Africa's Growth Tragedy: Does Rainfall Matter?

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[1] The author declares that the text and work presented in this Master thesis is original and that no sources other than those mentioned in the text and its references have been used in writing the Master thesis.

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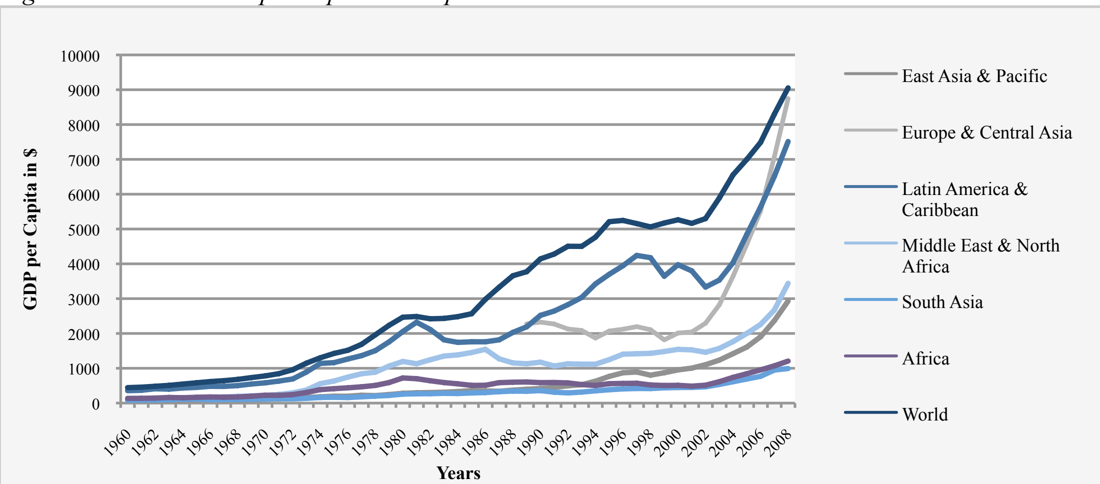
1. Introduction

The growth performance of Africa[4] is one of the most obdurate features of the world's economy (Bloom and Sachs, 1998; Collier and Gunning, 1999). Figure 1 shows the GDP per capita developments for different regions in the world. GDP per capita was more or less the same in the 1960s and until the 1980s there was some optimism about the economic development in Africa (Barrios et al., 2004). However, after the 1980s the economy stagnated in Africa, while in the other regions the economic development increased. This resulted in large differences in GDP per capita in the last decades. For example, in 2008 the average level of GDP per capita for Latin America and the Carribean was around $7,800, while it was $1,050 for Africa. Only South Asia has been following more or less the same development as Africa since the 1960s. Nevertheless, today 16 out of the twentieth poorest countries in the world are located in Africa (Easterly and Levine, 1998; Bloom and Sachs, 1998).

Figure 1 – Global GDP per capita development 1960-2008



Source: World Development Indicators (WDI)

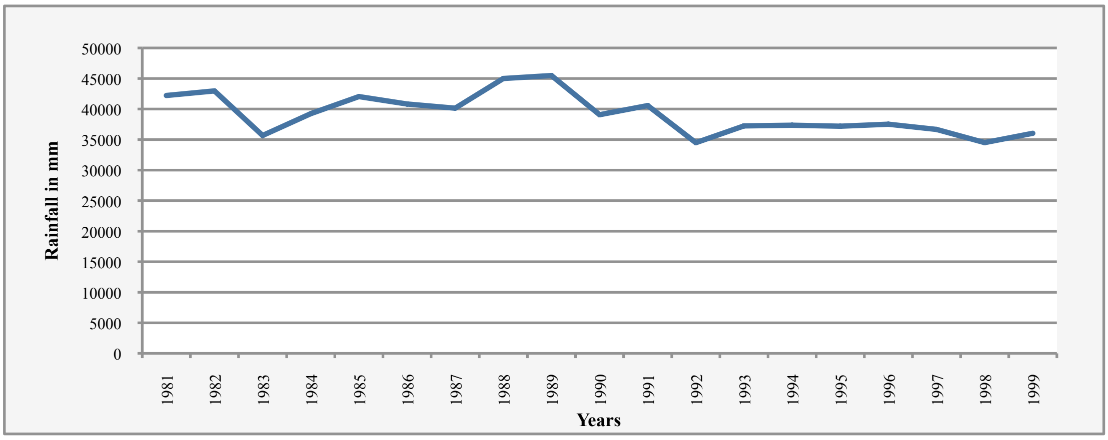
A wide range of research has been conducted to explain why Africa's economic growth performance is so far behind other developing countries. Research point out that factors, like the lack of human capital (e.g. Easterly and Levine, 1998; Artadi and Sali-i-Martin, 2003; Barro et al., 2000), limited access to international markets (e.g. Sachs and Warner, 1997; Artadi and Sali-i-Martin, 2003) underdeveloped financial systems (e.g. Easterly and Levine, 1998; Alfaro et al., 2004; Levine et al., 1997), geographical conditions (e.g. Sachs and Warner, 1997; Bloom and Sachs, 1998; O'Connell and Ndulu, 2000; Villa-Artadi and Sali-i-Martin, 2003), poor policies (e.g Collier and Gunning, 1999; Burnside and Dollar, 2000) and poor infrastructure (e.g. Asiedu, 2001) might explain why Africa's economic growth performance is so far ahead other developing countries. On the other hand, foreign aid (e.g.

[4] When Africa is used, the region North Africa is excluded since this region has a different regional economy and distinctive economic issues. (e.g. Barrios et al., 2004; Fiala, 2009)

Burnside and Dollar 2002; Dalgaard et al., 2004) and foreign direct investment (e.g. Alfaro et al., 2004; de Mello, 1997) did benefit the African economies in a positive way in the last decades.

One other aspect that is more frequently referred to, but empirically less investigated, is rainfall. On a global level, rainfall has increased on average in the last century (New et al., 2001). The case is different for Africa. As is shown in Figure 2, it first increased from 1983 to 1989, but after 1989 it decreased to a point that was lower than its initial level in 1981. This rainfall decline combined with the fact that the African continent is very sensitive to rainfall changes, makes that today around 60% of the African countries are considered to be vulnerable to drought and 30% of the countries are extremely so (Benson and Clay, 1998; IPCC, 2007; Barrios et al., 2004).

Figure 2 – Rainfall development in Africa 1981-1999



Source: Global Precipitation Climatology Project (GPCP)

Therefore it is interesting to survey if the developments of rain may have caused the poor economic growth performance of Africa after the 1980s. Not much empirical research has been done on this topic. Most authors focused on the impact that rainfall has on agricultural production (e.g. Nicholson, 2001; O'Connell and Ndulu 2000; Jury, 2001) and civil conflict (e.g. Miguel el al., 2004). However, it is tempting to see that most of the researches that did investigate the direct relation between rainfall and economic growth found a significant linear relation for Africa but not for other (developing) countries (Barrios et al., 2003; Miguel et al., 2004; Barrios et al., 2004; O'Connell et al., 2000). Only Fiala (2009) finds for a broader set of developing countries that rainfall has a positive influence on an economy, but that too much rain is detrimental.

The aim of this thesis is to investigate the relation between rainfall and economic growth for 41 African countries between 1981 and 1999[5]. Since the relation between rainfall and economic growth is complex it is crucial to consider also nonlinearity's in the model (Fiala, 2009). Dummy variables are used to test whether the effect of rainfall on economic growth differs per geographical region and if it matters if a country is considered to be tropical. This thesis contributes to the rainfall- economic growth literature because of the following. First of all, it is the first time that a non-linear term for rainfall is included for this set of countries[6]. Secondly, it is the first time that this relation is investigated for each geographical region in Africa. And finally, the combination of control variables that are used is new.

By using OLS a parabolic relation between rainfall and economic growth is found for Africa in general. This means that a minor increase in rainfall was detrimental for the economies in Africa, whereas a major increase in rainfall had a positive effect. An opposite effect is discovered for the tropical countries. Also the effects per region differed. Where a parabolic relation is determined in East Africa, the opposite relation seems to hold for Middle Africa. For South- and West Africa no significant results are found.

The reminder of this thesis is organized in the following way. Section 2 provides the theory about the channels in which rainfall affects economic growth. Section 3 describes the data and empirical strategy. Section 4 discusses the main outcomes of the regressions. This thesis ends with a conclusion and implications for further research.

[5] Unfortunately no sufficient rainfall data is publicly available for more recent years and a broader set of countries.

[6] E.g. next to Fiala (2009), Paxson (1992) explores the second order effects of rainfall shocks for savings in Thailand, but not for economic growth. Also Miguel et al. (2004) include a non-lineair term but do not find a significant result.

2. Rainfall Channels

Past research has shown that rainfall has a positive influence on the African economies (i.e. Miguel et al., 2004; Barrios et al., 2003; Barrios et al., 2004; O'Connell et al., 2000). For instance Miguel et al. (2004) conclude that rainfall is positively related to income growth in Sub-Saharan African (SSA) countries, not in the more industrialized countries. Also, Barrios et al. (2004) finds that lower rainfall negatively affect economic growth in SSA countries, but not in the Non Sub-Saharan Countries (NSSA) countries. Furthermore, O'Connell et al. (2000), note that the number of dry years is negatively correlated with economic growth for the African continent. Finally, Dell et al. (2008) do not detect significant results for a broader set of countries. Only, Fiala (2009) finds significant results for a broader set of countries between 1982 and 1999. By including a quadratic term for rainfall he finds for 121 countries that rainfall has a positive effect on an economy, but that too much rainfall may be detrimental for an economy.

Most authors that investigate the relation between rainfall and economic growth note that rainfall affects economic growth through different channels (e.g. Miquel et al., 2004; Dell et al., 2008; Barrios et al., 2004; Barrios et al., 2008; Fiala, 2009; IPCC 2007). These channels are described in the paragraphs of this chapter. Before these channels are described there are two aspects that are important to consider.

First, within these channels there are two different ways in which rainfall affects economic activity. First of all, rainfall can influence the *level* of output in an economy, for example by changing the agricultural yields. Secondly, rainfall may impact an economy's ability *to grow*, for example by affecting investments or institutions that influence productivity growth. In other words, the latter effect describes the more long-run effects that have a persistence effect on the economy and are therefore more severe (Dell et al., 2008; Fiala, 2009).
The second aspect that is important to consider is that the channels are depicted in reduced form and therefore do not identify the complex structural relationships between rainfall, the channels and GDP growth[7]. In fact this section focuses on the net effect that rainfall changes have on the different channels and their implications for economic growth (Dell et al., 2008).

2.1 Agriculture

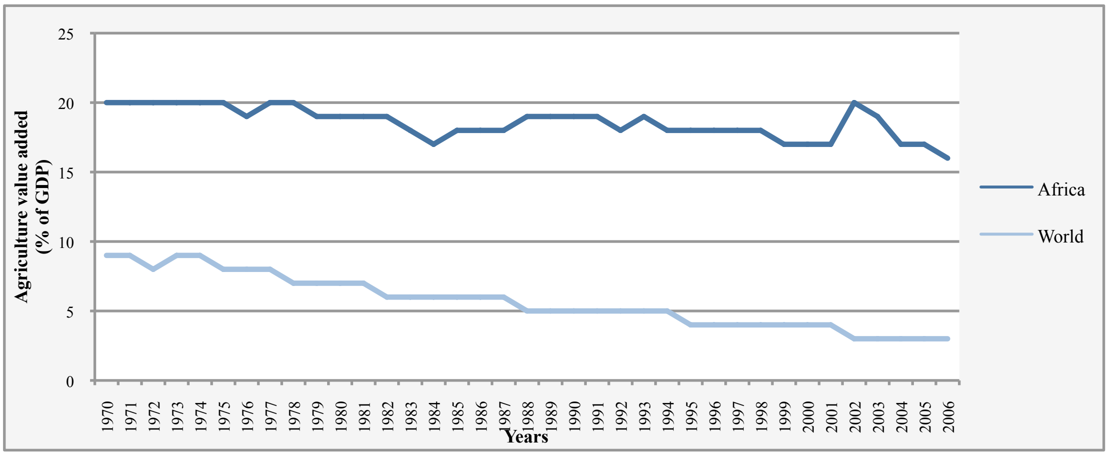
Agriculture is the largest single user of fresh water, accounting for more than 75% of human water use (Wallace, 2000). Rainfall, as the main source of fresh water, has therefore a

[7] E.g. less rain could cause lower agricultural production, with the resulting GDP reduction leading to political instability.

positive impact on agriculture production (Miquel et al., 2004; Dell et al., 2008; Barrios et al., 2004). However, too much rainfall may be harmful (Fiala, 2009).

The agricultural sector has a large impact on economic growth in Africa compared to the rest of the world (Barrios et al., 2008). This is shown in figure 3. As becomes clear, the agricultural sector contributed between 16 and 20 percent of the GDP in Africa between 1970 and 2006, whereas it was only around 3 to 8 percent in the rest of the world. Furthermore, the agricultural sector in Africa employs more than half of the labour force and serves as the main base for food security (Jury, 2001; Barrios et al., 2008). So rainfall has a positive impact on economic growth via agriculture. However, certain aspects on the African continent make that this relation is more complex than one would initially argue. In other words, an increase in rainfall does not necessarily lead to an increase in agricultural production. (Dell et al., 2008) This is because of the following reasons.

