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Abstract

This paper contributes to the existing literature on climatic variability and food security. It analyzes the effect of climatic shocks on food security for 77 developing countries from 1960 to 2008. Using two complementary indicators of food security (food supply, proportion of undernourished people), we find that climatic shocks reduce food supply in developing countries. The adverse effect is higher for African Sub Saharan countries than other developing countries. Second, food supply is a channel by which climatic shocks increase the proportion of undernourished people. Third, the negative effects of climatic shocks are exacerbated in presence of civil conflicts and are high for countries that are vulnerable to food prices shocks.

JEL Codes: D74;Q17; Q18 ; Q54

Keywords: Civil conflicts; Food Prices shocks; Food security; Climatic shocks

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1. Introduction

According to the United Nations Development Programme (2011), between 1990 and 2005 the number of people living under the international poverty[3] has reduced from 1.8 billion to 1.4billion. These results confirm some previous studies (Chen & Ravallion 2010) that conclude to a continued decline in global poverty during the last three decade. These authors show that the proportion of the world people living below the international poverty is gone from 52 percent in 1980 to 25 percent in 2005. However, progress is currently not fast enough and different with regions. From 1980 to 2005, the poverty rate in East Asia fell from 80% to 20 % and stayed at around 50 % in Sub-Saharan Africa. Despite national and international efforts in poverty reducing, the number of people suffering from chronic hunger has risen from 815 million in 1990 to 1.023 million in 2009 (Food and Agriculture Organization of the United Nations 2009) and a significant proportion of households dependent on agriculture are still exposed to the risks of food shortages and hunger.

There is a growing consensus in the scientific literature that the implications of climate change (higher temperatures, rainfall variability) might be major concerns to humanity since it affect many economic sectors as well as different aspects of human life. This is particularly true in low-income countries because these countries have low adaptive capacities and their economy is largely based on weather-sensitive agricultural production systems.

Many authors have analyzed the link between climate change and food security. Two groups of articles can be put forward. The first one concerns theoretical papers. Several theoretical analyzes conclude that climate change have negative impact on agricultural production and decreases national food availability. (Christensen et al. 2007) show that food production remains highly vulnerable to the influence of adverse weather conditions. (Menghestab Haile 2005) and (Dilley et al. 2005) confirm that the recent food crises in Africa that required large-scale external food aid have been attributed fully and partially to extreme weather events. (Ringler, Zhu, et al. 2010) conclude that climate change is a factor of childhood malnutrition in Sub-Saharan Africa. The second one is empirical papers. Because of an absence of suitable data, empirical economic studies are rare. Using panel data for Asian countries from 1998 to 2007, (Lee et al. 2012) show that high temperature and more precipitations in summer increase agricultural production while high fall temperatures are

[3] the international poverty line of $1.25 a day

harmful. (von Braun 1991) concludes in the case of Ethiopia that a 10% decrease in the amount of rainfall below the long run average leads to 4.4% reduction in the food production.

Despite these previous studies, little is known about mechanisms by which climatic shocks can affect food insecurity. This paper makes an empirical contribution to the debate on the causal effect of climate change on food security. It, explicitly, investigates the effects of climatic shocks on food security. We use panel data from 1960 to 2008 for 77 countries and alternative econometric methods (Fixed effects, Random effects). The results are as follows: First, we show that climatic shocks have negative effects on food security. Using two complementary indicators of food security, we find that climatic shocks reduce food supply in developing countries. The adverse effect is higher for African Sub Saharan countries than other developing countries. Moreover, food supply is a channel by which climatic shocks increase the proportion of undernourished people. Second, the negative effect of climatic shocks is exacerbated in presence of civil conflicts. Third, the effects are high for countries that vulnerable to food prices shocks. We contribute to the existing literature on climate variability and food security in several ways. First, while most of the literature is mainly theoretical, we apply an empirical method for 77 developing countries. Second, we employ climate variability data (rainfall shocks) from two different sources.

The plan of the paper is as follows. Section 2 presents a literature review on the relationship between climatic shocks and food security. Section 3 derives estimating equations and whereas section 4 shows empirical results. The last is devoted to concluding remarks and implications.

2. Literature Review

This section defines the concept of food security and gives an overview on the determinants of food security. It discusses on the effects of climatic shocks on food security.

2.1. Concept of Food security

2.1.1.Definition

Food security is a concept multidimensional and flexible that gained prominence since the World Food Conference in 1974. Many definitions of the concept have been developed (see Maxwell, 1996) as it has shifted from food production and importing capabilities at the macro-level to focus on individuals and their ability to avoid hunger and undernutrition (Foster, 1992). According to Reutlinger (1986), food security is defined as "access by all people at all times to enough food for an active healthy life". This definition is widely accepted by the World Bank and nongovernmental organizations. For the United Nations Development Program (UNDP, 1994) food security means that all people at all times have both physical and economic access to basic food. This requires not just enough food to go around. It requires that people have ready access to food-that they have an "entitlement" to food, by growing it for themselves, by buying it or by taking advantage of a public food distribution system.

Such a definition highlights the importance of food security as a basic human right (see e.g. Dreze and Sen, 1989; Sen, 1981, 1995). Tweeten (1997) emphasizes that the concept of food has three essential dimensions. The first dimension is food availability that refers to the supply of foodstuffs in a country from production or imports. This first dimension highlights the fact that there is a "bread basket" of food available for a population to consume, but it says nothing about how it is distributed. The second dimension is food access that refers to the ability to acquire food for consumption through purchase, production or public assistance. Indeed, food may be available but not necessarily accessible. The thirst dimension is food utilization, which concerns the physical use of food derived from human distribution. Food may be available to individuals who have access, but health problems may result from the imbalanced diet of food that is consumed.

2.1.2. Measures

Several indicators have been defined in literature for measuring the concept of food insecurity at the macroeconomic level. The first indicators used in literature on food insecurity are the energy balance per capita 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 food supply of a country meets the energy needs of its population under the hypothesis 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 measures of food security because they take into account two dimensions of food security: food supply for the energy balance and food access for the headcount rate of poverty.

Some authors (e.g. Maxwell et al.; 1992) use the mortality rate of children less than five years, the child malnutrition and the proportion of undernourished. The mortality rate of children under the age of five partially reflects the fatal synergy between inadequate dietary intake and unhealthy environments. It gives an idea of severity of food insecurity. The child malnutrition measures the prevalence of underweight in children under the age of five, indicating the proportion of children suffering from weight loss. The proportion of undernourished reflects the share of the population with insufficient dietary energy intake. Contrary to the previous indicators that covers a category of population (children), the proportion of undernourished is considered to be close to the definition of food insecurity.

