Do Climatic shocks matter for Food Security in Developing Countries?

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Abstract

This paper analyzes the effect of climatic shocks on food security over the period 1960-2008 for 77 developing countries. We apply modern econometric methods, use panel data and two indicators of food security that are malnutrition and food production. The results are as follows: Firstly we show that rainfall volatility is a factor of food insecurity in developing countries. Indeed rainfall instability reduces food production and increases the percentage of total undernourished population. Secondly we find that African countries are more vulnerable to rainfall instability than other regions. By reducing food production and increasing the proportion of undernourished population, rainfall instability is a factor of food insecurity in these countries.

Key words (JEL): Food Security (Q18), Income (O1), Climatic Shocks (Q54).

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Introduction

There is increasing evidence that greenhouse gases have already begun to warm the planet (Intergovernmental Panel on Climate Change (IPCC), 2007). This in turn will cause future climates to warm and will likely cause changes in precipitation patterns (IPCC, 2007). That could have significant negative impacts both in developed and developing countries. Predictions for 2050 by the US National Centre for Atmospheric Research show that the declining trend in rainfall that has started is set to continue and particularly the Southern Africa is expected to be 10-20 percent drier than the previous 50 years (Mitchell and Tanner, 2006). These predicted changes in climate are expected to have differential impacts on agricultural productivity and food security and other sectors across spatial and temporal scales. In the tropics and Africa in particular, changes in climate are expected to be detrimental to agricultural livelihoods (Dinar et al., 2008; Dixon et al., 2001). According to the International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD, 2009), climate change, coincident with increasing demand for food, feed, fibre and fuel, has the potential to irreversibly damage the natural resource base on which agriculture depends, with significant consequences for food insecurity.

The impact of climate change on food security has been identified as a major area of concern given marginal climatic conditions in many parts of world in generally and in developing countries in particularly. In Indeed, the predominance of rain-fed agriculture in much of Sub-Saharan African results in food systems that are highly sensitive to rainfall variability. Food security may be defined as a situation whereby ―all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life.

Several studies analyzed the effects of climate change on agriculture using various analysis methods. Some studies use the crop simulation approach to analyze the direct effect of climate change on individual crops (for example Rosenzweig and Parry 1994; Parry et al. 2004). These studies suggest that the yields of the major grains grown would fall precipitously with warming in the context of Africa. Recent studies analyzed impacts of climate change on dryland crops, irrigated crops and livestock separately and found that agricultural crop productivity will be adversely affected by any warming above current levels (Kurukulasuriya et al., 2006; Gonese, 2007; Kurukulasuriya and Mendelsohn, 2008; Seo and Mendelsohn, 2008, Nhemachena, 2009). For example, Nhemachena (2009) evaluated the aggregate impacts of climate change on income from all agricultural production systems in Africa and predict future impacts under various climate scenarios. The most of these studies are the microeconomic studies.

There is little evidence on the empirical link between climate change and food security but many theoretical predictions have been established. In generally, the food security implications of changes in agricultural production patterns and performance due to climate change are of two kinds: i) impacts on the production of food will affect food supply at the global and local levels, and higher yields in temperate regions could offset lower yields in tropical regions; ii) impacts on all forms of agricultural production will affect livelihoods and access to food, and producer groups that are less able to deal with climate change, such as the rural poor in developing countries, risk having their safety and welfare compromised (FAO, 2008). However, there is no detailed empirical study in macroeconomic area on impact of climate change on food security in the developing countries.

The objective of this article is to analyze the effects of climate shocks on food security over the period 1960-2008 for 77 developing countries. We focus on two indicators of food security that are malnutrition and food production. Our hypothesis is that rainfall shocks (instability) reduce food production and increase the proportion of undernourished people in a country. The results are as follows: Firstly we show that rainfall volatility is a factor of food insecurity in developing countries. Indeed rainfall instability reduces food production and increases the percentage of total undernourished population.