Figure 3 – Agriculture value added development 1970-2006



Source: World Development Indicators (WDI)

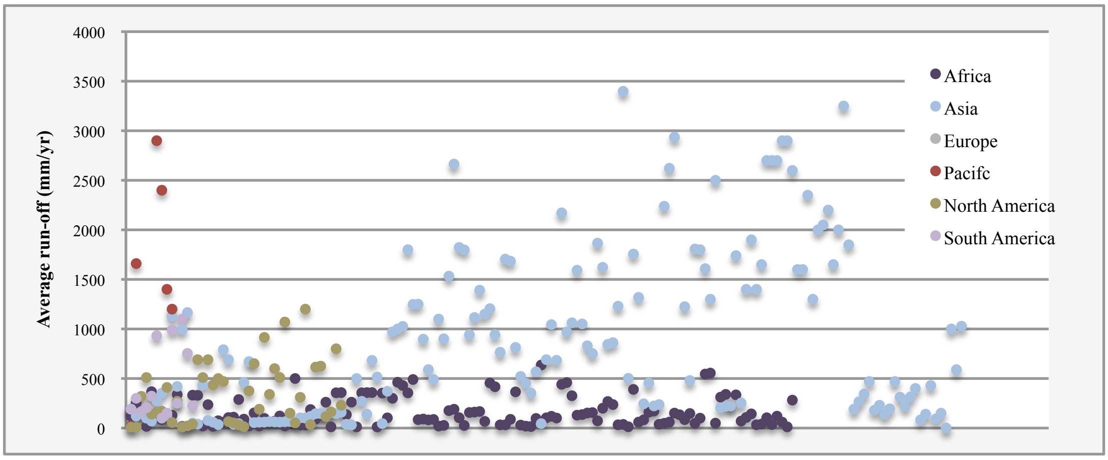
First, Africa has a large variation in the availability of water. This is because of the different geographic and climatic conditions on the continent. While in the tropical areas it rains al year round, the semi-arid and arid areas receive less rain. And particularly in the (semi) arid areas most crop production and livestock are located. This is because in the tropical areas production is hampered due to the high temperature, fragile soils, low yield potential and chronic diseases (Barrios et al., 2008). However, agricultural production is also not optimal in the arid and semi-arid areas. This is because the on average high temperatures reduce the availability of water in these areas. There are two mechanisms why this is the case. First of all, a high temperature leads to a high evapotranspiration rate[8], which in turn lowers the availability of water (Barrios et al., 2004; Barrios et al., 2008). Secondly, due to the high

[8] Evapotranspiration is the amount of water that remains in the soil after what is evaporated and what is transpired by plants as a part of their metabolic process. (Barrios et al., 2004)

temperature there is a drier soil. Since a drier soil absorbs more moisture, less water is left for agricultural production. So an increase in rainfall would not necessarily lead to an increase in agricultural production (Barrios et al., 2008; IPCC, 2007).

Second, although Africa has major water basins and rivers, the run-off[9] from these water sources is particularly low. This is visualized in figure 4. Figure 4 describes the average run-off of the rivers located on the different continents between 1972 and 1979. As becomes clear, the overall level of the average run-off of the African rivers is much lower compared to the rivers of the other continents. This low run-off is caused by the fact that the large rivers in Africa are located in the semi-dry or dry regions but a have their origin in the tropical areas. So although it rains all year round in the tropical areas not much water is left over in the drier regions because of the evaporation losses (IPCC, 2007; Barrios et al., 2004; Barrios et al., 2008; UNESCO, 1999).

Figure 4 – Average run-off rivers 1972-1979



Source: Database of World Rivers and their Sediment Yields, Food and Agricultural Organization (FAO), UN

Third, less than 10 percent of the African continent is irrigated compared to one fifth of the other developing countries. The other 90 percent of the land is rain-fed agriculture (Barrios et al., 2008; Jury, 2001). The issue with rain-fed agriculture is that, as the name already suggests, it heavily depends on rain. So the increase of rainfall should be major to affect agricultural production (Rockström et al., 2003). Fourth, the ability to invest in agriculture by households is limited due to the on average low household income in Africa. So an increase in rain does not affect agricultural production if households are not able to invest (Barrios et al., 2008). Fifth, most of the farmers do not own the land that they work on, due to less established property rights. Therefore, the preservation of the natural resources is seen as a

[9] River run-off includes all the water coming in directly to the hydrological network during rainfall or snowmelt, plus groundwater from the upper aquifers feeding rivers more or less evenly throughout a year. The extent of renewable water resources is estimated from total river run-off. (http://webworld.unesco.org/water/ihp/publications/waterway/webpc/pag15.html)

secondary objective and this could result in deforestation and land deterioration (Barrios et al., 2008). Sixth, since most of the agricultural production is exported, and since most of the African countries are price takers on the world's commodities markets, a loss in production due to lower rainfall has a major impact on income but does not affect the prices for agricultural products. This in turn leads to higher losses for farmers when rainfall decreases (Barrios et al., 2004). Finally, in general adaptation is minimal in Africa compared to for instance the Asian countries[10]. This is because of the high corruption and bad policies in Africa. Therefore in the short run it is not possible for farmers and governments to take the losses associated with rainfall into account in their technologies and production. In the long run this might be possible (IPCC, 2001; Barrios et al., 2008).

2.2 Energy production

The second channel is energy production. Rainfall significantly affects the energy production of a country as energy supply uses water both as an indirect and direct source of energy production (Magadza, 1996; Barrios et al., 2004). For instance hydroelectric power, which is the main source of electricity[11], uses the energy of flowing water to power generating turbines for producing electricity. Also thermal power generation uses water as input for their cooling device (Barrios et al., 2004). These methods of energy production are therefore heavily reliant on rivers as their source of water. But, as is stated before, the African major rivers perform lower compared to other areas in the world. So more rainfall is needed to increase the generation capacity of the energy production.

Furthermore, rainfall may also affect the construction of new and more productive plants (Barrios et al., 2004). When rainfall for example decreases and therefore the return on investment declines large projects will be postponed (Harrison and Withington, 2001).

2.3 Industry value added

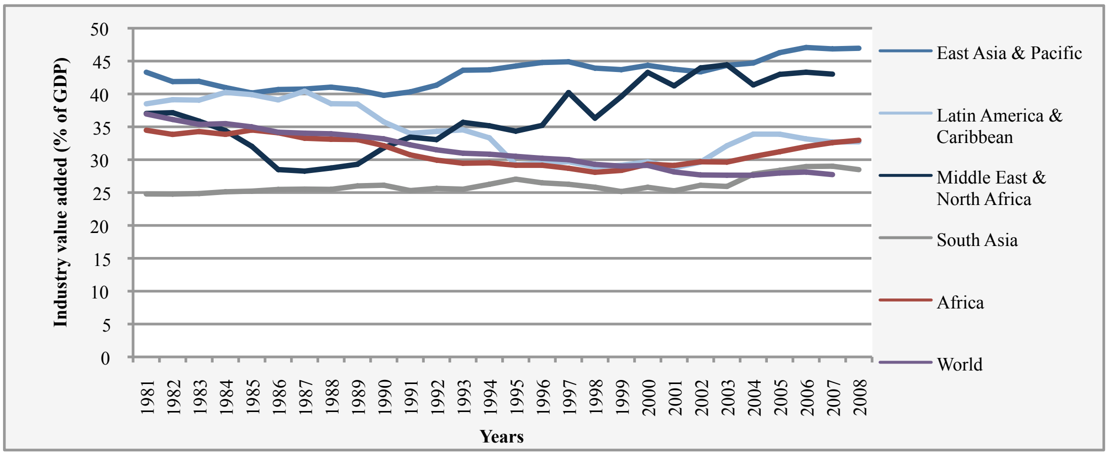
Figure 5 shows the industry value added as a percentage of GDP for six different regions between 1981 and 2008. As becomes clear, industry value added was in between 27 and 35 percent of GDP in Africa between 1981 and 2008. This percentage was on average much lower than most of the other regions. This percentage was only lower in the South Asian countries. So although the percentage of industry value added is much smaller in Africa compared to other regions in the world, it has still a positive impact on economic growth

[10] However, it should be pointed out that adaptation towards long-run changes in Africa is not well understood. (IPCC, 2001)

[11] It represents more than 47% of the total power generation in Africa compared to 34% in other developing countries. (Saundry, 2008)

(Dell et al., 2008; Fiala, 2009). Also, rainfall has a positive influence on industry value added in Africa (Dell et al., 2008). However too much rainfall may be detrimental (Fiala, 2009).

Figure 5 – Industry value added developments 1981-2008



Source: World Development Indicators (WDI)

2.4 Investment

It is widely recognized that investment positively affects economic growth (e.g. Anderson, 1997; Barro and Lee, 1994; Barrios et al., 2004). Theoretically, there is consensus that rain has a positive influence on the level of investment. Moreover it seems that especially in Africa investments are vulnerable to rainfall changes (e.g. Barrios et al., 2004). This is because of the following. First the financial system in Africa is the less developed in the world (Easterly and Levine, 1995). Since this is the case, it is not possible to have a substantial internal flow of resources when rainfall declines. This in turn might lead to a decrease in the overall investment level (Benson & Clay, 1998). Second, the households in Africa have in general a limited insurance capacity, which in turn affect their investments (Cristiansen et al., 2002). This is explained by the fact that when rainfall declines, households increase their precautionary savings in order to smooth their consumption levels, which divert funds from potential investments (Barrios et al., 2004). Empirically, the effects of rainfall on investment are mixed for Africa. For instance Rosenzweig and Binswanger (1993) find that rainfall has a positive effect on the level of investment. They argue that when rainfall declines, farmers tend to invest in portfolios that engage less risk, but are also less profitable. This in turn leads to an overall decline in the level of investment (Rosenzweig and Binswanger, 1993). On the other hand Dell et al. (2008) find a negative relation and Barrios et al. (2004) detect no relation.

2.5 Civil Conflict

The presence of civil conflict has damaging consequences for economic growth (Murdoch and Sandler, 2002; Miguel et al., 2004). Also, rainfall and civil conflict are negatively correlated. In other words, the less rain, the larger the likelihood of a conflict (Miguel et al., 2004; Levy et al., 2005). This relation can be explained by the following mechanisms. First, it is argued that rainfall shortages lead to a decrease in coastal areas and land availability, which could lead to civil conflict over limited resources (e.g. Buhang et al., 2008; Hauge and Ellingsen, 1998; Theisen, 2008). Second, as agricultural production decreases as a result of a rainfall decline, the opportunity costs of participating in a conflict diminishes (Hendrix and Glaser, 2002). The incidence of civil conflict is especially reliable for Africa, because of the low adaptation level due to the many bad policies and high corruption (Barrios et al., 2008; Benson & Clay, 1998).

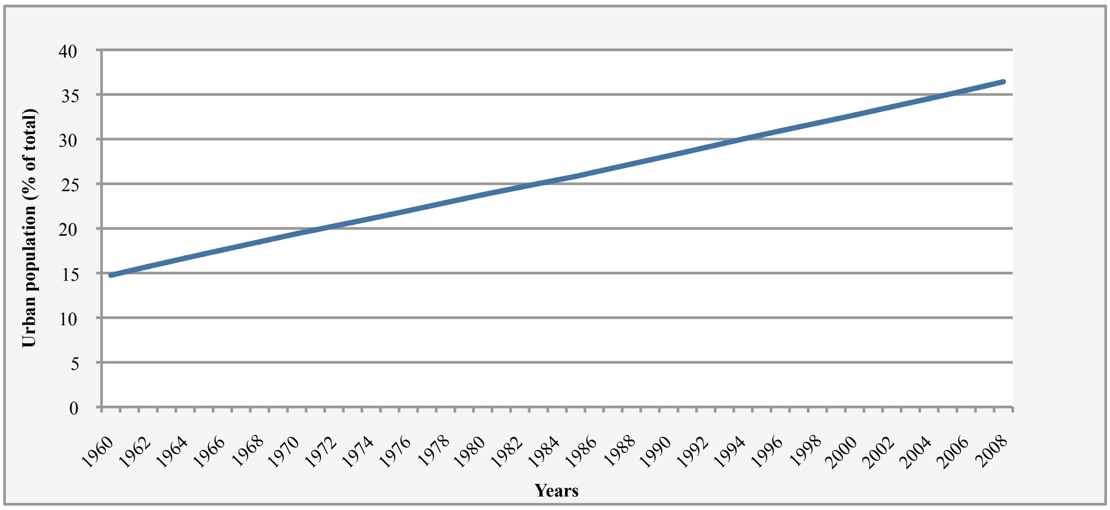
2.6 Population

Rainfall may have severe consequences for the population size, especially in Africa, where adaptation levels are low (Barrios et al., 2004; IPCC, 2007). The consequences of a rainfall decline may be direct or indirect. A direct effect of a rainfall decrease is the starvation and dehydration of a population. For example one of the main droughts in the Sahel between 1968 and 1973 caused 250,000 deaths (Barrios et al., 2004). An indirect effect of a rainfall decrease is the increased risk of malnutrition, water-and food borne diseases and poverty (IPCC, 2007; Dercon, 2001). Another indirect effect of rainfall is inequality. This is because on average people in drier regions are poorer (Cristiaensen et al., 2002).

2.7 Urbanization

Rainfall and urbanization are correlated in a negative way (Barrios et al., 2004). Moreover, if rainfall decreases and therefore the agricultural production declines, urbanization increases. In fact the decline in rainfall has lead to a growth in urbanization of 140% since 1960 (Barrios et al., 2004). This can be seen in figure 6. Figure 6 shows that the percentage of the urban population has increased from 1960 to 2008. This urbanization has a negative impact on the African economy, since, compared to other developing countries, most urban centres in Africa do not serve as engines of growth (David and Golden, 1954; Fay & Opal, 2000).

Figure 6 – Development urban population in Africa 1960-2008.



Source: World Development Indicators (WDI)

3 Data and Empirical Strategy

The channels described in the previous chapter suggest that rainfall growth is an important determinant for economic growth in Africa. This chapter elaborates more on the data and the empirical strategy that is used. The data covers 41 African countries between 1981 and 1999 and the methodological approach is obtained from Fiala (2009). Since the aim of this thesis is to investigate the influence of rainfall on the African economies, first the data, descriptive statistics and simple relation of these two variables will be described. After that, the empirical model will be indentified. Finally, the control variables and the dummy variables will be depicted. The outcomes of the regressions are described in the next chapter.

