Climate variability and food security in developing countries economics essay

Economics

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Abstract

This paper contributes to the existing literature on climate variability and food security. It analyzes the impact of climate variability on food security for 77 developing countries from 1960 to 2008. Using two complementary indicators of food security (food supply and proportion of undernourished people), we find that climate variability reduce food supply and the proportion of undernourished people in developing countries. The adverse effect is higher for African Sub Saharan countries than for other developing countries. We also find that the negative effects of climate variability are exacerbated in presence of civil conflicts and are high for the countries that are vulnerable to food prices shocks. JEL Codes: D74; Q17; Q18 ; Q54Keywords: Civil conflicts; Food Prices shocks; Food security; Climate variability

Introduction

According to the United Nations Development Programme (2011), between 1990 and 2005 the number of people living under the international poverty line[3]has reduced from 1. 8 billion to 1. 4billion. These results confirm some previous studies (Chen et Ravallion 2010) that conclude to a continued decline in global poverty during the last three decades. These authors show that the proportion of the world people living below the international poverty line varied from 52 percent in 1980 to 25 percent in 2005. However, progress is currently not fast enough and is 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. In the recent years, the debate on climate variability has led to a renewed interest on the effects of climate variability on agriculture. Many authors have analyzed the relationship between climate variability and the indicators of food security. We can distinguish two analysis groups. The first one concerns theoretical papers. Several theoretical analyzes conclude that climate variability has a negative impact on agricultural production and decreases food availability. Christensen et al. (2007) show that food production remains highly vulnerable to the influence of adverse weather. Haile (2005) and Dilley et al. (2005) confirm that food crises in Africa during last years which required large-scale external food aid have been attributed fully and partially to extreme weather events. Ringler et al. (2010) conclude that climate variability is a factor of childhood malnutrition in Sub-Saharan Africa. The second category of literature on the link between climate variability and food security concerns empirical analyses. The absence of suitable climatic data justifies the fact that there are little empirical studies in this area. 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. 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. However few papers focus on the effects of climate variability on food security. The objective of this paper is to contribute to the debate on the causal effect of climate variability on food security. We use two indicators of food security (food supply and proportion of undernourished people) and the fixed effect method applied to panel data from 1960 to 2008 for 77 developing countries. First, the results show that climate variability reduces food supply. The effect is higher for Sub-Saharan African countries than for other countries. Second, the negative effect of climate variability is exacerbated in presence of civil conflicts. Third, the effects are high for countries that are vulnerable to food prices shocks. Our analysis contributes to the existing literature on climate variability and food security in several ways. First, while most of the literature is mainly theoretical, we perform an empirical analysis of the effect of climate variability on food security for 77 developing countries. Second, we employ two different sources of climate variability data. Third, we identify the mechanisms by which climate variability can affect the indicators of food security. The plan of the paper is as follows. Section 2 contains a discussion of the literature review on the relationship between climate variability and food security. Section 3 discusses econometric method used to evaluate the effect of climate variability on the indicators of food security. Section 4 presents empirical results. The last section is devoted to concluding remarks and implications.

2. Relationship between Climate Variability and Food Security

There is an abundant economic literature on the relationship between climate variability and food security. This literature can be presented according to three different approaches: production-based approach, market approach and institutional failures. Before discussing of these approaches, we will define the concepts of food security and climate variability.

2. 1. Concepts of Food Security and Climate Variability

2. 1. 1. Concept of Food Security

Food security is a concept multidimensional and flexible that gained prominence since the World Food Conference in 1974. Many definitions of this food security 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 et Sen (1991), (Sen 1983a)). Tweeten (1997) emphasizes that the concept of food security 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. Concept of Climate Variability

The concept of climate Variability is related to the notion of climate change. According to Intergovernmental Panel on Climate Change (IPCC, 2007a), climate change refers to a change in the state of the climate that can be identified (e. g. using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural instability or as a result of human activity. This definition differs from that in the United Nations Framework Convention on Climate Change (UNFCCC), where climate change refers to a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods. Climate variability can be considered as a component of climate change. According to IPCC (2001d), climate variability refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all temporal and spatial scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability).