Recent analyzes refer to Global Hunger Index (GHI)4 to measure food insecurity. GHI is a statistical tool to measure and monitor hunger in the world by country and by region. It captures three dimensions of hunger: insufficient availability of food, shortfalls in the nutritional status of children, and child mortality, which is to a large extent attributable to under-nutrition. Accordingly, GHI includes the following three equally weighted indicators: the proportion of undernourished, the prevalence of underweight in children under the age of five, and the under-five mortality rate. It integrates different aspects of multifaceted phenomena like hunger and under-nutrition, reduces the impact of random measurement errors, and facilitates the use of statistics by policymakers and the public by condensing information. The Global Hunger Index ranks countries on a 100-point scale, with 0 being the best score (no hunger) and 100 being the worst. In general, values greater than 10 indicate a serious problem of hunger, values greater than 20 are alarming, and values exceeding 30 are extremely alarming. It seems to be the best indicator to measure food security. However, the use of this indicator for econometric analyses is problematic because it is not available over a long time.

2.2 What could explain food insecurity?

In the literature on food insecurity three approaches have been developed to highlight the explanatory factors of food insecurity: the production-based approach, the market-based approach and institutional failures.

[4] This indicator has been developed by International Food Policy Research Institute (IFPRI).

2.2.1. The production-based approach

The production-based approach is based on the assumption that the food insecurity is the result of a food availability decline (FAD). This approach is often based on analysis of the relation between the relationship between population growth and the ability of humans to confront scarcity of food and natural resources which has dominated the literature on food security (see for example Berry and Cline, 1979; Boserup, 1965, 1981; Cohen, 1965; Ehrlich et al. 1993; Smil, 1994). Indeed, when a country makes the transition from agriculture to industry, it faces to urbanization problem, demographic change, and effects of this transition on the environment. Harper (1996) thinks that, in these circumstances, food security can be maintained only through efforts to achieve a sustainable society that "meets the needs of the human population without compromising those of future generations".

The Malthusian and techno-ecological theories offer much information on population impacts on environment and threats to food security. In his book, Malthus (1798) thinks that the expansion of population follows a geometric progression whereas the food supply grows an arithmetic progression, and concludes that population growth outstrips the earth's ability to provide for its inhabitants. The Malthusian' theory has been strengthened by neo-Malthusians (see for example Ehrlich and Ehrlich, 1990; Ophuls and Boyan, 1992). These authors conclude that population growth is a threat to food security because it leads to a decrease in food availability. This decrease is intensified by problems of access and utilization of foodstuffs, which are exacerbated by the increasing scarcity. Food availability is at the core of environmentalism and needs to conserve resources. Therefore, sustainable methods of food production and economic development are essential. On this point, neo-Malthusians (see for example Ehrlich and Ehrlich, 1990) argue against "infinite substitutability" of the earth's resources, emphasizing the limits of adaptation to environmental change but demanding people to modify current patterns of consumption.

Contrary to neo-Malthusians, the techno-ecological theories believe that technology and human ingenuity have always adequately confronted existing scarcities and will continue to do so in the future. Following this idea, Boserup (1965) concludes that developing countries address urbanization problem and population growth by adapting new technologies and strategies of land-use intensification. Going in the same direction as Boserup, Simon (1981, 1990) suggests that population growth should not be considered a threat but an asset because humans are the most valuable natural resource for their problem-solving capabilities. Some authors, in addition technology, take into account political and economic actions in the relationship between population growth and food security. Cohen (1995) thinks that rational political and economic actions as well as utilization of science and technology contribute to efficiency in food production and distribution systems, thus reducing threats to food security. The authors as Tweeten and McClelland (1997) and Bongaarts suggest that effective trade policy and improvement in access to markets will help to limit food insecurity. For example, an increase in agricultural production or better food distribution via a good transport infrastructure may offset negative effects of population growth by increasing food availability and food access. In conclusion, infrastructural development and advances in technology must be adapted to meeting challenges of growing populations and diminishing resources.

2.2.2. The market-based approach

The market-based approach is based on the idea that famine is not due to the supply of food but due to the access to food. The concept of entitlement developed par Sen (1978, 1981) joined in part this approach. The author thinks that people have an entitlement to food. The concept of entitlement is defined as the set of all possible combinations of goods and services that a person can obtain using the totality of rights and opportunities. Entitlements depend mainly on two factors that are personal endowments and exchange conditions. The *endowments* are the combination of all resources legally owned by people, which include both tangible assets (such as land, equipment, animals, etc.) and intangibles such as knowledge and skill, labor power, membership of a particular community, etc. In developing countries, an important part of household's resources comes from labor activities. In other words, people's endowments are based on the revenues of employment and the possible earnings by selling non labor-assets. *Exchange conditions* allow people to use their resources to access the set of commodities through trade and production and the determination of relative prices of products or goods. Sen (1981, 2000) concludes later that an unfavorable shift in exchange conditions can be factors of food insecurity. Otherwise, a general shortfall of employment in the economy reduces the people' ability to acquire an adequate amount of food. In other words a change in relative prices of products or wage rate vis-à-vis food price can cause food insecurity.

They also find in the market-based approach of food security the studies on the relationship between economic performance and food insecurity. A poor economic performance can be a major cause of poverty. A person is considered to be in absolute poverty when he or she is unable to satisfy adequately his or her basic needs such as food, health, water, shelter, primary education, and community participation (Frankenberger 1996). The effects of poverty on hunger and undernutrition are pervasive. Poor households and individuals are unable to achieve food security, have inadequate resources for care, and are not able to utilize resources for health on a sustainable basis. In contrast, a sustained economic growth has a positive direct impact on food security by supporting agricultural production and hence food supply.

Wiesmann (2006) suggests that national incomes are central to food security and nutrition because household food security, knowledge, and caring capacity as well as health environments require a range of goods and services to be produced by the national economy or to be purchased on international markets. Using the Global Hunger Index (GHI) as measure of food security and Gross National Income (GNI) per capita, the author shows that the availability of economic resources at the national level largely determines the extent of hunger and undernutrition. Poor countries tend to have high GHI values.

