The effect of climate change on microfinance institutions in West Africa during the 21st century:

A panel data analysis

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Abstract:

This thesis is aiming at quantifying the effect of climate change on the share of borrowers at microfinance institutions (MFI). This research is based on two hypotheses having contradictory effects: the first hypothesis argues that because the global warming consequences are too strong, famers and people living off agricultural practices will be unable to repay their loans because of their decrease in agricultural productivity or will simply quit their job to find revenue elsewhere (decreasing effect on the share of borrowers at MFI). The second hypothesis argues that as temperature increases and climate is disturbed, the vulnerable population will try to adapt to the new conditions and mitigate their effect. To be able to adapt easily, they will turn to microfinance institutions to access financial opportunities (increase in the share of borrowers at MFI).

It is found that annual average temperature has a small positive impact on MFI while annual average precipitations are insignificant. As temperature increase by one percent the share of borrowers at MFI increases by 0.062 percent. This impact is much smaller than what the literature would suggest and might come from both hypothesis' validity as an average of both opposing effects.

The poverty proxy (the share of children under five years old being recorded as stunted) has a negative impact on the share of borrowers, when poverty increases by one percent, the share of borrowers decreases by 0.4 percent. The bank access rate is positively related to the share of borrowers at microfinance institutions and it has a coefficient of 1 so as bank access rate increases by 1 percent, the share of borrowers also increases by one. Finally, a one percent increase in inflation leads to a 0.44 percent decrease in the share of borrowers at MFI. Time Fixed Effect regression shows the important role time has on the evolution of the share of borrowers.

This research shows that global warming does not explain the entire evolution in the share or borrowers at MFI and that the consequences of climate change is not similar for the entire population.

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I. Introduction

Climate change has been an ongoing issue investigated by many scientists for the past few decades and microfinance is a newer mechanism which is spreading around the world with the goal to reduce poverty at low cost for the vulnerable population.

When thinking about poverty, microfinance and its institutions, Mohammed Yunus is the first person who started to find a solution. Yunus is an economist, social entrepreneur and banker who won a Nobel Peace Prize for his work on microfinance and the foundation of the Garmeen Bank in 2006 "for their efforts to create economic and social development from below". Mohammed Yunus is a pioneer in the concept of microfinance and microlending in India and inspired many more to create the same corporations around the world. Yunus' project started when he observed that many poor people living around his university campus could not escape poverty because no large bank or corporation would lend them money. This is when he started lending them small sums of money in the hope to better their quality of lives at low cost. Although all his professors discouraged him because of the high risks, Yunus always believed and advocated that business and risks go hand in hand and that investing in poor people might be more risky because of one simple explanation: for the poorer population, one small shock, one small issue such as a cyclone, a theft, a flood, a fire or any changes in weather condition, can devastate their whole lives. This is the ideology the Garmeen Bank is founded on, "never punish the borrower". Once of Garmeen bank started to lend small-easy-long-terms loans of 100 dollars to the poorer population, they realized than the repayment rate was very high and that the benefits affected the borrower's family as a whole. It is essential to understand that the poorer population does not have access to conventional financial coping strategies to face any shocks (economics, environmental, political and many more) which would alleviate the need to engage in riskier mechanisms. Financial exclusion is one of the most important causes of poverty around the world, Yunus (2004).

In 2007, the year after Yunus won his Prize, the Intergovernmental Panel on Climate Change (IPCC) and former United States president Albert Arnold (Al) Gore Jr won the Nobel Peace Prize "for their efforts to build up and disseminate greater knowledge about man-made climate change, and to lay the foundations for the measures that are needed to counteract such change". As Pachauri (2007) mentions in his Nobel lecture; it is vital to understand that the impacts of climate change on some of the poorest and the most vulnerable communities in the world could prove extremely unsettling. Furthermore, Pachauri (2007) states that those populations usually are in incapability to react to these environmental changes and will remain extremely vulnerable to the impact of climate change. The changes will later result in an economic decline, a loss of livelihood and a decrease in opportunity to maintain a sustainable level of existence, Pachauri (2007).

The fact that these two laureates are chosen a year apart reveals the emergence of this large social movement highlighting the importance that the two concepts need increasing visibility as they are currently fundamentally changing lives around the world, Hammill et al (2008).

The Intergovernmental Panel on Climate Change (IPCC) has since the 2007 Nobel Peace Prize written many other reports, urging politicians and policymakers to reduce the impact of human behavior on the planet, the ecological and human system. In the latest IPCC report in 2022, the authors heavily highlight that climate change has caused substantial damages, and increasingly irreversible losses in terrestrial, coastal and maritime ecosystems. Furthermore, it is also stated that around 3.4 billion people worldwide live in rural areas, and many are greatly vulnerable to climate change and its repercussions. Worldwide, 2010-2020 has been the hottest decade ever recorded and with around 60 percent of the Sub-Saharan population depending on agricultural practices to survive, Muggah (2021). Hence, the threats in this region are already observable, Muggah (2021). This is the reason why integrating climate adaptation into social protection programs, including cash transfers and public works programs such as microfinance, will increase the population's resilience to climate change, especially when supported by basic services and infrastructure, IPCC (2022). Nonetheless, those social programs also have important social impacts on the population by increasing children access to education, decrease food insecurity or even alleviate gender exclusion.

As Dowla has mentioned in a report for the Garmeen Bank in 2009, "Climate change will decrease the productivity of agriculture and will make investment by MFIs in this sector less profitable".
To link the two issues; climate change and microfinance, it is important to understand why they are intertwined. Microfinance institutions need to have a clear focus on climate change mainly because of the countries in which they operate are hit the hardest by global warming, Forcella (2016). Climate change causes loss of human and physical capital that impacts heavily the local population and this is the reason why adaptation is one of the most important notions when trying to solve the poorer population's issue with global warming, Forcella (2016). The IPCC report (2022) declares that economic damages from climate change have been detected in climate-exposed sectors, with regional effects on agriculture, forestry, energy, and through outdoor labor productivity. All of this shows how much rural population is and will be suffering from the harsh consequences of climate change. Muggah (2021) for the Igarapé Institute mentions in one of his report that West Africa because of its fragile countries, cities and communities will be especially hit the hardest by climate change which will lead to a strong increase in armed conflict and will disrupt the already fragile country.

The goal of this research is to understand and quantify the link between climate change and the change in the share of borrowers at microfinance institutions. This will be done by answering the following question "*what is the relationship between global warming and the share of borrowers at*

microfinance during the 21st century in West Africa?". This analysis is focusing on countries located in West Africa; Benin, Burkina Faso, Côte d'Ivoire, Mali, Niger, Senegal and Togo between 2006 and 2020. To answer this question, two hypotheses can be argued. The first one being that as the weather is increasingly changing and the harvests are suffering, the population will be unable to repay their current loans which would decrease the share of borrowers at MFI. Moreover, the increase in risk associated with climate change for agriculture-relying population might lead to a shift to other sectors, independent from the weather variation. The other hypothesis is the following: as temperature increases and climate is disturbed, the vulnerable population will try to adapt to the new conditions and mitigate their effect. To be able to adapt easily, they will turn to microfinance institutions to access financial opportunities. These two hypotheses will be developed in a later section.

The remainder of this thesis will proceed as follows. In section II, a literature overview and background information of the climate change and microfinance situations in West Africa is given. Section III will develop two different hypothesis which relate to the research question. In section IV, the data and the variables will be discussed. In section V, the methodology will be presented. The results of the different regressions will be discussed in section VI. In section VII, the robustness of the model will be verified. Finally, in section VIII, a conclusion will be provided.

II. Literature review

1. Climate Change and Agriculture in Africa

According to the IPCC (2022), the Sub-African part of the world is one of the areas most vulnerable to climate change. Furthermore, this is an issue which is far from being solved. In the last century, this continent has been witnessing a growing transformation of its climate due to the current impactful weather changes such as the increase in average temperatures, the change in precipitation and the many extreme weather events such as drought, floods and storms, IPCC (2007). A visual representation of the rising temperature and precipitation projections can be observed on figure 1 and 2. The figures have two sets of projections' each, Representative Concentration Pathway 2.6 (low concentration baseline) and Representative Concentration Pathway 8.5 (high concentration baseline) which are two different scenarios of climate models depending on the actions taken to decrease the CO_2 emissions by the population in the world, Van Vuuren et al (2011). These scenarios are modelled by the IPCC. According to Fitzpatrick, Parker et al (2020), by the end of the twenty first century, an average day in West Africa will be three to six degree Celsius hotter than what it is nowadays. This drastic increase will have tremendous results on every aspect of the population's lives and more especially on their agricultural practices. Collier, Conway and Venables (2008) mention that crop yields will be strongly affected, and the frequency of extreme weather events will drastically increase which will

further disrupt agricultural production. This will heavily impact the continent as its economy relies heavily on agriculture and on climate-related activities such as fishing and life-stock farming.

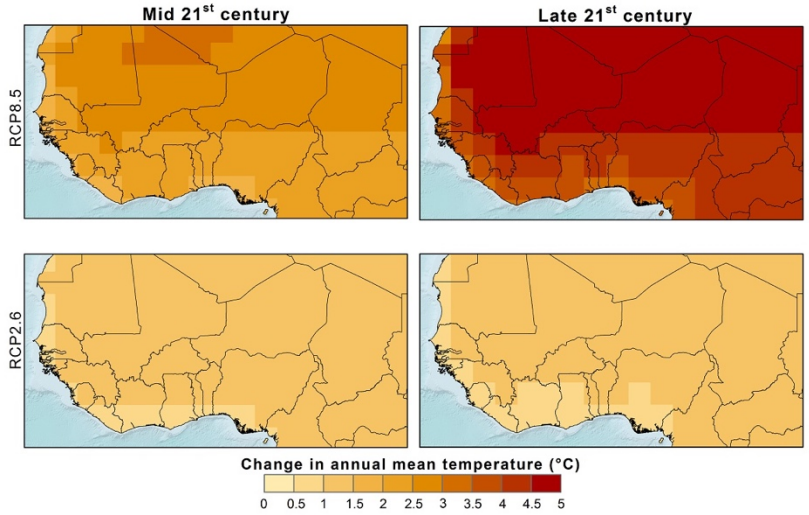

Figure 1: Change in Annual Mean Temperature in West Africa during the 21st century

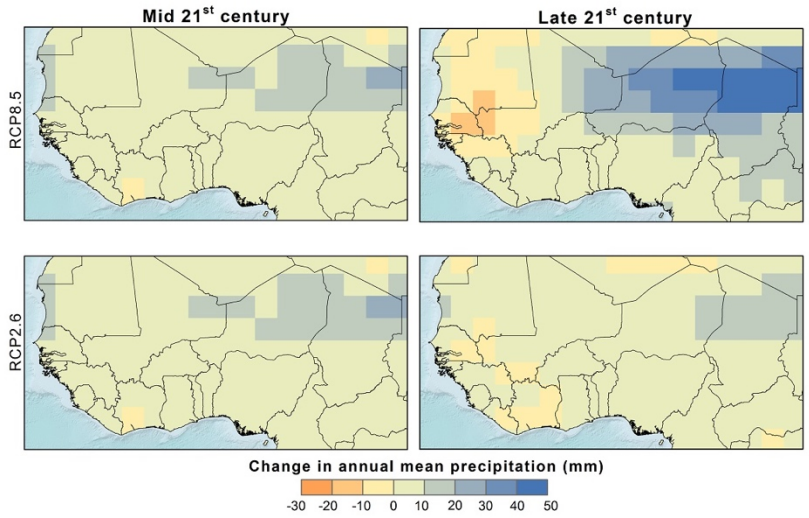

Figure 2: Change in Annual Mean Precipitation in West Africa during the 21st Century

This increase in climate variability does not only economically impact the continent but socially as well. Africa is experiencing considerable increase in food insecurity and health-related issues, United Nation Climate Change News (2020). Niang et al (2014) have declared in the IPCC report that the change of the yield of major cereal crops, which many regions heavily depend on as a source of income, will be negative with strong regional variations. Furthermore, maize, one of the most common crops harvested in sub-Saharan countries, is highly sensitive to temperature changes and even more sensitive when it rises above 30-degrees Celsius. This means that any day when the temperature rises above 30-degrees Celsius, the maize yield is reduced by 1 percent compared to drought-free rainfed conditions

(Lobell et al, 2011). Due to the important climate disruptions, African farmers will be faced with technological regress, their seeds might not grow as well as they used to, their water sources might run empty and extreme weather events might ruin entire productions during a single occurrence, (Serdeczny, 2017). These will lead to both macroeconomic and local issues because of the population's shock vulnerability, Collier, Conway and Venables (2008).