2. 2. Looking for Food Security and Climate Variability Indicators

2. 2. 1. Measurement indicators of Food Security

Several indicators of food security have been defined in the economic literature. The first indicators used are the energy balance per capita which is measured by the Dietary Energy Supply (DES) 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 food supply is distributed among individuals according to needs. The headcount rate of poverty highlights a problem of food access. So, these two indicators are considered as the partial measures of food security because they only 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 use other indicators: under-five mortality rate, child malnutrition and proportion of undernourished. The under-five mortality rate 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, as estimated by FAO, reflects the share of the population with inadequate dietary energy intake i. e. the proportion of people who are food energy deficient. Wiesmann (2004) shows that the proportion of undernourished and the prevalence of underweight in children both have the shortcoming that they do not reveal the most tragic consequence of hunger and under-nutrition that is premature death. Pelletier et al. (1994) suggest that the same level of child malnutrition in two countries can have quite different effects on the proportion of malnutrition-related deaths among children, depending on the overall level of child mortality. Wiesmann (2004) thinks that this limit of the indicator of child malnutrition is mitigated if they take in account of the under-five mortality rate. Pelletier et al. (1994) conclude that the data on mortality comprise other causes of death than malnutrition, and that the actual contribution of child malnutrition to mortality is not easy to track because the proximate cause of death is frequently an infectious disease. Furthermore, the indicators of child malnutrition and of infant mortality cover a category of population (children). Recent analyzes refer to Global Hunger Index (GHI)[4]to measure food insecurity (see Wiesmann, 2004). The GHI is a statistical tool to measure and monitor hunger in the world by country and by region. It captures three dimensions of hunger: i) insufficient availability of food, ii) shortfalls in the nutritional status of children, and iii) premature mortality caused directly or indirectly by undernutrition. The GHI combines the percentage of people who are food energy deficient, which refers to the entire population, with the two indicators that deal with children under five. Wiesmann (2004) thinks that the use of the GHI ensures that both the situation of the population as a whole and that of children, a particularly physiologically vulnerable subsection of the population, are took in account. It also 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. 2. Measurement indicators of Climate Variability

Measuring climate variability involves evaluating the gap between the achievements of climate variable (rainfall or temperature) and its equilibrium value. This equilibrium value refers to the existence of a permanent state or trend. Generally, we measure climate variability by the standard deviation or the average deviation in absolute value of the distribution of a variable relative to its mean or to its long-term trend. The standard deviation weights more strongly the extreme events compared to the average deviation. Other indicators of climate variability used in the literature such as the voussure coefficient, the asymmetry coefficient the variation coefficient and the standard deviation of the growth rate of a climate variable. The voussure coefficient (kurtosis coefficient) and the asymmetry coefficient (skewness coefficient) are respectively the three-order and four-order moments and get information about climate variability of countries and particularly the frequency of the extreme events.

2. 2 What could explain food insecurity?

We discuss in this part of the three approaches highlighting the explanatory factors of food insecurity.

2. 2. 1. The production-based approach

The production-based approach is based on the assumption that food insecurity is the result of a decrease in food availability. This approach is often based on analysis of 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 (Berry and Cline (1979); Boserup (1965); Ehrlich et al. (1993)). 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 (2000) 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) suggests that the expansion of population follows a geometric progression whereas food supply follows 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 (Ehrlich and Ehrlich, (1991), 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 (Ehrlich and Ehrlich, 1991) 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 (1965), Simon (1998) 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. In addition to technology, some authors take into account political and economic actions in the relationship between population growth and food security. Cohen (2008) 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 (1997) 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 a 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 food supply but due to food access. The concept of entitlement developed by Sen (1983) joined in part this approach. The author suggests 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

(1983, 2000) concludes later that an unfavorable shift in exchange conditions can be the 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. We 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 she is unable to satisfy adequately 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 have inadequate resources for care and are unable to achieve food security and 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 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. The authors emphasize that national income reflects the contribution of food production to overall income generated by households for countries with large agricultural sectors. Smith and Haddad (2000) also suggest that national income may improve women's relative status directly by freeing up resources for improving women's lives as well as men's. They conclude that there is a strong negative relationship between national income and poverty, as shown by the recent studies (see e. g., Ravallion (2008) and Easterly (2005)). These studies show that economic growth is necessary condition for poverty reduction. By promoting poverty reduction, economic growth may reduce the constraints on food access for households and is therefore a source of food security.