Smith and Haddad (2000) think that national income may enhance countries' health environments and services as well as women's education by increasing government budgets. It may also 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 overall income generated by households. The authors suggest also that national income may improve women's relative status directly by freeing up resources for improving women's lives as well as men's. The authors conclude that there is a strong negative relationship between national incomes and poverty, as shown by the recent studies (see e.g., Ravallion 2005; Easterly, 2007 Roemer and Gugerty 1997). These studies show that economic growth is necessary condition for poverty reduction. By promoting poverty reduction, economic growth may reduce the constraints on access to food for households and is therefore a source food security.

2.2.3. Institutional failures

Some authors (Keen, 1994, Devereux, 2001 and Sen, 1999) have put in light the importance of institutions as explanation of food insecurity. According to them the failure to deliver food can be due to the implementation of inappropriate policies or a failure to intervene by governments and the existence of civil conflicts.

Sen (1999) suggests that the working democracy and of political rights can help to prevent famines and other economic disasters. Indeed, authoritarian rulers tend to lack the incentives to take timely preventive measures. In contrast, democratic governments have to win elections and face public criticism, and have strong incentives to undertake measures to avert food insecurity and other catastrophes. For example, democracy can provide some empowerment through voting by the poor to receive human resource investments in health, education, and food transfers from government for broad-based development. In absence of elections, of opposition parties and of scope for uncensored public criticism, authoritarian governments don't have to suffer the political consequences of their failure to prevent food insecurity. However, democracy would spread the penalty of food insecurity to the ruling groups and political leaders. This gives them the political incentive to try to prevent any threatening food insecurity. Sen also thinks that a free press and the practice of democracy contribute greatly to bringing out information that can have an enormous impact on policies for food insecurity prevention (for example, information about the nature and impact of new production techniques on food supply). The author concludes that a free press and an active political opposition constitute the best early-warning system a country threatened by famines can have.

Smith and Haddad (2000) think that democracy is hypothesized to play a major role in food insecurity reducing. According to these authors, a more democratic government affects large revenues in education, health services, and income redistribution. This contributes to reduce the problems of food insecurity in the areas affected. Smith and Haddad also suggest that a more democratic government may be more likely to respond to the needs of all of its citizens, women's as well as men's. With respect to food security, the analyses of Drèze and Sen (1989) and others conclude that democracy is very important in averting food insecurity. More democratic governments may be more likely to honor human rights including the rights to food and nutrition (Haddad and Oshaug 1998) and to encourage community participation (Isham, Narayan, and Pritchett 1995), both of which may be important means for reducing child malnutrition.

Otherwise, other studies have established a link between civil conflicts and hunger. Indeed, in countries in conflict, population, households and individuals suffer disruptions in livelihoods, assets, nutrition and health. Combatants frequently use hunger as a weapon by cutting off food supplies and productive capacities, starving opposing populations into submission, and hijacking food aid intended for civilians. Warfare disrupts markets and destroys crops, livestock, roads, and land. Deliberate asset-stripping of households in conflict zones may cause those households to lose other sources of livelihood as the ongoing conflict leads to breakdowns in production, trade, and the social networks. The disruption of markets, schools, and infrastructure removes additional resources required for food production, distribution, safety, and household livelihoods. These consequences lead to aggravate food insecurity in countries in conflicts.

Green and Mavie (1994) show that the cumulative loss of output attributable to the 1982-1992 civil conflict in Mozambique exceeded $20 billion. The authors also conclude that this conflict removed over half of the country's population from customary livelihoods and devastated markets, communications, health services and infrastructure. Messer, Cohen and D'Costa (1998) have estimated the extent of food production losses due to conflict by examining trends in war-torn countries of sub-Saharan Africa during 1970-1994 and find that food production was lower in war years by a mean of 12.3 percent. This decrease in food production has the significant impacts on food availability because in these countries, a majority of the workforce earns its livelihood from agriculture. In addition, in eight of the countries, two-thirds or more of the workforce is engaged in agricultural activities (World Bank, 2000).

2.3. How do climatic shocks matter for food insecurity?

In this subsection we identify the potential channels through which climatic variability (e.g. droughts, rainfall and temperature volatility) is likely to affect food security in developing countries.

Climatic shocks and agriculture production

First, in short term, rainfall volatility affects food security through its impact on crop production. Droughts and floods impact negatively farm yields and the harvests, reducing household and national food availability, and agricultural income. Poor harvests threaten food security; to varying degrees according to the extent that country depends to agriculture for its food and income. In the longer term, (Kydd et al. 2004) think that weather risks (for example rainfall volatility) contribute to underinvestment and hence to long-run agricultural stagnation and rural poverty in countries that are dependent on rainfed agricultural. This leads to a decrease in food availability and limits food accessibility because of the decrease in income derived from crop sales.

Climatic shocks and households incomes

Second, rainfall volatility (droughts or floods) affects food security through household incomes. According to (International Labor Organization 2007), agriculture production is the primary source of livehoods for 36% (66%) of the world's (Sub-saharan Africa respectively) total working population. By reducing agriculture production, climatic shocks reduce the households' incomes coming from agriculture sector. Beyond the agriculture sector, (Sen 1983) considers that climatic shocks affect rural labor markets. By reducing incomes, climatic shocks (for example drought) reduce the demand for goods and services in affected communities, threatening the livelihoods of people who depend on indirectly on agriculture such as traders. In other words, when agricultural production in developing countries (especially in low income countries) is negatively affected by climatic shocks, households' incomes are reduced and their vulnerability to food insecurity increases. (Nhemachena et al. 2010) show that climatic variability (rainfall and temperature) adversely affect net farm revenues (from crop and livestock across various farm types and systems) translating into worsening food security situation in Africa.