Secondly we find that African countries are more vulnerable to rainfall instability than other regions. By reducing food production and increasing the proportion of undernourished population, rainfall instability is more a factor of food insecurity in these countries. This means that the climatic shocks (rainfall instability) observed is likely to explain part of the puzzle of developing countries (Africa)'s relatively poor performance and food insecurity

The plan of the paper is as follows. The next section outlines the arguments on the relation between climate change and food security. In section 3, we describe the empirical procedure and the data sources. Section 4 shows empirical results and the last is devoted to the conclusion

2. Literature Review

2.1 Determinants of food security

Food security is achieved when all people at all times have physical, social, and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life (FAO, 2001). This definition comprises four key dimensions of food supplies: availability, stability, access, and utilization. Availability refers to the overall ability of the agricultural system to fundamentals of crop and pasture production and the entire range of socio-economic and cultural factors that determine where and how farmers perform in response to markets. Stability refers to individuals who are at high risk of temporarily or permanently losing their access to the resources needed to consume adequate food. Access refers to having the means to acquire food through production or purchase. Utilization refers to food safety and quality aspects of nutrition.

Food insecurity is defined as the absence of food security and applies to a wide range of phenomena such as famine, periodic hunger and uncertain food supply. Food insecurity is caused by several factors. In this literature review, we identify the microeconomic and macroeconomic determinants.

2.1.1 Microeconomic Causes

Microeconomic determinants of food insecurity are related to low rates of agricultural production, low access to food, infrastructure and local markets, and environment health. Degradation and declining productivity of agricultural soils are serious threat on agriculture in many areas (FAO, 2004). Low productivity in the agricultural sector reduces considerably food supply, and that leads to high prices on the food markets. Some households have not access to food because of low incomes. Sufficient food available at the country or local level does not mean that all people are food secure. Low incomes, lack of roads and infrastructure, safe drinking water, primary health care and education all impact on people’s food consumption. There are food-surplus countries where underweight children are more important than in food deficit ones.

Economic environment characterized by a good transport and communication infrastructure and efficient financial system that facilitates access to credit are essential for food security to ensure low food prices and efficient markets that can respond to changes in demand. Indeed, infrastructure reduces the costs of transporting produce and inputs, and food storage. It allows information transfer between producers and markets, and gives farmers access to new technologies. Access to credits can reduce the obstacle to investing and innovating in the agricultural sector in the developing countries. The health environment of households is also crucial in explaining the incidence and intensity of food insecurity. Poor sanitation, lack of health facilities and water sources expose households to infectious diseases and health problems related to malnutrition. For example, HIV/AIDS mainly affects economically active adults, and so contributes to worsening and widespread food insecurity by undermining the capacity of households to work and produce or buy food, increasing the number of orphans and children with little or no care, and reducing social support mechanisms (POSTnote 2010).

2.1.2 Macroeconomic Causes

Macroeconomic causes are the factors that expressed at the country level. In this section, we identify four major factors that can impact food security: economic performance, population growth, income inequality, and political regime.

Several studies analyzed the relationship between economic performance and malnutrition (see Pritchett and Summers, 1996; Wiesmann 2006). Generally, poor economic performance is a major cause of poverty. Poverty affects both food security via accessibility and health and social environment. But, sustained economic growth has a direct impact on food security by supporting agricultural production and consequently food supply. However, the influence of economic performance should be linked with population growth. According to Malthus (1992), population growth causes an increase in pressure on agricultural resources. That penalizes agricultural productivity and consequently food production. In contrast, Boserup (1965) suggests that population growth is a source of creative pressure that favors technical progress and rising productivity in agriculture. Birdsall and Sinding (2001) find that a high level of fertility before demographic transition is an obstacle to reducing poverty while a decrease in fertility during transition helps to reduce poverty by giving more opportunities[3].

[3] When the birth rate begins to decrease, there is a change in the pyramid; the potential share of the labor force (15-64 years) increased and that of inactive (less than 15 years and over 64 years) decreased. If economic and social system allows these potential workers to acquire skills and qualifications and find productive employment, there is a temporary increase in the accumulation of physical and human capital to increase living standards (Williamson, 2001).