The key element to this global matter is that Africa is the continent that has been participating the least in CO_2 emissions but is the one suffering the most from global warming and its repercussions, IPCC Report (2022). The western countries such as the United States and Europe are the ones producing (directly or indirectly through their imports) the most. The United States is producing around 15 metric tons of CO2 every year, Europe is producing much less but is indirectly producing by taking advantage of the carbon loophole. This harmful practice is done by essentially importing goods that produce a lot of CO2 to avoid producing them locally and pretend to have a clean energy emission, Hasanbeigi, Springer and Global (2018). By acting this way, countries do not bear the responsibility of their polluting actions, leading Africa to increasingly suffer from them. With just 15 percent of the world's population, rich countries are responsible for 45 percent of CO_2 emissions, Hope (2009). This proves the fact that Africa is a victim of other's harmful behaviour which is beyond its own influence.
Whereas most other economies have to focus on reducing their carbon emissions to decrease their impact on climate change, Africa has an entire other mission: the local population has to find solutions to adapt themselves to the new climate, its repercussions and the associated shocks to the people and the continent's economy, Tadesse (2010). As mentioned by the Centre for Financial Inclusion (2022), there are four main pathways the population can use to face climate change: mitigation, resilience, adaptation and transitions.

It is for the uttermost importance for policymakers, foreign firms and polluting companies to understand that one single extreme event decrease the production yield by 90 percent for the weaker population Marmai, Franco Villoria and Guerzoni (2022) and the increase of those events will intensify farmers vulnerability to income shocks which is closely linked to their agricultural revenue. Ray (2021) states that Sub-Sahara's GDP would decrease by at least three percent in 2050.
It is clear that climate change is affecting the African population through a multitude of factors; human health is negatively affected, employment rate is decreasing, infrastructures are damaged, tourism might even be threatened (Serdeczny et al, 2017). Additionally, it is the poorer population which is affected the greatest; they are the ones relying on agriculture, the ones living in poorer and more exposed infrastructures, Leichenko and Silva (2014). This means that they are disproportionately hurt compared to the wealthiest population in their own countries and this gap is even larger when comparing their helplessness with the western "wealthy" world. Many authors (Hammil et al (2008), Forcella (2016), Dowla (2009), Muggah (2021) and many more) have tried to investigate the impact climate change is

having on the population but very few have tried to analyse how the local population is adapting to the change. As mentioned earlier, adaptation is a key element in the fight against global warming and microfinance institutions are fundamental players in this battle.

This analysis is focusing on countries located in West Africa between 2006 and 2020. It is projected for those countries to experience severe impacts on food production, including through declines in agricultural productivity, population displacement, local market destabilisation, severe food security risks inducing negative repercussions for human health and employment additionally limiting or even hindering economic growth, Ray (2021). West Africa's agriculture relies heavily on precipitation and the monsoon season which is triggered by the yearly temperature and the atmospheric pressure, Sultan and Gaetani (2016). The important weather changes and high variation in rainfall has increased the difficulty to predict any future result for crop productivity and this increases the local population uncertainty over their personal future, Sultan and Gaetani (2016). It is an academic consensus that the future of West Africa will be based on adaptability, Sultan and Gaetani (2016). The only way for farmers to protect themselves from further climate related issues is to increase their insurance against these hazardous events, have financial support to build new infrastructure or buy new weather-resistant seeds and hedge against climate risks, Berg, Quirion and Sultan (2009).

Climate change is a threat to the poor population and microfinance is able to reduce their vulnerability to this threat; an efficient way farmers could reach adaptation and decrease their helplessness against climate change is through microfinance and micro-credit, Hammil et al (2008). Nonetheless, the increase in risk associated with climate change might lead to a decrease in the share of borrowers because of their exposure to those risks.

2. Microfinance in Africa

Microfinance is defined by Chirkos (2014) as an institution providing savings and credit services for small and medium size enterprises which mobilize rural savings. These credit services are done using straightforward procedures that originate from the local population itself and that they understand. As mentioned earlier, the large exposure these financial institutions have been gaining is mostly due to Muhammad Yunus. According to the Microfinance Information Exchange (MIX) the number of institutions range from 1,000 to 2,500 serving some 67.6 million beneficiaries all around the world. The main issue for the poorer population is that larger banks and institutions do not accept to lend them money because they do not have the background or the official documents proving they are able to pay back debt. These individuals are facing impossible constraints implemented by the traditional institutions, Mol (2005). Furthermore, for the less fortunate part of the population high interest rates are not an issue, they are willing to pay a very large amount simply to have access to this monetary opportunity but the mainstream institutions do not give them the occasions to have access to

such benefits. The issue for poor borrowers in commercial banks or institutions is the rejection of their applications, Duflo and Banerjee (2011).

Microfinance institutions give the less fortunate population opportunities to borrow small sums of money to be able to enter the market, participate in the economy, without any type of collateral and even make profit, Duflo and Banerjee (2011). Additionally, the interest needs to be paid every short period of time, often weekly; this allows for the borrowers to quickly discover the issues in their investment early in their borrowing cycle and avoid longer heavy debt, Sengupta and Aubuchon (2008). The advantages from borrowing at microfinancing institutions are not only financial; those institutions promote gender equality, they increase the probability to start a business, the opportunity to hedge against environmental crisis, help attain a higher level of education and allow many more benefits to come from this simple mechanism, Littlefield, Morduch and Hashemi (2003).

Very often, microfinance is based on either joint liability or group lending which makes every borrower accountable for the other's repayment, Duflo and Banerjee (2011). The institutions appreciate this practice because they often face asymmetric information (moral hazard or adverse selection) with the borrowers. The goal of joint liability or group lending is to transfer the monitoring and repayment responsibility from the bank staff to the borrowers themselves. This is positive for the lending institutions as it considerably reduces transaction costs and increase the repayment rate as compared to individual lending, Ghatak and Guinnane (1999). Moreover, this practice combined with local information significantly mitigates asymmetric information by prompting associated monitoring as all lenders are responsible for repaying the loan's interest, Sangwan and Nayak (2020). This practice has greatly improved the repayment rate and made microfinancing safer for the institution themselves. The details of the mechanism depend on the institutions; groups can range from five to ten members and there are many ways to adjust the regulations to the liking of the institutions and the borrowers, Duflo and Banerjee (2011). The key takeaway from microfinancing is that both parties (borrowers and lenders) work hand in hand and are partners.

Nonetheless, microfinancing in Africa is double-edged. According to Lafourcade et al (2005), African MFI are dynamic and perform positively compared to institutions in other parts of the world as they help and support savings mobilization and help access savings deposit. Unfortunately, the authors concluded that because the institutions operate in rural areas with a low population density and weak infrastructures, they are facing high operation costs which hinder their productivity and activities. African institutions need considerable improvement and innovation in technology, communication and lending products, Lafourcade and al (2005). Lafourcade et al (2005) further mention that the small-scale impact of these institutions can slow their efficiency level. The positive aspect of microfinance in

Africa is the ability for institutions to reach the population of remote rural areas, the ones that are usually left out and underserved by larger commercial banks, Jarotschkin (2013).

Microfinance has a lot of positive aspects but is however facing some limitations. The first limitation being that when targeting the poor, these institutions mainly target the "economically active" poor population and not the uttermost poor population, the one at the lowest level of the pyramid of wealth, Agrawala and Carraro (2010). Moreover, as it will be shown in the data in a later section, the entire poorer population does not have access to microfinance opportunities and thus do not have access to the benefits it generates (table 1). This might create a gap and deepens the inequalities within an already fragile population.

Today, microfinance is playing a key role for the population in fostering their climate change adaptation, Agrawala and Carrao (2010). By enabling their beneficiaries to adapt and access better infrastructure more easily, the population is able to face the new conditions in a safer way. It is crucial to keep in mind the important risks for the rural population associated with global warming and because of their high vulnerability, borrowing at MFI might simply be too much of a burden for the highly susceptible population. Climate change and microfinance have a close link and a particular relationship which will be developed in the next section.

3. Climate Change and Microfinance

There is a growing body of literature trying to link the harmful environmental consequences of global warming with microfinance. The poorer population will have to find adaptation strategies to protect themselves and their families against the income shocks they will face due to the rising temperature, the extreme weather events regular occurring, changes in precipitation and many more, Beg, Morlot, Davidson, Afrane-Okesse, Tyani, Denton, Rahman et al (2002). Microfinance institutions (MFI) should care about this emergent issue for multiple reasons mentioned by Forcella (2013). The main issue according to Forcella (2013) is that the countries in which MFI operate are the ones with the riskiest economies and have the most vulnerable populations. Moreover, agricultural productivity will decrease, livestock investment will be negatively hit, MFI property and equipment could be destroyed, Forcella (2013). On a more economic note, borrowers might have difficulties repaying their debt, savings might decrease, and MFI will experience growing pressure to forgive debt and as Forcella (2013) and Dowla (2008) mentions; climate change is a new source of risk microfinance institutions will have to take into account. The institutions now face a choice: adaptation or mitigation. Forcella (2013) defines mitigation as human actions to reduce the emissions or increase the earth's CO2 intake capability by promoting renewable energies, environmentally friendly activities and educating the population. On the other hand, adaptation is another strategy based on strengthening the capacity to respond to the changes and reduce the adverse impacts such as building infrastructures, Dowla (2008).

Regarding Africa's inhabitants, they are more sensitive to adaptation strategies as they are not the ones polluting much. Moreover, because the poorer population is heavily relying on agriculture and climate-sensitive sources of income, they will be the ones needing capital and resources to respond to the shocks, this is when microfinance institutions and micro-credit come into play.

These institutions can provide to the vulnerable population tools and resources to accumulate, manage and mobilize their assets to shield themselves from the various stresses they can encounter due to shocks they might experience resulting from climate change, Hammil et al (2008). As mentioned by Thurow (2013), in the past, MFI used to simply provide loans for the population to be able to expand their businesses or create new opportunities. Recently, one of the most important parts of MFI is to provide adaptation opportunities, insurance and better risk spreading for the local communities, Thurow (2013). Hammil et al (2008) state that the most powerful case for MFI is its ability to help households build and diversify their assets, diversify their sources of income to mitigate risk and provide support. This proves the importance of microfinance Institutions in poorer countries that are heavily affected by climate change.

Microfinance Institutions are forced to adapt to the new climate most of their clients live in. Nowadays, borrowers can sometimes renegotiate their loans, they can schedule their repayment, create climate-proof loans (borrowers need to follow specific building design to ensure protection against cyclones or typhoons) and some can even change the terms and the delivery of the loans they borrowed, Dowla (2008). All of these processes are key elements for adaptation and should not be overlooked by institutions if they still want borrowers to value credit and if they want to help them survive this global crisis.

Moreover, there are many sectors where MFI can achieve great success and there are many different areas which need help such as agriculture, small enterprises and remote groups. Rippley (2012) mentions in his paper some areas and opportunities in which MFI should invest to reduce the global warming impact on the population; enhancing clean energy product, low-carbon agriculture, projects based on the communities, financial projects to help borrowers manage risk, carbon-free finance, smart-subsidies, advocacy, education and awareness most of which are customer-level interventions. Today, the question MFI should ask is "how much does the population value those opportunities to safely face climate change's effects?". Forcella et al (2016) conclude in their paper that the introduction of tailored programs that provide adapted services to rural populations might actually mitigate the climatic risks faced by farmers and help them adapt to the new situation. Finally, the aim of microfinance institutions is having a positive impact on the population and helping farmers adapt to the new climate they will face in the future.

III. Hypothesis

It is understood nowadays that microfinance can foster farmers' adaptation to important changes in their daily practices which could reduce their vulnerability and shield them from weather-related disasters. Many previous papers have investigated this relationship in a theoretical manner but none of them has tried to quantify the results and the relationship between the two variables. The goal of this thesis is to demonstrate that the intuition behind the previous research is right and to further understand the special bond linking microfinance and climate change.

The link between microfinance and climate change can be addressed in two different ways. The first hypothesis argues that a rise in average temperature and the precipitations' disruption would decrease the number of borrowers in microfinance institutions. This could happen as MFI borrowers will struggle to repay their debts and increase their poverty level because of the agricultural changes and their harvest disturbance due to global warming. This would lead them to bankruptcy and inability to repay their micro-loans. The agricultural issues farmers will face might grow to be increasingly important and devastating, leading farmers to be unable to meet their credit costs which will decrease the number of borrowers. Furthermore, the population relying on agriculture to generate revenue might simply move away from this lifestyle and make profit in other sectors not relying on the weather (hypothesis 1).