Climatic shocks and food prices

Climatic shocks impact food security through its strongly negative effect on food prices. Indeed, weather shock that undermines the harvests, leads to food availability decline. Since the demand for food is highly price inelastic, a decrease in marketed supplies can lead to an important increase in food prices, reducing food accessibility. Moreover, (Aker 2010) considers that climatic shocks can have an effect on traders' entry and exit, in response to the profitability of food trading. A positive (or negative) climatic shock can increase (or reduce) profits and incite traders to entry (or exit) local market. This can affect food supply in the local market and food security through food price dispersion. Using theoretical models (simulating model, global circulation model and a equilibrium general model), Ringler et al. (2010) find that climatic variability (higher temperatures and mixed precipitation changes) will lead to changes in yield and area growth, higher food prices and therefore lower affordability of food, reduced calorie availability, and growing childhood malnutrition in Sub-Saharan Africa

Climatic shocks and economic resources

Climatic shocks can impact food security through economic growth. (Dell et al. 2008) show that climatic shocks have large and negative effects on economic growth in poor countries, reducing total productivity and global output (through agricultural yields, investments, scientific research and political stability). By affecting negatively economic growth, climatic shocks also reduce economic resources. Hence, they affect the ability of countries to: (i) purchase food on international markets; (ii) to invest in technology, services and infrastructure that support food and agricultural production; (iii) to finance public services and investments in health, education available to the governments to meet the needs of its population such as food needs. This contributes to undermine food security.

Climatic shocks and civil conflicts

Climatic shocks can be a factor of food insecurity by increasing the risk of civil conflicts. Some authors (see (Buhaug 2008) suppose that in long term, climate shocks will likely lead to greater scarcity and variability of renewable resources. By reducing available natural resources and households incomes, climatic shocks decrease opportunity cost of fighting and increase the risk of civil conflicts. The exacerbation of the scarcity of resources and the risk of civil war caused by climatic shocks may increase food insecurity. Other authors (see (Miguel et al. 2004) find that climatic shocks such as rainfall variability and higher temperatures are associated with less conflict.

3. Empirical Analysis

This section presents the empirical model of the effect of climatic shocks on food security. The analysis consists to specify the econometric model and describes data.

3.1. Empirical Methodology

The objective of our article is to analyze relationship between climatic shocks and food security over the period 1960-2008 for 77 developing countries. For this purpose, we use the following equation:

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

With X the matrix of control variables, $CS_{i,t}$ is the climatic shocks (rainfall instability) 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 effect. The period is 1960 to 2008 and data are compiled in five-year averages (1960-1964, 1965-1969,…). $Y_{i,t}$ is indicator of food security. We use two alternative measures which are food supply and the proportion of undernourished population. The control variables used are: the level of development measured by income per capita, population growth, democratic institutions.

We identify the potential heterogeneities in the relationship between climatic shocks and food security. First, we focus on the impact conditional on the civil conflicts (equation 2). In other words, we test if the effects of climatic shocks can be different depending on whether the country was under conflict. Second, we analyze whether the climatic vulnerability of countries could modify the marginal impact of climatic shocks on food security (equation 3). Finally, we look at the effects of climatic shocks in a context of food prices vulnerability (equation 4).

$$Y_{i,t} = \alpha_i + \beta CS_{i,t} + \beta_1 CS_{i,t} * Conflict_{i,t} + \theta Conflict_{i,t} + \omega X_{i,t} + \gamma_t + \varepsilon_{i,t} \quad (2)$$

$$Y_{i,t} = \alpha_i + \beta CS_{i,t} + \beta_2 CS_{i,t} * ClimVul_{i,t} + \theta ClimVul_{i,t} + \omega X_{i,t} + \gamma_t + \varepsilon_{i,t} \quad (3)$$

$$Y_{i,t} = \alpha_i + \beta CS_{i,t} + \beta_3 CS_{i,t} * FPVul_{i,t} + \theta FPVul_{i,t} + \omega X_{i,t} + \gamma_t + \varepsilon_{i,t} \quad (4)$$

With $Conflict_{i,t}$: the country was under conflict; $ClimVul_{i,t}$ is climatic vulnerability and $FPVul_{i,t}$ is the vulnerability of countries to food price shocks.

To estimate the effect of climatic shocks on food security, we use adequate econometric techniques. The model (equations (1) to (4)) 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. The measure of food security and climatic shocks

Measures of food security used in the economic literature (see section 2.1.2.) are either partial or unavailable over a long period. For this reason, we use two complementary indicators of food security: food supply and proportion of undernourished in the total population.

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 (See annex). 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).

For robustness tests, we use an alternative indicator of rainfall instability measured by the standard deviation of the growth rate.

3.3. Data sources and description of variables

The time period under study is 1960-2008 for 77 developing countries. The data on population growth, income per capita, proportion of undernourished people are from World Development Indicators (2011). Those on democratic institutions, civil conflicts, climatic vulnerability, rainfall shocks and food supply come respectively from Polity IV (2010), (Center for Systemic Peace 2010), (Wheeler 2011), (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”. 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. Civil conflicts are defined as the magnitude score of episode(s) of civil warfare involving that state in that year. Climate vulnerability is a index that show where extreme climate events (weather-related disasters, rising seas, and the loss of agricultural productivity) are most likely to occur, and the likelihood that an individual in each country would be affected. Rainfall instability is defined as the absolute deviation of the yearly average of rainfall from its own trend (long term mean of rainfall 1950-2008).

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.

Economic development (income per capita) has a positive effect on food supply. Our results are similar to previous studies (e.g. (Smith & Haddad 2000). Indeed, the economic resource availabilities increase the capacity of countries to meet the food needs by acquiring through domestic production and import foods. The size of population reduces food supply. Our results follow previous authors ((Malthus 1992) who show that population growth can reduce food supply through a high pressure on agricultural resources and a negative effect on agricultural productivity. 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.

Rainfall volatility has a negative and significant effect on food supply. These results can be explained by several arguments. Firstly, rainfall variability (for example droughts or flooding) is a source of high uncertainty on food production. This increases fluctuation in agriculture production and reduce household's incomes. For countries that depend on the weather conditions ((rain-fed agriculture) for agriculture production, rainfall variability has negative effect on food production and availability. Second, by reducing agriculture production in developing countries, rainfall volatility can have negative effect on economic growth ((Dell et al. 2008). These countries have low ability to purchase food on international markets (food import). In other words, rainfall volatility can reduce national food supply (food production and import) and increase food insecurity.