Merrick (2002) shows that food security depends more on agricultural and trade policy. However, he admits that population growth can exacerbate the harmful effects of inappropriate policies. Also, wealth inequalities affect hunger and malnutrition mainly indirectly through their impact on poverty. Indeed, a high degree of inequality promotes the growth of poverty and leads to constraints on food access for some households and is consequently a source of food insecurity.

The political context has a direct impact on food security. Drèze and Sen (1989) and Sen (1999) show that famine has never occurred in a country respecting the democratic rules. This result reflects the idea that political and civil rights contribute to the protection of economic and social rights, including the right to food. Some studies analyzed the relationship between armed conflicts and malnutrition (see Messer and al. 1998; Sen 2000; Wiesmann 2006). These studies show that conflicts have a direct impact on food security by limiting both food availability (collapse of agricultural production) and accessibility (change in relative prices, rising unemployment, lower revenues and rising poverty).

Nowadays, with global warming whose implications on environment have a significant impact on the agricultural sector; a central issue emerges: What would be the link between climate change and food security? Several theoretical hypotheses have been advanced. Most often, studies analyze the relationship between climate change and the different components of food security.

2.2 Effects of Climate Change on Food Security

There is great evidence that the greenhouse gas emissions have already begun to warm the planet (Intergovernmental Panel on Climate Change, 2007). This will probably cause climate changes, which in turn could have significant negative impacts both in developed countries than in developing countries. Among a wide range of negative effects, climate change tends to exacerbate the scarcity of resources and may increase food insecurity. In the following parts, we analyze the effects of climate change on each of these aspects of food security cited in the first part.

2.2.1 Climate change effect on food availability

Climate change affects food production directly through changes in agro-ecological conditions and indirectly by affecting growth and distribution of incomes, and thus demand for agricultural produce. Here, we analyze the direct effects of climate change on food production and availability. Changes in temperature and precipitation associated with continued emissions of greenhouse gases will bring changes in land suitability and crop yields (Schmidhuber and Tubiello, 2007). However, the impacts of mean temperature increase will be experienced differently, depending on location (Leff, Ramankutty and Foley, 2005). For example, moderate warming (increases of 1 to 3 ºC in mean temperature) is expected to benefit crop and pasture yields in temperate regions, while in tropical and seasonally dry regions, it is likely to have negative impacts, particularly for cereal crops. Warming of more than 3 ºC is expected to have negative effects on production in all regions (IPCC, 2007c). The supply of meat and other livestock products will be influenced by crop production trends.

For climate change implications such as rainfall, soil moisture, temperature and radiation, crops have thresholds beyond which growth and yield are compromised (Porter and Semenov, 2005). For example, cereals and fruit tree yields can be damaged by a few days of temperatures above or below a certain threshold (Wheeler et al., 2000). A study of IPCC (2007c) shows that the increases in mean temperature (6°C above long-term means) in European countries in 2003 led to a significant drop in crop yields (for example 36 percent for maize in Italy and 25 percent for fruit in France). Generally, increased intensity and frequency of storms, altered hydrological cycles, and precipitation variance also have long-term implications on the viability of current world agro-ecosystems and future food availability.

2.2.2 Climate change effect on food stability

Climate change has an effect on the stability of food supplies. Indeed, increases in the frequency and severity of extreme events such as cyclones, floods, and droughts bring greater fluctuations in crop yields and local food supplies and higher risks of landslides and erosion damage. These climate change implications are a particular threat to food stability and could bring about both chronic and transitory food insecurity. In rural areas that depend on rainfed agriculture for an important part of their local food supply, changes in the amount and timing of rainfall within the season and an increase in weather variability are likely to aggravate the precariousness of local food systems (FAO, 2008). In semiarid areas, the effect of climate fluctuations more pronounced and more widespread on food production are more severe because droughts can dramatically reduce crop yields and livestock numbers and productivity (IPCC, 2001).

