use efficient irrigation systems and downstream farmers might not use irrigation at all since they scarcely obtain any water from the stream. It is thus possible that government intervention can provide solutions that are more efficient than the current ones. By setting up water management systems such as tradable water rights and giving loans and incentives to build efficient irrigation systems, the water can be used more efficiently and saved in dams and aquifers. This will not reduce the number of droughts, but the effects can be mitigated in a substantial way. Thus, the less water that falls over a country the more important it becomes to have a proper water management system without perverse incentives.

Even though malaria has proven to be a difficult to eradicate, there have been some improvements in containing the disease through the implementation of insecticide-treated mosquito nets (ITNs) and indoor residual spraying (IRS). However, both these measures only control the spread of malaria, rather than eliminating the disease. During the last decade WHO has amplified its efforts to distribute ITNs and to increase the use of IRS in high-risk countries, which has led to a decrease in the number of reported malaria cases (WHO 2010, vii). Hence, if preventive policies are put in place it is possible to contain the spread of malaria. Nonetheless, all these policies require massive funding something that is not available in many of the countries beleaguered by malaria. The international community must therefore play an active role in combating malaria.

Another important implication to consider on a global level is the issue of climate change and the possible adverse growth effects it might have. The *Intergovernmental Panel on Climate Change* concluded that anthropogenic climate change is a substantial risk for the future and that a continued global warming might exacerbate natural disasters such as droughts, among many adverse consequences (IPCC 2007, 11f). Given the analysis provided by this thesis this may not only be a direct cost, but might also affect long run growth adversely, which could further increase the total costs of climate change. Hence, global policymakers, who care about promoting worldwide growth, and especially growth in poor economies, should consider this in the cost-benefit analysis of climate change policy.

6. Conclusions

The current wealth distribution of the world has been prevalent for a long time, with rich countries in Northern and Western Europe and poor countries in the south. For millennia philosophers and scientists have developed theories of differences in culture, human character, organisation of the society and economic development in relation to climate. Out of these theories the climate theory developed by Montesquieu has been the focal point and a hypothesis test was developed to study it. The aim of this thesis has been to look at the relationship between climate and economic growth in a modern framework, to discover the climatic factors that influence economic growth. The most significant factors found were droughts and malaria.

No proof was found for the theory presented by Montesquieu, i.e. a climate like that in France is not optimal for economic growth. There is a connection between climate and growth, but factors other than the unscientific assertions Montesquieu made has to be established. The empirical analysis shows that the most significant factors of those studied were droughts and malaria. The analysis points to mainly two mechanisms by which malaria and droughts decrease economic growth. The first and most obvious one is a decrease in total factor productivity, meaning that a high pervasiveness of droughts and malaria lowers the output produced with a given input of factors of production, such as human capital and agricultural land. The second mechanism is a more subtle effect caused by altered investment incentives. By reducing total factor productivity, the returns to investment in for example human capital decrease, and therefore less human capital is accumulated.

It is important to point out that the results presented in the empirical analysis are not final. The regression models are sensitive to specification, and this thesis does not claim to have found the "true" growth model. Instead, it provides a contribution to the plethora of empirical growth studies. Further research on the subject is needed in order to provide a deeper understanding of the growth process in relation to climate and tangible policy recommendations.

The main areas for further research that would contribute to the analysis put forward in this thesis; are the climate's relation to population growth and human capital accumulation. The regression analysis conducted implies that there may be an important connection between temperature and population growth, which would also give significant implications for economic growth. Moreover, the process of human capital accumulation in relation to factors such as disease, total factor productivity and low life expectancy need to be studied in greater depth. In a modern economy where information and creativity become ever more important countries unable to educate their population will fall behind.