Table 1: Effects of climatic shocks on food security

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 instititions	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: Effects of climatic shocks on food security: Adding control variables

Dependent variable	Food supply					
	(1)	(2)	(3)	(4)	(5)	(6)
Rainfall volatility	-0.365***	-0.336***	-0.318***	-0.332***	-0.361***	-0.372***
	(-7.532)	(-6.878)	(-6.395)	(-6.695)	(-7.440)	(-4.570)
Rainfall	-0.339***	-0.313***	-0.296***	-0.307***	-0.406***	-0.344***
	(-7.552)	(-6.943)	(-6.444)	(-6.682)	(-6.006)	(-4.355)
Income per capita	0.0162***	0.0160***	0.0159***	0.0168***	0.0162***	0.0143***
	(4.984)	(4.981)	(4.942)	(5.188)	(4.979)	(3.550)
Population growth	-2.630	-2.740	-1.022	-2.301	-2.507	-11.13**
	(-0.914)	(-0.961)	(-0.355)	(-0.804)	(-0.871)	(-2.013)
Democratic institutions	-0.462	-0.374	-0.349	-0.419	-0.512	-2.950*
	(-0.426)	(-0.347)	(-0.325)	(-0.388)	(-0.472)	(-1.900)
Cereal production land		5.46e-06***				
		(3.408)				
Agricultural land			2.003***			
			(3.683)			
Arable land				2.520***		
				(2.853)		
Rainfall squared					1.73e-05	
					(1.326)	
Exchange rate (REER)						0.000113
						(0.230)
Intercept	757.5***	694.2***	618.5***	681.6***	802.8***	817.6***
	(13.28)	(11.67)	(9.112)	(10.88)	(12.08)	(7.784)
Observations	626	626	626	626	626	293
Countries	71	71	71	71	71	33
R-squared	0.289	0.304	0.306	0.300	0.291	0.317

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

The next step (table 2) consists of adding other control variables to check the robustness of results to changes in the baseline model: agricultural variables (Cereal production land, agricultural land and arable land) and squared term of rainfall level. Results show that rainfall volatility has a negative effect on food supply. The coefficient associated to rainfall volatility is negative and significant. Land for cereal production (column 2), agriculture land (column 3) and arable land (column 4) contribute to food supply. A policy allowing better land use increases food production and supply.

In previous columns, we found a negative effect of rainfall level on food supply. In column 5, we include a squared term of rainfall level and test a non linear relationship between rainfall level and food supply. We can suppose that too much rainfall reduce food supply. The results are not signicant5 suggesting that a negative effect of rainfall on food supply.

4.2. Heterogeneity on the effect of climatic shocks

In this section, we identify the potential heterogeneities in the relationship between climatic shocks and food security. First, we focus on the impact conditional on the civil conflicts. Second, we analyze whether the vulnerability to climatic shocks could modify the marginal impact of climatic shocks on food security. Finally, we look at the effects of climatic shocks in a context of food prices vulnerability.

4.2.1. The importance of civil conflicts

The hypothesis tested is that the effect of climatic shocks on food insecurity is high for countries that are in conflict. In table 3, we add civil conflicts in column (2) and interative term (Rainfall volatility * Civil conflict) in column (3). Results (column (2)) show that civil conflicts have negative effect on food supply. Indeed, civil conflicts can negatively affect harvests and reduce active population in the agricultural sector because the armed leaders can recruit farmers by offering them high incomes. This leads to a decrease in food availability through the collapse of agricultural production.

We also find that the effect of rainfall volatility on food supply is more important for the countries in conflict (column 3). A characteristic of civil conflicts is its negative effect on market access, political and social networks. First, they destroy infrastructure, social services, assets and livelihoods, displace populations, social cohesion, institutions and norms and create fear and distrust. In addition, civil conflicts disrupt farming systems (irrigation schemes) and production (crop production, livestock production and off-farm activities) operated by households. Second, market disruption increases difficulties of households in getting to markets to sell and buy goods, and the loss of earnings capacity, savings and formal and informal risk-sharing networks. Third civil conflicts have negative effects on economic growth by reducing investments, economic infrastructures. This can considerably reduce government's revenues (e.g tax revenue) and significantly weaken its ability to "invest in people", for instance to provide better nutrition, and on-the-job training that would lead to improved living conditions. These effects can be factors of poverty trap ((Kremer & Miguel 2007), increasing vulnerability and food insecurity.

Climatic shocks are likely to increase this vulnerability and dampen livelihoods of households affected by civil conflicts. Indeed the destruction of assets caused by civil conflicts, as well as unstable economic, social and political environments, will impact significantly the ability of countries to face to climatic shocks. In other words the effects of climatic shocks on food supply are more severe with civil conflicts.

Table 3: Effects of climatic shocks on food security: the importance of civil conflict

Dependent variable	**Food supply**		
	(1)	(2)	(3)
Rainfall volatility	-0.365***	-0.374***	-0.372***

	(-7.532)	(-7.612)	(-7.583)
Rainfall	-0.339*** (-7.552)	-0.345*** (-7.623)	-0.344*** (-7.618)
Rainfall volatility * Civil conflict			-0.415** (-1.990)
Civil conflict		-34.67*** (-2.804)	-52.29*** (-3.445)
Income per capita	0.0162*** (4.984)	0.0155*** (4.749)	0.0153*** (4.701)
Population growth	-2.630 (-0.914)	-3.484 (-1.200)	-3.626 (-1.252)
Democratic institutions	-0.462 (-0.426)	-0.211 (-0.193)	-0.128 (-0.118)
Intercept	757.5*** (13.28)	768.8*** (13.35)	768.1*** (13.37)
Observations	626	617	617
Number of countries	71	71	71
R-squared	0.289	0.295	0.301

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: Effects of climatic shocks on food security: the importance of climate vulnerability

Dependent variable			Food supply		
	(1)	(2)	(3)	(4)	(5)

Rainfall volatility	-0.365***	-0.308***	-0.366***	-0.358***	-0.363***
	(-7.532)	(-4.981)	(-7.343)	(-7.127)	(-7.328)
Rainfall	-0.339***	-0.335***	-0.339***	-0.339***	-0.339***
	(-7.552)	(-7.453)	(-7.545)	(-7.541)	(-7.541)
Rainfall volatility * Climate vulnerability1		-0.00215			
		(-1.500)			
Income per capita	0.0162***	0.0161***	0.0162***	0.0163***	0.0162***
	(4.984)	(4.949)	(4.974)	(4.999)	(4.985)
Population growth	-2.630	-2.882	-2.626	-2.581	-2.602
	(-0.914)	(-1.001)	(-0.910)	(-0.895)	(-0.902)
Democratic institutions	-0.462	-0.516	-0.461	-0.458	-0.457
	(-0.426)	(-0.476)	(-0.424)	(-0.422)	(-0.421)
Rainfall volatility * Climate vulnerability2			0.000138		
			(0.0374)		
Rainfall volatility * Climate vulnerability3				-0.00121	
				(-0.535)	
Rainfall volatility * Climate vulnerability4					-0.00154
					(-0.231)
Intercept	757.5***	752.8***	757.6***	757.1***	757.3***
	(13.28)	(13.19)	(13.26)	(13.26)	(13.26)
Observations	626	626	626	626	626
Number of countries	71	71	71	71	71
R-squared	0.289	0.292	0.289	0.289	0.289

Climate Vulnerability (1)…(4) correspond respectively to cdi (climate drivers: extreme weather, sea level rise and agricultural productivity loss), cv(climate vulnerability: climate drivers weather adjusted for income and Regulation) , wcdi (extreme weathers only: floods, droughts, extreme heat, wind storms and wild fires) and wcv (extreme weather adjusted for income and Regulation). 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.