2.2.3 Climate change effect on utilization food

Some analyzes highlighted the effect of climate change on food utilization. The utilization component of food security is generally relates to nutritional aspects of food consumption. Most poor households receive what micronutrients they do get through the consumption of plants. There are main ways by which climate change could directly affect micronutrient consumption: by changing the yields of important crop sources of micronutrients, by altering the nutritional content of a specific crop, or by influencing decisions to grow crops of different nutritional value.

Taub and al. (2008) show that higher CO2 concentrations can lower protein content in various food crops, particularly in the context of low nitrogen inputs. These declines would be amplified by any yield losses, and would hit hardest in poor areas where nitrogen application rates are low and where crops constitute a primary source of dietary protein. Rosenzweig and Binswanger (1993) show that climate can shape the decisions farmers make about what crops to grow. This could potentially alter planting decisions in ways that alter micronutrient availability.

Moreover, climate change has the potential to affect health status directly, in ways that alter an individual's ability to utilize food. In areas with limited access to clean water and sanitation infrastructure, diarrheal disease is a leading killer, and contributes directly to child mortality and poor food utilization by limiting absorption of nutrients. Some studies showed that extreme rainfall events, droughts, and warming temperatures increase the incidence of diarrheal disease (Checkley and al. 2000; McMichael and al. 2006). Similarly, climate change implications could affect disease incidence, for example a prolonged drought increase the risk of meningitis outbreak, or a prolonged flood increases the probability of cholera outbreaks (McMichael and al. 2006; Canfalonieri and al. 2007). Thus, the affected population lowers their ability to effectively use food.

2.2.4 Climate change effect on food accessibility

Generally, most food is not produced by individual households but acquired through buying, trading and borrowing (Du Toit and Ziervogel, 2004). Climate impacts on income-earning opportunities can affect the ability to buy food, and a change in climate or climate extremes may affect the availability of certain food products, which may influence their price. High prices may make certain foods unaffordable and can have an impact on individuals' nutrition and health.

Changes in the demand for seasonal agricultural labour, caused by changes in production practices in response to climate change, can affect income-generating capacity positively or negatively. Mechanization may decrease the need for seasonal labour in many places, and labour demands are often reduced when crops fail, mostly owing to such factors as drought, flood, frost or pest outbreaks, which can be influenced by climate. On the other hand, some adaptation options increase the demand for seasonal agricultural labour.

Local food prices in most parts of the world are strongly influenced by global market conditions, but there may be short-term fluctuations linked to variation in national yields, which are influenced by climate, among other factors. An increase in food prices has a real income effect, with low-income households often suffering most, as they tend to devote larger shares of their incomes to food than higher-income households do (Thomsen and Metz, 1998).

3. Empirical Analysis

3.1. Estimation method

The objective of the paper is to analyze the effect of climate shocks on food security and also to identify one potential channel transmission. We think that one hand, climate shocks have direct effect on food insecurity and other part, indirectly through food prices.

a) *Effect of climatic shocks on food security*

The first equation analyses the effect of climatic shocks on food security.

$$Y_{i,t} = \alpha_i + \beta CS_{i,t} + \omega X_{i,t} + \gamma_t + \varepsilon_{i,t} \quad (1)$$

With X the matrix of control variables, $CS_{i,t}$ is the climatic shocks in a country (i) at a period t and our interest variable. $\varepsilon_{i,t}$ is the error term, γ_t is time effect and α_i represents country fix- effects. The period is 1960 to 2008 and data are compiled in five-year averages. Our sample is made of 122 developed and developing countries. $Y_{i,t}$ is the variable of food security ; We use alternative measures which are:

- the proportion of undernourished population

- the index of per capita food production

Moreover the effects can be different depending on whether the country was under conflict or not. Finally, we look at if the effects are different for African countries.

$$Y_{i,t} = \alpha_i + \beta CS_{i,t} * Africa + \omega X_{i,t} + Africa + \gamma_t + \varepsilon_{i,t} \qquad (2)$$

With $Africa$: the African countries

Estimation strategy

In order to estimate this model we use adequate econometric techniques. The panel data take into account transversal, temporal dimensions observed and unobserved heterogeneity of countries. It is adequate to apply Fixed Effects (FE).