The other hypothesis supports the assumption that to adapt to new environmental challenges faced by the rural population, farmers and smallholders will increase their borrowings. This increase in loan taking will be used to adapt their agricultural practices to face the new environmental issues. Farmers can adjust to small changes in temperature or rainfall by growing more resilient crops or simply changing the crops they are currently growing, Rippley (2012). This would result in a positive relationship between climate change and microfinance institutions. Areas that used rainfall might start to introduce irrigation; for example, coffee is harvested in mountainous areas that are becoming too hot to grow certain varieties. Nonetheless those areas might be used for other types of crops and the coffee cultivation might just move upward on the mountain, Rippley (2012). It is obvious that these agricultural changes will need monetary investments that farmers probably do not have, and this is the reason why the number of MFI borrowers might sharply increase due to global warming. The population's will to adapt and mitigate the global warming effect will lead them to increase the share of borrowers at microfinance institutions (hypothesis 2).

This thesis will estimate the relationship between climate change and the share of borrowers at microfinance institutions. As the relationship is probably an average of both effects, the result from the

test will expose which hypothesis is dominant. This research expects for the second hypothesis to be dominant and that most farmers and people living off agricultural practices to turn to microfinance institutions to increase the financial buffer to adapt to the new climate conditions.

Understanding the effect of climate change on microfinance institutions will be useful for policymakers and political leaders in the countries investigated as it will show how the population is impacted by the substantial changes generated by global warming. By recognizing the importance of microfinance, policymakers and political leaders might further increase their support for such "priority sector" and recognize their role for the vulnerable local population (Duflo and Banerjee, 2011).

IV. Data Description

In this section, the dataset used to quantify the relationship between climate change and the share of depositors at microfinance institutions is specified. The choice of the different variables is explained, and the sources for each variable used is mentioned. The fourteen variables are clustered into five different groups to create an easier interpretation: the climate variables, the agricultural variables, the demographic variables, the financial variables and the additional variables. The goal with these groups is to separate the effect each group has on microfinance institutions.

1. Sources

The data is retrieved from a few sources; the Central Bank of the States of West Africa, The Climate Change Knowledge Portal of the World Bank, the Food and Agriculture Organisation and the World Bank. Different databases are used as the different kind of information used cannot be found in one single place. The sample covers seven countries located in West Africa between 2006 and 2020 which creates a dataset of 98 observations. There are a few missing data observations leading to some regressions with less observations than others. This analysis is done on seven countries located in West Africa. The choice of the countries is based on the availability of the data. The countries investigated are the following: Benin, Burkina Faso, Côte d'Ivoire, Mali, Niger, Senegal and Togo (figure 3).

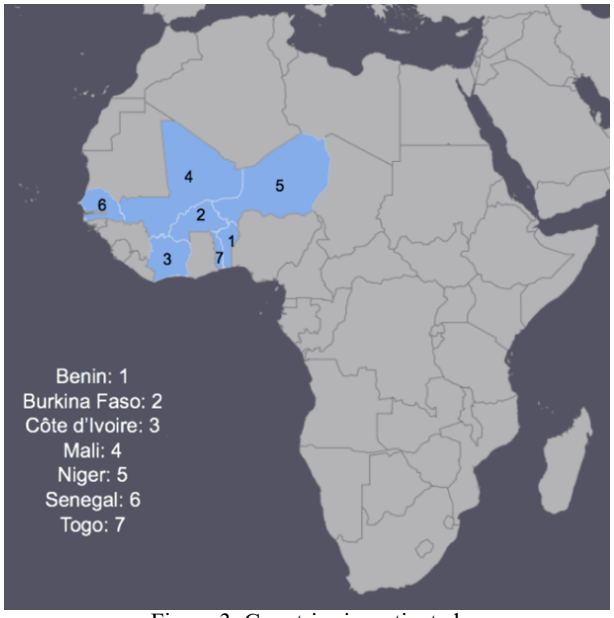

Figure 3: Countries investigated

2. Variables

A. Dependent variable: Microfinance service usage rate

Microfinance service usage rate is the dependent variable of the regression (mfservrate). This represents "the number of persons holding accounts in microfinance institutions divided by the total population". This dataset is retrieved from the Central Bank of West Africa (Banque Centrale des Etats de l'Afrique de l'Ouest). Figure 4 and table 1 shows the evolution of the share people holing an account at microfinance institutions over the years in each country. The evolution is not similar for all the countries, some countries such as Togo and Benin have experienced a strong change whereas other countries such as Niger, Mali and Côte d'Ivoire have not experienced much of a change in the share of borrowers in their microfinance institutions. Microfinance borrowing is associated with a will from the population to protect themselves from climate change risks (MIX, 2022) but also to start new small-scale businesses or escape poverty (Duflo and Banerjee, 2011).

	Mean	SD	Min	Max
Benin	0.339956	0.0963116	0.18133	0.4771
Burkina Faso	0.1482973	0.0462933	0.05467	0.20968
Côte d'Ivoire	0.0835073	0.020145	0.0577	0.1211
Mali	0.13137	0.0062237	0.12192	0.1473
Niger	0.0846667	0.0206414	0.05525	0.11218
Senegal	0.243012	0.0678514	0.12319	0.3538
Togo	0.3323607	0.1377464	0.11597	0.49351

Table 1: Summary Statistics per country for the microfinance service rate variable

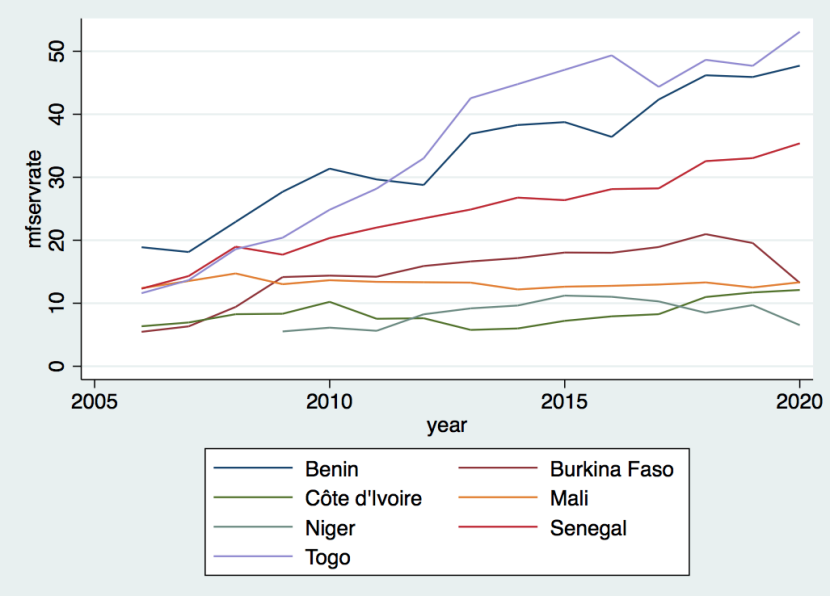

Figure 4: Microfinance service usage rate in the seven countries analysed, Banque Centrale des Etats de l'Afrique de l'Ouest (2022).

B. Independent variables: Climate Change Variables

As mentioned previously in section I, climate change is mainly experienced by the African population through perturbations in temperature and precipitation. This is the reason why average annual temperature and average annual precipitation levels are the two variables used to proxy for climate change.

Average Temperature

The annual average temperature (anntemp) the first independent variable used in this model and is expected to have a positive effect on MFI. The average temperature is used as a proxy for global warming and the interpretation of this variable is straightforward, it is recorded in degree Celsius. Figure 5 displays the evolution of the average annual temperature per country over the years. The pattern of highs and lows is mostly similar for the seven countries. Table 1 shows the summary statistics of the data for the annual average temperature and precipitation per country and it is clear that the seven countries are experiencing the same average yearly temperature which lies between 27 and 29 with a clear average around 28 degree Celsius. When observing the evolution of the temperature over the years, the change is not obvious but there is an increase of around 0.5 degree Celsius between 2006 and 2020 but when comparing the countries, it is clear that there are important differences. These differences and the 0.5-degree Celsius increase will be the baseline of the research.

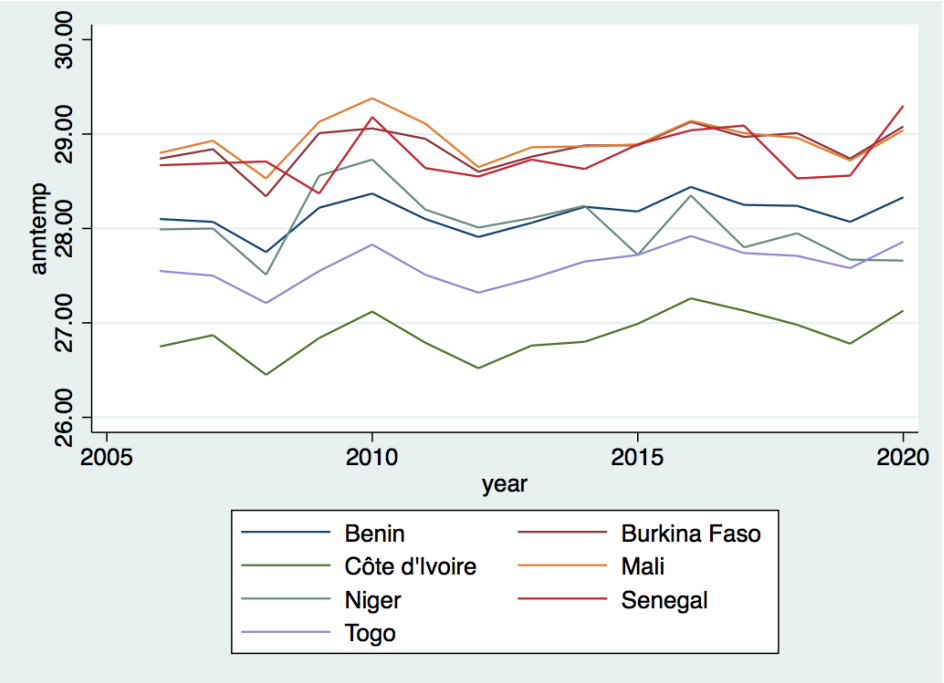

Figure 5: Annual average temperature in the seven countries investigated, The Climate Change Knowledge Portal of the World Bank (2022).

Average Precipitation

As average annual temperature is used as a first proxy for climate change, the annual average precipitation (annprecip) is used as a second proxy for climate change. Average annual precipitation is recorded as millimetres (mm) per year. West Africa heavily depends on the summer monsoon for its rain-fed agriculture and this is the reason why a negative relationship with the share of microfinance borrowers is expected, Duryan (2010). As rainfall increases, more opportunities might arise for the local population as an increase in precipitation might help grow and harvest different seeds and decrease the need for irrigation infrastructures which might simply decrease the financial support offered by MFI. Investigating the precipitation behaviour in West Africa seems to be a significant component of a climate change analysis. The IPCC (2012) has emphasised the connection between global warming and precipitation variability and the threats to the local environment, population, food supply and ecosystem in the affected areas. Variability itself is not measured in this research and it will focus on the changes from one year to other where the variance between the different countries investigated is exploited. Figure 6 shows the evolution of the precipitation for the seven countries; when looking at 2006 and 2020, no real change can be observed. Nonetheless during that time period change happened; Togo is experiencing an increase of approximatively 300mm of rain between 2006 and 2010 and Benin's yearly precipitation is increasing by 250mm between 2015 and 2019. These changes most likely have an impact on the population. Furthermore, it can be observed in table 2 and figure 6 that some countries are much drier than others; Niger and Mali have an average precipitation below 500mm per year

whereas Côte d'Ivoire, Togo and Benin have an average precipitation above 1000mm. Using the precipitation variable is to investigate if the variability between the years and the countries has an impact on the number of borrowers at microfinance institutions. Including different countries that are experiencing different types of weather (dry or humid) could help the precision of the model.