2. 2. 3. Institutional failures

Some authors such as Keen (1994) and Sen (2000) 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 (2000) suggests that the working democracy and of political rights can help to prevent famines and other economic disasters. Indeed, authoritarian rulers tend to lack 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 may 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 Dreze et Sen (1991) 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 relationship between civil conflicts and hunger in developing countries. Indeed, in the countries in conflict, population, households and individuals suffer disruptions in livelihoods, assets, nutrition and health. The 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 the conflict regions 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 the countries in conflict. Green and Mavie (1994) show that the cumulative loss of output attributable to civil conflict of 1982-1992 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, health services and communication infrastructure. Messer et al. (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 does climate variability matter for food insecurity?

There are many channels through which climate variability is likely to affect food security in developing countries. Here we discuss potential channels.

Climate variability and agriculture production

Most of developing countries are particularly vulnerable because their economies are closely linked to agriculture. Agriculture on which millions people of developing countries depend on for our food is under threat from climate variability. Thus, climate variability has the potential to harm food security through its negative effect on crop production. For example, higher average temperatures and changing rainfall patterns impact negatively farm yields and the harvests, reducing household and national food availability and agricultural income. Poor harvests threaten food security. This threat is very important for countries dependent on agriculture for their food and income. Kydd et al. (2004) think that rainfall variability contributes 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.

Climate variability and households' income

Climate variability can harm food security through its adverse impact on households' income coming from agricultural sector. By reducing households' income, climate variability leads to a decrease in demand for goods and services in the affected communities. This threats the livelihoods of people who depend on indirectly of agriculture such as traders. This threat is particularly high in Africa because according to an International Labor Organization report (2007), agricultural production is the primary source of livelihoods for 66% of the total active population in Africa. Nhemachena et al. (2010) show that rainfall variability and higher average temperatures negatively affect households' income coming from agricultural crops and livestock. This contributes to harm food security in Africa. Sen (1983a) considers that beyond the agricultural sector, climate variability adversely affects labor market in the rural areas, thus leading to a decrease in households' income and a decrease in food basket.

Climate variability and food prices

Climate variability impacts food security through its great negative effect on food prices. Indeed, climate variability such as higher average temperatures that undermines the harvests, leads to a decrease in food availability. Since the demand for food is highly price inelastic, a decrease in marketed supply may lead to an important increase in food prices, thus reducing food accessibility. Moreover, Aker (2010) considers that climate variability may have an effect on traders' entry and exit in response to the profitability of food trading. Indeed, climate variability leading to an increase (decrease) profits may incite the traders to entry (or exit) local market. This may reduce food supply in the local market and harm food security through food price dispersion. Using theoretical models[5], Ringler et al. (2010) find that climate variability such as higher temperatures and mixed precipitation changes will lead to changes in yield and area growth, higher food prices and hence lower affordability of food, reduced calorie availability, and growing childhood malnutrition in Sub-Saharan Africa

Climate variability and economic resources

Climate variability can impact food security at the macroeconomic level through its effect on economic growth. Dell et al. (2008) show that climate variability has large and negative effects on economic growth in the poor countries. This can translate into by a decrease in economic resources and a negative effect on the countries' ability to purchase food on international markets; to invest in technology, services and infrastructure that support food and agricultural production; and to finance public services and investments in health, education to meet the needs of its population such as food needs. This contributes to undermine food security.

Climate variability and civil conflicts

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

3. Empirical Analysis

This section presents the method used to analyze the effects of climate variability on food security. Firstly we specify the econometric model and then we describe the variables and the data source.

3. 1. Empirical Model

The objective of our paper is to analyze relationship between climate variability and food security over the period 1960-2008 for 77 developing countries. For this purpose, we define the following equation:(1)With X the matrix of control variables, is the variable of climate variability in a country i at the period t and it represents our interest variable. is the error term, is time effect and represents country effect. The data cover the period from 1960 to 2008 and are compiled in five-year averages (1960-1964, 1965-1969…). is the food security indicator. We use two alternative measures of food security: food supply and the proportion of undernourished. The definitions of these two variables are presented in the following section. Our control variables are main determinants of food security that have been discussed in the section 2. 2: the level of development measured by income per capita, population growth and democratic institutions. We also use the complementary control variables to check the robustness of our results: cereal production land, arable land and real effective exchange rate. We identify the potential heterogeneities in the relationship between climate variability and food security. We are interested in two types of heterogeneities. First, we test if the effects of climate variability can be different depending on whether the country was under conflict (equation 2). Second, we analyze the impact of climate variability on food security in the context of food price shock vulnerability (equation 3). The procedure for calculating of the variable of food price shock vulnerability is presented in the following section.(2)(3)With the conflict variable and the vulnerability of countries to food price shocks. We use adequate econometric techniques to estimate the impact of climate variability on food security. The equations 1 to 3 of our model are estimated with ordinary least squares method (OLS). 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. Data sources and description of variables

