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CLIMATE VARIABILITY AND FOOD CRISES IN BURKINA FASO: A COMPUTABLE GENERAL EQUILIBRIUM ANALYSIS

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Abstract

This paper is an attempt to assess the impact of climate change on households' food security in Burkina Faso using a computable general equilibrium (CGE) model in which we incorporate a random parameter that captures the effect of climate fluctuations on crop yields and on international food prices. The CGE model has been calibrated to reproduce past trends of Burkina Faso's economy. The results of our simulations show that the impact of increased climatic shocks, due to climate change is felt more by rural poor who highly depend on agriculture. However, given the strong relationship between agriculture and the rest of the economy, low income households in urban areas are also affected. Conversely, the impact of climatic shocks is not as significant for urban non-poor given the level and source of revenue as well as the diversification of their consumption. The results also illustrate the complexity of the mechanisms at work in the explanation of a food crisis occurrence.
Keywords: *Climate change, food security, computable general equilibrium*
JEL Codes: C68 , Q18

1. Introduction

Climate change has gained significant attention over the past few decades due to its detrimental effect on food security (Srivastava, Gaiser, Paeth, & Ewert, 2012). In most developing countries, the agricultural sector represents the main source of livelihood for a large part of the population and significantly contributes to national gross domestic product (GDP). Consequently, the decline in agricultural production induced by climate change might seriously weaken food security and worsen the living conditions of both rural and urban populations.

Numerous crops model simulations show that there is much uncertainty around the impact of climate change on agricultural yields. Predictions range from a large drop in crops (Schlenker & Lobell, 2010) to a slight decline (Nelson, 2009) and even a more or less significant increase (Butt, McCarl, Angerer, Dyke, & Stuth, 2005). A study by Parry, Rosenzweig, Iglesias, Fischer, and Livermore (1999) shows that climate change has no significant impact on global food production. The National Academy of Sciences even finds that yields of corn, soybeans, and cotton increase with high temperature up respectively to 29° C, 30° C, and 32° C (Schlenker & Roberts, 2009).

Most studies concerned with economy wide effects of climate change formulate climate change as agricultural productivity shocks. The physical shocks are first calibrated to be consistent with climate change scenarios and then transformed into shocks to parameters of the agricultural-industry production functions in the CGE models. In many cases, the shocks are applied to Total Factor Productivity (TFP) in agriculture. This idea was emitted in the work of Reid, Sahl, n, Stage, and MacGregor (2008), Thurlow, Zhu, and Diao (2008), Zhai, Lin, and Byambadorj (2009), Bezabih, Chambwera, and Stage (2011) and Arndt, Asante, and Thurlow (2015).

Climate change modeling also takes other forms in the literature, including energy-demand effect, human health effect, and tourism effect. For energy-demand effect (see for example Bosello, Roson, & Tol, 2007; D. W. Jorgenson et al., 2004), shocks are imposed to theCGE model based on econometric estimates of the elasticitiesof demand for various forms of energy with respect to temperature. These econometric estimates translate climate change into changes in the demand for energy. The demand shocks are then mapped to shifts parameters of the household demand or production function equations of the CGE model. Human health effect is reported in Bosello, Roson, and Tol (2006). In this kind of modeling, climate change is supposed to have impact through mortality and morbidity due to disease. Results of these studiesare used tomap climate-change scenario into mortality/morbidity scenarios formulated at the level of regional disaggregation of the CGE model. The implications of these scenarios for labour supply are applied as shocks to household demand parameters and to the structure of public consumption to represent the effect on private and public demand for health services that are implied by the changes in morbidity. Finally, climate change is sometimes assumed to impact the economy through its impact on tourism. Hamilton (2004) provides an example. Econometric estimate of the effects of climate change on bilateral tourist flows are used to formulate region-specific shocks on the structure of household spending and on consumers' income. An increase/decrease in tourism increases/decreases the share of household spending allocated to tourism services and effects income available for consumption spending in that region.

Notwithstanding the uncertainty around the impact of climate change on crops, a great number of studies rely on crop models' projections to assess the economy-wide effects of climate change (see for example: Arndt et al., 2015; GüPnther Fischer, Frohberg, Parry, & Rosenzweig, 1995; Günther Fischer, Shah, N. Tubiello, & van Velhuizen, 2005; Parry et al., 1999). However, there is now a growing consensus that climate change tends to cause increased variability in rainfall leading to frequent, more intense, and less predictable weather swings (FAO, 2008; Schar et al., 2004; Wheeler, Craufurd, Ellis, Porter, & Vara Prasad, 2000). Many crops in sub-saharan Africa have annual cycles and their yields fluctuate with climate variables, including precipitation and temperature. Precipitations determine the availability of freshwater and the soil moisture levels. Temperature and soil moisture in turn define the lenght of the arable season and control the crops' growth. Weather variability, especially changes in rainfall patterns, is a critical factor for rainfed agriculture (Dinar & Mendelsohn, 2011).

