Rainfall Shocks, Food Prices Vulnerability and Food Security: Evidence for Sub-Saharan African Countries

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Abstract

This paper investigates the effects of rainfall shocks caused by climate change on food security in sub-Saharan Africa (25 countries) compared to developing countries (77 developing countries) over the period 1960-2008. For this purpose, we use panel data and apply econometric methods. Results suggest that rainfall volatility is a factor of food insecurity (through food supply reduction) in developing countries. Moreover, the adverse effects of rainfall shocks are higher in sub-Saharan African than other regions. Second the adverse effects of climatic shocks are exacerbated for countries that are vulnerable to food prices shocks.

Key words (JEL): Food Price Shocks (E3), Food Security (Q18), Rainfall 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 African countries.

This paper investigates the effects of rainfall shocks caused by climate change on food security in sub-Saharan Africa (25 countries) compared to other developing countries over the period 1960-2008. For this purpose, we use panel data and apply econometric methods. Results suggest that rainfall volatility is a factor of food insecurity (through food supply reduction) in developing countries. Moreover, the adverse effects of rainfall shocks are higher in sub-Saharan African than other regions. Second the adverse effects of climatic shocks are exacerbated for countries that are vulnerable to food prices shocks.

The plan of the paper is as follows. The next section outlines the relationship between climate change, rainfall shocks 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. Climatic Change, Rainfall shocks and 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.

2.1. 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. 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).

2.3. 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.

2.4. 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 investigate the role of climatic shocks on food security in sub-Saharan African countries compared to the rest of the developing world. For this purpose, we use the following equation:

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

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 fixed 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. $FS_{i,t}$ is food availability. Control variables are population growth, food prices, democratic institutions and income per capita.

In order to investigate wheter the relationship between rainfall shocks and food security is different across sub-saharan African (SSA) countries and other developing countries (Non sub-saharan African NSSA), we interact our rainfall shocks with SSA dummy.

$$FS_{i,t} = \alpha_i + \beta_1 CS_{i,t} + \beta_2 CS_{i,t} * Africa + \omega X_{i,t} + Africa + \gamma_t + \varepsilon_{i,t} \qquad (2)$$

Moreover, we test the potential effects of climatic shocks on food security in a context of food prices vulnerability. Climatic shocks can increase vulnerability of countries to food price shocks. Indeed climatic shocks could influence agricultural productivity and production that are important in household's revenues in developing countries. As the household's incomes (from agriculture) are negatively affected by climatic shocks, the part of food expenses on total consumption (food dependency) increases. Moreover, by affecting economic growth ((Dell et al. 2008), climatic shocks can lower the resources capacities and increase food import burden of countries. Hence the negative effect of climatic shocks on food supply can increase with vulnerability of countries to food price shocks.

$$FS_{i,t} = \alpha_i + \beta CS_{i,t} + \beta_3 CS_{i,t} * FPVul_{i,t} + \theta FPVul_{i,t} + \omega X_{i,t} + \gamma_t + \varepsilon_{i,t} \qquad (3)$$

with $FPVul_{i,t}$ is the vulnerability of countries to food price shocks.

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. The model (equations (1) to (3)) is estimated with Ordinary Least Squares (OLS) method. But this estimator is biased because it does not take into account unobserved heterogeneity of countries. This allows us to apply Fixed Effects (FE) and Random Effect (RE) estimators. We use the Hausman test to choose the adequate estimator among the two estimators.

3.2. Measure of food security and rainfall volatilty

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.

For our paper, we use per capita food supply. The per capita food supply of each food item available for human consumption is then obtained by dividing the quantity of food item concerned on the population actually partaking of it. In other words, food supply is calculated as the difference between, on the one hand, production, the trade balance (imports – exports) and any change in stocks, and on the other hand, all utilizations other than human consumption (seed, livestock feed, etc.). In our paper, the selected commodities for the calculation of food supply are: maize, millet, rice, sorghum, soybeans, sugar and wheat. Food supply obtained is an arithmetic average of food supplies of selected commodities expressed in kcal/person/year.

The instability of a variable is measured relative to a reference value. It can be defined as the difference between a variable and the reference value. Variance is the typical measure of instability. In the economic literature, the instability can be calculated with different methods. We use data from Guillaumont and Simonet (2011). According to them, rainfall instability is defined as the absolute deviation of the yearly average of rainfall from its own trend (long term mean of rainfall 1960-2008).