3.2. Determinants of food security

3.2.1. Food security

Food security is achieved when all people at all times have physical, social, and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life (FAO, 2001). This definition comprises the four dimensions of food supplies developed in the literature: availability, stability, access, and utilization. From this definition of food security, food insecurity can be defined as the absence of food security and applies to a wide range of phenomena such as famine, periodic hunger and uncertain food supply. Several indicators have been defined to measure the concept of food insecurity.

The first two indicators that have been used to measure food insecurity are the energy balance per capita and per day which is measured by the Dietary Energy Supply, and the headcount rate of poverty defined as the proportion of people with an income below one dollar per day. The energy balance is a measure of national food availability that help to know how the food supply of a country meets the energy needs of its population under the assumption that the food supply is distributed among individuals according to needs. For people who have an income below one dollar per day are likely to face problems of food access. These two indicators are considered as the partial measure of food security because it measures only some dimensions of food security: food supply for the energy balance and food access for the headcount rate of poverty.

Another indicator has been used in some studies: child malnutrition which is a measure of nutrition security. This indicator measures the prevalence of underweight among children under five. This indicator is considered by Maxwell and Frankenberger (1992) and Rogers (1997) as a good measure of food insecurity. Other studies used the proportion of undernourished in the total population. In this case, a person is malnourished if his average energy intake is less than the minimum necessary to maintain physical and moderate activity. The proportion of undernourished people is considered to be close to the definition of food insecurity by FAO.

There are analyses that consider the mortality rate among children under five years to measure food insecurity. This indicator gives an idea of the severity of food insecurity. Indeed, child hunger, which leads to infant mortality, is the most severe form of food insecurity. Recent studies refer to Global Hunger Index (GHI) developed by International Food Policy Research Institute (IFPRI) to measure food insecurity. This indicator is an arithmetic average of three indicators: child malnutrition, proportion of undernourished people and mortality rate among children under five years. It seems to be the best indicator to measure food security. We cannot use in this paper because it is not available on the long time. It has been calculated for only few years.

In our empirical analysis, we use two indicators of food security: the proportion of undernourished people and index of per capita food production. The proportion of undernourished people provides a measure of the extend of the hunger problem for the region/country and thus may be considered a measure of food insecurity.

3.2.2. Control variables

We will now describe in more details determinants of the explanatory variables (the proportion of undernourished population and the index of per capita food production) that have been using in our equation. There are a number of factors that can influence the proportion of undernourished population, such as the level of development, population growth, the food prices, income inequality, the level of education and the political environment.

Economic performance can have an effect on food security. According Smith and Haddad (2000), the economic resource availabilities increase the capacity of countries to provide of goods and services for population. Indeed, governments can increase the level of budgets that enhance countries ‘health environments and service as well as education. Secondly it may boost national food availability by improving resources available for purchasing food on international markets, and, for countries with large agricultural sectors, it reflects the contribution of food production to over all income generated by households. Thirdly, it may improve women’s relative status directly by freeing up resources for improving women’s lives as well as men’s. Furthermore, Egypt massively subsidizes basic foods like bread, sugar, and cooking oil (Ahmed et al. 2001). While this food subsidy program has surely helped the poorest to meet their dietary energy needs, its focus on energy-dense, nutrient-poor foods has fostered overconsumption of dietary energy among the population, with widespread overweight and obesity as a negative result (Asfaw 2006). Finally, there is a strong negative relationship between national incomes and poverty, as shown by many studies (Ravallion and Chen 1997; Roemer and Gugerty 1997). They show that economic growth is necessary condition for poverty reduction. In others words, because it promotes poverty reduction, economic growth can reduce the constraints on access to food for households and is therefore a source food security.