The data used in this study cover the period from 1960 to 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, rainfall variability and food supply come respectively from Polity IV (2010), Center for Systemic Peace (2010), Guillaumont and Simonet (2011) and Food and Agriculture Organization of the United Nations (2011). Income per capita is measured by GDP per capita which is in constant US dollars. Population growth is the annual growth rate of the population. We use the index of polity 2 to appreciate the degree of democracy in a country. This index 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 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". Civil conflicts are defined as the magnitude score of episodes of civil warfare involving the country. Regarding the food security indicators, we use food supply and proportion of undernourished people because the global hunger index which is currently considered the best indicator of food security is not available over the long time. 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 magnitude of inequality in access to food. Food supply is from Food Balance Sheets produced by FAO for every country, which gives 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, we selected the main cereals (maize, rice, sorghum, millet, and wheat), soybeans and sugar for the calculation of food supply. These commodities represent an important proportion in food of populations in most of developing countries. Food supply obtained is a simple average of food supplies of selected commodities expressed in kcal/person/year. Climate variability is measured by rainfall variability, which is defined as the average deviation in absolute value of the distribution of rainfall relative to its mean or to its long-term trend. The choice of variable of rainfall variability is based on Guillaumont and Simonet (2011). We perform robustness tests using an alternative indicator of climate variability. It is the standard deviation of the growth rate of rainfall, which is frequently used in the economic analyses. We also perform the impact of extreme variability of rainfall on food security using the four-order moment of rainfall. We construct the variable of vulnerability to food price shocks using the procedure developed by de Janvry and 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 consumption, 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). Table 1: Definitions and Sources of variables

Variables

Definition

Source

Food SupplyFood supply refers to the total amount of goods available as human food during the reference period. Food Balance Sheets, FAO (2011)Percentage ofUndernourishedPeopleThe percentage of the population whose food intake is insufficient to meet dietary energy requirements continuously. WDI (2011)Rainfall variabilityThe average deviation in absolute value of the distribution of rainfall relative to its mean or to its long-term trend. Guillaumont andSimonet (2011)RainfallIt is the annual rainfall average. Guillaumont andSimonet (2011)Food Price IndexFood Price Index is a geometric average of the world prices of maize, rice, wheat, sorghum, soybean and sugar. Calculated by theauthors using the data from IFS (2011)Food Price ShockVulnerability (PSVul)PSVul index is a weighted[6]average of 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. Calculated by theauthors using thedata from WDI (2011)Civil ConflictsCivil conflicts are defined as the magnitude score of episodes of civil warfare involving the country. Center for Systemic Peace (2010)Income per capitaGross Domestic Product per capitaWDI (2011)Population GrowthAnnual growth rate of the populationWDI (2011)Democratic Institutions (Index)This index 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). Polity IV (2010)Arable landArable land is the land under temporary agricultural crops (multiple-cropped areas are counted only once), temporary meadows for mowing or pasture, land under market and kitchen gardens and land temporarily fallow (less than five years). WDI (2011)Cereal ProductionLandCereal[7]production area refers to harvested area or Land under cereal production. WDI (2011)Real EffectiveExchange Real(REER)REER is the nominal effective exchange rate (a measure of the value of a currency against a weighted average of several foreign currencies) divided by a price deflator or index of costs. IFS (2011)Source: constructed by the authors.