3.1. Data

3.1.1 Rainfall data

The primary data that are used for this thesis are derived from a number of sources. Appendix A gives an overview of all the variables and the sources that are used. As becomes clear, the main independent variable of interest is rainfall. Since it is difficult to estimate rainfall data, a dataset is used that is obtained by Miguel et al. (2004)[12]. In this dataset Miguel et al. (2004) estimate rainfall data from different sources. The data from the Global Precipitation Climatology Project (GPCP) is preferred since it is the only source that at the same time includes both gauge and satellite data, corrects for systematic errors in gauge measures and rejects gauge measures thought to be unreliable (Rudof, 2000; Miguel et al., 2004). Therefore this thesis also uses rainfall data from the GPCP. The GPCP data are collected from satellites and weather stations at 2.5 latitude and longitude degree grids and are measured in mm of average rainfall per day. To estimate the yearly average rainfall in mm, Miguel et al. (2004) added the daily rainfall to yearly numbers and specified each grid-box per country[13]. By doing this, a panel dataset for rainfall is derived for 41 African countries[14] in a time span between 1981 and 1999. Due to the fact that no other sufficient rainfall data are available, this research has to limit its scope to this limited number of countries and years as well. On aspect in regard to the rainfall measure that is important to note is exogeneity since it hampered many studies that examined other determinants of Africa's poor growth performance. One may argue that economic growth (or the lack of) could affect, through political decision-making,

[12] The rainfall data is from a dataset that Miguel et al. use in their article 'Economic shocks and civil conflict: An instrumental variables approach'. I want to thank Edward Miguel for sharing the dataset on rainfall. For the full dataset please view http://elsa.berkeley.edu/~emiguel/data.shtml.

[13] Where a grid box is located in more than one country, each grid-box is assigned to the country with the largest stage, except where a country would otherwise have been left out with any grid-boxes. (Barrios et al., 2003; Miguel et al., 2004)

[14] The list of countries is stated in appendix B.

aspects as environmental degradation and desertification and therefore the amount of rain. However, Nicholson (1994) does not find evidence for such an effect (Barrios et al., 2003).

3.1.2 Economic data

Data on economic growth are widespread. For this variable GDP per capita in US dollars in constant 2005 prices is used from The Penn World Tables (PWT) version 6.3, which is in line with Dell et al. (2008) and Barrios et al. (2003).

3.2. Descriptive statistics

3.2.1 Africa in total

Table 1 shows the descriptive statistics of rainfall and GDP per capita for the 41 African countries between 1981 and 1999. As table 1 shows, the total amount of rainfall that fell in Africa between 1981 and 1999 amounted 72,9582.20 mm. On average rainfall was 1,007.71 mm a year in this time period, with a minimum of 96,11 mm a year and a maximum of 2,587.64 mm a year. Furthermore, GDP per capita was on average $2,210.64 between 1981 and 1999, with a minimum of $440.64 and a maximum of $10,342.90. So both rainfall and GDP per capita were quite volatile in Africa between 1981 and 1999.

Table 1 - Descriptive statistics GDP per Capita and Rainfall in Africa

	GDP per Capita ($ in constant 2005 prices)	**Rainfall (mm/year)**
Mean	2,210.64	1,007.71
Maximum	10,342.90	2,587.64
Minimum	440.64	96.11
Sum	1,600,502.00	72,9582.20

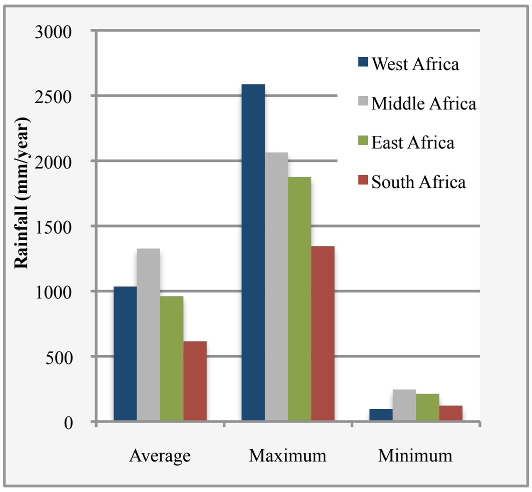
Source: PWT 6.3. and GPCP

3.2.2 Africa in regions

As is mentioned in the previous chapter, the African continent is characterized by different climates. In order to capture the influence of the different climates on the economy, it is important to distinguish Africa into different parts. This paper divides the 41 African countries into four different regions based on the distinction of the United Nations[15]. These regions are West Africa, East Africa, Middle Africa and South Africa. Table 2 of Appendix B gives a full overview of the countries that are included in the four different regions. The region North Africa is excluded because of two reasons. First North Africa is a different region with different economic conditions (Barrios et al., 2003). Second, Sudan is the only country in North Africa that is included in the dataset of Miguel et al.

[15] UN distinction: http://unstats.un.org/unsd/methods/m49/m49regin.htm#africa

Figure 7 – Descriptive statistics rainfall per region.

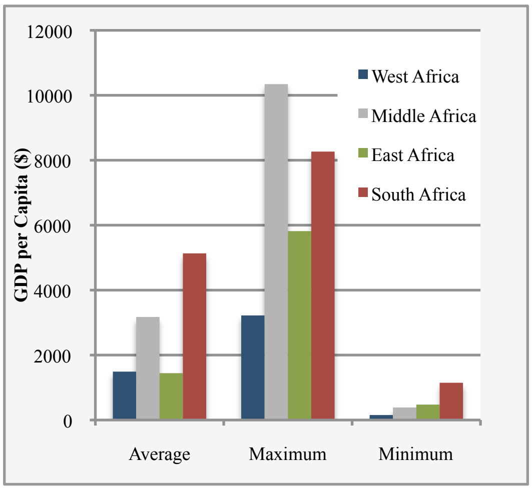


Source: GPCP

Figure 7 and table 4 in Appendix C show the descriptive statistics of the level of rainfall per region during 1981 and 1999. It becomes clear that there is a large difference in climates across the regions. Middle Africa, which is characterized by a tropical climate, had with its average of 1,326.78 mm the most rainfall per year. South Africa, on the other hand has an arid climate. An arid climate receives almost no rainfall (Bloom and Sachs, 1998; Barrios et al., 2004). Therefore it is not surprising that in this region the level of rainfall was the lowest with 615.85 mm per between 1981 and 1999. The amount of rainfall of West Africa and East Africa are in between those regions. West Africa has a semi-humid climate[16] and received with 1,035.63 mm the second largest amount of rainfall per year between 1981 and 1999. On the other hand, in East Africa, rainfall was somewhat lower and was on average 961.58 mm a year. This level is quite high for a region that is characterized by a semi-arid climate[17]. The reason why East Africa received quite some rainfall despite its semi-arid climate is due to the mountains that are located in this area. These mountains receive much more rain compared to the land at sea level (Bloom and Sachs, 1998; Barrios et al., 2004). It also becomes clear from figure 7 and table 4 in Appendix C that in all four regions rainfall was quite volatile across the years. Especially West Africa showed large differences in its maximum and minimum level of rainfall per year. In South Africa on the other hand this difference was much smaller. However, with a maximum of respectively 1,345.26 mm year and a minimum of 121.89 mm, this difference was still quite severe.

[16] A sub-humid climate is characterized by substantial rainfall during the wet seasons, but less rainfall during the much longer dry seasons (Bloom and Sachs, 1998; Barrios et al., 2004).
[17] This climate is characterized by some rain during the wet seasons, but suffers from extreme unreliability and few permanent water sources (Bloom and Sachs, 1998; Barrios et al., 2004).

Figure 8 – Descriptive statistics GDP per Capita per region.



Source: GPCP

Figure 8 and table 4 in Appendix C show the descriptive statistics of GDP per capita. As becomes clear, South Africa had with $5,132.10 on average the highest GDP per capita between 1981 and 1999. Middle Africa was with a GDP per capita of on average $3,172.72 the second richest region. East and West Africa were on average the poorest regions, with GDP per capita of respectively $1,443.21 and $1,490.06.

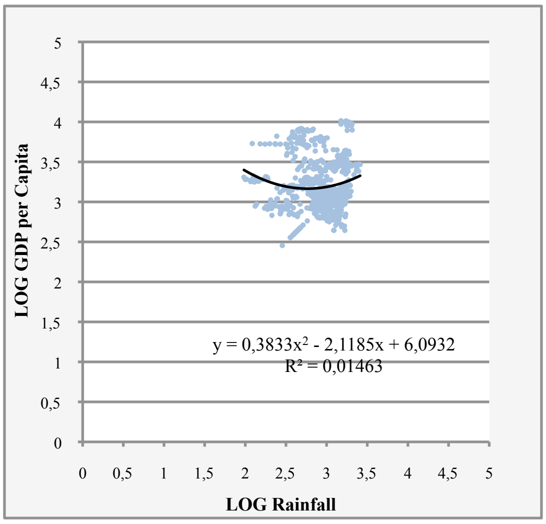
Also the level of GDP per capita was characterized by large volatility across the years[18]. This was especially the case in South Africa and Middle Africa.

[18] This is shown in the large differences in maximum and minimum values of GDP per capita in all four regions.

3.3. Relation Rainfall and GDP per capita

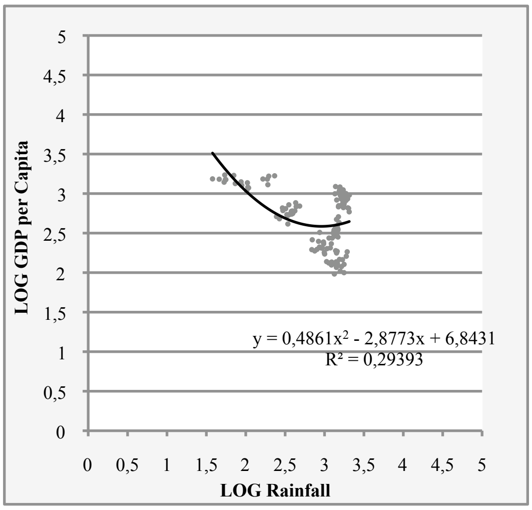
Figure 9 shows a scatter plot of rainfall and per capita in logarithms. Logarithms are used to measure growth, which is in line with Dell et al. (2008). As is shown in figure 9, there is a parabolic relation between the two variables. So, a minor increase in rainfall growth leads to a small decrease in economic growth, whereas a major increase in rainfall growth leads to an increase in economic growth. This finding is contrary to the findings of Fiala (2009). However the R-squared is very low due to large number of outliers. So this could be an indication that the relation lacks statistical power (Pyndyck and Rubinfeld,1997).

Figure 9 – Scatter plot rainfall growth and GDP per Capita growth for Africa.



Source: GPCP and PWT 6.3

Figure 10 – Scatter plot rainfall growth and GDP per capita growth for Middle Africa.



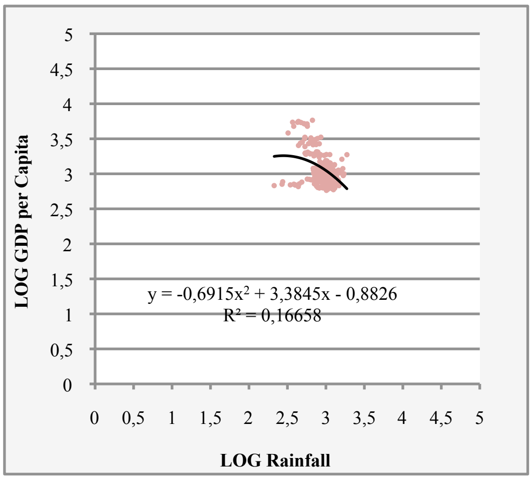
Source: GPCP and PWT 6.3

As is described before, different regions with various climates and economic realities characterize Africa. Therefore it is interesting to view the scatter plots of rainfall and GDP per capita for each region and each country. This is done in Appendix D. Furthermore figure 10 shows the scatter plot for Middle Africa. As becomes clear, rainfall growth and GDP per capita growth are also characterized by a parabolic relation in Middle Africa, in which the negative effect dominates the positive effect. However, this parabolic relation does not hold for all the countries that are located in Middle Africa. As becomes clear from figure 4 of Appendix D, the countries Zaire and Cameroon are characterized by a positive relationship between rainfall growth and GDP per capita growth. West Africa shows the same result as Middle Africa. Also in this region a parabolic relation is shown, which does not hold for all countries.[19] As becomes clear from figure 3 in Appendix D, in the countries Sierra Leone and Liberia in West Africa rainfall growth

[19] This is shown in figure 1 of Appendix D.

has a positive effect on GDP per capita growth. East Africa and South Africa show different results compared to West Africa and Middle Africa. This is seen in figure 11 and figure 2 of Appendix D. In East Africa and South Africa rainfall growth and economic growth are characterized by an inverse parabolic relationship, which is in line with the findings of Fiala (2009). So a minor increase in rainfall is beneficial for an economy, but too much rainfall harms an economy (Fiala, 2009). This outcome should be seen with some caution because of the following. First, the negative relationship dominates the parabolic relationship. This is especially the case in East Africa. Second, some countries within these regions show different results. For instance in Somalia in East Africa there is a parabolic relationship[20]. Third, since it is not possible to show the t-values, it is unknown if the relations are significant[21]. Fourth, the R-squared is very low due to the large number of outliers. So the relationship between rainfall growth and economic growth is quite complex and different per country and region. Therefore it is important to capture all the effects in one empirical model. This model will be described in the next paragraph.