Political institutions are important determinants of food security. Indeed, the more demo cratic a government, the greater the percentage of revenues that may be spent on public good (education, health, food). It may respond to the needs of citizens. A more democratic government may also be more likely to respond to the needs. According to previous authors such as Drèze and Sen (1989), democracy may be more likely to honor human rights (including the food and nutrition) and to encourage community participation, both of which may reduce food insecurity.

3.2.3. Data sources

This study is based on panel data corresponding to five year averages. It covers a period from 1960 to 2008 for 77 developing countries and uses the data on the proportion of undernourished people, index of per capita food production, income per capita, inflation, population, cultivated lands, rainfall volatility, and positive and negative rainfall shocks. All data are from World Development Indicators (2011) except the data on rainfall volatility and rainfall shocks that are from Guillaumont P. and Simonet C. “Designing an index of structural vulnerability to climate change”, mars 2011. The proportion of undernourished people is the percentage of people not having access to sufficient, safe and nutritious food meets their dietary needs and food preferences for an active and healthy life. This indicator takes into account the amount of food available per person nationally and the extend of inequality in access to food. Food production index covers food crops that are considered edible and that contain nutrients. Coffee and tea are excluded because, although edible, they have no nutritive value.

Income per capita is GDP per capita which is gross domestic product divided by midyear population. Data on GDP are in constant U.S. dollars. Inflation as measured by the consumer price index reflects the annual percentage change in the cost to the average consumer of acquiring a basket of goods and services that may be fixed or changed at specified intervals, such as yearly. We considered annual population growth rate.

Cultivated land is the land under cereal production which refers to harvested area, although some countries report only sown or cultivated area. Cereals include wheat, rice, maize, barley, oats, rye, millet, sorghum, buckwheat, and mixed grains. Production data on cereals relate to crops harvested for dry grain only. Cereal crops harvested for hay or harvested green for food, feed, or silage and those used for grazing are excluded.

Positive and negative rainfall shocks are the sum of positive monthly rainfall deviations and the sum of negative monthly rainfall deviations respectively. They calculated using a trend since 1950. It is the sum of the years of regression residuals of the rainfall on a trend and monthly dummies.

4. Results

Tables (1) and (2) shows the results of the effects of rainfall shocks on food insecurity (percentage of total undernourished population and food production per capita).

Columns (1) and (4) of tables (1) and (2) indicate that rainfall volatility increases food insecurity in developing countries. Rainfall volatility has a positive effect on the percentage of total undernourished population. Similarly rainfall volatility has a negative effect on Food production. The coefficients of rainfall volatility are significant at 5% and 1% respectively. Our results are robust with (or without) temporal effects).

Results indicate that rainfall volatility reduce food production. Indeed rainfall volatility can reduce land suitability, crop yields (Schmidhuber and Tubiello (2007)) and have a negative effect on food production. In other words rainfall volatility can have effects on the viability of the economic systems, food production and availability. It increases the percentage of total undernourished population.

Estimates show that the level of rainfall has no effect on food production and the percentage of total undernourished population.

An interesting question is to analyze the effect of positive and negative shocks on food insecurity. Columns (2) and (5) of tables (1) and (2) shows that positive rainfall shocks have positive effect on food production and negative effect on the percentage of total undernourished population respectively. We find that negative rainfall shocks have a negative effect on food production and positive effect on the percentage of total undernourished population respectively. The effects of negative shocks are similarly to rainfall volatility. These results put in light that behind the volatility of rainfall, negative shocks of rainfall increase food insecurity.

Other interesting results are the effects of some controls variables. The level of economic development has a positive effect on food security. Tables (1) and (2) show that income per capita increases the level of food production. Income per capita reduces the constraints on access to food for households and is therefore a source food security. Moreover high incomes allow an economy to increase investments in food sectors (Smith and Haddad (2000)). The level of development can increase national food availability by improving resources available for purchasing food on international markets.

Demographic expansion (population growth) has no effect on the proportion of undernourished population. Our results are different to previous authors such as Merrick (2002) who conclude that population growth can exacerbate the harmful effects of inappropriate policies on food security. Table (2) suggests that an increase in cultivated lands has a positive effect on food production which favors food security.