3.3. 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. The data on population growth, income per capita are from World Development Indicators (2011). Those on democratic institutions, rainfall shocks and food supply come respectively from Polity IV (2010), (Guillaumont & Simonet 2011) and (Food and Agriculture Organization of the United Nations 2011).

Income per capita (GDP per capita) is gross domestic product divided by population. Data on GDP are in constant U.S. dollars. We consider annual population growth rate. As democratic institutions, we choose the index of polity(2), which is a score obtained by differencing of the index of democracy and index of autocracy on a scale going from +10 (democracy) to -10 (autocracy). The indicator of democracy is characterized by the effective existence of institutional rules framing of the power and the presence of institutions enabling citizens to express their expectations and choose political elites. The autocracy is characterized by the absence or the restriction of political competition, economic planning and control. The exercise of the power is slightly constrained by institutions and the leaders are only selected within a “political elite”. Food supply is determined from food balance sheets produced by FAO for every country, charting the quantity of food available for human consumption. Food balance sheets show for each primary commodity and a number of processed commodities potentially available for human consumption the sources of supply and its utilization. The total quantity of foodstuffs produced in a country added to the total quantity imported and adjusted to any change in stocks that may have occurred since the beginning of the reference period gives the supply available during that period. On the utilization side a distinction is made between the quantities exported, fed to livestock, used for seed, processed for food use and non-food uses, lost during storage and transportation, and food supplies available for human consumption. The per capita food supply of each food item available for human consumption is then obtained by dividing the quantity of food item concerned on the population actually partaking of it. In other words, food supply is calculated as the difference between, on the one hand, production, the trade balance (imports – exports) and any change in stocks, and on the other hand, all utilizations other than human consumption (seed, livestock feed, etc.). In our paper, the selected commodities for the calculation of food supply are: maize, millet, rice, sorghum, soybeans, sugar and wheat. Food supply obtained is an arithmetic average of food supplies of selected commodities expressed in kcal/person/year.

We construct the variable of vulnerability to food price shocks using the procedure developed by (De Janvry & Sadoulet 2008) and (Combes et al. 2012). According to the authors, countries are vulnerable to food price shocks if they meet the following three criteria: (1) high food dependency; (2) a high food import burden and (3) low income. High food dependency, measured by the share of total food imports in the total household consumption, highlights the importance of food in the basket of goods consumed by the representative household in a given country. A large share of food items in the basket means that the household will be hit by an increase in food prices. High food import burden, measured by the ratio of food imports to total imports, emphasizes the strong dependency of a country on the food imports. Level of income, measured by Gross Domestic Product per capita stresses the capacity of a country to constitute food safety nets for domestic consumers. To calculate the vulnerability index, we use the principal component analysis (PCA) applied to three variables: the ratio of food imports to total household, the ratio of total imports to total imports of goods and services and the inverse of the level of GDP per capita. We use the inverse of the level of GDP per capita to be sure that the level of development is negatively correlated to the degree of vulnerability to food price shocks. We normalize the vulnerability index so that it ranges between 0 and 10, with higher values corresponding to high levels of vulnerability. The variables used to calculate the vulnerability index are from World Development Indicators (2011).

4. Results

4.1. Results of baseline equation

Table (1) shows the results of the effects of rainfall shocks on food insecurity with different econometric methods (ordinary least squared (OLS), fixed effects (FE), and random effects (RE)). OLS method (columns (1) and (2)) doesn't take into account unobserved heterogeneity of countries; hence we apply fixed effects (FE) and random effect (RE) estimators. Finally, we keep fixed effect estimator (column 4) because the results of Hausman test shows that the fixed effect model is more appropriate than the random effect model.

Table (1) shows that the level of economic development (income per capita) has a positive effect on food supply. These results can be explained by the fact that the level of development 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)). Third, 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. Contrary to previous authors ((Dreze & Sen 1991), we find that democratic institutions (polity 2) have no effect on food supply. This may be explained by the fact that we use a composite indicator.

Whatever the method used, we find that rainfall volatility has negative effect on food supply. These results can be explained by the fact that rainfall volatility reduces agriculture production and households' incomes. Indeed rainfall volatility can reduce land suitability, crop yields (Schmidhuber and Tubiello (2007)) and may have negative effects on the viability of the economic systems, food production and availability.

These results are similar for African countries? Two arguments can justify the specificity of African countries. 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%). They may be more affected by rainfall volatility.