Figure 11 – Scatter plot rainfall growth and GDP per capita growth for East Africa.



Source: GPCP

3.4. Empirical Model

By using OLS the following specification is estimated.

$$Log(Y_{lit}) = \alpha + \beta Log(X_{lit}) + \gamma_1 Log(R_{lit}) + \gamma_2 Log(R^2_{lit}) + \delta_1 Log(R_{lit} * I_{it})$$

$$+ \delta_2 Log(R^2_{lit} * I_{it}) + \omega I_{it} + \varepsilon_{it} \quad (1)$$

Where Y denotes GDP per capita, X the control variables, which will be described in the next paragraph, R the measure for rainfall and I the different dummy variables, which will be described in paragraph 4.5. The estimators β, γ, δ and ω show the effect on Y of respectively the control variables, the measure of rainfall, the interaction term between rainfall and the dummy variable and the dummy variable itself. Furthermore, α is the constant term and ε is the error term. Moreover, the subscript i denotes the country, t the time and l denotes the number of lags. So the subscript l could be 0 (no

[20] This is shown in figure 6 in Appendix D.
[21] This argument holds for all the scatter plots.

lags), 1 (1 lag) 2 (2 lags) and so on. Lags are included in equation (1) to measure the influence that rainfall has on an economy's ability to grow, as is described in chapter 2 (Fiala, 2009; Dell et al., 2008). Two other things from equation (1) are interesting to point out. First, both the left hand side and the right hand side are in logarithms. This is one way to measure growth and is in line with Dell et al. (2008)[22]. This so called log-log or log-linear model makes that the effect of the independent variables on the dependent variable are measured as elasticities (Pyndyck and Rubinfeld, 1997). Second, a second order effect of rainfall is included on the left hand side, which is in line with Fiala (2009)[23]. Including this second order effect is crucial for understanding the complex relationship of rainfall and economic growth (Fiala, 2009).

3.5. Control Variables

The control variables that are included in the model are a combination of the control variables that are used by Fiala (2009) and Miguel et al. (2004) and the variables that are widely mentioned in the economic growth literature[24].

3.5.1 Economic control variables

The economic control variables are respectively population[25] (e.g. Dell et al., 2008, Barrios et al., 2004), gross domestic investment (e.g. Barios et al., 2004, Barro et al., 1994, and Borenzstein et al., 1997), openness (e.g. Barios et al., 2004, Dell et al., 2008), initial GDP[26] (e.g. Dell et al., 2008, Barios et al., 2004 and Barro & Lee, 1994) and government consumption (e.g. Barios, et al., 2004, Barro et al., 1994 and Borenzstein et al., 1997). The data from these control variables are obtained from PWT 6.3, which is in line with Barrios et al. (2004). The expected effect of these variables on economic growth is ambiguous. While Barrios et al. (2003) find that government consumption has positive influence on the economy, Barro and Lee (1994) find the opposite result. Also the effect of population growth on the economy is not clear. While Barro and Lee (1994) and Fiala (2009) conclude that population growth has a negative effect on the economy, Barrios et al. (2004) do not find such outcome. There is consensus, on the other hand, about the effect on openness, domestic investment and initial GDP on an economy. While initial GDP has a negative affect on economic growth (i.e. Borensztein et al., 1997; Barrios et al., 2004) due to the conditional convergence effect

[22] Dell et al. (2008) used mainly levels of annual average rainfall (and temperature), but also considered to use logarithms (see the footnote in their article on p.14).
[23] Also Miguel et al. (2004) attempted to use a non-linear term in their regressions, but did not find a significant result (Fiala, 2009).
[24] An overview of all the variables is stated in Appendix A.
[25] Please note that Fiala (2009) and Miguel et al. (2004) also use this variable. However, this variable is included in the economic variable section, since population growth is commonly used in economic growth studies (e.g. Dell et al., 2008, Barrios et al., 2004).
[26] Please note that Fiala (2009) and Miguel et al. (2004) also use this variable. However, this variable is included in the economic variable section, since intial GDP per capita is commonly used in economic growth studies (e.g. Dell et al., 2008, Barios et al., 2004 and Barro & Lee, 1994).

(Barro and Lee, 1994; Barrios et al., 2004), the variables openness and domestic investment seem to positively influence an economy (Barro and Lee, 1994; Barrios et al., 2004).

3.5.2 Other control variables

The variables that are used by Fiala (2009) and Miguel et al. (2004) and that are included in the dataset are the following. First, the time invariant variables ethnic fractionalization[27], religious fractionalization, and the share of mountains in a country are utilised. These variables are constructed by Fearon and Laitin (2003). To create these variables, Fearon and Laitin (2003) employed respectively the CIA Factbook for religious fractionalization, the Atlas Marodov Mira for ethnic fractionalization and the work of A.J. Gerard for the share of mountains in a country. Second, a measure of democracy is used from the Polity IV dataset. This dataset covers states that have a total population of 500,000 or more in the most recent year between 1800-2008[28]. The dataset contains an index that ranges between -10 and +10. The index can be converted into 3 regime categories, where autocracies score between -10 to -6, anocracies between -5 and +5, and democracies between +6 to +10. To use logarithms, the number 15 is added to this index to get positive numbers[29] (Polity IV index, 2008). Third, the time invariant variable percentage of land in agriculture from the World Development Indicators (WDI) is included. The time invariant control variables percentage of land irrigated and percentage of urban population are also included in the model of Fiala (2009) and Miguel et al. (2004). However, due to the lack of sufficient data these control variables will not be used in this thesis.

The effects of these variables on economic growth are mixed. While ethnic fractionalization and the share of mountains in a country affect economic growth in Africa in a positive way, no results are found for religious fractionalization and percent of land in agriculture (Fiala, 2009). Furthermore, the Polity IV index seems to have a negative influence on economic growth (Fiala, 2009).

3.6 Dummy Variables

As equation (1) shows, both time and country specific dummy variables are used as interaction with rainfall growth to capture the effect on economic growth. The following dummies are included[30]. First, a tropical dummy is incorporated from the Global Development Network Growth Database of

[27] This variable is also used by Burnside & Dollar (2000).
[28] This measure of democracy is also used by Dell et al. (2008). More information about this measure can be found on http://www.systemicpeace.org/polity/polity4.htm.
[29] Please note that negative numbers can not be converted into logarithms (http://oakroadsystems.com/math/loglaws.htm).
[30] A full overview of the dummy variables is stated in Appendix A.

the Worldbank[31], which is in line with Barrios et al. (2004) and Fiala (2009)[32]. This dummy is one if the absolute value of latitude is less than or equal to 23[33]. Second, regional dummies of the regions West Africa, Middle Africa, East Africa and South Africa are used to define if the effects of rainfall on economic growth differ per region. Third, a high rainfall dummy is included to test the importance of high rainfall years beyond the quadratic term, which is in line with Fiala (2009). This high rainfall dummy is 1 for the years where rainfall growth was above 20%.

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[31] This database can be found on: http://econ.worldbank.org/WBSITE/EXTERNAL/EXTDEC/EXTRESEARCH/0,,contentMDK:20701055~pagePK:64214825~piPK:64214943~theSitePK:469382,00.html

[32] Barrios et al. (2004) and Fiala (2009) also use an oil-producing dummy which is one if a country produces oil. However, because of the lack of data availability this dummy is not included in this thesis.

[33] A list of the tropical countries is stated in table 3 of Appendix B.

4 Results

This chapter describes the empirical research that is conducted given the empirical strategy that is described in the previous chapter. A few reminders of earlier remarks may be mentioned before showing the results. First of all, the outcomes of the regressions are only valid from 1981 to 1999. Due to data difficulties, no recent conclusions can be drawn. Second, 41 African countries are included, with only one country in the region North Africa. Therefore, no conclusions can be made for this region. Third, the control variables that are time-invariant are not concluded in the regressions since these variables are captured in the country fixed effects[34]. Fourth, since Fiala (2009) is the only one until now that included second order effects in analyzing the influence of rainfall on the economy, the comparison with respect to the second order effect is limited to this research.

The chapter is structured in the following way. At first the outcome of the regression for Africa as a whole is provided. After that the outcome for the tropical countries within Africa is shown. Then the outcomes for the different regions are discussed.

4.1 OLS regression of the full dataset

The first specification regresses the logarithm of rainfall on the logarithm of GDP per capita, as is specified in equation (1)[35]. This regression contains 41 countries and 19 years, which makes a total panel of 686 observations[36/37]. The outcomes of the main regression are stated in table 2 and will be explained per variable in the next section. The complete outcomes of this specification can be found in table 5 of Appendix E.

4.1.1 Rainfall

As becomes clear from the regression outcomes in table 5 of Appendix E, the rainfall measure is statistical significant. Furthermore, as table 3 shows, rainfall growth and economic growth are characterized by a parabolic relationship at a 5 percent significance level. Since all variables are in logarithms, a 10 percent increase of rainfall leads to a 6.83 percent decrease in GDP per capita before the vertex[38]. After the vertex, a 10 percent increase in rainfall

[34] These variables are ethnic fractionalization, religious fractionalization, % of mountains in a country, % of land in agriculture and initial GDP. They are shown in Appendix A.
[35] No dummies are included in the full dataset. Therefore I is zero in equation (1).
[36] The complete list of countries is given in Appendix B.
[37] Due to missing data in some African countries, there are less observations than is expected (i.e. 19*41= 779). Also, as is show in table 5 of Appendix E, not all regressions have 686 observations, because of the lags and the control variables that are included.
[38] The highest or lowest point on a parabola is called the vertex. If the x^2 is positive the vertex is the lowest point in the parabola. If the x^2 is negative then the vertex is the highest point (earthmath.com).

Table 2 – OLS Regression of equation (1) with use of the complete dataset.

Dependent variable: GDP per Capita
Number of observations: 686

Variable	Coefficient	Standard error
Rainfall	-0.6829**	0.3322
Rainfall^2	0.0636**	0.0257
Investment	0.0394**	0.0175
Openness	-0.0898***	0.0263
Polity(-1)	-0.0540***	0.0203
Intercept	9.6663***	1.1718
Adjusted R-squared		0.9619

Notes: (1) All variables are in logarithms. (2) The numbers in this table are the same as the numbers in regression 4 of table 5 in Appendix E. (3) ***, ** and * denote significant levels of respectively 99%, 95% and 90%. (4) Both time-fixed as country-fixed effects are included. (5) Only the significant outcomes are shown. (6) The complete outcome is shown in table 5 of Appendix E.

(measured as rainfall^2) leads to 0.64 percent increase in GDP per capita. So, the negative influence dominates the relation between rainfall and GDP per capita. Furthermore, rainfall does not only affect the level of the growth of the economy, but also its ability to grow (Dell et al., 2008). This is seen in the fact that the parabolic relationship between rainfall and GDP per capita holds until 2 lags[39]. After 2 lags, no significant results are found.

Two things with respect to the above described rainfall measures are important to note. First of all, the rainfall measures are robust. As table 3 shows, the signs of the rainfall measures do not differ in the regressions with respectively no control variables (Regression 1), control variables (Regression 2) and multiple lags (Regression 3 and 4) Second, the quadratic term captures the effects of too much rainfall. This conclusion is based on the outcomes of table 6 in Appendix E. In this regression specification a dummy for periods of rainfall above the 20% is included. Since all of the interaction terms of rainfall and dumhighrain are not significant, one may conclude that the effects of too much rainfall are captured in the quadratic term. So large storms, such as hurricanes, do not on average have an effect on the economy beyond the quadratic relationship (Fiala, 2009).

[39] This is shown in table 5 of Appendix E.

Table 3 – OLS Regression of equation (1) with use of the complete dataset specified for rainfall.

Dependent variable: GDP per Capita				
	(1)	**(2)**	**(3)**	**(4)**
Lograinfall	-0.7158**	-0.6829**		
	(0.3261)	(0.3322)		
Lograinfall^2	0.0669***	0.0636**		
	(0.0252)	(0.0257)		
Lograinfall(-1)			-0.7128**	
			(0.3583)	
Lograinfall(-1)^2			0.0653**	
			(0.0278)	
Lograinfall(-2)				-0.8321**
				(0.3629)
Lograinfall(-2)^2				0.0721**
				(0.0281)
Adjusted R-squared	0.9594	0.9619	0.9563	0.9582
Observations	743	686	691	651

Notes: (1) All variables are in logarithms. (2) The numbers in this table are the same as the numbers in regression 4 of table 5 in Appendix E. (3) ***, ** and * denote significant levels of respectively 99%, 95% and 90%. (4) The standard errors are in parenthesis (5) Both time-fixed as country-fixed effects are included. (6) The complete outcome is shown in table 5 of Appendix E.

The parabolic relationship between rainfall and GDP per capita, as is described before, is also found in the previous chapter. However, this outcome is different from what Fiala (2009) concludes and therefore not what is expected based on the hypothesis in the introduction. However, Fiala (2009) uses also data from countries outside Africa. And as is stated in chapter 2, particular in Africa there are certain aspects that make the effects of rainfall on economic growth more complex. Two of these characteristics are mentioned below. First, the economies in Africa adapt slowly to rainfall changes due to bad policies and a high corruption rate (Benson and Clay, 1998; IPCC, 2001). So if the initial positive consequences of rainfall (e.g. increase in industry value added and agricultural production) are misused by bad policies, economic growth could be negatively influenced. After a while the African policies adapt to the increased rainfall level in a way that might beneficial for an economy (Benson and Clay, 1998; Barrios et al., 2004). Second, most of the farmers do not own the land that they work on, due to less established property rights. Therefore, when rainfall increases farmers do not take fully advantage of these increases. After a while when farmers take the benefits of the increased rainfall into account, agricultural production increases (Barrios et al., 2008). And this in turn positively influences economic growth (Fiala, 2009).