4. Results

4. 1. Results of baseline equation

Table (2) shows the results of the effects of rainfall variability on food insecurity with different econometric methods: ordinary least squared (OLS), fixed effects (FE) and random effects (RE). The results of OLS method are in the columns (1) and (2) and they don't take into account unobserved heterogeneity of countries. This justifies the fact that we apply fixed effects (columns 3 and 4) and random effect (columns 5 and 6) estimators. Hausman test shows that the fixed effect model is more appropriate than the random effect model. Income per capita has a positive effect on food supply. Our results are similar to previous studies (see e. g. Smith et Haddad, 2000). Indeed, the economic resource availabilities increase the capacity of countries to meet the food needs through an increase in national production and/or import foods. The size of population reduces food supply. This result is similar to that of 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 (e. g. Dreze et Sen, 1991), we find that democratic institutions have no effect on food supply. This may be explained by the fact that we use a composite indicator. Rainfall variability has a negative and significant effect on food supply. These results can be explained by several arguments. Firstly, changing rainfall patterns rainfall is a source of high uncertainty on food production. This increases fluctuations in agricultural production and reduce household's incomes. For countries that depend on the weather conditions (rain-fed agriculture) for agriculture production, rainfall variability has a negative effect on food production and availability. Second, by reducing agriculture production in developing countries, rainfall variability reduces agricultural incomes and hence negatively affects 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 2: Impacts of rainfall variability on food supplyDependent variableFood SupplyOLS(1)(2)FE(3)(4)RE(4)(6)Rainfall variability-0. 0716***-0. 0912***-0. 417***-0. 365***-0. 0716**-0. 0912***(-2. 749)(-3. 722)(-8. 506)(-7. 532)(-2. 536)(-3. 333)Rainfall0. 13160. 1166-0. 0040. 0310. 0661***0. 0638***(0. 68)(0. 79)(-0. 54)(0. 36)(3. 99)(3. 69)Income per capita0. 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 instititions0. 7780. 409-0. 219-0. 4620. 7780. 409(0. 862)(0. 497)(-0. 196)(-0. 426)(0. 687)(0. 378)Intercept454. 0***414. 3***872. 1***757. 5***454. 0***414. 3***(12. 87)(11. 91)(15. 67)(13. 28)(15. 46)(13. 96)Temporal dummiesObservationsNo626Yes626No626Yes626No626Yes626Countries717171717171R-squared0. 2160. 289Note: 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 1960-2008Table 3: Impacts of rainfall variability on food supply: adding control variables (FE model)Dependent variable(1)(2)Food Supply(3)(4)(5)Rainfall variability-0. 365***-0. 336***-0. 332***-0. 361***-0. 372***(-7. 532)(-6. 878)(-6. 695)(-7. 440)(-4. 570)Rainfall0. 031-1. 653. 315-

1. 651. 28(0. 36)(-1. 29)(0. 62)(-1. 29)(-4. 355)Income per capita0. 0162***0. 0160***0. 0168***0. 0162***0. 0143***(4. 984)(4. 981)(5. 188)(4. 979)(3. 550)Population growth-2. 630-2. 740-2. 301-2. 507-11. 13**(-0. 914)(-0. 961)(-0. 804)(-0. 871)(-2. 013)Democratic institutions-0. 462-0. 374-0. 419-0. 512-2. 950*(-0. 426)(-0. 347)(-0. 388)(-0. 472)(-1. 900)Cereal production land5. 46e06***(3. 408)Arable land2. 520***(2. 853)Rainfall squared1. 73e-05(1. 326)Exchange rate (REER)0. 00011(0. 230)Intercept757. 5***694. 2***681. 6***802. 8***817. 6***(13. 28)(11. 67)(10. 88)(12. 08)(7. 784)ObservationsCountries6267162671626716267129333R-squared0. 2890. 3040. 3000. 2910. 317Note: 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 1960-2008The next step consists of adding other control variables to check the robustness of results to changes in the baseline model: cereal production land, arable land, squared term of rainfall level and real effective exchange rate. The results of table (3) show that rainfall variability has a negative effect on food supply. The coefficient associated to rainfall variability is negative and significant. The results obtained for cereal production land (column 2) and for arable land (column 3) are positive and significant. Thus, a policy allowing better land use increases food production and supply. The real effective exchange rate has no effect on food supply. We include the squared term of rainfall level to test a non linear relationship between rainfall level and food supply because we suppose that too much rainfall reduce food supply. The results show that rainfall squared has a positive effect but no significant on food supply.

4. 2. Heterogeneity on the impact of climate variability

In this section, we identify the potential heterogeneities in the relationship between climate variability and food security. First, we test if the impact of climate variability can be different depending on whether the country was under conflict. Second, we analyze the impact of climate variability on food security in the context of food price shock vulnerability.

4. 2. 1. The importance of civil conflicts

We suppose that the impact of climate variability on food security is high for countries that are in conflict. We test this hypothesis by adding in our estimations the variable of civil conflicts and a interactive term (rainfall variability*civil conflicts). The results of the table (4) show that civil conflicts have negative effect on food supply (column 2). 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 impact of rainfall variability 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, civil conflicts destroy infrastructure, social services, assets and livelihoods, social cohesion, institutions and norms, and they displace populations 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 going to market to sell and buy goods, and this leads to a loss of earnings.