Table (2) shows the results of the effect of rainfall instability on food supply in Sub Sahara countries and developing countries. Columns (1) and (2) show that the negative effect of climatic shocks is higher in SSA than in other developing countries. These results suggest that SSA countries are more vulnerable to rainfall volatility than other developing countries. By reducing food supply, rainfall instability is more a factor of food insecurity in African countries than other regions. The predominance of rain-fed agriculture in much of Sub-Saharan African results in food systems that are highly sensitive to rainfall variability.

Table 1: Effects of climatic shocks on food security for developing countries

Dependent variable			**Food Supply**			
	OLS		FE		RE	
	(1)	(2)	(3)	(4)	(4)	(6)
Rainfall volatility	-0.0716***	-0.0912***	-0.417***	-0.365***	-0.0716**	-0.0912***
	(-2.749)	(-3.722)	(-8.506)	(-7.532)	(-2.536)	(-3.333)
Rainfall	-0.0764***	-0.0630***	-0.417***	-0.339***	-0.0764***	-0.0630***
	(-3.282)	(-2.909)	(-9.408)	(-7.552)	(-3.997)	(-3.304)
Income per capita	0.0178***	0.0165***	0.0172***	0.0162***	0.0178***	0.0165***
	(3.395)	(3.572)	(5.095)	(4.984)	(5.916)	(5.684)
Population growth	-9.688**	-7.001*	-2.827	-2.630	-9.688***	-7.001**
	(-2.190)	(-1.807)	(-0.979)	(-0.914)	(-3.301)	(-2.404)
Democratic institutions	0.778	0.409	-0.219	-0.462	0.778	0.409
	(0.862)	(0.497)	(-0.196)	(-0.426)	(0.687)	(0.378)
Intercept	454.0***	414.3***	872.1***	757.5***	454.0***	414.3***
	(12.87)	(11.91)	(15.67)	(13.28)	(15.46)	(13.96)
Temporal dummies	No	Yes	No	Yes	No	Yes
Observations	626	626	626	626	626	626
Countries	71	71	71	71	71	71
R-squared			0.216	0.289		

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 Security for Sub Saharan African

Dependent variable	Food Supply	
	Developing Countries (1)	Sub-saharan African Countries (2)
Rainfall volatility	-0.358***	-0.554***
	(-7.371)	(-5.986)
Rainfall	-0.336***	-0.570***
	(-7.410)	(-7.072)
Income per capita	0.0162***	0.0256***
	(5.004)	(3.010)
Population growth	-2.396	5.322
	(-0.813)	(1.452)
Democratic institutions	0.141	-0.00778
	(0.134)	(-0.00474)
Intercept	754.1***	772.9***
	(13.08)	(9.689)
Observations	626	230
Countries	71	25
R-squared	0.285	0.253

4.2. Does Food price shocks exacerbate the effect of rainfall shocks?

An interesting question is to analyze the potential impact of rainfall volatility in a context of food prices shocks? Food price shocks occur when a country experience a sharp and sudden increase in food prices.

Food price shocks occur when a country experiences a sharp and sudden increase in food prices. We consider that climatic shocks can increase vulnerability of countries to food price shocks. Indeed climatic shocks could influence agricultural productivity and production that are important in household's revenues in developing countries. As the household's incomes (from agriculture) are negatively affected by climatic shocks, the part of food expenses on total consumption (food dependency) increases. Moreover, by affecting economic growth ((Dell et al. 2008), climatic shocks can lower the resources capacities and increase food import burden of countries. Hence the negative effect of climatic shocks on food supply can increase with vulnerability of countries to food price shocks.

Table (3) presents the results of the nonlinear effect of climatic shocks on food supply, depending upon the level of vulnerability of countries to food price shocks. Results (column (2)) indicate that the associated coefficients of additive (climatic shocks) and the interactive terms (rainfall volatility*vulnerability of countries to food price shocks) are negative and significant. This result reveals that the negative effect of climatic shocks on food supply increases with the level of vulnerability of countries to food price shocks. Countries that are more vulnerable to food prices shocks are less able to maintain food supply. These results can be explained by the fact that vulnerable countries have very little policy space and limited fiscal and administrative capacity to organize safety nets to import food and protect their population from climatic shocks (De Janvry & Sadoulet 2008). Indeed, policy instruments available to facilitate food accessibility by increasing agricultural production or imports are limited or ineffective.