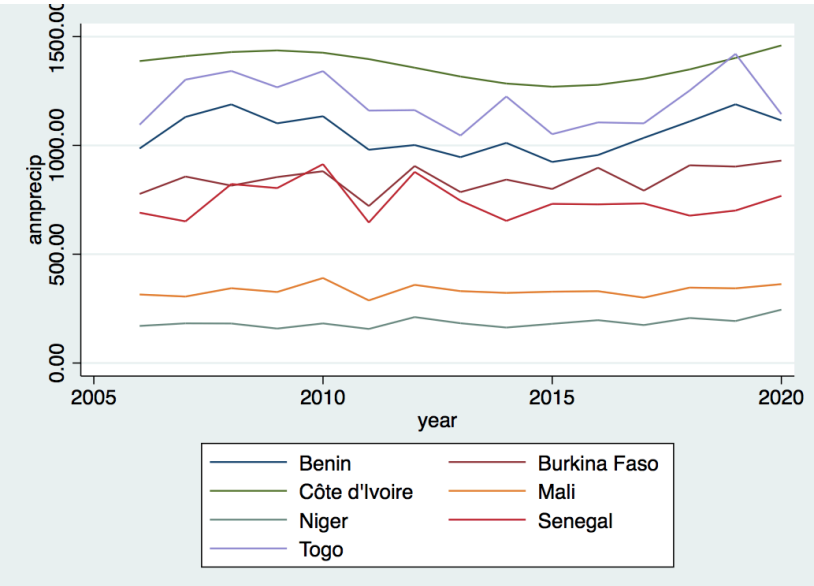

Figure 6: Average annual precipitation in the seven countries investigated, The Climate Change Knowledge Portal of the World Bank (2022).

country	Stats	anntemp	annprecip
Benin	Mean	28.155	1053.93
	SD	0.177	88.99
	Min	27.75	924.14
	Max	28.44	1188.93
Burkina Faso	Mean	28.866	844.769
	SD	0.208	60.761
	Min	28.34	721.55
	Max	29.13	930.22
Côte d'Ivoire	Mean	26.878	1367.313
	SD	0.227	63.175
	Min	26.45	1269.8
	Max	27.26	1459.37
Mali	Mean	28.935	332.757
	SD	0.215	26.272
	Min	28.53	287.66
	Max	29.38	390.6
Niger	Mean	28.033	185.7
	SD	0.343	22.926
	Min	27.51	156.66

	Max	28.73	245.25
Senegal	Mean	28.772	743.002
	SD	0.268	81.666
	Min	28.37	645.66
	Max	29.3	913.84
Togo	Mean	27.608	1201.095
	SD	0.197	116.156
	Min	27.21	1045.42
	Max	27.92	1420.72

Table 2: Summary Statistic per country for the climate change variables

Dummy Variables

Furthermore, two weather dummy variables are included to account for any flood (flood) or drought (drought) events experienced by the seven countries. This data is collected by the Emergency Event Database from the Université Catholique de Louvain. These events were gathered in a more precise manner than how it is used in this research. The database has recorded the exact location (province, longitude and latitude) of the flood or drought event. This means that some countries had more than one drought or flood event collected by the Emergency Event Database as some suffered two flood or drought events in two different areas. To create a dummy variable, the data was simplified as a yearly measure where a drought or flood event is documented as 1 and a 0 when no event was recorded. As mentioned by Ebi and Bowen (2016), droughts and floods are extreme events directly attributed to precipitation variability and have detrimental consequences for the area and its population. Furthermore, one single extreme event can ruin years of work for a population which relies on agricultural practices to generate income. It is because of the strong impact drought or flood has on the population that these dummy variables are included in this research. Extreme weather events have a complex definition but the IPCC includes drought and flood as disasters impacting the natural physical environment. Such events are expected to have a strong impact on the rural poorer population through the effect on the land and their activities which heavily rely on the climate. Those two dummies are expected to have a positive impact on microfinance because as their happening increases, the population will need a larger financial buffer to protect themselves from their occurring which will be provided by MFI.

C. Robustness variables: Agricultural Variables

In addition to the climate change variables, it is important to account for the vulnerable population's sources of income as they borrow at microfinance institutions to increase their liquidity and broaden their financial opportunities. This research focuses on climate change and its repercussion on the population through changes in agriculture which might further change their behaviours. As it can

be observed in table 3, the rural population is above 50 percent for all the countries investigated and this implies that a large part of the population relies on agriculture in West Africa.

Rural population (rurpoprate) is a headcount of the number of people living in rural areas defined by the national statistical offices. To simplify the interpretation, it is transformed into a percentage of the total population. This data comes from the World Bank Development Indicators and it is calculated as the share of rural population on the total population. Rural population's impact on MFI could go in both directions. One hypothesis is that rural population increases because of the attractiveness of agricultural life which would be more profitable than living in cities. The move to a profitable area would lead to a decrease of MFI borrowers. On the other side, an increase in rural population could stem from a movement out of cities because of the lack of opportunities there which forces the population to move and find more profitable opportunities in rural areas. This would lead to an increase in borrowing as the newer population would need financial help to settle in their new area. The effect on microfinance institutions depends on the cause of the shift in rural population and will be investigated in the result section.

Agricultural employment (agriemplrate) closely linked with rural population and likewise, is retrieved from the World Bank Development Indicators. As defined by the World Bank (2022), employment is defined as persons of working age who were engaged in any activity to produce goods or provide services for pay or profit and the agriculture sector consists of activities in agriculture, hunting, forestry and fishing. The population included in this percentage is anyone who is working in this field, self-employed or employed by a larger farm, anyone who creates revenue by working in this field. This variable is expressed as a percentage of the total population of each country. This research expects agricultural employment to have a negative relationship with the share of the population borrowing at MFI as more people are employed or active in this field, less of them might need financial support provided by MFI. Nonetheless, the link between climate change and agricultural employment might be ambiguous because as the employment increase, the same size of investment will be needed, the same amount of irrigation infrastructure will be invested in, the same share of wells will be built and this is part of the reason why investigating agricultural employment might add dept to this research.

The last agricultural variable included is agricultural land (agrilandrate) and its data comes from the Food and Agriculture Organization (FAO) of the United Nation. It is defined by the FAO as "land used for cultivation of crops and animal husbandry". The original variable was not defined in a percentage form which led the original variable to be divided by the country's total area to create a percentage variable. As explained in the literature, the variable's effect on MFI is expected to be ambiguous just as rural population; as more land is available, a larger share of the population might actually profit from its benefits and less might need financial support but on the other hand, as more

land is available, a larger part of the population might need financial resources to exploit the land and start new projects which would increase the share of borrowers.

For these three agricultural variables, there are effects increasing and decreasing the share of borrowers that are influencing the variables' coefficients, the goal of the regressions will be to uncover which effect is dominant. It is important to keep in mind that rural population and agricultural employment are intuitively closely related which might further lead to some multicollinearity issue. Multicollinearity is part of the reason why the variables are investigated in groups and individually. In the righthand-side of table 3, the correlation between these variables can be analysed and against expectations, the correlation between rural population and the other variables is not tremendously high, around 0.58 but the other two variables (agricultural land and agricultural employment) have a correlation ratio of 0.89. The agricultural variables included are to some extend correlated to the climate variables but not to the share of borrowers at MFI (table 4). None of the variables are positively nor highly correlated with the share of borrowers (table 4). Furthermore, as the share of borrowers is negatively related to the three agricultural variables this might actually be a hint on the relationship between the MFI and the agricultural sector. Additionally, it can be observed that the climate variables are positively related to the share of borrowers (table 4) which is a sign supporting the second hypothesis.

Country	Stats	rurpoprate	agrilandrate	agriempl
Benin	Mean	0.553	0.031	0.424
	SD	0.023	0.009	0.024
	Min	0.516	0	0.383
	Max	0.58951	0.034	0.459
Burkina Faso	Mean	0.736	0.038	0.407
	SD	0.026	0.0154	0.135
	Min	0.694	0	0.262
	Max	0.777	0.045	0.641
Côte d'Ivoire	Mean	0.514	0.060	0.453
	SD	0.019	0.0168	0.031
	Min	0.483	0	0.401
	Max	0.543	0.066	0.495
Mali	Mean	0.616	0.309	0.666
	SD	0.036	0.086	0.029
	Min	0.561	0	0.623
	Max	0.672	0.336	0.7
Niger	Mean	0.837	0.331	0.744
	SD	0.001	0.092	0.011
	Min	0.834	0	0.725
	Max	0.838	0.367	0.759

Senegal	Mean	0.549	0.042	0.358
	SD	0.019	0.012	0.038
	Min	0.519	0	0.301
	Max	0.579	0.048	0.416
Togo	Mean	0.609	0.065	0.407
	SD	0.023	0.003	0.05
	Min	0.572	0.058	0.324
	Max	0.644	0.068	0.463

Table 3: Summary Statistics per country for the agricultural variables, World Bank Development Indicators.

	mfserv~e	anntemp	annpre~p	rurpop~e	agrila~e	agriempl
mfservrate	1.0000					
anntemp	0.0496	1.0000				
annprecip	0.3068	-0.6559	1.0000			
rurpoprate	-0.3619	0.3243	-0.6190	1.0000		
agrilandrate	-0.4280	0.2484	-0.8219	0.5231	1.0000	
agriempl	-0.5579	0.1029	-0.6892	0.5638	0.8899	1.0000

Table 4: Correlation matrix of the agricultural variables.

D. Robustness variables: Demographic Variables

Additionally to the agricultural variables, it is important to include demographic variables in the model as those could clarify some population variation and how changes in population impact microfinance borrowing. The two variables included in this model are the rate of children under five years old recorded as being stunted in the country (childstunted) and a dummy variable controlling for epidemic (epidemic) event in the country per year.

The number of children under five years old that are stunted variable is used as a proxy for poverty as the GINI coefficient and other types of poverty measures are not available yearly. Stunted children are defined as impaired growth and development that children experience from poor nutrition, repeated infection, and inadequate psychosocial stimulation, World Health Organization (2015). This variable seems to be an appropriate proxy as children that are malnourished and subject to diseases are usually the ones living in poorer infrastructures and with less wealth and economic means to fight these issues. The children being recorded as stunted variable is retrieved from the Food and Agriculture Organization from the United Nation. Poverty is playing an important role in the understanding of the link between climate change and microfinance institutions. It is the poorer population the one suffering the most from global warming but also is the one targeted by MFI to borrow money to adapt and mitigate the effect of the change in environment they live in. The number of children being stunted is decreasing (figure 7) over the years which implies a decrease in poverty, this could be linked to an increase in borrowers at microfinance institutions (table 5). This research is expecting the proxy for poverty to have

a negative relationship with the share of borrowers at MFI. The hypothesis is as follow; as more people live in difficult situations or stuck in a poverty trap, they are less willing to innovate, start a business and be entrepreneurs and are not attracted to MFI for financial help. This will be investigated in a later section.

Similarly to the dummy variables for drought and flood event, the dummy variable for epidemic event is retrieved from the Emergency Event Database from the Université Catholique de Louvain. This dummy accounts for when an epidemic event has been detected. As for the previous dummy variables included, the database had more than one epidemic event recorded per year but to facilitate the analysis, years with at least one event is recorded as 1 and years without any event is recorded as 0. Some examples of epidemic events are bacterial disease, viral disease or parasitic disease. Moreover, the epidemic dummy would be projected to have a negative relationship with MFI as an epidemic outbreak would increase the vulnerability of the population and decrease their willingness to innovate and start a business.

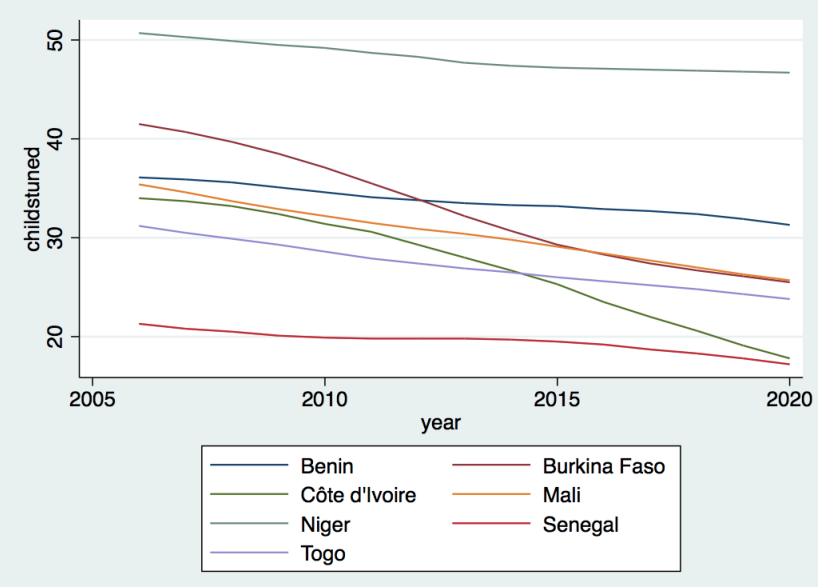

Figure 7: Evolution of children under five years old recorded as being stunted, Food and Agriculture Organization of the United Nations (2022).

	mfserv~e	childs~d	epidemic
mfservrate	1.0000		
childstunted	-0.3408	1.0000	
epidemic	-0.1421	0.4118	1.0000

Table 5: Correlation Matrix of the demographic variables and the share of borrowers at MFI.