4.1.2 Investment

According to table 5 of Appendix E, the investment measure is statistical significant and robust. Furthermore, table 2 shows that investment growth has a minor positive influence on economic growth on a 5 percent level, which is in line with the findings of Barro and Lee

(1994) and Barrios et al. (2004). Since all variables are in logarithms, a 10 percent increase of investment leads to a 0.39 increase in economic activity.

4.1.3 Openness

Also the results of openness seem to be robust and statistically significant according to table 5 of Appendix E. Furthermore table 2 shows that openness has a minor negative influence on economic growth on a one percent significance level. In this case, a 10 percent increase in openness leads to a 0.90 percent decrease in GDP per capita. This is contrary to the findings of Barro and Lee (1994) and Barrios et al. (2004). However, Rodríguez and Rodrik (1999) find little evidence that openness is associated with economic growth. They argue that most of the fast growing economies are open to trade, so that there could be an inverse causation between the two variables. Besides, also Rodrik (1998) notes that in Africa the factors human resources, physical infrastructure, macroeconomic stability, and the rule of law are more important to economic growth than whether countries are open to trade.

4.1.4 Political stability

Political stability is measured by the Polity IV index and lagged with one year in line with Fiala (2009). As becomes clear from table 2, political stability has a minor negative influence on economic growth on a one percent significance level. This means that if this index increases with 10 percent, the economy is harmed by 0.54 percent. Also Fiala (2009) found a negative relationship. Since one can argue that the largest values of the Polity IV index are democracies[40], you might say that democracies do not have a positive effect on economy in Africa. Barro (1996) and Helliwell (1994) did also find a negative relation between democracies and economic growth. However, this negative effect is counterbalanced by the fact that a democracy exerts on growth via education and investment (Helliwell, 1994).

4.2 OLS regression of the dataset with tropical dummy

The second specification regresses the logarithm of rainfall on the logarithm of GDP per capita as is specified in equation (1) by using a dummy variable for tropical countries[41]. The full sample still includes 41 countries and 19 years, which add up to a panel of 686

[40] As is stated in chapter 3, this index ranges between -10 and +10, where autocracies score between -10 to -6, anocracies between -5 and +5, and democracies between +6 to +10. Since the number 15 is added to the index to get positive numbers to use logarithms, the largest numbers are democracies.

[41] As is mentioned in chapter 3, a country is considered to be tropical if its latitude is less than or equal to 23. (Global Development Network Growth Database of the Worldbank). A list of the tropical countries is stated in table 3 of Appendix B.

observations[42]. The main outcomes of this regression are stated in table 4. Only the outcomes with respect to rainfall will be discussed, since the control variables are already mentioned in the last paragraph. A full overview of the results can be seen in table 7 of Appendix E.

Table 4 – OLS Regression of equation (1) with use of a tropical dummy.

Dependent variable: GDP per Capita
Number of observations: 686

Variable	**Coefficient**	**Standard error**
Dumtrop*Rainfall	0.3127**	0.1320
Dumtrop*Rainfall^2	-0.0414**	0.0171
Adjusted R-squared		0.9621

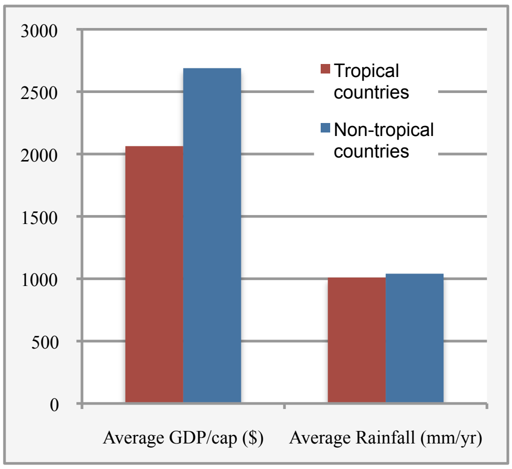
Notes: (1) All variables are in logarithms. (2) ***, ** and * denote significant levels of respectively 99%, 95% and 90%. (3) Both time-fixed as country-fixed effects are included. (4) The numbers in this table are the same as the numbers in regression 2 of table 7 in Appendix E. (5) Only the outcomes with respect to rainfall are shown. (6) The complete outcome is shown in table 7 of Appendix E.

As becomes clear, in the tropical countries rainfall affects GDP per capita in an inverse parabolic way where the positive effect dominates the negative. This can be seen in the positive sign of dumtrop*rainfall and negative sign of dumtrop*rainfall^2. So before the vertex, a 10 percent increase of rainfall leads to a 3.13 percent increase in GDP per capita. After the vertex a 10 percent increase in rainfall leads to a 0.41 decrease in GDP per capita[43]. This inverse parabolic relationship is also significant at a 10 percent level when one lag is included. So this rainfall has also a persistence effect on the economies of the tropical countries (Dell et al., 2008). Also Fiala (2009) finds an inverse parabolic relationship and concludes that rainfall is beneficial for an economy, but than too much rainfall may be harmful. Since 35 out of the 41 countries are considered to be tropical it is quite remarkable that this is the opposite result from what is concluded for all countries. Therefore it is important to have a closer look at the differences between the tropical and non-tropical countries.

[42] Due to missing data in some African countries, there are less observations than is expected (i.e. 19*41= 779). Also, as is shown in table 7 of Appendix E, not all regressions have 686 observations, because of the lags that are included.
[43] Note that all variables are in logarithms.

Figure 12 shows the difference between GDP per capita and rainfall for the tropical and non-tropical countries. As becomes clear, on average rainfall does not differ too much between both regions. So tropical countries receive not necessarily more rain than non-tropical countries. However, non-tropical countries could also have tropical regions (Bloom and Sachs, 1998). Non-tropical countries, on the other hand, are on average much richer compared to the tropical countries. This is not surprising since most of the non-tropical countries are located in South-Africa, the region with the highest GDP per capita[44]. Since this is the case, it is interesting to see if there is also an inverse parabolic relation in the region South Africa. The outcome of the OLS regression for South Africa as is specified in equation (1) is shown in table 8 of Appendix E. As becomes clear no significant results are found for the interaction term dumsouth*rainfall and sumsouth*rainfall^2. Therefore it is not possible to conclude if the inverse parabolic relationship of the tropical countries is caused by the same relationship in South Africa.

Figure 12 – The differences in GDP per capita and Rainfall for tropical and non-tropical countries.



Source: GPCP and PWT 6.3

4.3. OLS regression of the dataset with regional dummies

The specifications in this paragraph regress the logarithm of rainfall on the logarithm of GDP per capita as is specified in equation (1) by using dummy variables for each region[45]. Table 5 shows the main outcomes for East Africa. As becomes clear rainfall growth and GDP per capita growth are characterized by an inverse parabolic relationship on a 10 percent significance level, which is in line with Fiala (2009) and therefore with the hypothesis as is stated in the introduction. Since all variable are in logarithms, a 10 percent increase in rainfall leads to a 6.39 percent increase in GDP per capita before the vertex, whereas the same increase in rainfall leads to a decline of 1.38 percent of GDP per capita after the vertex. So the positive relation dominates in this case. This effect of rainfall affects only the level of GDP

[44] This is shown in figure 8 of chapter 3.
[45] These regions are the same as the regions defined in chapter 3.

per capita, but not the ability to grow, since no significant results are found when lags are included[46] (Dell et al., 2008).

Table 5 - OLS Regression of equation (1) with use of a dummy for East Africa.

Dependent variable: GDP per Capita Number of observations: 686		
Variable	**Coefficient**	**Standard error**
Dumeast*Rainfall	0.6386*	0.9969
Dumeast*Rainfall^2	-0.1383*	0.0756
Adjusted R-squared		0.9623

Notes: (1) All variables are in logarithms. (2) ***, ** and * denote significant levels of respectively 99%, 95% and 90%. (3) Both time-fixed as country-fixed effects are included. (4) The numbers in this table are the same as the numbers in regression 2 of table 10 in Appendix E. (5) Only the outcomes with respect to rainfall are shown. (6) The complete outcome is shown in table 10 of Appendix E.

The picture is the opposite for Middle Africa. In this region GDP per capita is influenced by rainfall in an inverse parabolic way, as was the case for Africa in general. This is shown in table 6[47]. In this case a 10 percent increase in rainfall first leads to a decrease of 0.04 percent, but after the vertex it leads to a 1.57 percent increase in GDP per capita. However, rainfall only affects the economy's ability to grow in Middle Africa, since only significant levels are found when 2 lags are included. For West Africa no significant results are found[48].

Table 6 - OLS Regression of equation (1) with use of a dummy for Middle Africa.

Dependent variable: GDP per Capita Number of observations: 651		
Variable	**Coefficient**	**Standard error**
Dummiddle(-2)*Rainfall	-0.0038*	1.2409
Dummiddle(-2)*Rainfall^2	0.1572*	0.0912
Adjusted R-squared		0.9623

Notes: (1) All variables are in logarithms. (2) ***, ** and * denote significant levels of respectively 99%, 95% and 90%. (3) Both time-fixed as country-fixed effects are included. (4) The numbers in this table are the same as the numbers in regression 4 of table 9 in Appendix E. (5) Only the outcomes with respect to rainfall are shown. (6) The complete outcome is shown in table 9 of Appendix E.

[46] Only the term Lograinfall(-1)^2*Dumeast is significant at a 10 percent level, but the term Lograinfall(-1)*Dumeast not, so therefore one can not say what the exact relation is. See table 10 Appendix E for more details.
[47] All outcomes of Middle Africa are stated in table 9 of Appendix E.
[48] The terms Lograinfall*Dumwest and Lograinfall^2*Dumwest in table 11 of Appendix E are not significant.

5 Concluding Remarks

This thesis investigates the influence of rainfall on economic growth by using a panel dataset of 41 African countries between 1981 and 1999. By applying OLS a parabolic relation between rainfall and GDP per capita is found. So a minor increase in rainfall negatively affected GDP per capita, whereas a major increase had a positive effect. This outcome is contrary to the findings of Fiala (2009) and to the outcomes of the tropical countries. In both cases an inverse parabolic relation is found. Also the effects per region are different. While in Middle Africa, a parabolic relation between rainfall and GDP per capita is detected, the opposite is true for East Africa. These contrary results may be caused by the fact that rainfall indirectly affects an economy via different channels. And especially in Africa this indirect effect is complex because of the different geographical conditions and local realities. So rainfall did have an impact on the poor economic growth performance of Africa in the last decades. However, this impact differed per country and per region. Therefore, more empirical research should be done to investigate what has caused these mixed results.

6 References

Alfaro, L., Chanda, A., Kalemni-Ozcan, S., Sayek, S. (2004). FDI and economic growth: the role of local financial markets. Journal of International Economics, Volume 64.

Anderson, D. (1997). Investment and Economic growth.

Asiedu, E. (2001). On the Determinants of Foreign Direct Investment to Developing Countries: Is Africa Different?

Barrios, S., Bertinelli, L., Strobl, E. (2003). Dry times in Africa. CREDIT research paper.

Barrios, S., Bertinelli, L., Strobl, E. (2004). Rainfall and Africa's growth tragedy.

Barrios, S., Ouattara, B., Strobl, E. (2008). The impact of climatic change on agricultural production: Is it different for Africa? Food Policy, Volume 33.

Barro, R.J., Lee, J.W. (1994). Sources of Economic Growth, Carnegie-Rochester Conference Series on Public Policy 40.

Barro, R.J. (1996). Democracy and Growth. Journal of Economic Growth. Volume 1.

Benson, C., Clay, E. (1998). The impact of drought in Sub-Saharan economies. World Bank technical paper No. 401.

Binswanger, H.P., Khandker, S.R. (1992). How infrastructure ad financial institutions affect agricultural output and investment in India.

Bloom, D.E., Sachs, J.D. (1998). Geography, Demography and economic growth in Africa, Brookings paper on economic activity in Africa, Volume 2.

Borensztein, E., De Gregorio, J., Lee, J.W. (1998). How does foreign direct investment affect economic growth? Journal of International Economics, 45.

Buhaug, H. Lujala, P. (2005). Accounting for scale: measuring geography in quantitative studies of civil war, Political Geography, Volume 24.

Burnside, C., Dollar, D. (2000). Aid, Policies and Growth. The American Economic Review, Volume 90.

Collier, P., Gunning, W. (1999). Explaining African Economic Performance. Journal of Economic Literature, Volume 37.

Cristiaensen, L., Demery, L., Paternostro, S. (2002) BOOK: Growth, distribution and poverty in Africa.

Dalgaard, C.J., Hansen, H., Tarp, F. (2004) On the Empirics of Foreign Aid and Growth. The Economic Journal, Volume 114.

Dell, M., Jones, B.F., Olken, B.A. (2008). Climate change and economic growth: evidence from the last half century.

De Mello, L.R. (1997). Foreign Direct Investment in developing countries and growth: A selective survey. Journal of Development Studies, Volume 34.

Dercon, S., (2001). The impact of economic reforms on households in rural Ethiopia 1989-1995. Office of the Chief Economist, Africa Region, The World Bank, mimeo (May).

Dollar, D., Kraay, A. (2000). Growth is good for the poor. Journal of Economics growth, 7.

Easterly, W., Levine, R. (1997). Africa's Growth Tragedy: Policies and Ethnic Divisions. The Quartely Journal of Economics, Volume 112.

Fay, M., Opal, C. (2000). Urbanization without growth: A not so uncommon phenomenon. World Bank Working paper, 2412.

Fearon, J., Laitin, D. (2002). Ethnicity, Insurgency, and Civil War, American Political Science Review, 97.

Fiala, N. (2009). When more is too much: The effect of rainfall shocks on economic growth and civil conflict. University of California.

Gradstein, M., Justman, M. (2002). Education, Social Cohesion, and Economic Growth. The American Economic Review, Volume 92.