Moreover, world food markets may present greater price volatility because of a greater unpredictability in world agricultural production. Indeed, price volatility is mainly driven by unpredictable weather conditions (OECD-FAO, 2011). This situation might jeopardize farmers' earnings and the access to food for both rural and urban consumers.

This paper addresses the impact of climate change on food security in Burkina Faso. We use a dynamic computable general equilibrium (CGE) model to analyze the effects of a greater volatility of crops and world food prices. Compared to other models (econometric and statistical methods such as Vector Error Correction Model (VECM), Structural Equation Modelling) the CGE models are more suited for food security analysis as They have the particularity of taking into account, in more detail way, all the components of an economy, following the theory of general equilibrium. Thus, their development relies on the construction of comprehensive and coherent database, the Social Accounting Matrices (MCS). These models simulate the functioning of goods and factor markets and capture the interactions between production and employment structures, incomes of production factors, income distribution between households, and demand structure. All these interactions are essential in analyzing food security that is a multidimensional concept. Moreover, CGE models, which are essentially neoclassical in inspiration, have evolved and incorporate a number of characteristics that enable them to come closer to reality, for example: (i) labor market imbalances due to rigid wages of some categories of workers, (ii) the rigidity of some prices; and (iii) the immobility of capital between productive sectors in the short term (Zidouemba & Gérard, 2015).

After describing the CGE model used for our analysis (section 2), we attempt to empirically validate the CGE model for Burkina Faso, i.e., we check to what extent the model is able to reproduce changes in some relevant variables including the GDP growth, the sectoral GDPs growth, and agricultural productions (section 3). Finally, we present and discuss our simulations and results (section 4) before concluding (section 5).

2. The CGE Model

2.1. General Characteristics of the Model[1]

It is a classical CGE model: (i) consumer maximizes utility subject to an income constraint; (ii) producer maximizes profit subject to a technical constraint defined by production function, (iii) consumers hold fixed factors (Capital, Land and Labor), so that the remuneration of these factors form their income, (iv) the quantities of supplied goods are equal to the quantities requested; (v) the market equilibrium is instantaneous and determines the quantities produced and consumed, imports and exports for various goods as well as prices of goods and services and remuneration of production factors; (vi) government's budget balances expenditure (government consumption and transfers) with revenues from various taxes as well as transfers from the rest of world (Official Development Aid); (vii) imperfect substitution between goods produced in different countries (Armington) has been retained.

An exogenous price for salaried workers allows to account for wage rigidities and the existence of unemployment. Initial unemployment is set at 18% for non-agricultural salaried labor and at 1.1% for agricultural salaried labor. These rates correspond to the 2005 urban and rural unemployment rates, respectively (INSD, 2008). This may have important consequences for the results, as any increase in activity will result in an increase in the volume of employment rather than an increase in labor payments (as this would have been the case under a full employment assumption). Commodity prices are assumed to balance commodity markets.

We explicitly model the difficulty for workers to move from one activity to another, with a view to reproducing jobs opportunities scarcity outside the agricultural sector as well as the required skills and the time needed for training (Françoise Gérard, Dury, Bélières, Keita, & Benoit-Cattin, 2012). We define four aggregate sectors: agriculture, agro-industries, other industries, and services. Labor is then assumed to be perfectly mobile within the 10 years

[1] A detailed description of the model can be found in Zidouemba (2014)

simulation horizon only among sectors belonging to the same aggregate sector (e.g. agricultural labor can move from the rice sector to corn sector but not to the education sector). This implies differentiating labor wages between aggregate sectors. Capital is assumed to be sector-specific.

Government savings and all tax rates are fixed, while government consumption is flexible, to balance government accounts. The nominal exchange rate is set at its initial level, which reflects the peg between the CFA franc and the Euro. Both foreign savings and the real exchange rate thus clear the external balance (as the consumer price index is flexible). Regarding the savings-investment balance, the closure is savings-driven (or a neoclassical closure), wherein investment is determined by the sum of private, government and foreign savings.