E. Robustness variables: Financial Variable

Climate change and global warming is only a part of this research, the other side is focusing on microfinance institutions and the financial services availability for the poorer rural population in West Africa. This is the reason why the variable bank access rate (bankaccessrate) is included in the model. This variable's calculation is "the number of persons holding accounts in banks, postal services, savings banks and the treasury over the total adult population" and is retrieved from the "Banque Centrale des Etats de l'Afrique de l'Ouest" or the Central Bank for the State of West Africa. It is expressed as a percentage as it helps with the interpretation and is depicted on figure 8.

The variable is correlated with the microfinance service (0.7363) rate which can be observed on the following table 7. As it is shown in the graph (figure 8) and the table 6, some countries have much lower financial availability for the population than other. Niger has a much lower financial inclusion and financial support (barely above zero) than some other countries such as Togo but for all the countries investigated, the share of people having access to financial opportunities is very low (never above 23 percent). The graphs also display the different evolution between the countries; Niger is always at the bottom of the graphs with a very small positive evolution whereas Togo and Benin have much higher levels of financial inclusion and a much stronger growth rate. Intuitively, this variable is projected to be positively related to MFI as more people have access to financial services closer to where they live, a larger share of the population will enjoy those services and use them to expand their opportunities in which ever sector they work in.

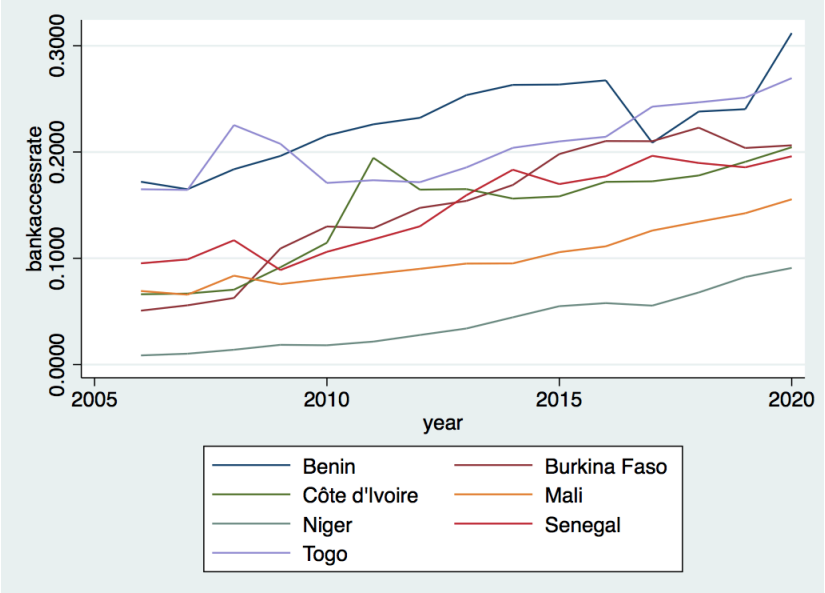

Figure 8: Bank access rate in the seven countries analysed, Banque Centrale des Etats de l'Afrique de l'Ouest (2022).

Country	Mean	SD	Min	Max
Benin	0.229	0.040	0.165	0.312
Burkina Faso	0.151	0.06	0.051	0.223

Côte d'Ivoire	0.144	0.049	0.066	0.205
Mali	0.101	0.028	0.066	0.156
Niger	0.041	0.027	0.009	0.091
Senegal	0.147	0.041	0.089	0.196
Togo	0.207	0.035	0.164	0.27

Table 6: Summary Statistics per country for the bank access rate variable.

	mfservrate	bankaccessrate
mfservrate	1.0000	
bankaccessrate	0.7363	1.0000

Table 7: Correlation matrix Financial variables.

F. Robustness variables: Additional Variables

To add an extra layer of robustness to this research, other macroeconomic variables are added to the model, to see if it impacts by any means the relationship between climate change and microfinance. This is done by including the Gross Domestic Product and the Inflation (GDP deflator) in the regression and the summary statistics of the variables can be observed on table 8, the mean for the GDP growth varies between 4 and 5 percent for all the countries but inflation can be very different for the countries. Mali has an average inflation of 3.6 percent whereas Benin and Côte d'Ivoire are averaging around 1.8 which is almost twice lower. Moreover, some countries experienced spikes of inflation as high as 11 or 12 percent (Mali, Niger and Togo) whereas the other only has an increase up to 5 or 7 percent. The data is retrieved from the World Bank Development Indicators. This research will try to test the influence increasing the share of borrowers at MFI and whether it comes from global warming and weather disruption rather than from some other macroeconomic variables such as the additional ones included in this research. The GDP variable is expected to have a small positive relationship with the share of borrowers at MFI and inflation is expected to behave the same way, a small but positive impact on the share of borrowers. These variables are included as an additional check and to prevent an omitted variable bias.

	Stats	GDP	inflation
Benin	Mean	0.046	0.019
	SD	0.018	0.024
	Min	0.018	-0.004
	Max	0.072	0.077
Burkina Faso	Mean	0.054	0.026
	SD	0.017	0.034
	Min	0.019	-0.022
	Max	0.084	0.092
Côte d'Ivoire	Mean	0.052	0.019

	SD	0.04	0.025
	Min	-0.054	-0.021
	Max	0.108	0.057
Mali	Mean	0.040	0.036
	SD	0.024	0.031
	Min	-0.012	0.005
	Max	0.071	0.122
Niger	Mean	0.056	0.028
	SD	0.024	0.029
	Min	0.02	-0.004
	Max	0.105	0.101
Senegal	Mean	0.041	0.020
	SD	0.02	0.027
	Min	0.013	-0.017
	Max	0.074	0.082
Togo	Mean	0.047	0.025
	SD	0.021	0.033
	Min	-0.012	-0.005
	Max	0.065	0.118

Table 8: Summary Statistics of the additional macroeconomics variables.

To conclude this section, this research is composed of 14 variables grouped in different clusters. The variables are summarised in table 9. Each variable will be regressed individually and in clusters but this will be extensively developed in the following section.

Variable name	Name	Defintion
mfservrate	Microfinance service rate	Dependent variable
anntemp	Annual average temperature	Independent climate variable
annprecip	Annual average precipitation	Independent climate variable
drought	Drought dummy	Independent climate variable (additional)
flood	Flood dummy	Independent climate variable (additional)
rurpoprate	Rural population (rate)	Independent agricultural variable: robustness
agrilandrate	Agricultural land (rate)	Independent agricultural variable: robustness
agriemplrate	Agricultural employment (rate)	Independent agricultural variable: robustness
childstunted	The rate of children under five years old recorded as being stunted	Independent demographic variable: robustness
epidemic	Epidemic dummy	Independent demographic variable: robustness

bankaccessrate	Bank access rate (the number of persons holding an account at financial institutions)	Independent financial variable: robustness
GDP	GDP annual growth	Independent macroeconomic variable: robustness
inflation	Inflation (GDP deflator)	Independent macroeconomic variable: robustness

Table 9: summary of the 14 variables

V. Methodology

This section describes the model and explain the methods used to quantify the effect of climate change on microfinance institutions and depositors' behaviour. The data used is a panel data on seven countries of West Africa during a 14 years period between 2006 and 2020. An limitation with this sample is the small size of the dataset. The number of observations often lies around 102 and decreases to 95 for the agricultural employment variable, it is known that smaller sample size decreases the accuracy of the model. Having a small sample when running a panel data regression might lead to bias in the results and interpretation. Nonetheless, the results might still be insightful and shed light on the importance of microfinance in the West African region in the 21st century.

1. The regressions

The goal of this thesis is to observe the relationship between climate change and the share of people borrowing at microfinance institutions. This will be done with a step-up method to clearly analyse the effect each added variables has on the relationship between climate change and the share of borrowers at microfinance institutions. The direction the analysis is following is including different clusters of variables such as agricultural, demographic, financial and macroeconomic ones and analysing their impact on the share of borrowers. Including additional variables that are not fully affected by climate change is done to check for the robustness of the model.

By analysing the variables in groups and individually, the model is correcting for each effect the groups of variables can have on the share of the population borrowing at MFI. The reason behind the double analysis of each variables (individual and clustered) is to avoid a multicollinearity issue as some variables in the clusters are correlated. Multicollinearity is defined as a high correlation between the independent variables that are used to explain movement in the dependent variable.
This section is developing each regression equation that will be ran afterwards.

The first regression will simply regress the climate change variables against the share of people holding an account at MFI.

$$(1)\ mfservrate_{it} = \alpha + \beta_1(anntemp)_{it} + \beta_2(annprecip)_{it} + \varepsilon_{it}$$

Once the first climate change variables are included, the dummies for flood and drought are added to the model.

$$(2)\ mfservrate_{it} = \alpha + \beta_1(anntemp)_{it} + \beta_2(annprecip)_{it} + \beta_3 drought_{it} + \beta_4 flood_{it} + \varepsilon_{it}$$

$$(3)\ mfservrate_{it} = \alpha + \beta_1(anntemp)_{it} + \beta_2(annprecip)_{it} + \beta_3 drought_{it} + \varepsilon_{it}$$

$$(4)\ mfservrate_{it} = \alpha + \beta_1(anntemp)_{it} + \beta_2(annprecip)_{it} + \beta_3 flood_{it} + \varepsilon_{it}$$

As mentioned previously, there are four different groups of variables that will be first studied individually and then altogether. To correct the effect of climate change on MFI, it is important to include how climate change has impacted the population's behaviour the areas studied. This is why regressions including the agricultural variable will be ran, altogether at first and individually later. It is done individually because there is a relatively high correlation between the variables (table 4).

$$(5)\ mfservrate_{it} = \alpha + \beta_1(anntemp)_{it} + \beta_2(annprecip)_{it} + \beta_3 rurpop_{it} + \beta_4 agrilandrate_{it} + \beta_5 agriemplrate_{it} + \varepsilon_{it}$$

$$(6)\ mfservrate_{it} = \alpha + \beta_1(anntemp)_{it} + \beta_2(annprecip)_{it} + \beta_3 rurpoprate_{it} + \varepsilon_{it}$$

$$(7)\ mfservrate_{it} = \alpha + \beta_1(anntemp)_{it} + \beta_2(annprecip)_{it} + +\beta_3 agrilandrate_{it} + \varepsilon_{it}$$

$$(8)\ mfservrate_{it} = \alpha + \beta_1(anntemp)_{it} + \beta_2(annprecip)_{it} + \beta_3 agriemplrate_{it} + \varepsilon_{it}$$

After having studied the agricultural variables, the demographic variables are examined: the percentage of children under five years old being recorded as stunted and an epidemic dummy are included.

$$(9)\ mfservrate_{it} = \alpha + \beta_1(anntemp)_{it} + \beta_2(annprecip)_{it} + \beta_3 childstunted_{it} + \beta_4 epidemic_{it} + \varepsilon_{it}$$

$$(10)\ mfservrate_{it} = \alpha + \beta_1(anntemp)_{it} + \beta_2(annprecip)_{it} + \beta_3 childstunted_{it} + \varepsilon_{it}$$

$$(11)\ mfservrate_{it} = \alpha + \beta_1(anntemp)_{it} + \beta_2(annprecip)_{it} + \beta_3 epidemic_{it} + \varepsilon_{it}$$

Once the agricultural and demographic variables are studied, the financial availability and accessibility of microfinance institutions in each country are examined using the additional variables accounting for bank access and availability in each country

$$(12)\quad mfservrate_{it} = \alpha + \beta_1(anntemp)_{it} + \beta_2(annprecip)_{it} + \beta_3 bank\ acces\ rate_{it} + \varepsilon_{it}$$

The final group of variables are the ones added to check that the increase in depositors in microfinance institutions comes from a direct change due to climate change and not from other macroeconomic variables such as GDP and Inflation in the countries investigated. By adding these additional variables, the goal is to prove the robustness of the climate change variables.

$$(13)\quad mfservrate_{it} = \alpha + \beta_1(anntemp)_{it} + \beta_2(annprecip)_{it} + \beta_3 GDP_{it} + \beta_4 inflation_{it} + \varepsilon_{it}$$

$$(14)\quad mfservrate_{it} = \alpha + \beta_1(anntemp)_{it} + \beta_2(annprecip)_{it} + \beta_3 GDP_{it} + \varepsilon_{it}$$

$$(15)\quad mfservrate_{it} = \alpha + \beta_1(anntemp)_{it} + \beta_2(annprecip)_{it} + \beta_3 inflation_{it} + \varepsilon_{it}$$

Finally, the last regression that is ran is including all the variables from all the different groups.

$$(16)\quad mfservrate_{it} = \alpha + \beta_1(anntemp)_{it} + \beta_2(annprecip)_{it} + \beta_3 drought_{it} + \beta_4 flood_{it} + \beta_5 rurpoprate_{it} + \beta_6 agrilandrate_{it} + \beta_7 agriemployrate_{it} + \beta_8 childstunted_{it} + \beta_9 epidemic_{it} + \beta_{10} bank\ access\ rate_{it} + \beta_{11} GDP_{it} + \beta_{12} inflation_{it} + \varepsilon_{it}$$

In the results section, each table is reporting the results from each equation where the number of the equation is mentioned at the top of the tables.