4.2.2. The role of Climate vulnerability

Previous subsection put in light the conditional effect of climatic shocks on food supply of countries under conflicts. Climatic shocks reduce food supply of countries under conflicts.

In addition to political vulnerability, we analyze whether the climatic vulnerability of countries could modify the marginal impact of climatic shocks on food security.

According to (Wheeler 2011), countries are vulnerable to climate change if they meet the following three criteria: (i) High vulnerability to changes in extreme weather, sea level rise (risk from sea level rise) and agricultural productivity loss; (ii) Low income and (iii) High size of population. A low level of climatic indicator means that countries are more vulnerable and are less resilient to climate events. We can suppose a high effect of climatic shocks on food supply for countries that are vulnerable to climate change. Results of table (column (2) to (5)) show that climatic vulnerability of countries doesn't modify the marginal impact of climatic shocks on food supply. In other words, the effects of climatic shocks on food supply are not different for countries that are more vulnerable to climate change. Our results are counterintuitive and can be explained by the fact the data of Wheeler (2011) are available for one year (2008).

4.2.3. The importance of food price shocks vulnerability

The last hypothesis tested is the potential effects of climatic shocks on food supply 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.

Results are shown in table 5. Column 2 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 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.

Table 5: Effects of climatic shocks on food security: the role of Vulnerability to food price shocks

Dependent variable		**Food supply**		
	(1)	(2)	(3)	(4)

Rainfall volatility	-0.365***	-0.287***	-0.210***	-0.183***
	(-7.532)	(-5.278)	(-3.767)	(-3.132)
Price vulnerability		-0.557***	-0.476***	-0.467***
		(-6.359)	(-5.426)	(-4.938)
Rainfall volatility * Price vulnerability		-0.000721*	-0.000901**	-0.00107***
		(-1.832)	(-2.331)	(-2.714)
Rainfall	-0.339***	-0.287***	-0.222***	-0.202***
	(-7.552)	(-5.974)	(-4.519)	(-3.859)
Food price			0.167***	0.107**
			(4.461)	(2.128)
Price volatility				0.146
				(1.381)
Income per capita	0.0162***	0.00728**	0.00480	0.00415
	(4.984)	(2.134)	(1.420)	(1.194)
Population growth	-2.630	-11.15***	-7.048*	-6.002
	(-0.914)	(-2.684)	(-1.692)	(-1.373)
Democratic institutions	-0.462	-0.984	-0.746	-0.290
	(-0.426)	(-0.891)	(-0.690)	(-0.269)
Intercept	757.5***	783.1***	667.0***	650.4***
	(13.28)	(13.21)	(10.50)	(9.662)
Observations	626	500	500	470
Number of countries	71	69	69	69
R-squared	0.289	0.365	0.394	0.364

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

4.3. Robustness

Five robustness checks have been implemented.

4.3.1. Alternative indicators of climatic shocks

First, the effect of climatic shocks on food supply in a context of food prices vulnerability was re-examined with two alternative indicators of rainfall volatility. 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). It supposes that rainfall series have a deterministic trend. Because rainfall is unpredictable, we hypothesize that rainfall series run a stochastic trend. We compute and test rainfall volatility (columns 3 and 4 of table), defined as the 5-year rolling standard deviation of the growth rate of rainfall series. Moreover we use rainfall series from another source ((Mitchell et al. 2004) in columns 5 and 6. Whatever the indicators used, results reveal that the negative effect of climatic shocks on food supply increases with the level of vulnerability of countries to food price shocks.

4.3.2. Inertia of food supply

Another issue is to analyze if food supply in developing countries is characterized by inertia phenomena. In other words, does lagged level of food supply is a determinant of the current level of food supply? We include this variable (lagged level of food supply) in our baseline equation. The dynamic nature of the specified model requires system-GMM estimation (one step and two steps). Columns (2) and (3) of table show that the lagged level of food supply has no effect on its current level. There is not an inertia phenomena for food supply in developing countries.

Table 6: Alternative indicators of climatic shocks

Dependent variable	Food supply					
	(1)	(2)	(3)	(4)	(5)	(6)
			Tendance stochastique		Mitchell et al	
Rainfall volatility	-0.358***	-0.277***	-0.129***	-0.268***	-0.380***	-0.0514***
	(-7.371)	(-5.048)	(-5.030)	(-3.610)	(-3.530)	(-4.610)
Price vulnerability		-0.562***	-0.464***	-0.427***	-0.557***	-0.469***
		(-6.391)	(-4.968)	(-4.521)	(-5.337)	(-4.071)
Rainfall volatility * Price vulnerability		-0.000771**		-0.00873**		-0.00772*
		(-1.976)		(-2.134)		(-1.790)
Rainfall	-0.336***	-0.284***	0.00999	0.00820	0.00642	0.00366
	(-7.410)	(-5.837)	(0.615)	(0.507)	(0.441)	(0.251)
Income per capita	0.0162***	0.00713**	-0.00689*	-0.00663*	-0.00119	-0.00113
	(5.004)	(2.099)	(-1.941)	(-1.877)	(-1.514)	(-1.433)
Population growth	-2.396	-10.85***	4.172	2.327	0.775	0.300
	(-0.813)	(-2.614)	(0.966)	(0.531)	(0.251)	(0.0971)
Democratic institutions	0.141	0.0768	0.137	0.0571	0.754	0.679
	(0.134)	(0.0728)	(0.144)	(0.0601)	(1.256)	(1.132)
Intercept	754.1***	779.7***	444.7***	446.8***	449.1***	449.2***
	(13.08)	(13.01)	(18.86)	(19.03)	(24.56)	(24.63)
Observations	626	500	434	434	544	544
R-squared	0.285	0.362	0.347	0.355	0.186	0.192
Number of countries	71	69	69	69	69	69