Third, civil conflicts have negative effects on economic growth by reducing investments and 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 (see e. g. Kremer and Miguel, 2007), increasing vulnerability and food insecurity. Climate variability is 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 climate variability. In other words, the effects of climate variability on food supply are more severe in the countries in conflict. Table 4: impact of climate variability on food security: importance of civil conflictsDependent variable(1)Food supply(2)(3)Rainfall variability-0. 365***-0. 374***-0. 372***(-7. 532)(-7. 612)(-7. 583)Rainfall0. 031-2. 525-0. 844(0. 36)(-0. 85)(-0. 83)Rainfall volatility * Civil conflicts-0. 415**(-1. 990)Civil conflicts-34. 67***-52. 29***(-2. 804)(-3. 445)Income per capita0. 0162***0. 0155***0. 0153***(4. 984)(4. 749)(4. 701)Population growth-2. 630-3. 484-3. 626(-0. 914)(-1. 200)(-1. 252)Democratic institutions-0. 462-0. 211-0. 128(-0. 426)(-0. 193)(-0. 118)Intercept757. 5***768. 8***768. 1***(13. 28)(13. 35)(13. 37)ObservationsNumber of countries626716177161771R-squared0. 2890. 2950. 301Note: 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 importance of food price shocks vulnerability

In this section, we test the potential effects of climate variability on food supply in a context of food price shocks vulnerability. Climate variability can increase vulnerability of countries to food price shocks. Indeed, climate variability could affect agricultural productivity and production and hence household's incomes because income from agriculture represents a large proportion of total household's income in developing countries. As household's incomes are negatively affected by climate variability, the part of food expenses on total consumption (food dependency) increases. Moreover, by affecting economic growth (Dell et al. 2008), climate variability can lower the resources capacities and increase food import burden of countries. Hence the negative effect of climate variability on food supply can increase with vulnerability of countries to food price shocks. Table 5 presents the results of the nonlinear impact of climate variability on food supply, depending upon the level of vulnerability of countries to food price shocks. The results indicate that the associated coefficients to the variable of vulnerability to food price shocks and to interactive term (rainfall variability*price vulnerability) are negative and significant. This result reveals that the negative impact of climate variability 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 and Sadoulet, 2008). Indeed, policy instruments available to facilitate food accessibility by increasing agricultural production or food imports are limited or ineffective. Table 5: impact of climate variability on food security: vulnerability to food price shocksDependent variableFood supply(1)(2)(3)(4)Rainfall variability-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)Rainfall0. 031-0. 00062-0. 880-0. 0038(0. 36)(-0. 18)(-0. 94)(-0. 92)Food price0. 167***0. 107**(4. 461)(2. 128)Price volatility0. 146(1. 381)Income per capita0. 0162***0. 00728**0. 004800. 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)Intercept757. 5***783. 1***667. 0***650. 4***(13. 28)(13. 21)(10. 50)(9. 662)ObservationsNumber of countries626715006950069470 69R-squared0. 2890. 3650. 3940. 364Note: 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 checks

4. 3. 1. Alternative indicators of climate variability

In our previous estimations, we used the average deviation in absolute value of the distribution of rainfall relative to its long-term trend as measure of rainfall variability. This indicator supposes that rainfall series have a deterministic trend. We check the robustness of our results using the standard deviation of the growth rate of rainfall. The standard deviation of the growth rate of a variable as variability measure is largely used in the economic analyses (e. g. exchange rate instability, economic growth instability). This indicator supposes that rainfall series run a stochastic trend. The new variable of rainfall variability is defined as the 5-year rolling standard deviation of the growth rate of rainfall series. We also check the robustness of our results using another data source on climate. It is the database developed by Mitchell et al. (2004). The results of table (6) reveal that the negative effect of rainfall variability on food supply increases with the level of vulnerability of countries to food price shocks whatever the variability indicator or the database used.