2. The choice of regression: Fixed or Random Effects

The first step in this research is to to choose the correct model, fitting the data the best. When using panel data, two types of regressions can be performed; the first one is using fixed effect which cluster the different groups (in this case; countries) within the data and correct for the differences between these groups. By clustering the data into groups, the differences between these groups are exploited. A Fixed Effect model could be necessary when there are not enough variables correcting for the differences between the countries but in this case, it might simply correct too much of the differences made by climate change and the effect might disappear.

The other type of regression that can be performed on this data is a regression using random effect. This regression does not differentiate between the groups (countries) within the data. A Random

Effect model assumes that individual effect (heterogeneity) is not correlated with any regressor and then estimates error variance specific to each groups (countries).
To choose between a Fixed Effect or Random Effect regression a Hausman test will be performed on the dataset. The Hausman test on equation 1 has a null hypothesis in favour of using Random Effect so when the p-value is high, the null hypothesis of using Random Effects cannot be rejected but when there is a low p-value, the test is in favour of using a Fixed Effect model.

When running the Hausman test on the first equation gives a p-value of 0.2345 which fails to reject the null hypothesis and favours a Random Effect model (table 14 in the appendix). This result is logical as the countries investigated are similar because of their location or their economic and financial development. Using Fixed Effects would have absorbed all variation between the countries. It is important that the model does not absorb all the variation between the countries because those variations are important to understand the link between the independent variable and the dependent ones or the additional robustness variables.
Once the model using Random Effect is chosen, the panel data regressions can be run.

3. Data analysis

When analyzing the results from this research the main outputs approached are the R-squared and the p-value corresponding to the coefficients of each variables. Moreover, the rho will be quickly touched upon. The R-squared is a popular measure of goodness of fit in ordinary regression, for each regression's outputs, the R-squared is given three times: within, between and overall. In this thesis, the "between" R-squared will be the one analysed, the R-squared is interpreted as how well the regression fits the data. Consequently, the larger the R-squared the better but this measure depends on many factors and should be analysed with precautions. This is why the rho is considered as a supplementary goodness of fit measure. The rho represents the ratio of individual specific error variance to the composite (entire) error variance, Park (2011). A large rho means that the individual specific error account for a large proportion of the composite error variance but can also be interpreted as a goodness of fit. As rho and the R-squared are both goodness of fit measure, this research will focus on the R-squared to analyse the different models.

As mentioned in a previous section, the model used is a panel data Random Effect model chosen through a Hausman test using a step-up way to investigate the significance of the variables and the weight they have on the share of depositors taking deposits at microfinance institutions. The result section will check the outputs given once the 14 regressions from the previous section are ran in Stata. As in the previous section, the results will be analyzed clustered in different groups of variables. The regressions are controlled for heteroscedasticity to avoid bias in the results by using the robust option on Stata.

VI. Results

1. Weather Variables

The equation (1) gives only one significant p-values for the average annual temperature but a low R-squared (0.1) which means that the average annual temperatures and precipitations in West Africa are only playing a part in the reason of the increase in microfinance depositors. The results from the regression can be observed in table 10 where only the temperature variable has a significant coefficient. These results were somewhat expected and are not surprising as the annual average temperatures were predicted to have an effect on the share of people holding an account at MFI (either a positive or negative effect, as mentioned in the two hypotheses). The only surprising side of the results is the size of the effect (0.06). Such a small increase in the share of borrowers when the temperature rise by one degree is minor and almost negligible. The temperature coefficient is 0.06. This coefficient means that a one degree increase in annual temperature increases the share of depositors by 0.06 percent. As mentioned previously, a day in West Africa will be 3 to 6 degrees Celsius hotter by the end of the 21st century. This would mean that in 80 years, the number of depositors taking loans in microfinance will be between 0.18 and 0.36 percent higher. This shows that there is a small positive impact of climate change on the share of borrowers, this impact is much smaller than what the literature would suggest. Thinking back at the hypotheses mentioned in section III, this small result might come from both hypothesis' validity and be an average of both effects: a part of farmers that are hurting from the rising temperature are probably turning to MFI to have access financial resources to adapt to the new climate (hypothesis 2) but others might simply be too overwhelmed by the weather changes, unable to repay their loans and are just quitting the agricultural sector and finding revenue opportunities elsewhere (hypothesis 1). Moreover, the insignificance of the precipitation variable is surprising and implies that the differences in precipitation (mm) between the countries and the years investigated do not impact the share of borrowers at MFI.

The rho in this regression is 0.69 which means that 69 percent of the variance is explained by the error term which varies across time and countries. In other words, this means that country specific error can explain 69 percent of the entire error term.

2. Weather Dummies

When adding the two weather dummy variables (equation 2), drought and flood, the model's R-squared increases to 0.35. This increase can be partly explained by the simple addition of two variables, nonetheless the increased R-squared might come from the usefulness of the added variables at explaining the model. The p-value of average annual temperature, precipitation and flood are significant at the 5 percent level but the drought dummy leads to an insignificant result (table 11). The coefficient of the flood dummy is negative in both regressions (equation 2 and 3) meaning that if there is a flood event in the country, the people using MFI services decreases by 0.63 percent which support

the first hypothesis, the share of population borrowing decreases. One single extreme event decreases the production yield by 90 percent for the weaker population Marmai, Franco Villoria and Guerzoni (2022). This might be the reason why when a flood event happens, the share of the population borrowing decrease because the consequences are so enormous that they are unable to repay their current loans (hypothesis 1). The insignificance of the drought variables both individually (equation 3) and grouped (equation 2) means that there is no correlation between drought and the share of people using MFI services across time and countries. Once the dummies are added to the model, the rho decreases to 0.604. This means that country specific error explains less of the total error in the model indicating that there are broader errors outside the model that are not picked up by the variables included.

Variables	Results equation 1
Annual Average Temperature	.0612506**
	(.0275287)
Average Annual Precipitation	.0000519
	(.0000433)
_cons	-1.574054**
	(.7340953)
R-squared (between)	0.1019
Rho	0.69595482
Number of Observations	102

*** p<0.01, ** p<0.05, * p<0.1

(robust standard errors)

Table 10: Results from Equation 1, regression of the climate variables on the share of borrowers at MFI.

Variables	Results equation 3	Results equation 4	Results equation 2
Annual Average Temperature	.0609209 **	.0668913 **	.0674247**
	(.0264501)	(.0288092)	(.0298984)
Average Annual Precipitation	.0000678 *	.0001003 ***	.0000831**
	(.0000378)	(.0000355)	(.0000335)
Drought (dummy)	.004602		-.0066999
	(.0135129)		(.0157166)
Flood (dummy)		-.0633178 *	-.0630785*
		(.0356754)	(.0362593)
_cons			-1.729368**
			(.8126245)
R-squared (between)	0.1581	0.3851	0.3509
Rho	0.64140303	0.5618586	0.65408182
Number of Observations	102	102	102

*** p<0.01, ** p<0.05, * p<0.1

(robust standard errors)

Table 11: Coefficients from the climate variables individually regressed on the share of borrowers at MFI and regressed as a group.

VII. Robustness of the model

1. Agricultural Variables

Equation (5) which includes the three agricultural variables does not provides any significant coefficient when including all the variables together as it can be observed on table 12 and the R-squared is very low (0.007). These are interesting results as they imply that the agricultural side of the global warming issue does not impact the microfinance institution and that changes in agricultural land, rural population or agricultural employment do not have any effect on the share of depositors at microfinance institutions, these results were not expected. Moreover, this implies that when correcting for the agricultural impact of global warming, the effect is not as expected. This could be explained by a high correlation between the agricultural variables and the precipitation variable (table 4), their correlation is high and negative. The rho's value is high and around 0.94 which means that country specific errors are accounting for a large proportion of the entire error term. Once the variables are added individually, the rho stays around 0.8. implies that the specific error variation which means that the individual error specific to share of borrowers account for large proportion of the composite error variance. This means that 80 percent of the error is explained by the error term.

When the rural population variable is included alone in the model (equation 6), annual average precipitation is significant but with a lower coefficient than before (table 12). The rural population has a very strong negative relationship (-1.5) with the share of people holding an account at MFI. This implies that an increase of one percent in the rural population in West Africa leads to a decrease in microfinance borrowing by 1.5 percent. This could be explained by the fact that countries with a higher rate of urban population (thus a lower rate of rural population) have better infrastructures for microfinance institutions because the population have easier contact and access to each other in cities. The urban population might find it easier to create groups to engage in group-lending and thus increase the share of borrowers engaging in microfinance borrowing because of the proximity of their environment Moreover, the urban environment could simply favor and be more suitable for financial achievement, leading the urban population to have higher chances of success when innovating or starting their own small business venture.

Adding agricultural land in the model (table 12, equation 7) does not improve the model as there are no significant coefficients. All the variables' p-values are above the 10 percent level, which means that correcting for the agricultural effect of climate change does not improve the model.

The last agricultural variable included in this analysis is the agricultural employment rate (table 11, equation 8). The p-values for the climate variables are insignificant. When this variable is included

alone, it has a low p-value and its coefficient is large and highly negative which translate into a one percent increase in agricultural employment would decrease the share of borrowers by 0.67 percent. The agricultural employment coefficient is negative which implies that as agricultural employment increases, the share of people using MFI services decrease. This follows the intuition that as more people are active in the rural sector, less will actually need the financial help provided by those institutions but also that the setting in urban areas favor micro-lending.

Variables	Results Equation 6	Results Equation 7	Results Equation 8	Results Equation 5
Annual Average Temperature	.0279146*	.0487132	.0209399	.0205764
	(.0165154)	(.0313366)	(.0189365)	(.0171687)
Average Annual Precipitation	-.0000886	-.0000177	-.0000898	-.0000691
	(.0000677)	(.0000572)	(.0000577)	(.0000734)
Rural Population	-1.496776**			-1.393035
	(.7000884)			(1.33946)
Agricultural Land		-.2206094		.8101988
		(.240447)		(.7567311)
Agricultural Employment			-.6760618**	-.2857795
			(.335809)	(.3390836)
_cons				.5837923
				(.6081357)
R-squared (between)	0.1477	0.1362	0.2953	0.0072
Rho	0.81891838	0.78380447	0.81388366	0.94308935
Number of Observations	102	96	95	95

*** p<0.01, ** p<0.05, * p<0.1

(robust standard errors)

Table 12: Coefficients from the agricultural variables individually regressed on the share of borrowers at MFI and regressed as a group.