Grey, R., Leach, B. (2010). New errors in IPCC Climate change report. The Telegraph, published 6th February 2010.

Harrison, G.P., Whittington, H.W. (2001) Impact of climate change on hydropower investment. Proceedings of the 4th International Conference on Hydropower Development (Hydropower '01)

Hauge, W., Ellingsen, T. (1998). Beyond environmental scarcity: causal pathways to conflict, Journal of Peace Research 35, 3

Intergovernmental Panel on Climate Change (IPCC), (2001). Climate Change 2001: Impacts, adaptation, and vulnerability. Contribution of Working Group II to the Third Assessment report of IPCC.

Intergovernmental Panel on Climate Change (IPCC). (2007). Climate change 2007: Synthesis report. An assessment of the Intergovernmental panel on Climate change

Jury, M.R. (2001). Economic Impacts of Climate Variability in South Africa and Development of Resource Prediction Models. Journal of Applied Meteorology, Volume 41.

Levine, R. (1999). Law, Finance and economic growth. Journal of Financial Intermediation, Volume 8.

Levy, M. A., Thorkelson, C., Vörösmarty, C., Douglas, E., Humphreys, M. (2005). Freshwater availability anomalies and outbreak of internal war: results from a global spatial time series analysis.

Magadza, C.H.D. (1996). Climate change: some likely multiple impacts in southern Africa. Climate change and World Food Security Springer-Verlag.

Miquel, E., Satyanath, S., Sergenti, E. (2004). Economic shocks and civil conflict: An instrumental variables approach. Journal of Political Economics Vol. 112, no 4J.

Miquel, E., 2003, Poverty and Witch killing. Manuscript. Berkeley: University of California.
O'Connell, S.A., Ndulu, B.J. (2000). Africa's Growth Experience, mimeo.

Murdoch, J.C., Sandler, T. (2002). Economic Growth, Civil Wars, and Spatial Spillovers. Journal of Conflict Resolution, Vol. 46

New, M., Tod, M., Hulme, M. and Jones, P. (2001). Precipitation measurements and trends in the twentieth century. International Journal of Climatology, Volume 21.

Nunnenkamp, P. (1997). Foreign direct investment in Latin America in the era of globalized production. UNESCO.

Nicholson, S.E. (2001). Climatic and environmental change in Africa during the last two centuries. Climate Research, Volume 17.

Paxon, C. (1992). Using Weather Variability to Estimate the Response of Savings Transitory Income in Thailand. American Economic Review, Volume 82.

Pyndyck, R., Rubinfeld, D. (1997). Econometric Models and Economic Forecasts. Fourth Edition.

Rockström, J., Barronzand, J. and Fox, P. (2000). Water productivity in Rain-fed agriculture: Challenges and Opportunities for Samlleholder Farmers in Drought-prone Tropical Agrecosystems.

Rodrik, D. (1998). Trade Policy and Economic Performance in Sub-Saharan Africa. NBER Working paper No. W6562. Harvard University.

Rodríguez, F., Rodrik, D. (1999). Trade policy and economic growth: A skeptic's guide to the cross-national evidence.

Rosenzweig, M.R., Binswanger, H.P. (1993) Wealth, Weather Risk and the Composition and Profitability of Agricultural Investments. The Economic Journal, Volume 103
Accessed: 31/03/2010 04:11

Rudolf, B. (2000). Satellite Based Global Precipitation Estimates and Validation Results. Proceeding of the SAP workshop on Climate Monitoring.

Saundry, P., Sachs, J.D., Warner, A.M. (1997). Sources of slow growth in African countries. Journal of African Economies.

Saundry, P. (2008). AP Environmental Science Chapter 14- Renewable, University of California. http://www.eoearth.org/article/AP_Environmental_Science_Chapter_14-_Renewable#Hydroelectric_energy

Theisen, O. M. (2006). Renewable resource scarcity and internal armed conflict: a quantitative reassessment. Paper presented at the 47th Annual Meeting of the International Studies Association, San Diego, CA,

Trzeciak-Duval, A. (1999). A decade of transition in central and eastern Europe agriculture. European review of agricultural economics. Volume 26 (3).

Villa-Artadi, E., Sali-i-Martin, X. (2003). The Economic Tragedy of the 20th Century: Growth in Africa.

Wallace, J.S. (1990). Increasing agricultural water use efficiency to meet future food production. Agriculture, Ecosystems and Environment, Volume 82.

Wilson, J.S. (2002). Liberalizing Trade in Agriculture: Developing Countries in Asia and the Post-Doha Agenda. World Bank - Development Research Group

7 Appendix

Appendix A: Variables

Table 1 – Variable Description.

Variable	Definition	Nature	Source
Rainfall	Average yearly rainfall in mm.	Time varying (annual): 1981-1999	Global Precipitation Climate Project (GPCP)
GDP/Cap	Real GDP per capita in US dollars in constant 2005 prices.	Time varying (annual): 1950-2007	Penn World Tables (PWT) 6.3
Initial GDP	Real GDP per capita in US dollar in constant 2005 prices in year 1981.	Time invariant	Penn World Tables (PWT) 6.3
Population	Population in thousands	Time varying (annual): 1950-2007	Penn World Tables (PWT) 6.3
Openness	Share of export plus import in real GDP, measured in %.	Time varying (annual): 1950-2007	Penn World Tables (PWT) 6.3
Government	Share of government spending in real GDP, measured in %.	Time varying (annual): 1950-2007	Penn World Tables (PWT) 6.3
Investment	Share of gross domestic investment in real GDP, measured in %.	Time varying (annual): 1950-2007	Penn World Tables (PWT) 6.3
Relfract	Religious Fractionalization.	Time invariant	Fearon and Laitin (2003)
Ethfract	Ethnic-linguistic fractionalization based on the Atlas Marodov Mira.	Time invariant	Fearon and Laitin (2003)
Polity	Polity IV Index. This index ranges between -10 (Full autocracy) and +10 (full democracy).	Time varying (annual): 1800-2008	Polity IV Index
Agriland	Share of land of country that is agriculture land in %.	Time invariant	World Development Indicators (WDI)
Mnest	Mountainous Terrain of a country in %.	Time invariant	Fearon and Laitin (2003)
Dumtropical	1-0 dummy for a tropical climate	Time invariant	Global Development Network Growth Database
Dumregion	1-0 dummy for the regions West Africa, Midde Africa, East Africa and South Africa.	Time invariant	United Nations
Dumhighrain	1-0 dummy for periods with rainfall above the highest 20%.	Time varying. (annual): 1981-1999	GPCP

Appendix B: Regions

Table 2 – The different regions in Africa.

West Africa	Middle Africa	East Africa	South Africa
Guinea-Bissau	Cameroon	Uganda	South Africa
Gambia	Gabon	Kenya	Namibia
Mali	Central Africa Republic	Tanzania	Lesotho
Senegal	Chad	Burundi	Botswana
Benin	Republic of Congo	Rwanda	Swaziland
Mauritania	Zaire	Somalia	Madagascar
Niger	Angola	Djibouti	Sudan
Ivory Coast		Ethiopia	
Guinea		Mozambique	
Burkina Faso		Zambia	
Liberia		Zimbabwe	
Sierra Leone		Malawi	
Ghana		Madagascar	
Togo			
Nigeria			

Notes: (1) This distinction of countries per region is based on the definition of the United Nations (see: http://unstats.un.org/unsd/methods/m49/m49regin.htm#africa). (2) The region North Africa is excluded because of two reasons. First North Africa is a different region with different economic conditions (Barrios et al., 2003). Second, Sudan is the only country in North Africa that is included in the dataset of Miguel.

Table 3 – Tropical countries in Africa

Tropical countries
Guinea-Bissau, Gambia, Mali, Senegal, Benin, Mauritania, Niger, Ivory Coast, Guinea, Burkina Faso, Liberia, Sierra Leone, Ghana, Togo, Nigeria, Cameroon, Gabon, Central African Republic, Chad, Republic of Congo, Angola, Uganda, Kenya, Tanzania, Burundi, Rwanda, Somalia, Djibouti, Ethiopia, Mozambique, Zambia, Zimbabwe, Malawi, Namibia, Botswana.

Notes: (1) in general, a country is considered to be tropical when the absolute value of latitude is less than or equal to 23. (Global Development Network Growth Database of the Worldbank)

Appendix C: Descriptive statistics

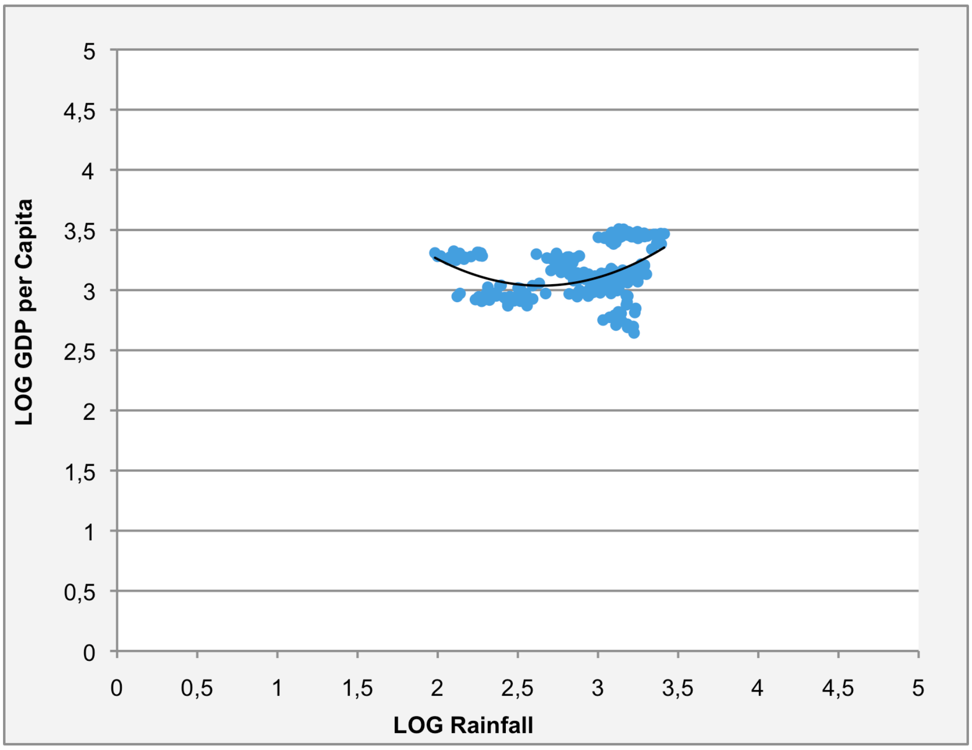
Table 4 – Descriptive statistics GDP per Capita and Rainfall per region.

		GDP per Capita ($)	Rainfall (mm/year)
West Africa			
	Average	1,490.06	1,035.63
	Maximum	3,220.81	2,587.64
	Minimum	153.44	96.11
	Sum	422,586.06	286,870.04
Middle Africa			
	Average	3,172.72	1,326.78
	Maximum	10,342.59	2,063.98
	Minimum	385.94	245.60
	Sum	421,585.98	175,135.57
East Africa			
	Average	1,443.21	961.58
	Maximum	5,816.82	1,876.09
	Minimum	474.75	212.43
	Sum	321,397.27	222,123.94
South Africa			
	Average	5,132.10	615.85
	Maximum	8,265.32	1,345.26
	Minimum	1,147.10	121.89
	Sum	433,191.30	52,347.13

Source: PWT 6.3. and GPCP

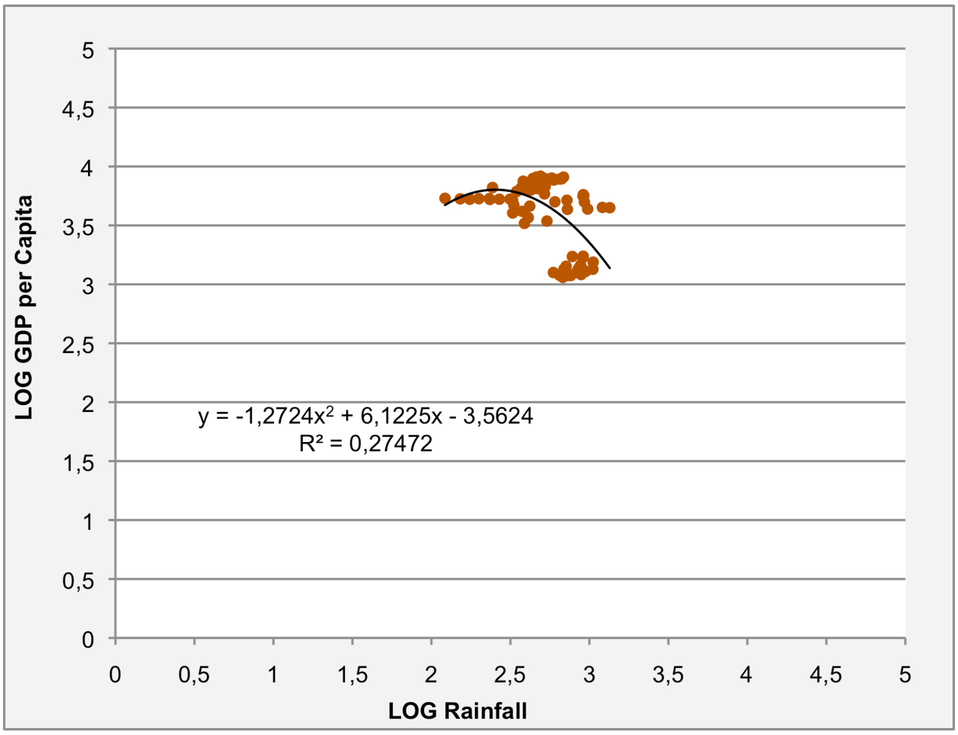
Appendix D: Scatter plots rainfall and GDP per capita

Figure 1 – Scatter plot rainfall growth and GDP per Capita growth for West Africa.