4. 3. 2. Inertia of food supply

Another issue is to see if food supply in developing countries is characterized by inertia phenomena. In other words, we want to know if the lagged level of food supply is a potential determinant of the current level of food supply. We check this by including the 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). The results of table (7) show that the lagged level of food supply has no effect on its current level (columns 2 and 3). There is not an inertia phenomena for food supply in developing countries. Table 6: impact of climate variability on food security: alternative indicator of climate variability and another databaseDependent variableFood supply(1)(2)(3)(4)(5)(6)

Stochastic TendanceMitchell's databaseRainfall variability-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)Rainfall0. 0310. 0042210. 009990. 008200. 006420. 00366(0. 36)(0. 29)(0. 615)(0. 507)(0. 441)(0. 251)Income per capita0. 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. 1722. 3270. 7750. 300(-0. 813)(-2. 614)(0. 966)(0. 531)(0. 251)(0. 0971)Democratic institutions0. 1410. 07680. 1370. 05710. 7540. 679(0. 134)(0. 0728)(0. 144)(0. 0601)(1. 256)(1. 132)Intercept754. 1***779. 7***444. 7***446. 8***449. 1***449. 2***(13. 08)(13. 01)(18. 86)(19. 03)(24. 56)(24. 63)Observations626500434434544544R-squared0. 2850. 3620. 3470. 3550. 1860. 192Number of countries716969696969Note: 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 1960-2008Table 7: impact of climate variability on food security: inertia of food supplyDependent variable Food SupplyFixed effect(1)GMM-systemOne step(2)GMM-systemTwo step(3)Lagged food supply0. 020. 04(1. 612)(1. 01)Rainfall variability-0. 362***-0. 0214***-0. 0215***(-7. 528)(-23. 61)(-22. 07)Rainfall0. 031-0. 0008520. 000133(0. 36)(-0. 160)(0. 0218)Income per capita0. 0163***0. 0006480. 00118(5. 008)(0. 535)(0. 849)Population growth-2. 3838. 9448. 369(-0. 806)(1. 518)(1. 201)Democratic institutions-0. 184-1. 128*-0. 631(-0. 169)(-1. 953)(-1. 065)Intercept754. 6***-28. 95-16. 69(13. 09)(-1. 009)(-0. 548)Observations626567567R-squared0. 287CountriesAR(1)AR(2)Hansen testInstruments71710. 000. 260. 3457710.

000. 250. 3457Note: 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

Given that food security is a multidimensional concept, we use another complementary indicator to check the robustness of our results: the proportion of undernourished people. A person is malnourished if his average energy intake is less than the minimum necessary to maintain physical and moderate activity. Table (8) presents the results of the impact of climate variability on the proportion of undernourished people. We find that rainfall variability increases the proportion of undernourished people. The results are robust by adding other control variables (rainfall squared, arable land, cereal production land, food prices and food price volatility). Table 8: impact of climate variability on proportion of undernourished people – Fixed Effect EstimationDependent variableFood Supply

(1)(2)(3)(4)(5)(6)Rainfall variability0. 0528***0. 0514***0. 0354**0. 0475***0. 0499***0. 0495***(3. 375)(3. 273)(2. 285)(3. 056)(2. 726)(2. 730)Rainfall0. 1071-0. 0009-0. 2213-0. 0695-0. 00062. 9162(0. 18)(-1. 18)(-0. 68)(-1. 05)(-0. 19)(1. 04)Income per capita-0. 000172-0. 000125-0. 000689-0. 000239-8. 25e-05-0. 000154(-0. 327)(-0. 237)(-1. 323)(-0. 458)(-0. 151)(-0. 290)Population growth0. 611*0. 5680. 707**0. 5540. 4760. 519(1. 657)(1. 528)(1. 977)(1. 514)(1. 165)(1. 313)Democratic institutions0. 1050. 09570. 1300. 08840. 1210. 0951(0. 767)(0. 695)(0. 981)(0. 652)(0. 822)(0. 665)Rainfall square-1. 91e-06-1. 93e-06-2. 32e-06(-0. 956)(-1. 006)(-1.

175)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**-14. 55-35. 93*-38. 02*-38. 39*

(-2. 276)(-2. 425)(-0. 762)(-1. 923)(-1. 753)(-1. 779)Observations314314314314282287Countries797979797174R-squared0. 1570. 1600. 2310. 1880. 3780. 141Note: 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. 4. Heterogeneity for African countries