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8. Appendix 1

Table 6

Countries		
Afghanistan	Germany	New Zealand
Albania	Ghana	Nicaragua
Algeria	Greece	Niger
Argentina	Guatemala	Norway
Australia	Guyana	Pakistan
Austria	Haiti	Panama
Bahrain	Honduras	Papua New Guinea
Bangladesh	Hong Kong	Paraguay
Barbados	Hungary	Peru
Belgium	Iceland	Philippines
Belize	India	Poland
Benin	Indonesia	Portugal
Bolivia	Iran	Romania
Botswana	Iraq	Rwanda
Brazil	Ireland	Senegal
Brunei	Israel	Sierra Leone
Bulgaria	Italy	Singapore
Burundi	Jamaica	South Africa
Cambodia	Japan	Spain
Cameroon	Jordan	Sri Lanka
Canada	Kenya	Sudan
Central African Republic	Korea, Republic of	Swaziland
Chile	Laos	Sweden
China	Lesotho	Switzerland
Colombia	Liberia	Syria
Congo, Dem. Rep.	Luxembourg	Taiwan
Congo, Republic of	Macao	Tanzania
Costa Rica	Malawi	Thailand
Cote d`Ivoire	Malaysia	Togo
Cuba	Maldives	Tonga
Cyprus	Mali	Trinidad &Tobago
Denmark	Malta	Tunisia
Dominican Republic	Mauritania	Turkey
Ecuador	Mauritius	Uganda
Egypt	Mexico	United Kingdom
El Salvador	Mongolia	United States
Fiji	Morocco	Uruguay
Finland	Mozambique	Venezuela
France	Namibia	Vietnam
Gabon	Nepal	Zambia
Gambia, The	Netherlands	Zimbabwe

9. Appendix 2

Table 7 – continued on next page

Variable	Description	Source[1]
grwth7009	Average growth 1970-2009	Penn World Tables
log_GDP70	Logarithm of GDP/capita PPP in 1970	Penn World Tables
log_EDU7009	Logarithm of average of total years of education 1970-2009	Barro-Lee
log_INV7009	Logarithm of average investment share of GDP 1970-2009	Penn World Tables
log_NGD	Logarithm of average population growth 1970-2009 plus 0.05	Penn World Tables
Meantemp	Average mean temperature, 1961-1990	Tyndall Centre
Absdiff.france	Absolute difference from the average mean temperature in France	Tyndall Centre
DpMDrought	Deaths per thousand by drought	EM-DAT
DpMEpidemic	Deaths per thousand by epidemic	EM-DAT
DpMExtremetempe	Deaths per thousand by extreme temperature	EM-DAT
DpMFlood	Deaths per thousand by flood	EM-DAT
DpMMassmovement	Deaths per thousand by mass movement wet	EM-DAT
DpMStorm	Deaths per thousand by storm	EM-DAT
DpMWildfire	Deaths per thousand by wildfire	EM-DAT
DpMTotal	Deaths per thousand by natural disaster, the sum of all DpM variables above	EM-DAT
TApMDrought	Total affected per thousand by drought	EM-DAT
TApMEpidemic	Total affected per thousand by epidemic	EM-DAT
TApMExtremetemp	Total affected per thousand by extreme temperature	EM-DAT

[1] The variables have been transformed and computed in various ways for the purpose of this thesis, for a description on how and an explanation of why, please refer to the section *Choice of variables and sample*

TApMFlood	Total affected per thousand by flood	EM-DAT
TApMMassmovemen	Total affected per thousand by mass movement wet	EM-DAT
TApMStorm	Total affected per thousand by storm	EM-DAT
TApMWildfire	Total affected per thousand by wildfire	EM-DAT
TApMTotal	Total affected per thousand by natural disaster, the sum of all TApM variables above	EM-DAT
TCGDPDrought	Total cost per GDP of drought	EM-DAT
TCGDPExtremetem	Total cost per GDP of extreme temperature	EM-DAT
TCGDPFlood	Total cost per GDP of flood	EM-DAT
TCGDPMassmoveme	Total cost per GDP of mass movement wet	EM-DAT
TCGDPStorm	Total cost per GDP of storm	EM-DAT
TCGDPWildfire	Total cost per GDP of wildfire	EM-DAT
TCGDPTotal	Total cost per GDP of natural disaster, the sum of all TCGDP variables above	EM-DAT
ME	Malaria ecology	Sachs (2003)