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 7: **Inertia of food supply**

Dependent variable	Food Supply		
	Fixed Effect	GMM-System One step	GMM-System Two step
	(1)	(2)	(3)
Lag of.Food supply		0.02	0.04
		(1.612)	(1.01)
Rainfall volatility	-0.362***	-0.0214***	-0.0215***
	(-7.528)	(-23.61)	(-22.07)
Rainfall	-0.337***	-0.000852	0.000133
	(-7.431)	(-0.160)	(0.0218)
Income per capita	0.0163***	0.000648	0.00118
	(5.008)	(0.535)	(0.849)
Population growth	-2.383	8.944	8.369
	(-0.806)	(1.518)	(1.201)
Democratic institutions	-0.184	-1.128*	-0.631
	(-0.169)	(-1.953)	(-1.065)
Intercept	754.6***	-28.95	-16.69
	(13.09)	(-1.009)	(-0.548)
Observations	626	567	567
R-squared	0.287		
Countries	71	71	71
AR(1)		0.00	0.00
AR(2)		0.26	0.25
Hansen test		0.34	0.34
Instruments		57	57

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.

4.3.3. Complementary indicator of food security

Second, because food security is a multidimensional concept, we use another complementary indicator used in the literature: the proportion of undernourished people in the total population. A person is malnourished if his average energy intake is less than the minimum necessary to maintain physical and moderate activity. Following the economic literature, we construct a model of the malnutrition explained by income per capita, population growth, democratic institutions and the level of rainfall.

Table () presents result of the effect of climatic shocks on the proportion of undernourished population (basic equation). We find that rainfall volatility increases the proportion of undernourished population. Results are robust by adding other control variables (rainfall square, agricultural land, arable land, cereal production land, food prices and food price volatility).

An interesting question is to see if food supply can be a factor by which climatic shocks affect proportion of undernourished population. In indeed, food supply can be an important factor th at comfort the access of people to food. In other words, by reducing food supply, climatic shocks aggravate malnutrition. To test this hypothesis, we include in the baseline equation, the transmission channel (food supply) allowing climatic shocks to affect indirectly the proportion of total undernourished population.

Table 8: Effect of climatic shocks on Proportion of total undernourished population

Dependent variable	**Percentage of total undernourished population**						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Rainfall Volatility	0.0528***	0.0514***	0.0320**	0.0354**	0.0475***	0.0499***	0.0495***
	(3.375)	(3.273)	(2.124)	(2.285)	(3.056)	(2.726)	(2.730)
Rainfall	0.0524***	0.0588***	0.0372**	0.0417**	0.0567***	0.0492***	0.0483**
	(3.287)	(3.401)	(2.245)	(2.453)	(3.326)	(2.603)	(2.580)
Income per capita	-0.000172	-0.000125	-0.000880*	-0.000689	-0.000239	-8.25e-05	-0.000154
	(-0.327)	(-0.237)	(-1.728)	(-1.323)	(-0.458)	(-0.151)	(-0.290)
Population growth	0.611*	0.568	0.519	0.707**	0.554	0.476	0.519
	(1.657)	(1.528)	(1.496)	(1.977)	(1.514)	(1.165)	(1.313)
Democratic institutions	0.105	0.0957	0.0988	0.130	0.0884	0.121	0.0951
	(0.767)	(0.695)	(0.769)	(0.981)	(0.652)	(0.822)	(0.665)
Rainfall square		-1.91e-06	-1.52e-06	-1.93e-06	-2.32e-06		
		(-0.956)	(-0.811)	(-1.006)	(-1.175)		
Agricultural land			-0.607***				-0.0131
			(-5.851)				(-1.274)
Arable land				-0.644***			-38.39*
				(-4.569)			(-1.779)
Cereal production land					-1.09e-06***		
					(-2.792)		
Food prices						-0.00732	
						(-1.215)	
Food prices volatility							-0.0131
							(-1.274)
Intercept	-41.52**	-45.24**	7.725	-14.55	-35.93*	-38.02*	-38.39*
	(-2.276)	(-2.425)	(0.393)	(-0.762)	(-1.923)	(-1.753)	(-1.779)
Observations	314	314	314	314	314	282	287
Countries	79	79	79	79	79	71	74
R-squared	0.157	0.160	0.271	0.231	0.188	0.378	0.141

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 9: Channel of food supply

Dependent variable	Percentage of total undernourished population	
	(1)	(2)
Rainfall Volatility	0.0528***	0.0100
	(3.375)	(0.581)
Rainfall	0.0524***	0.00561
	(3.287)	(0.303)
Income per capita	-0.000172	0.000889*
	(-0.327)	(1.658)
Population growth	0.611*	0.411
	(1.657)	(1.158)
Democratic institutions	0.105	0.120
	(0.767)	(0.947)
Food supply		-0.0728***
		(-7.043)
Intercept		-38.39*
		(-1.779)
Observations	294	287
Countries	74	74
R-squared	0.152	0.141

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

In column (2), we include food supply. We find that food supply has a negative effect on malnutrition. Moreover, the coefficient of climatic shocks becomes no significant. The non significance of the coefficient associated with climatic shocks indicates that climatic shocks increase malnutrition through food supply. By increasing malnutrition through food supply, climatic shocks are source of food insecurity.

4.3.4. Heterogeneity for African countries

Finally, we look at if the effects of climatic shocks on food supply are different for Sub Saharan Africa 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. The predominance of rain-fed agriculture in much of Sub-Saharan African results in food systems that are highly sensitive to rainfall variability. Moreover (Guillaumont & Simonet 2011) and (Wheeler 2011)[5] conclude that these countries are the most vulnerable to climate change.

Table (10) shows the results of the effect of rainfall instability on food supply in Sub Sahara countries and developing countries. Columns (1) and (3) show that the negative effect of

[5] Wheeler (2011) shows that, in the top 25 states, 19 are from Sub-Saharan Africa.

climatic shocks is higher in SSA than in other developing countries. Moreover for Sub-Saharan Africa (column (4)), the adverse effect of climatic shocks on food supply is high in a context of food prices vulnerability.