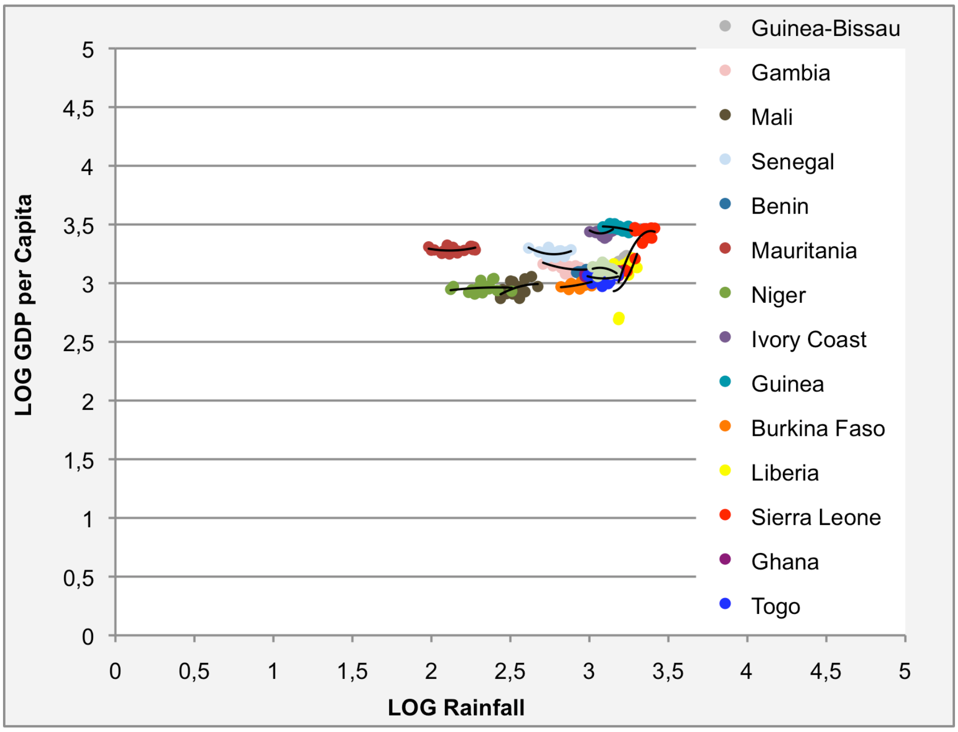
Source: GPCP

Figure 2 – Scatter plot rainfall growth and GDP per Capita growth for South Africa.



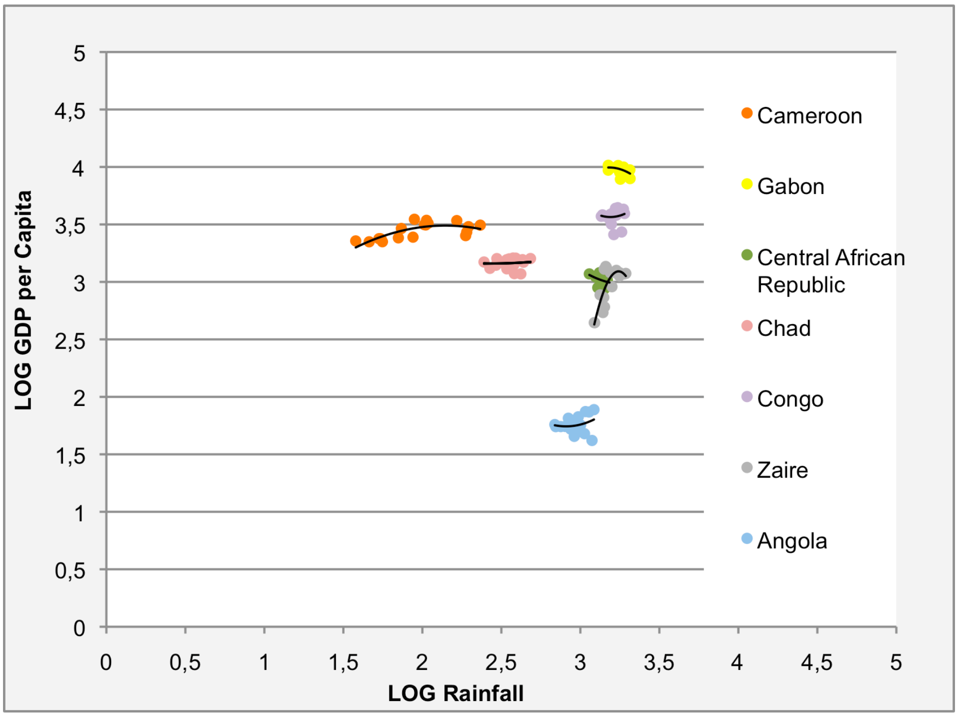
Source: GPCP

Figure 3 – Scatter plot rainfall growth and GDP per Capita growth per country in West Africa.



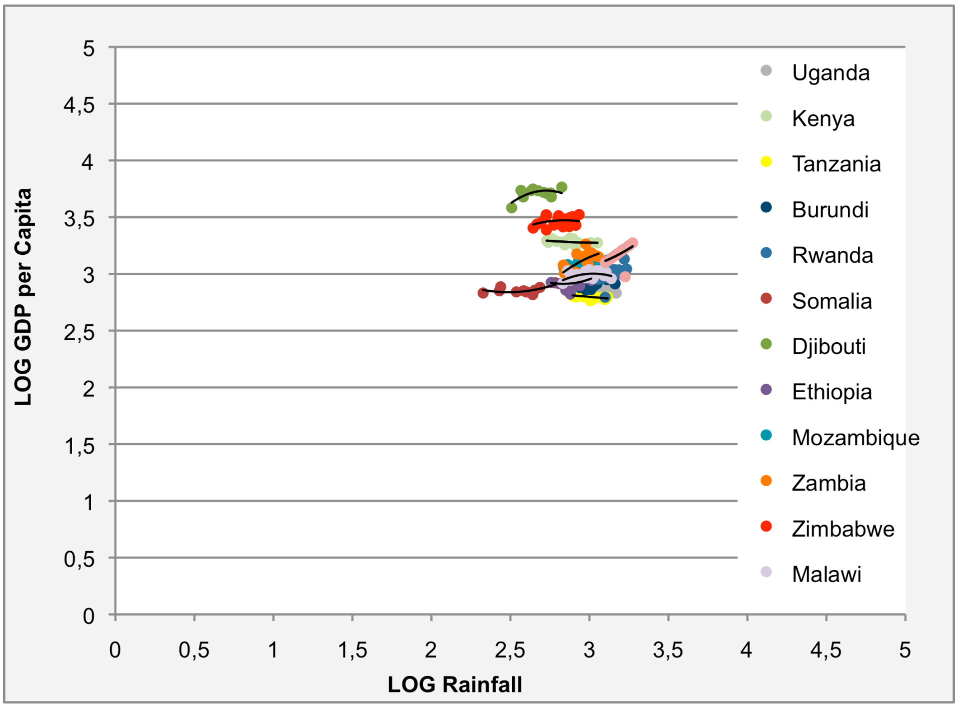
Source: GPCP

Figure 4 – Scatter plot rainfall growth and GDP per Capita growth per country in Middle Africa.



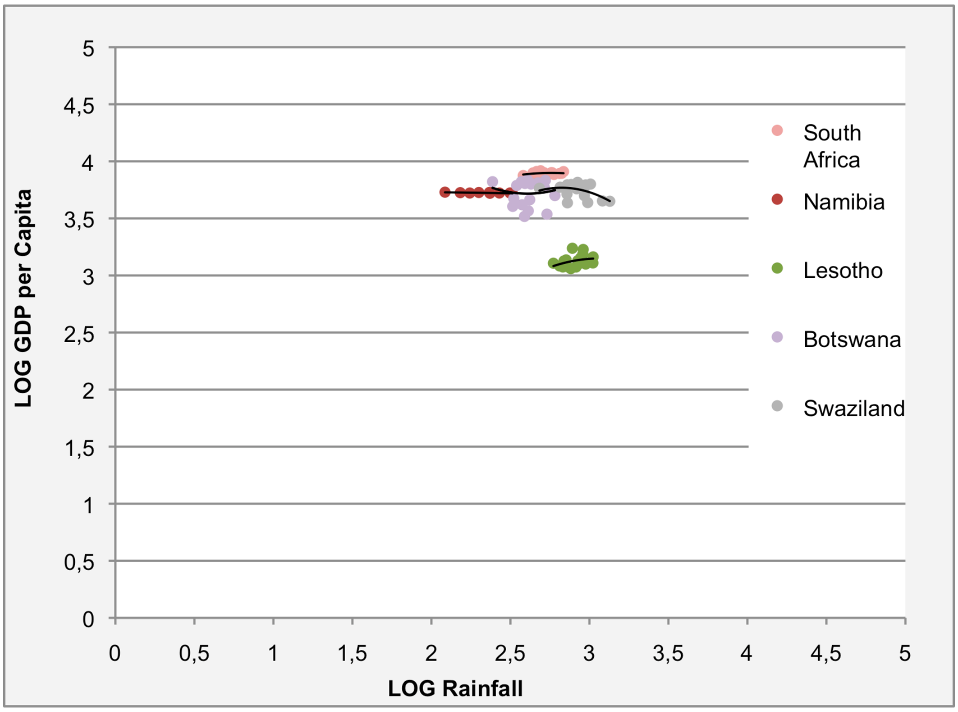
Source: GPCP

Figure 5 – Scatter plot rainfall growth and GDP per Capita growth per country in East Africa.



Source: GPCP

Figure 6 – Scatter plot rainfall growth and GDP per Capita growth per country in South Africa.



Source: GPCP

Appendix E: Regression Outcomes

Table 5 – OLS regression outcomes Africa.

VARIABLE:	(1)	(2)	(3)	(4)	(5)	(6)
Intercept	9.1495***	9.6674***	10.3844***	9.6663***	10.0001***	10.6088***
	(1.0581)	(1.5325)	(2.0795)	(1.1718)	(1.2600)	(1.2805)
Logpopulation				0.0057	0.0086	0.0105
				(0.0149)	(0.0161)	(0.0158)
Loginvestment				0.0394**	0.0461**	0.0612***
				(0.0175)	(0.0187)	(0.0194)
Loggovernment				0.0463	0.0113	-0.0036
				(0.0317)	0.0334	(0.0340)
Logopenness				-0.0898***	-0.1019***	-0.1051***
				(0.0263)	(0.0279)	(0.0281)
LogPolity(-1)				-0.0540***	-0.0664***	-0.0664***
				(0.0203)	(0.0218)	(0.0222)
Logagriland				-0.1042	-0.1304*	-0.1642**
				(0.0701)	(0.0730)	(0.0786)
Lograinfall	-0.7158**	-0.5606*	-0.6394*	-0.6829**		
	(0.3261)	(0.3323)	(0.3525)	(0.3322)		
Lograinfall^2	0.0669***	0.0535**	0.0586**	0.0636**		
	(0.0252)	(0.0258)	0.0274	(0.0257)		
Lograinfall(-1)		-0.4102	-0.2741		-0.7128**	
		(0.3367)	(0.3452)		(0.3583)	
Lograinfall(-1)^2		0.0396	0.0292		0.0653**	
		(0.0262)	(0.0269)		(0.0278)	
Lograinfall(-2)			-0.3311			-0.8321**
			(0.3471)			(0.3629)
Lograinfall(-2)^2			0.0298			0.0721**
			(0.0270)			(0.0281)
Country fixed effects	Y	Y	Y	Y	Y	Y
Country time effects	Y	Y	Y	Y	Y	Y
Adjusted R-squared	0.9594	0.9617	0.9636	0.9619	0.9563	0.9582
Observations	743	702	661	686	691	651

Notes: (1) Robust standard errors are in parenthesis. (2) ***, ** and * denote significant levels of respectively 99%, 95% and 90%. (3) After 2 lags, the results were not significant. Therefore the results after 2 lags are not included in this table.

Table 6 – OLS regression outcomes Africa with high rainfall dummy.

VARIABLE:	**(1)**	**(2)**	**(3)**	**(4)**
Intercept	9.6130***	9.7317***	9.4206***	9.6602***
	(1.1720)	(1.1803)	(1.2481)	(1.2077)
Logpopulation	0.0060	0.0063	0.0057	0.0085
	(0.0149)	(0.0149)	(0.0151)	(0.0148)
Loginvestment	0.0395**	0.0414**	0.0375**	0.0546***
	(0.0175)	(0.0176)	(0.0179)	(0.0186)
Loggovernment	0.0471	0.0461	0.0413	0.0293
	(0.0317)	(0.0318)	(0.0320)	(0.0326)
Logopenness	-0.0887***	-0.0889***	-0.0867***	-0.0911***
	(0.0263)	(0.0263)	(0.0266)	(0.0267)
LogPolity(-1)	-0.0536***	-0.0528***	-0.0551***	-0.0562***
	(0.0203)	(0.0203)	(0.0205)	(0.0208)
Logagriland	-0.1043	-0.1069	-0.1051	-0.1362*
	(0.0701)	(0.0702)	(0.0708)	(0.0762)
Dumhighrain	-0.0215			
	(0.0170)			
Lograinfall	-0.6855**	-0.7271**		
	(0.3320)	(0.3355)		
Lograinfall^2	0.0650**	0.0686***		
	(0.0257)	(0.0261)		
Lograinfall(-1)			-0.5741	
			(0.3524)	
Lograinfall(-1)^2			0.0532*	
			(0.0272)	
Lograinfall(-2)				-0.5849*
				(0.3409)
Lograinfall(-2)^2				0.0515*
				(0.0264)
Lograinfall*Dumhighrain		0.0174		
		(0.0276)		
Lograinfall^2*Dumhighrain		-0.0031		
		(0.0041)		
Lograinfall(-1)*Dumhighrain			-0.0009	
			(0.0283)	
Lograinfall(-1)^2*Dumhighrain			0.0004	
			(0.0043)	
Lograinfall(-2)*Dumhighrain				0.0042
				(0.0279)
Lograinfall(-2)^2*Dumhighrain				-0.0008
				0.0042
Country fixed effects	Y	Y	Y	Y
Country time effects	Y	Y	Y	Y
Adjusted R-squared	0.9619	0.9619	0.9613	0.9631
Observations	686	686	686	646

Notes: (1) Robust standard errors are in parenthesis. (2) ***, ** and * denote significant levels of respectively 99%, 95% and 90%. (3) After 2 lags, the results were not significant. Therefore the results after 2 lags are not included in this table.