Columns (3) and (4) Table (3) show that the adverse effect of climatic shocks on food supply in a context of food prices shocks is higher in Sub Saharan Africa countries that developing countries. Indeed these countries have two characteristic: (1) they are more vulnerable to food prices shocks because they are net food importers and they are less resilient; (2) they are more vulnerable to climate change.

Table 3: Climatic shocks and Food supply: the importance of food prices shocks

Dependent Variable	Food Supply			
	Developing Countries (1)	(2)	African Countries (3)	(4)
Rainfall volatility	-0.358***	-0.277***	-0.554***	-0.631***
	(-7.371)	(-5.048)	(-5.986)	(-4.371)
Food Price vulnerability		-0.562***		-0.426***
		(-6.391)		(-2.919)
Rainfall volatility*Food Price vulnerability		-0.000771**		-0.00139*
		(-1.976)		(-1.805)
Rainfall	-0.336***	-0.284***	-0.570***	-0.721***
	(-7.410)	(-5.837)	(-7.072)	(-7.199)
Income per capita	0.0162***	0.00713**	0.0256***	0.00900
	(5.004)	(2.099)	(3.010)	(0.465)
Population growth	-2.396	-10.85***	5.322	16.35**
	(-0.813)	(-2.614)	(1.452)	(2.467)
Democratic institutions	0.141	0.0768	-0.00778	-0.0403
	(0.134)	(0.0728)	(-0.00474)	(-0.0223)
Intercept	754.1***	779.7***	772.9***	952.8***
	(13.08)	(13.01)	(9.689)	(10.20)
Observations	626	500	230	164
Number of countries	71	69	25	24
R-squared	0.285	0.362	0.253	0.369

Note: t-statistics are presented in parentheses under the estimated coefficients. ***, ** and * indicate significance of the estimated coefficient at 1, 5 and 10%, respectively. Temporal dummies are included. The study period is 1960-2007.

5. Conclusion

In this paper, we have examined the potential effects of climatic shocks (rainfall volatility) on food security that have taken place in sub-Saharan Africa (25 countries) compared to other developing countries over 1960-2008. Our results suggest that rainfall volatility is a factor of food insecurity (through food supply reduction) in developing countries. Moreover, the adverse effects of rainfall shocks are higher in sub-Saharan African than other regions. Second the negative effect of climatic shocks is exacerbated for countries that are vulnerable to food prices shocks.

Our results impose serious challenging questions for policymakers and suggest policy implications. Because African countries accounts for less that 5% of world greenhouse gas emissions, these countries should receive special attention from developed countries and international institutions. They can or should incite African countries to adopt agricultural techniques that optimize water use through increased and improved irrigation systems and crop development. Moreover international community may finance stabilization mechanisms (government budget or development projects for the regions adversely affected by climatic shocks) with aid (named "climatic aid"). This "climatic aid" can be allocated to countries that are both more exposure to effects of climate change and vulnerable to food price shocks.

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Appendix B: Tables

Table B.1: Descriptive statistics

Variable	Mean	Std. Dev.	Min	Max
Food supply	389.04	153.74	18.63	1318.99
Rainfall volatility	-0.89	91.53	-471.73	632
Rainfall	1200.57	812.04	16.81	3882.82
Food Shock price vulnerability	46.15	64.45	0.84	381.48
Per capita GDP	6396.13	10374.16	84.28	95885.27
Population growth	1.88	1.54	-4.64	16.24
Democratic institutions	-0.52	5.64	-10	10

Table B.2: **List of countries**

Albania	Honduras	Nicaragua
Argentina	Croatia	Nepal
Azerbaijan	Haiti	Pakistan
Burundi	Indonesia	Panama
Burkina Faso	India	Peru
Bangladesh	Iran	Philippine
Bulgaria	Jamaica	Paraguay
Bolivia	Kenya	Rwanda
Brazil	Kowait	Sudan
Botswana	Liberia	Senegal
Chile	Libya	El Salvador
China	Sri Lanka	Syria
Cote d'Ivoire	Lithuania	Togo
Cameroon	Morocco	Thailand
Colombia	Moldavia	Trinidad and Tobago
Costa Rica	Madagascar	Tanzania
Algeria	Mexica	Uganda
Ecuador	Mali	Ukraine
Egypt	Mongolia	Uruguay
Ethiopia	Mozambique	Venezuela
Fiji	Mauritania	South Africa
Gabon	Malaysia	Zambia
Ghana	Niger	Zimbabwe
Guatemala	Nigeria	