In the recursive loop, investments in each industry determine the supply of capital available per sector for the next period. An original rule of sectoral allocation of investment has been retained. Indeed, the share of each sector in total investment is set so that the trends of sectoral productions obtained with model fit with trends observed in reality. This allows demonstrating the ability of CGE models to reproduce some major stylized facts. It is assumed that existing capital depreciates from one year to another at a rate determined exogenously. Demand for capital goods by sector is determined as a fixed share of total investment.

Population growth is exogenously imposed on the model based on separately computed growth projections (3.1% per year). It is assumed that a growing population generates a higher level of consumption demand and therefore raises the supernumerary income level of household consumption. It is assumed to be no change in the marginal rate of consumption for commodities, implying that new consumers have the same preferences as existing consumers.

2.2. Agricultural Yields and World Food Prices Volatility

It is assumed that producers decide, at the beginning of the season, on the volume of crop production to produce based on prices of inputs and factors of production according to classical profit maximization. They do not include the parameter of climatic vagary because it is not known until the time of harvest.

$$XDP_{it} = \chi_i(\eta_i CI_{it}^{-\phi_i} + (1-\eta_i)VA_{it}^{-\phi_i})^{\frac{-1}{\phi_i}} \quad (1)$$

Where XDP_{it} is planned production by sector i at time t, CI_{it} the aggregated intermediate consumption, VA_{it}, the value added and χ_i, η_i and ϕ_i exogenous parameters. The parameters of the functional forms (elasticities) are taken from the literature and not estimated by an econometric model. They are presented in table A in appendix.

However, the finale production observed at time of harvest may be significantly different from the planned production due to climate vagaries.

$$XDO_{it} = XDP_{it} * randprod_{it} \quad (2)$$

with $randprod_{it} \sim$ Uniform(0.8, 1.2)

A random parameter $randprod$ is applied to planned production to take into account possibilities of production greater or lesser than that planned, i.e. 80% or 120% of planned production. It is the real or observed production which enters in the market chain and thus determines domestic food prices.

Equation (3) presents the international prices in local currency PM_{ct} as the international prices in foreign currency augmented by imports taxes and multiplied by nominal exchange rate and a random coefficient $randprice$.

$$PM_{ct} = PWM_c * (1 + tm_c) * EXR_{ct} * randprice_{ct} \quad (3)$$
with $randprice_{ct} \sim$ Uniform(0.8, 1.2)

As in the case of domestic production, world food prices are subject to stochastic variations due to the volatility of production in other regions of the world. This allows measuring, not only, the direct impact of climate change related to domestic production volatility, but also the indirect impact associated with word production volatility.

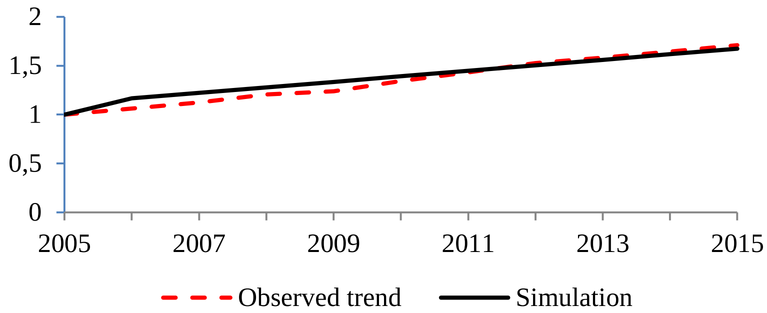
3. The CGE Model Empirical Validation

CGE modeling validation attempts have generally taken two forms (Dixon & Rimmer, 2013) (Dixon & Rimmer, 2013): i) an econometric estimation of the behavioral parameters of the model, in particular the elasticities of the functional forms retained (Armington and CET) (Arndt, Robinson, & Tarp, 2002; D. Jorgenson, 1984); and (ii) A comparison of the results provided by the model with the actual observed data (Cook, 1980; Johansen, 1960; Taylor, Bacha, Cardoso, & Lysy, 1980; Zidouemba, 2014). It seems that since the 1980s, very few CGE modelers have tried to validate the results of their models with real statistics (Dixon & Rimmer, 2013) probably because of the difficulty of the task in the presence of a multitude Shocks that affect the economy (Kehoe, 2005). Indeed, in the presence of numerous exogenous shocks, the model becomes unverifiable because one can always attribute a deviation to a drought, a flood or any natural disaster (F. Gérard, 2010).

However, Borges (1986) considers that the weakness of CGE model lies in the difficulty to assess how well the model fits the data and traces the historical trend. This view is especially true for static CGE model which does not describe a period of time. According to Schubert (1993), this problem is less acute in the case of dynamic CGE, as it is possible to compare the results provided by the model over several periods and series actually observed. Thus, a calibration effort has been made to ensure that the model reproduces the major trends occurred since the year of construction of the social accounting matrix (Year 2005).