Table1: Impact of Rainfall shocks on Malnutrition in Developing countries

Dependent variable	**Percentage of total undernourished population**					
	(1)	(2)	(3)	(4)	(5)	(6)
Rainfall volatility	0.0107**			0.0112**		
	(2.406)			(2.525)		
Positive Rainfall shocks		-0.0168**			-0.0176**	
		(-2.410)			(-2.542)	
Negative Rainfall shocks			0.0145*			0.0150*
			(1.69)			(1.734)
Income per capita	-0.00126**	-0.00127**	-0.00132**	-0.00112*	-0.00113*	-0.00119*
	(-2.101)	(-2.119)	(-2.182)	(-1.838)	(-1.845)	(-1.938)
inflation	-0.0016***	-0.00165***	-0.00154***	-0.00158***	-0.00164***	-0.00153***
	(-3.489)	(-3.609)	(-3.339)	(-3.431)	(-3.550)	(-3.282)
Rainfall (log)	6.386	5.718	3.049	5.993	5.335	2.485
	(1.311)	(1.219)	(0.673)	(1.234)	(1.140)	(0.549)
Population growth	0.0681	0.115	0.0684	-0.0252	0.0232	-0.0206
	(0.139)	(0.234)	(0.138)	(-0.0514)	(0.0474)	(-0.0415)
Intercept	-21.32	-14.66	-0.773	-18.83	-12.15	2.817
	(-0.653)	(-0.475)	(-0.0249)	(-0.578)	(-0.394)	(0.0909)
Temporal dummies	No	No	No	Yes	Yes	Yes
Observations	300	300	300	300	300	300
Number of countries	77	77	77	77	77	77
R-squared	0.096	0.096	0.084	0.112	0.112	0.098

Note: t-statistics are presented in parentheses under the estimated coefficients. ***, ** and * indicate significance of the estimated coefficient at 1, 5 and 10%, respectively. The study period is 1960-2008

Table 2: Impact of rainfall shocks on Food production in Developing countries

Dependent variable	**Per capita food production Index**					
	(1)	(2)	(3)	(4)	(5)	(6)
Rainfall volatility	-0.0406***			-0.0165*		
	(-3.085)			(-1.904)		
Positive Rainfall shocks		0.0613***			0.0325*	
		(2.756)			(1.951)	
Negative Rainfall shocks			-0.0563**			-0.0265*
			(-2.482)			(-1.788)
Income per capita	0.0192***	0.0191***	0.0195***	0.00514***	0.00841***	0.00520***
	(11.09)	(11.00)	(11.27)	(4.018)	(5.927)	(4.071)
inflation	0.00139	0.00156	0.00126	-0.00202	-0.00140	-0.00209
	(0.702)	(0.783)	(0.634)	(-1.542)	(-0.944)	(-1.591)
Rainfall (log)	-59.95***	-54.53***	-50.01***	-6.621	-8.564	-3.529
	(-4.292)	(-4.061)	(-3.877)	(-0.699)	(-0.823)	(-0.407)
Cultivated lands	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***
	(9.131)	(9.042)	(9.227)	(4.671)	(4.571)	(4.704)
Intercept	413.1***	367.9***	352.1***	121.6*	116.3*	104.1*
	(4.316)	(4.077)	(3.910)	(1.891)	(1.679)	(1.737)
Temporal dummies	No	No	No	Yes	Yes	Yes
Observations	602	602	602	602	602	602
Number of id	79	79	79	79	79	79
R-squared	0.320	0.317	0.316	0.717	0.630	0.717

Note: t-statistics are presented in parentheses under the estimated coefficients. ***, ** and * indicate significance of the estimated coefficient at 1, 5 and 10%, respectively. The study period is 1960-2008.

4.1. Heterogeneity for African countries

The effects of rainfall shocks on food security are different for African countries? Two arguments can justify the specificity of African countries. According to According to Davis et al. (2007) and World Bank (2006), between 60% and 100% of African households derive their income from agricultural activities. Moreover, Sub-Saharan Africa countries have on average the highest percent of population in rural areas (70%) and highest land devoted to agriculture (49%), along with the lowest percent of land irrigated of any region (4.5%).