Table 7 – OLS regression outcomes Africa with tropical dummy.

VARIABLE:	**(1)**	**(2)**	**(3)**	**(4)**
Intercept	9.6523***	9.3668***	9.7215***]	10.3748***
	(1.1759)	(1.1765)	(1.2700)	(1.2921)
Logpopulation	0.0057	0.0072	0,0103	0.0114
	(0.0149)	(0.0149)	(0.0161)	(0.0158)
Loginvestment	0.0393***	0.0393**	0.0445**	0.0611***
	(0.0175)	(0.0175)	(0.0187)	(0.0194)
Loggovernment	0.0462	0.0476	0,0141	-0.0004
	(0.0318)	(0.0317)	(0.0334)	(0.0341)
Logopenness	-0.0897***	-0.0940***	-0.1029***	-0.1061***
	(0.0263)	(0.0262)	(0.0278)	(0.0281)
LogPolity(-1)	-0.0542***	-0.0564***	-0.0681***	-0.0656***
	(0.0203)	(0.0202)	(0.0218)	(0.0222)
Logagriland	-0.1044	-0.0786	-0,1142	-0.1483*
	(0.0702)	(0.0707)	(0.0735)	(0.0795)
Dumtrop	0.0237			
	(0.1458)			
Lograinfall	-0.6844**	-0.8800**		
	(0.3326)	(0.3435)		
Lograinfall^2	0.0637**	0.0931***		
	(0.0258)	(0.0285)		
Lograinfall(-1)			-0.8364**	
			(0.3673)	
Lograinfall(-1)^2			0.0853***	
			(0.0303)	
Lograinfall(-2)				-0.9226**
				(0.3640)
Lograinfall(-2)^2				0.0875***
				(0.0304)
Lograinfall*Dumtrop		0.3127**		
		(0.1320)		
Lograinfall^2*Dumtrop		-0.0414**		
		(0.0171)		
Lograinfall(-1)*Dumtrop			0.2250*	
			(0.1361)	
Lograinfall(-1)^2*Dumtrop			-0.0303*	
			(0.0177)	
Lograinfall(-2)*Dumtrop				0.1702
				(0.1333)
Lograinfall(-2)^2*Dumtrop				-0.0235
				(0.0176)
Country fixed effects	Y	Y	Y	Y
Country time effects	Y	Y	Y	Y
Adjusted R-squared	0.9618	0.9621	0,9564	0.9582
Observations	686	686	691	651

Notes: (1) Robust standard errors are in parenthesis. (2) ***, ** and * denote significant levels of respectively 99%, 95% and 90%. (3) After 2 lags, the results were not significant. Therefore the results after 2 lags are not included in this table.

Table 8 – OLS regression outcomes Africa with South Africa dummy.

VARIABLE:	(1)	(2)	(3)	(4)
Intercept	11.2245***	9.6300***	9.9330***	10.5555***
	(1.7210)	(1.2160)	(1.3070)	(1.3235)
Logpopulation	-0.0638***	0.005047	0.0070	0.0095
	(0.0196)	(0.0149)	(0.0161)	(0.0158)
Loginvestment	-0.1529***	0.0397**	0.0472**	0.0613***
	(0.0381)	(0.0176)	(0.0187)	(0.0194)
Loggovernment	-0.2970***	0.0473	0.0109	-0.0040
	(0.0400)	(0.0318)	(0.0334)	(0.0340)
Logopenness	0.2646***	-0.0903***	-0.1026***	-0.1050***
	(0.0366)	(0.0263)	(0.0278)	(0.0281)
LogPolity(-1)	-0.0761	-0.0521**	-0.0621***	-0.0641***
	(0.0596)	(0.0203)	(0.0219)	(0.0222)
Logagriland	-0.2065***	-0.1061	-0.1358*	-0.1672**
	(0.0500)	(0.0703)	(0.0730)	(0.0787)
Dumsouth	1.1688***			
	(0.0836)			
Lograinfall	-0.5226	-0.7706**		
	(0.5704)	(0.3714)		
Lograinfall^2	0.0355	0.0712**		
	(0.0449)	(0.0284)		
Lograinfall(-1)			-0.8314**	
			(0.4036)	
Lograinfall(-1)^2			0.0764**	
			(0.0310)	
Lograinfall(-2)				-0.9429**
				(0.4052)
Lograinfall(-2)^2				0.0822***
				(0.0311)
Lograinfall*Dumsouth		0.8701		
		(0.9384)		
Lograinfall^2*Dumsouth		-0.0747		
		(0.0757)		
Lograinfall(-1)*Dumsouth			1.2307	
			(0.9770)	
Lograinfall(-1)^2*Dumsouth			-0.1087	
			(0.0786)	
Lograinfall(-2)*Dumsouth				1.1022
				(0.9987)
Lograinfall(-2)^2*Dumsouth				-0.0959
				(0.0801)
Country fixed effects	N	Y	Y	Y
Country time effects	Y	Y	Y	Y
Adjusted R-squared	0.3978	0.9619	0.9564	0.9582
Observations	686	686	691	651

Notes: (1) Robust standard errors are in parenthesis. (2) ***, ** and * denote significant levels of respectively 99%, 95% and 90%. (3) After 2 lags, the results were not significant. Therefore the results after 2 lags are not included in this table.

Table 9 – OLS regression outcomes Africa with Middle Africa dummy.

VARIABLE:	**(1)**	**(2)**	**(3)**	**(4)**
Intercept	5.2367***	9.5896***	10.5454***	11.1636***
	(1.8932)	(1.2911)	(1.3927)	(1.4061)
Logpopulation	-0.0597***	0.0062	0.0101	0.0109
	(0.0217)	(0.0149)	(0.0161)	(0.0158)
Loginvestment	0.0282	0.0417**	0.0475**	0.0647***
	(0.0407)	(0.0176)	(0.0188)	(0.0195)
Loggovernment	-0.3967***	0.0467	0.0135	0.0001
	(0.0440)	(0.0318)	(0.0334)	(0.0340)
Logopenness	0.4453***	-0.0912***	-0.1035***	-0.1083***
	(0.0381)	(0.0263)	(0.0278)	(0.0281)
LogPolity(-1)	0.0765	-0.0519**	-0.0626***	-0.0611***
	(0.0643)	(0.0204)	(0.0218)	(0.0223)
Logagriland	0.1353**	-0.1080	-0.1397*	-0.1698**
	(0.0560)	(0.0702)	(0.0731)	(0.0786)
Dummiddle	0.4416***			
	(0.0663)			
Lograinfall	0.8052	-0.5715		
	(0.6295)	(0.3529)		
Lograinfall^2	-0.0835*	0.0539*		
	(0.0496)	(0.0275)		
Lograinfall(-1)			-0.4878	
			(0.3780)	
Lograinfall(-1)^2			0.0467	
			(0.0296)	
Lograinfall(-2)				-0.5781
				(0.3840)
Lograinfall(-2)^2				0.0511*
				(0.0300)
Lograinfall*Dummiddle		-0.4541		
		(1.1305)		
Lograinfall^2*Dummiddle		0.0421		
		(0.0829)		
Lograinfall(-1)*Dummiddle			-1.8529	
			(1.2356)	
Lograinfall(-1)^2*Dummiddle			0.1449	
			(0.0907)	
Lograinfall(-2)*Dummiddle				-2.0038*
				(1.2409)
Lograinfall(-2)^2*Dummiddle				0.1572*
				(0.0912)
Country fixed effects	N	Y	Y	Y
Country time effects	Y	Y	Y	Y
Adjusted R-squared	0.2683	0.9619	0.9564	0.9583
Observations	686	686	691	651

Notes: (1) Robust standard errors are in parenthesis. (2) ***, ** and * denote significant levels of respectively 99%, 95% and 90%. (3) After 2 lags, the results were not significant. Therefore the results after 2 lags are not included in this table.

Table 10 – OLS regression outcomes Africa with East Africa dummy.

VARIABLE:	**(1)**	**(2)**	**(3)**	**(4)**
Intercept	5.2708***	9.0642***	9.3319***	10.4140***
	(1.9911)	(1.2705)	(1.3643)	(1.4162)
Logpopulation	-0.0666***	0.0041	0,0072	0.0104
	(0.0222)	(0.0148)	(0.0160)	(0.0158)
Loginvestment	-0.0243	0.0428**	0.0467**	0.0624***
	(0.0416)	(0.0175)	(0.0187)	(0.0195)
Loggovernment	-0.3521***	0.0474	0,0155	-0.0028
	(0.0450)	(0.0316)	(0.0334)	(0.0341)
Logopenness	0.4031***	-0.0936***	-0.1034***	-0.1052***
	(0.0399)	(0.0261)	(0.0278)	(0.0281)
LogPolity(-1)	0.0488	-0.0531***	-0.0658***	-0.0661***
	(0.0674)	(0.0202)	(0.0217)	(0.0222)
Logagriland	0.0312	-0.1051	-0.1294*	-0.1624**
	(0.0542)	(0.0697)	(0.0728)	(0.0787)
Dumeast	-0.2145***			
	(0.0611)			
Lograinfall	0.9724	-0.9547***		
	(0.6666)	(0.3525)		
Lograinfall^2	-0.0898*	0.0896***		
	(0.0524)	(0.0275)		
Lograinfall(-1)			-0.9648**	
			(0.3821)	
Lograinfall(-1)^2			0.0878***	
			(0.0300)	
Lograinfall(-2)				-0.9312**
				0,387547
Lograinfall(-2)^2				0.0817***
				(0.0304)
Lograinfall*Dumeast		1.6386*		
		(0.9969)		
Lograinfall^2*Dumeast		-0.1383*		
		(0.0756)		
Lograinfall(-1)*Dumeast			1,6377	
			(1.0568)	
Lograinfall(-1)^2*Dumeast			-0.1328*	
			(0.0804)	
Lograinfall(-2)*Dumeast				0.5426
				(1.1196)
Lograinfall(-2)^2*Dumeast				-0.0467
				(0.0851)
Country fixed effects	N	Y	Y	Y
Country time effects	Y	Y	Y	Y
Adjusted R-squared	0.2334	0.9623	0,9565	0.9581
Observations	686	686	691	651

Notes: (1) Robust standard errors are in parenthesis. (2) ***, ** and * denote significant levels of respectively 99%, 95% and 90%. (3) After 2 lags, the results were not significant. Therefore the results after 2 lags are not included in this table.

Table 11 – OLS regression outcomes Africa with West Africa dummy.

VARIABLE:	(1)	(2)	(3)	(4)
Intercept	11.5686***	9.2685***	9.7622***	10.6692***
	(1.8761)	(1.2315)	(1.3200)	(1.3601)
Logpopulation	-0.0670***	0.0026	0.0051	0.0102
	(0.0210)	(0.0149)	(0.0162)	(0.0158)
Loginvestment	-0.0110	0.0370**	0.0437**	0.0606***
	(0.0392)	(0.0176)	(0.0188)	(0.0195)
Loggovernment	-0.3793***	0.0484	0.0126	-0.0040
	(0.0426)	(0.0316)	(0.0334)	(0.0340)
Logopenness	0.4804***	-0.0894***	-0.1012***	-0.1046***
	(0.0373)	(0.0262)	(0.0278)	(0.0281)
LogPolity(-1)	0.1389**	-0.0541***	-0.0662***	-0.0664***
	(0.0624)	(0.0202)	(0.0218)	(0.0222)
Logagriland	0.0174	-0.1120	-0.1331*	-0.1680*
	(0.0510)	(0.0706)	(0.0736)	(0.0793)
Dumwest	-0.4546***			
	0,048795			
Lograinfall	-1.0959*	-0.2017		
	0,625873	(0.4923)		
Lograinfall^2	0.0704	0.0228		
	(0.0491)	(0.0379)		
Lograinfall(-1)			-0.3942	
			(0.5262)	
Lograinfall(-1)^2			0.0382	
			(0.0407)	
Lograinfall(-2)				-0.8602
				(0.5456)
Lograinfall(-2)^2				0.0733*
				(0.0421)
Lograinfall*Dumwest		-0.9174		
		(0.6538)		
Lograinfall^2*Dumwest		0.0835*		
		(0.0506)		
Lograinfall(-1)*Dumwest			-0.6312	
			(0.7066)	
Lograinfall(-1)^2*Dumwest			0.0581	
			(0.0550)	
Lograinfall(-2)*Dumwest				0.0288
				(0.7264)
Lograinfall(-2)^2*Dumwest				0.0012
				(0.0566)
Country fixed effects	N	Y	Y	Y
Country time effects	Y	Y	Y	Y
Adjusted R-squared	0.3099	0.9622	0.9564	0.9581
Observations	686	686	691	651

Notes: (1) Robust standard errors are in parenthesis. (2) ***, ** and * denote significant levels of respectively 99%, 95% and 90%. (3) After 2 lags, the results were not significant. Therefore the results after 2 lags are not included in this table.