2. Demographic Variables

The demographic regressions with all the variables included (table 13, equations 9) and individually included (table 13, equation 10 and 11), do not give different results. The three regressions give low R-squared, ever higher than 0.15. In these regressions, the share of children being recorded as stunted is used as a proxy for poverty. The temperature coefficient is only significant when the epidemic dummy is included (table 13, equation 11) and has a similar coefficient as observed before. The rate of children being recorded as stunted is significant when included alone (equation 10). These results imply that the poverty level in West Africa influence the microfinance institutions borrowers' behaviours. As the coefficient for children being stunted is around -0.4, an increase of one percent in children under five years old recorded as being stunted will decrease the share of borrowers at MFI by 0.4 percent. This coefficient supports the evidence that poorer countries have less people enjoying the MFI benefits. As found by Banerjee, Breza, Duflo and Kinnan (2019), microfinance and credit opportunities are

beneficial only for the population who actually had an existing business. The population who only started a business because of their microfinance access did not experienced an escape from the poverty trap, Banerjee, Breza, Duflo and Kinnan (2019). This support the evidence that when the population is stuck in a state of extreme poverty, small group-loans access does not actually make a difference.

On the other side, it does not matter to the MFI if the country faces any epidemic out brakes as the epidemic dummy is never significant. Moreover, in the three regressions, the precipitation variable is never significant, similarly to the grouped regressions for the agricultural variables (equation 5). Analogously to the model with the agricultural variables, the rho is around 0.8 for the individual regressions.

Variables	Results Equation 10	Results Equation 11	Results Equation 9
Annual Average Temperature	.0441605	.0600711 **	.0454227
	(.0272158)	(.0297097)	(.029321)
Average Annual Precipitation	.0000107	.0000324	-2.23e-06
	(.0000363)	(.0000499)	(.0000427)
Children (<5 y/o) Stunted	-.3978527**		-.4033558**
	(.1818763)		(.2006801)
Epidemic (dummy)		-.0091071	.0024407
		(.0108208)	(.0074894)
_cons			-.9594431
			(.8062082)
R-squared (between)	0.1331	0.0501	0.0976
Rho	0.7623085	0.75307534	0.82345846
Number of Observations	102	102	102

*** p<0.01, ** p<0.05, * p<0.1

(robust standard errors)

Table 13: Coefficients from the demographic variables individually regressed on the share of borrowers at MFI and regressed as a group.

3. Financial Variable

When including the bank access rate variable and regressing equation 12, the R-squared increases to 0.74 which is a large step compared to the regression performed before (table 14). The additional variable has a significant p-value and its coefficient is high. This coefficient translate into a one percent increase bank access rate would increase the share of borrowers at microfinance institutions by 1 percent. This is intuitive as more people have access to these institutions, more people have easier access to financial services and the rate of people taking loans at microfinance institutions will increase. The issue faced once including this financial variable is that the climate variables are transformed into insignificant values.

Variables	Results Equation 12

Annual Average Temperature	.0290305
	(.02296)
Average Annual Precipitation	.0000109
	(.0000278)
Bank Access Rate	1.008019***
	(.2809322)
_cons	-.7803689
	(.6561138)
R-squared (between)	0.7424
Rho	0.34020432
Number of Observations	102

*** p<0.01, ** p<0.05, * p<0.1

(robust standard errors)

Table 14: Coefficients from the financial variable regressed on the share of borrowers at MFI.

4. Additional Macroeconomic Variables

The last set of variables that have been included in the model are integrated to further check the robustness of the hypotheses. These additional variables are the GDP annual growth and Inflation, which are broader macroeconomic variables. The regression of equation 13 includes the two variables (table 15). The grouped regression (equation 14) has a low R-squared of only 0.1 and only one out of the two added variables with a coefficient significant: inflation. The coefficient for inflation is negative (-0.44) and this suggest that an increase in inflation leads to a significant decrease of around 0.44 percent in the rate of depositors. This could be explained by the influence of commercial banks' and other institutions' interest rate on the financial health of MFI, nonetheless the direct impact the inflation has on the population also has significant influence of the share of borrowers. The fact that GDP is not significant is surprising as it would be expected that more developed and richer countries have easier microfinance growth and that those institutions have better infrastructure to sustain this growth.

The large inflation influence on the share of MFI borrowers could be explained through its effect on interest rates. When inflation increases, commercial banks and institutions' interest rate increase as well. Higher interest rates decrease the attractiveness for the population to borrow and thus would decrease the share of borrowers. By looking closely on the population; as inflation rise, prices rise and interest rates rise impacting the entire population which affect their daily lives. This important macroeconomic change could heavily affect the population's financial behaviour and might decrease their borrowing's incentives because of the increase in interest rates. In regression number 15, regressing inflation by itself, the temperature coefficient is significant but the precipitation one is not.

When the variables are included individually (table 15, equation 14 and 15), a slightly higher R-squared can be observed for the GDP regression (equation 14) but only the climate variable being significant surprisingly including the precipitation variable. The temperature coefficient does not

change much (around 0.06) and in this case, the precipitation variables being significant its coefficient is extremely small (0.00006) but still implies a positive relationship with the share of borrowers at MFI. This very small coefficient could be explained because a one millimetre (mm) change in precipitation is small and does not affect the population much. The scale of the variable could be changed for a better interpretation. As mentioned previously, the GDP variable is not significant.

Equation 15's regression produces two significant coefficients; inflation and annual average temperature (table 15). The coefficient for the temperature variables is significant and around 0.055 which is slightly lower than what has been found before. The inflation variable's coefficient is negative and low which as mentioned previously implies a negative relationship between the share of people having an account at MFI and the inflation across time in the countries investigated. A one percent increase in inflation will decrease the share of borrowers at MFI by 0.52 percent. The R-squared is very low (0.09), which means that these variables clearly do not explain entirely the model.

Variables	Results Equation 14	Results Equation 15	Results Equation 13
Annual Average Temperature	.0620863 **	.0552768 **	.0567483**
	(.0305155)	(.0236075)	(.0275899)
Average Annual Precipitation	.000062*	.0000419	.0000516
	(.0000357)	(.0000433)	(.0000373)
GDP	.6674077		.5880476
	(.4896804)		(.4841229)
Inflation		-.5202286***	-.4411345**
		(.1866358)	(.1729136)
_cons			-1.46479 **
			(.7465388)
R-squared (between)	0.1112	0.0977	0.1050
Rho	0.72401768	0.75560771	0.78029944
Number of Observations	102	102	102

*** p<0.01, ** p<0.05, * p<0.1

(robust standard errors)

Table 15: Coefficients from the additional macroeconomic variables individually regressed on the share of borrowers at MFI and regressed as a group.

5. Overall Random Effect Regression

When all the twelve variables are included (equation 16) in the same model, the between R-squared increases to 0.81 (table 17) which is a large increase compared to what has been found previously but might be explained by the additions of all variables in the model. Moreover, very few variables have actually significant coefficients; only the epidemic dummy and the bank access rate variables have p-values low enough to be considered significant in this research. This result is surprising

as even the temperature variable does not have a significant coefficient. Against the expectations expressed in the hypotheses in section III, when including the 12 variables in the model, the agricultural variables did not have much of an impact on the share of borrowers at microfinance institutions. This suggests that changes in the agricultural variables are not having an influence on the rise of the share of borrowers at MFI across countries and time. In this overall regression, the rho is equal to zero. A rho of zero means that the variability within the groups is large relative to between those groupsThe reasons for these low results might come from the fact that the dataset is small as there are only 95 observations in the model and many of the variables are correlated (table 16) which is a result of multicollinearity. Furthermore, when a large number of variables is included in a regression, it is difficult for the model to find significance for each of the twelve variables.

	mfiservrate	anntemp	annprecip	flood	drought	ruropprate	agrilandrate	agriempl	bankaccessrate	childstun	epidemic	GDP	inflation
mfiservrate	1.00												
anntemp	0.05	1.00											
annprecip	0.31	-0.66	1.00										
flood	-0.46	0.11	-0.26	1.00									
drought	-0.13	0.22	-0.38	0.01	1.00								
ruropprate	-0.36	0.32	-0.62	0.30	0.27	1.00							
agrilandrate	-0.43	0.25	-0.82	0.27	0.27	0.52	1.00						
agriempl	-0.56	0.10	-0.69	0.35	0.22	0.56	0.89	1.00					
bankaccessrate	0.74	-0.16	0.61	-0.41	-0.28	-0.56	-0.66	-0.78	1.00				
childstunted	-0.36	-0.01	-0.43	0.25	0.17	0.77	0.53	0.73	-0.52	1.00			
epidemic	-0.1	-0.03	-0.16	0.19	0.12	0.34	0.17	0.33	-0.3	0.42	1.00		
GDP	0.04	-0.05	-0.01	-0.04	-0.11	0.08	0.02	-0.03	0.06	0.03	0.10	1.00	
Inflation	-0.17	0.04	-0.09	0.2	0.12	0.1	0.14	0.23	-0.21	0.13	0.19	-0.19	1.00

Table 16: Correlation Matrix of all variables.

Variables	Results Equation 16
Annual Average Temperature	.0136421
	(.0384061)
Average Annual Precipitation	-.0000713
	(.0000994)
Drought (dummy)	-.0067302
	(.0163246)
Flood (dummy)	-.0510917
	(.0413644)
Rural Population	-.1236495
	(.3795731)
Agricultural Land	.0514938
	(.4281574)
Agricultural Employment	-.1721144
	(.4965651)
Children (<5 y/o) Stunted	.1897757
	(.5147439)
Epidemic (dummy)	.0324513**
	(.0164056)
Bank Access Rate	1.378179 ***
	(.3288575)
GDP	-.136429
	(.2119999)
Inflation	.0580225
	(.0939136)
_cons	-.2043076
	(1.052432)
R-squared (between)	0.8108
Rho	0
Number of Observations	95

*** p<0.01, ** p<0.05, * p<0.1

(robust standard errors)

Table 17: Coefficients from all the variables regressed on the share of borrowers at MFI together.

Finally, adding the variables both individually and in clusters shed light on some important factors which influenced the share of MFI borrowers across countries and time but did not clearly explained their exact role and the direction of their influence as their significance is not strong. The exception is the bank access rate coefficient which is always significant. The reason for such ambiguous result could be that the two hypotheses mentioned in section III are both valid, this will be developed in the next section.

6. Time Fixed Effect Regression

When investigating the relationship between the share of borrowers at microfinance institutions and climate change, there is a small chance the increase in the share of borrowers simply comes from the intrinsic improvement to the industry. The evolution and expansion of the MFI industry might come from increasing interest from the local population but the reason underlying the growing interest is still to be defined; climate change adaptation, education, entrepreneurial activities, … The expansion of MFI services might actually not only come from climate change but could be also simply due to time and

this is the reason why a time Fixed Effect regression is included in this research. A Fixed Effect model will be run as additional robustness check regardless of the Hausman test not being in favour of using this model. Fixed Effect regression are different from Random Effects because they control for the effect of time-invariant variables with time-invariant effects whereas the Random Effect model assumes the unobserved variables to be uncorrelated with observed variables, Allison (2009). The clustered regression are the ones used in this section: equations 1, 2, 5, 9, 12, 13 and 16. As for the random effect, the regressions are controlled for multicollinearity using the robust option on Stata. The year fixed effect results from equation 1 can be observed in the first column of table 18 and is done to control for differences over time. The time fixed effect included in this regression allows to eliminate bias from unobservable variables that change over time but are constant over the countries and it controls for factors that differ across countries but are constant over time. The interpretation of the table is the following, the coefficient shows the differences between the years and the base year (2006) and every year can be thought of as a year dummy. The significance of the yearly dummies implies that evolution through time actually plays a role in the increase in share of borrowers at microfinance institutions. This finding puts the results and the relationship uncovered previously between climate change and microfinance into perspective. This could imply that part of the increase in the share of borrowers might simply come from time and not from the change in annual temperatures.