Table3: Impact of Rainfall shocks on Malnutrition in Sub Saharan African

Dependent variable	**Percentage of total undernourished population**	
	(1)	(2)
Rainfall volatility	0.01000**	0.0104**
	(2.239)	(2.338)
Rainfall volatility *Africa	0.0156	0.0194*
	(1.441)	(1.766)
Income per capita	-0.00126**	-0.00108*
	(-2.112)	(-1.767)
inflation	-0.00159***	-0.00155***
	(-3.483)	(-3.371)
Rainfall (log)	8.258	8.331*
	(1.642)	(1.662)
Population growth	0.127	0.0415
	(0.259)	(0.0848)
Intercept	-33.95	-34.79
	(-1.006)	(-1.033)
Temporal dummies	No	Yes
Observations	300	300
Number of countries	77	77
R-squared	0.104	0.124

Note: t-statistics are presented in parentheses under the estimated coefficients. ***, ** and * indicate significance of the estimated coefficient at 1, 5 and 10%, respectively. The study period is 1960-2008

Table 4: Impact of Rainfall shocks on Food Production in Sub Saharan African

Dependent variable	**Per capita food production Index**	
	(1)	(2)
Rainfall volatility	-0.0346***	-0.0118
	(-2.604)	(-1.346)
Rainfall volatility *Africa	-0.0732**	-0.0542***
	(-2.554)	(-2.790)
Income per capita	0.0193***	0.00514***
	(11.23)	(4.046)
inflation	0.00138	-0.00207
	(0.700)	(-1.586)
Rainfall (log)	-67.96***	-11.81
	(-4.771)	(-1.231)
Cultivated lands	7.93e-06***	2.72e-06***
	(8.836)	(4.328)
Intercept	468.9***	158.4**
	(4.800)	(2.428)
Temporal dummies	No	Yes
Observations	602	602
Number of countries	79	79
R-squared	0.328	0.721

Note: t-statistics are presented in parentheses under the estimated coefficients. ***, ** and * indicate significance of the estimated coefficient at 1, 5 and 10%, respectively. The study period is 1960-200

Table (3) shows the results of the effect of rainfall instability on the percentage of total undernourished population in Sub Sahara countries. We find that not only the coefficients associated to rainfall volatility and the interactive term (rainfall volatility *Africa) are significantly positive but also the magnitude of the interactive is higher than additive term. We can conclude that the effect of rainfall instability on the percentage of total undernourished population is higher in Sub Sahara countries than in other regions.

Results of table (4) indicate that rainfall instability reduces food production in African countries. The reduction is higher in Sub Sahara countries than in other regions.

On the whole, the results of the tables (3 &4) suggest that African countries are more vulnerable to rainfall instability than other regions. By reducing food production and increasing the proportion of undernourished population, rainfall instability is more a factor of food insecurity in African countries than other regions.

5. Conclusion

This paper analyses the effect of climatic shocks on food security over the period 1960-2008 for 77 developing countries. We use two indicators of food security that are malnutrition and food production. The results are as follows: Firstly we show that rainfall volatility is a factor of food insecurity in developing countries. Indeed rainfall instability reduces food production and increases the percentage of total undernourished population.

Secondly we find that African countries are more vulnerable to rainfall instability than other regions. By reducing food production and increasing the proportion of undernourished population, rainfall instability is more a factor of food insecurity in these countries. This means that the climatic shocks (rainfall instability) observed is likely to explain part of the puzzle of developing countries (Africa)'s relatively poor performance and food insecurity.

Our results suggest policy implications. Because rainfall instability have adverse effect on food production and malnutrition in both developing and African countries, it seems evident that policy makers should take appropriate decisions. One of them is the diversification of African economies that are less reliant on agriculture. These countries should adopt agricultural techniques that optimize water use through increased and improved irrigation systems and crop development.

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