We interested in the effects of climate variability on food security in the context of Sub- Saharan Africa countries. Indeed, these countries have two main characteristics: (i) they are more vulnerable to food prices shocks because they are net food importers and they are less resilient, and (ii) they are more vulnerable to climate variability (see e. g. Guillaumont and Simonet (2011) and Wheeler (2011)[8]). The predominance of rain-fed agriculture in most of Sub-Saharan Africa countries makes that food systems are highly sensitive to rainfall variability. Table (10) shows the results of the effect of rainfall variability on food supply in developing countries in generally and in Sub-Saharan Africa countries in particularly. The results show that the negative effect of rainfall variability on food supply is higher in SSA countries than in other developing countries (columns 1 and 3). In addition, rainfall has a positive and significant effect on food supply in SSA countries. The adverse effect of rainfall variability on food supply is high in a context of food prices vulnerability for SSA countries (column 4). Table 9: Impact of climate variability on food security in African CountriesDependent VariableFood SupplyDeveloping CountriesAfrican Countries

(1)(2)(3)(4)Rainfall variability-0. 358***-0. 277***-0. 554***-0. 631***(-7. 371)(-5. 048)(-5. 986)(-4. 371)Price vulnerability-0. 562***-0. 426***(-6. 391)(-2. 919)Rainfall variability*Price vulnerability-0. 0007**-0. 0013*(-1. 976)(-1. 805)Rainfall0. 0310. 00420. 1254**0. 0071**(0. 36)(0. 29)(2. 02)(2. 11)Income per capita0. 0162***0. 0071**0. 0256***0. 0090(5. 004)(2. 099)(3. 010)(0. 465)Population growth-2. 396-10. 85***5. 32216. 35**(-0. 813)(-2. 614)(1. 452)(2. 467)Democratic institutions0. 1410. 0768-0. 0077-0. 0403(0. 134)(0. 0728)(-0. 0047)(-0. 0223)Intercept754. 1***779. 7***772. 9***952. 8***(13. 08)(13. 01)(9. 689)(10. 20)Observations626500230164Number of countries71692524R-squared0. 2850. 3620. 2530. 369Note: 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 estimates were based on analysis of the impact of rainfall variability on food security but are silent about the asymmetric and extreme events effects. However, there are important differences between the effects of positive and negative rainfall variability on food supply. Table (10) presents the results of negative and positive rainfall variability on food supply. The results suggest that negative rainfall variability is associated with a food supply reduction whereas positive rainfall variability is associated with a food supply improvement (column 2). We also find that rainfall variability is asymmetric because the losses due to negative rainfall variability are not perfectly compensated by the gains due to positive rainfall variability. We also interested in the effects of extreme rainfall variability on food supply. We use the skewness coefficient that is the four-order moment of rainfall. This coefficient gets information about the frequency of the extreme events. The results of table 10 show extreme rainfall variability has a negative impact of food supply (column 3). The impact of extreme rainfall variability is largely higher than the impact of normal rainfall variability on food supply. Table 10: Analysis of asymmetric and extreme rainfall variability effectsDependent VariableFood Supply

(1)(2)(3)Rainfall variability-0. 365***

(-7. 485)Positive rainfall variability0. 21***(4. 890)Negative rainfall variability-0. 398***(-6. 711)Extreme rainfall variability-12. 36**(-2. 388)Rainfall0. 031-0. 319-0. 00678(0. 36)(-0. 407)(-0. 393)Income per capita0. 0159***0. 0157***-0. 00287(4. 935)(4. 864)(-0. 785)Population growth-2. 453-2. 5494. 252(-0. 831)(-0. 863)(1. 566)Democratic institutions-0. 646-0. 678-0. 0568(-0. 639)(-0. 670)(-0. 0606)Intercept762. 7***746. 8***437. 9***

(13. 20)(12. 45)(17. 46)Observations626626461R-squared0. 2850. 2860. 179Number of countries717171Note: t-statistics are presented in parentheses under the estimated coefficients. ***, ** and * indicate significance of the estimatedcoefficient 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 climate variability and food security. The main objective of paper is to analyze the effects of climate variability on food security using data panel over the period 1960-2008 for 77 developing countries. The results of our estimates are as follows: first, we show that climate variability has a negative effect on food security whatever food security indicator used (food supply and proportion of undernourished people). We also find that the adverse effect of climate variability on food security is higher for African Sub Saharan countries than for other developing countries. Second, the negative effect of climate variability on food security is exacerbated in countries in conflict. Third, the effects are high for countries that vulnerable to food prices shocks. Our results are important in terms of recommendations of 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 could increase 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 aid automatic mechanisms which will be related to magnitude of effects of climate variability on food security. For example, the international community may finance stabilization mechanisms (government budget or development projects for the regions adversely affected by climate variability) with aid (named " climatic aid"). When the effect of climate variability 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 variability 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.