Variables	Results from equation 1 (original 7 countries included)	Results from equation 1 (5 additional countries included)
Annual Average Temperature	.0694857*	.0310101
	(.0333524)	(.0250897)
Average Annual Precipitation	-.0000266	-.0000466
	(.0001137)	(.0000465)
2007	.0082685	.0182512
	(.0108569)	(.0124149)
2008	.0649356**	.063612**
	(.0264034)	(.0257805)
2009	.0531762*	.0584759**
	(.0240966)	(.0219449)
2010	.054783*	.0702639**
	(.0256956)	(.0253661)
2011	.0743378**	.0770906**
	(.0297321)	(.0300481)
2012	.1075388**	.0900252**
	(.0420507)	(.0356078)
2013	.1206122*	.1004782**
	(.0502715)	(.0404809)
2014	.1237859*	.1045682**
	(.0527277)	(.0429245)

2015	.1324665*	.1069313**
	(.0535806)	(.0421841)
2016	.1166306*	.1026248**
	(.0515021)	(.0400304)
2017	.1317855**	.1114208**
	(.0511595)	(.0420424)
2018	.1618949**	.1331013**
	(.0598648)	(.0501123)
2019	.1740817**	.1366658**
	(.0636136)	(.0531018)
2020	.110939**	.1037999**
	(.043594)	(.0368797)
_cons	-1.836191*	-.7391914**
	(.9067848)	(.6576764)
R-squared (between)	0.0081	0.2158
Rho	.85211181	.87666478
Number of Observations	102	163

Table 18: Time Fixed Effect model on original and additional sample

7. Additional countries

As mentioned earlier, only including seven countries is severely reducing the sample size. This robustness check is done by adding five new countries in the regression. The five countries are still located in Africa but the interpretation of their independent variable is slightly different; it is the "Persons Borrowing from Deposit Taking Microfinance Institutions (MFIs)" and is retrieved from the Federal Reserve Economic Data. The original variable from the FRED was a head count but once it is divided by the total population of each country, it becomes a percentage of the total population, just as for the original seven countries. The variables are not totally similar but this is the best that can be done to have the closest interpretation between the additional variables and the original one. The countries and time frame available are the following: Djibouti (2008-2019), Burundi (2007-2016), Rwanda (2008-2020), Kenya (2010-2020) and Madagascar (2006-2020). The summary statistics can be seen on table 20. The only regression that will be run with the additional countries is the first one including only the average annual temperature and precipitation variables as these are the main focus of this research. The countries do not have a complete dataset for all the years investigated but still including those increases the number of observations from 102 to 163. Table 19 shows the results for the Random Effects regression for the additional countries. In the case of additional countries included, the coefficient for annual average temperature is significant at the one percent level but is lower (0.028) than what has been found earlier (0.06) which implies that a one percent increase in average annual temperature (in Sub-Saharan Africa) leads to a 0.027 percent increase in the share of borrowers at MFI. The decrease in the coefficient might simply come from the slight difference in the interpretation of the "mfservrate" variable for the additional countries as their value is much lower than the ones for the

original seven countries (table 20). Nonetheless, this results still implies a positive relationship between annual average temperature and the share of borrowers. Another improvement detected is the increase in the R-squared, it used to be 0.1 and it increases to 0.4.

The conclusion of this last robustness check including five additional countries seems to increase the goodness of fit of the model as the R-squared increase but because of the slight difference in the independent variable's values, the coefficient decreases. Moreover, the impact of the increase of the average annual temperature is nevertheless positive.

Variables	Results for additional countries
Annual Average Temperature	.0276352***
	(.0081978)
Average Annual Precipitation	.0000376
	(.0000285)
_cons	-.6412542***
	(.1991687)
R-squared (between)	0.4046
Rho	.7248985
Number of Observations	163

*** p<0.01, ** p<0.05, * p<0.1

(robust standard errors)

Table 19: Regressions additional five countries

	Stats	mfservrate	anntemp	annprecip
Djibouti	Mean	.0005205	28.568	245.5947
	SD	.0000306	.2976383	34.24376
	Min	.0004756	28.17	196.68
	Max	.0005672	29.1	317.6
Burundi	Mean	.0025141	20.69533	1259.068
	SD	.0007075	.1879919	125.3417
	Min	.0013004	20.47	961.12
	Max	.0038454	21.06	1492.25
Rwanda	Mean	.004637	19.446	1231.202
	SD	.0026852	.1978744	98.57873
	Min	.0016247	19.22	1081.09
	Max	.0106614	19.84	1382.46
Kenya	Mean	.0072975	25.23933	756.9593
	SD	.0023725	.2206635	136.8462
	Min	.0040802	24.92	608.32
	Max	.0122066	25.56	1100.16
Madagascar	Mean	.0067316	22.828	1422.455
	SD	.002177	.2038277	89.68885
	Min	.0028368	22.4	1229.51

	Max	.0109932	23.15	1530.56

Table 20: Summary statistics for the additional five countries (robustness)

VIII. Final remarks

After having analysed the results from all the regressions performed, it seems that climate change has a small but positive effect on the share of people having an account in microfinance institutions in West Africa (0.06 percent). This can be stated because when performing all the regressions, not one time was a negative coefficient found which support the evidence of a positive effect. This small effect will nonetheless be growing in the near future as the temperature are expected to keep increasing, Fitzpatrick, Parker et al (2020). Observing the results, it seems clear that climate change is not the only factor affecting the share of borrowers at MFI. As a reminder, the variables significant when individually regressed with the climate variables were the flood dummy, the rural population, agricultural employment, the share of children stunted, the bank access rate and the inflation. The only two variables significant in the overall regression were the bank access rate and the epidemic dummy. The results are ambiguous as all the variables are correlated and depend on the other variables included in the regression (multicollinearity).

The first answer and main takeaway from the research is; the annual average temperature effect on the MFI borrowers' behaviour in West Africa has a rather small but positive relationship. The reason behind this interesting small effect would be an average of the two hypotheses discussed in section III. Defrance and Iizumi (2019) have mentioned in their research that an increase in temperature will decrease the productivity of farmers. Of course, productivity is not quantified and not included in this research but an increase in MFI borrowing due to rising temperatures could stem from the population's underlying will to counter a fall in agricultural productivity and increase their resilience (hypothesis 2). This argument could be turned around and the decrease in productivity could discourage the farmers leading them to be unable to pay their interest on their loans and stop borrowing from MFI (hypothesis 1). As global warming will have a social and economic impact on the communities, the population could turn to financial institutions to shield themselves from these variations but the drastic changes might decrease the population's revenue to a point where they cannot actively participate in group lending opportunities offered by MFI. This argument highlights the idea that there are many factors not included in this research that could influence the share of borrowers through changes in environmental conditions.

The results suggest that the answers lie in between, that part of the population behave one way and others the other way. The average of the two comportment and both hypotheses is the reason behind the almost low significance of the temperature coefficient.

The average annual precipitation level does not have the same impact as temperatures; its effect on the share of MFI's account holders is very often insignificant (constant high p-values in regressions). This means that there is not enough evidence supporting that the precipitation level does impact the share of borrowers at MFI across countries and time or simply that the two hypotheses lead to insignificant results. This suggest that modifications in rainfall patterns do not affect the population much.

When investigating the variables individually, the first individually significant variable in the model is the flood dummy. An extreme flood event can ruin years of work for farmers. The effect is small and positive which could mean that when a flood happens, the famers need financial assistance helping them to recover from such disaster and turn to MFI to access financial opportunities.

Turning to the robustness check variables, the rural population and agricultural employment have individually an impact on the share of borrowers at MFI but the strength of this effect is ambiguous and like for the other variables, it might simply be an average of both hypotheses. The coefficient for the rural population is negative, implying a negative relationship with the share of MFI borrowers when the climate variables are included in the model. The two effects are explained in the agricultural result section. This can be looked at from two different perspectives: either there are significant differences between urban and rural microfinance opportunities or there is a rural population dynamic which leads to a decrease in MFI borrowing. Comparably to the climate variables, the effect of the agricultural variables is ambiguous but stronger. In this situation, both hypotheses could be argued but the choice of the right one is rather complicated.

When analysing the proxy for poverty, it has a negative effect on microfinance institutions; as poverty increases, the number of people holding an account in MFI will decrease. This relationship is interesting and could be supported by the fact that once people fall into the poverty trap which is defined as a vicious cycle where poverty induces poverty and in the case of microfinance institutions, poor people in the poverty trap do not turn to the financial opportunities offered by MFI. As more people fall into poverty; more people are hopeless about their financial health and do not even apply and to save themselves from poverty, reducing the number of borrowers at MFI. This result is in line with the first hypothesis.

The bank access rate comes up as a the most influential variable in this research as it is significant both individually and when all the other variables are included. It is defined as "the number of persons holding accounts in banks, postal services, savings banks and the treasury over the total adult population". As mentioned in a previous section, as more people have an easier access to financial

institutions includes which includes MFI, the share of borrowers and people actively using those services will increase.

Finally, inflation is a more general variable which is less directly linked with the variables investigated but it also has a clear impact on MFI as inflation and the price increase affects the entire country's population. This is why changes in inflation have an impact on MFI and its borrowers, the entire population is suffering from increases in inflation and thus might turn to financial support to smoothen the rising prices' impact.

The issue of multicollinearity has been mentioned earlier. To try and solve this issue, variables were added and removed from the models but without any positive outcomes; no regression provides more significant coefficient than what has been found in previous regression models.

When investigating the Fixed Effect model, it is observed that time plays an important part in the evolution of the share of borrowers at MFI. This implies that part of the increase in the share of borrowers might simply come from time and not from the change in annual temperatures.

IX. Conclusion

The aim of this research was to identify and quantify the effect climate change and global warming has on microfinance institution in West Africa during the 21st century. This is investigated through a panel data regression on seven countries (Benin, Burkina Faso, Côte d'Ivoire, Mali, Niger, Senegal and Togo) between 2006 and 2020. The data is retrieved from the United Nation Climate Change Portal, the Central Bank of the West Africa States and the Food and Agriculture Organisation of the United Nation.

After having regressed the equations with individual variables and clustered into groups, it is shown that average annual temperatures in each country have only a small but positive impact on the share of borrowers in microfinance institutions. Higher temperatures lead to an increase in the share of borrowers at microfinance institutions. The impact of the other variables was ambiguous but the flood dummy (-0.06), the rural population (-1.49), agricultural employment (-0.67), the share of children (<5 years old) recorded as stunted (-0.4), the bank access rate (1.00) and the inflation (0.44) were significant when individually included in the model. The research is based on two hypotheses, the first one being that the increase in temperature leads to such important changes in agricultural conditions that the increase in risk associated are too much for the population. The increase in risks shift of the population away from microfinance either because they are unable to repay their interest or simply because they rather find revenue opportunities elsewhere and thus separate themselves from MFI. The other

hypothesis suggest that the agricultural population has a will to adapt and mitigate the global warming effects and shield themselves from those risks by borrowing at microfinance institutions. By borrowing at MFI, the vulnerable population might be able to buy weather resilient crops or improve their infrastructures. Nonetheless, after having regressed a Fixed Effect model, there is an evidence of the time component playing a part in the evolution of microfinance institutions.

The research's findings are therefore not as insightful as expected and the conclusion is ambiguous as the results could simply be an average of both hypotheses. The variables used to control for any changes made by global warming on the agricultural practices did not have any strong impact when included in the clustered and the complete model which is against the expectations expressed. The effect of global warming on MFI is positive and small but not as large as some would assume. This research results are useful and helpful for the policymakers as this proves there is a causal link between the rising temperatures and the share of borrowers at microfinance institutions but the bottom-line effect is still ambiguous and could lead to further research.

For future research, an improvement would be to include a larger period of time and a larger country sample could be used. Investigating the entire Sub-Saharan African continent, South America or Asia and investigating the evolution of microfinance institutions since 1990 would have brought more dept to the research and a more detailed assessment of global warming's impact on the population. Unfortunately, because of the precision of the dependent variables and the database, it would have been complicated to add other countries. Moreover, the poorer countries around the world have poorer databases which complicates the research. A behavioural research could be performed to understand the direct consequences of climate change on the population and how they adapt to these changes. A variable accounting for the vulnerable share of the population or the agricultural productivity could actually help the preciseness of the model but finding such variable is rather complex. A variable accounting for the agricultural productivity could also be insightful to understand how climate change directly affects the agricultural activities. Besides, further research could be completed to clearly detangle the precise effect of the rising temperature on the population and field interviews could be done to better understand the underlying choices of the population to survive and adapt to this climate crisis as well as their behaviour towards financial opportunities brought by microfinance institutions.

Finally, the results from this research show an effect of climate change on microfinance but the underlying cause of this effect is still rather unclear and ambiguous and could motivate further researches.

X. Appendix

Table 14: Results from the Hausman test

```
                 ---- Coefficients ----
             |      (b)          (B)            (b-B)     sqrt(diag(V_b-V_B))
             |       fe           re          Difference       Std. err.
-------------+------------------------------------------------------------
     anntemp |    .0692597     .0612506        .0080091
   annprecip |   -.0000612     .0000519       -.0001131        .0000665
------------------------------------------------------------------------------
                           b = Consistent under H0 and Ha; obtained from xtreg.
            B = Inconsistent under Ha, efficient under H0; obtained from xtreg.

Test of H0: Difference in coefficients not systematic

    chi2(2) = (b-B)'[(V_b-V_B)^(-1)](b-B)
            =   2.90
Prob > chi2 = 0.2345
```

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