Table 10: Heterogeneity for African Countries

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

4.3.5. Asymmetric and extreme events effects

Previous results analyse the impact of rainfall volatility but are silent about their asymmetric and extreme events effects on food supply. Indeed previous results could mask important

differences on the effects of positive and negative rainfall volatility on food supply. In column (2) of table 12, we present the results of negative and positive rainfall shocks on food supply.
Results suggest that negative rainfall shocks are associated with food supply reduction whereas positive rainfall shocks are associated with food supply improvement. However the shocks are asymmetric because the losses due to negative shocks are not perfectly compensated by the gains during the positive shocks.

Column (3) indicates that extreme rainfall volatility has a negative impact of food supply. The effect of extreme rainfall shocks is almost 34 times higher than the effect of normal rainfall shocks. In other words, high rainfall volatility has extreme adverse effect on food supply.

Table 12: Asymmetric and extreme rainfall shocks

	Food Supply		
	(1)	(2)	(3)
Rainfall Volatility	-0.365***		
	(-7.485)		
Positive shocks		0.21***	
		(4.890)	
Negative shocks		-0.398***	
		(-6.711)	
Extreme Rainfall shocks			-12.36**
			(-2.388)
Rainfall	-0.343***	-0.339***	-0.00678
	(-7.542)	(-7.407)	(-0.393)
Income per capita	0.0159***	0.0157***	-0.00287
	(4.935)	(4.864)	(-0.785)
Population growth	-2.453	-2.549	4.252
	(-0.831)	(-0.863)	(1.566)
Democratic institutions	-0.646	-0.678	-0.0568
	(-0.639)	(-0.670)	(-0.0606)
Intercept	762.7***	746.8***	437.9***
	(13.20)	(12.45)	(17.46)
Observations	626	626	461
R-squared	0.285	0.286	0.179
Countries	71	71	71

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 1960-2008.

5. Conclusion

This paper contributes to the existing literature on climatic variability and food security. It analyzes the effect of climatic shocks on food security for 77 developing countries from 1960 to 2008. The results are as follows: First, we show that climatic shocks have negative effects on food security. Using two complementary indicators of food security, we find that climatic shocks reduce food supply in developing countries. The adverse effect is higher for African Sub Saharan countries than other developing countries. Moreover, food supply is a channel by which climatic shocks increase the proportion of undernourished people. Second, the negative effect of climatic shocks is exacerbated in presence of civil conflicts. Third, the effects are high for countries that vulnerable to food prices shocks.

Our results are important for economic policies. An important intervention to reduce food insecurity would be the implementation of effective mitigation strategies of risks. In line with this, promoting measures that enhance the food production systems in the developing countries thereby increasing their capacity to withstand the rainfall instability is imperative.

One approach would be to invest in agricultural research, extension, and methods for reducing food production losses related to climate variability. Given the large uncertainties about future rainfall patterns in many developing countries, careful consideration should be given to major investments in infrastructure to support irrigation and water resources development in order to limit the effects of food production reducing.

Another approach, probably important for international community, is to help developing countries, particularly the least developing countries (LDCs) through automatic mechanisms which will be lead to magnitude of effects of climatic shocks on food security. For example, the international community can finance stabilization mechanisms (government budget or development projects for the regions adversely affected by climatic shocks) with aid (named "climatic aid"). When the effect of climatic shocks is negative and more important, the level of "climatic aid" will have to increase. This "climatic aid" can be given to developing countries that are both more exposure to effects of climate change and vulnerable to food price shocks.

The third way to reduce the magnitude of effects of climatic shocks in the developing countries is to diversify the structure of their economy.

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Appendix B: Tables

Table B.1: Variables definition and sources

Variables	Definition	Source
Food supply	Food supply refers to the total amount of the commodity available as human food during the reference period. Food supply are the total of food Production + food import- food exports+ food stocks variation.	FAO (2011)
Percentage of total undernourished population	The percentage of the population whose food intake is insufficient to meet dietary energy requirements continuously.	WDI (2011)
Rainfall volatility	It is the absolute deviation of the yearly average of rainfall from its own trend (long term mean of rainfall 1950-2008).	Guillaumont and Simonet (2011)
Rainfall	It is the yearly average of rainfall.	Guillaumont et Simonet (2011)
Food Price	The food price index is a geometrically average of the world price of the following foods:maize, rice, sugar, soybean, soybean oil, sorgho and wheat.	Authors from WDI (2011)

Food Price vulnerability	The FPV index is a weigted[6] average of the following variables: the ratio of food imports to total household consumption; the ratio of total food imports to total imports of goods and services and the inverse of the level of GDP per capita.	AuthorsWorld Development Indicators (2011)
Civil conflicts	Civil conflicts are defined as the magnitude score of episode(s) of civil warfare involving that state in that year.	(Center for Systemic Peace 2010)
Climatic Vulnerability	It is an index that show where extreme climate events (weather-related disasters, rising seas, and the loss of agricultural productivity) are most likely to occur, and the likelihood that an individual in each country would be affected	Wheeler 2011)
Income per capita	Gross Domestic Product per capita	WDI (2011)
Population growth	annual population growth rate	WDI (2011)
Democratic institutions	The Polity Score captures the regime authority spectrum on a 21-point scale ranging from -10 (hereditary monarchy) to +10 (consolidated democracy).	Polity IV (2010)
Agricultural land	Agriculture area as percentage of total land area	WDI (2011)
Arable land	Arable area as percentage of total land area	WDI (2011)
Cereal production land	Cereal[7] production area refers to harvested area or Land under cereal production	WDI (2011)

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

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
Shock price vulnerability	46.15	64.45	0.84	381.48
Civil conflict	0.03	0.33	0	4
Per capita GDP	6396.13	10374.16	84.28	95885.27

[6] To calculate this index, we use the principal component analysis (PCA) applied to three variables.

[7] Cereals include wheat, rice, maize, barley, oats, rye, millet, sorghum, buckwheat and mixed grains.

Population growth	1.88	1.54	-4.64	16.24
Democratic institutions	-0.52	5.64	-10	10
Land under cereal production	2.22e+07	7.10e+07	0	6.95e+08
Agricultural land	37.67	21.19	0	90.55
Arable land	13.30	12.94	0	71.65
Agricultural irrigated land	10.56	13.73	0	71.58
Undernourished population	15.32	13.71	5	70

Table B.3: **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	