This section presents a series of graphs (figures 1 to 8) allowing to see different trends of relevant variables from the simulation of the CGE model compared to really observed trends between 2005 and 2015. Since we are interested in the trends we didn't consider the stochastic parameter that applies neither to agricultural production, nor to international prices. These graphs show that our CGE model is able to reproduce the past evolution of Burkina Faso's economy.

Between 2005 and 2015, annual growth of the GDP has been 5.52%. Agriculture has experienced an average annual growth of 3.03% against 7.01% for industry and 5.51% for the service sector. Grain production experienced very different growth rates. Rice production has increased significantly with an average annual growth rate of 16.53%, a 4-fold increase over ten years. Corn production has also experienced a significant growth. Indeed, its average annual growth rate stood at 9.13%. Unfortunately, the main grain production in the country (traditional grains made of millet,sorghum and fonio) has not grown appreciably as its average annual growth rate was only 1.94%. This partly explains why the agricultural GDP growth has been much lower than the non-agricultural sectors. The growth of gross national income per capita has been also moderate and was 2.2% per year.



Source: Simulation & Word Development Indicators
Figure 1. Simulated and Observed GDP

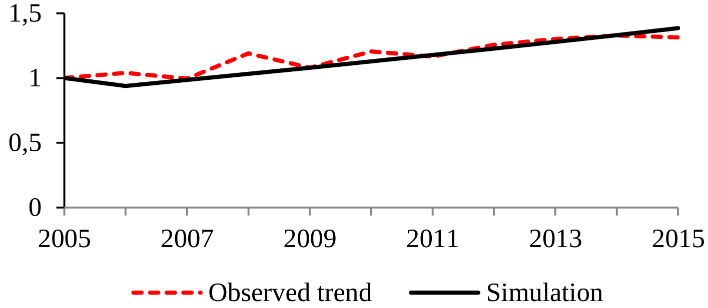


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Figure 2. Simulated and Observed Agricultural GDP

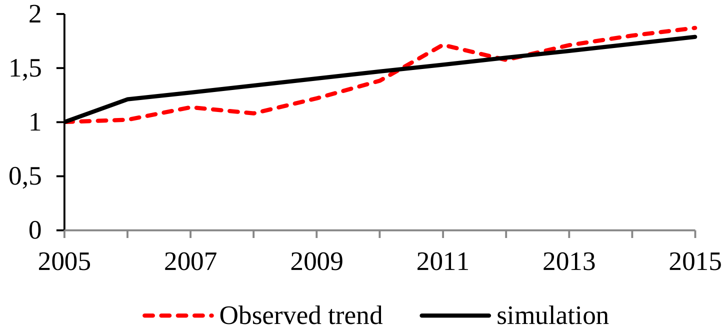

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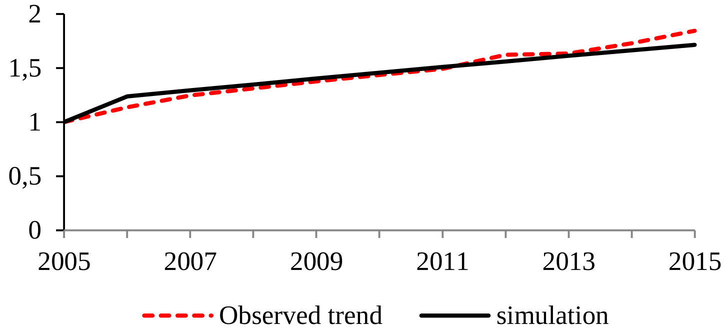
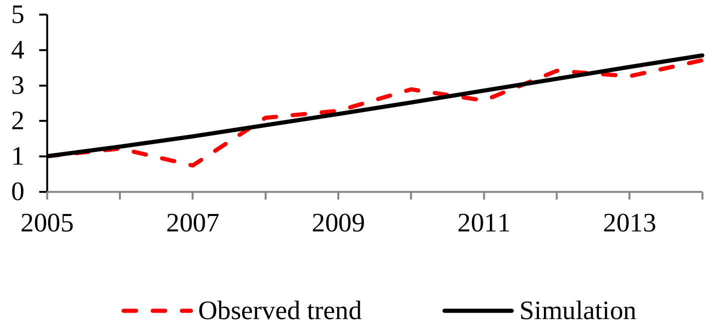
Figure 3. Simulated and Observed industrial GDP

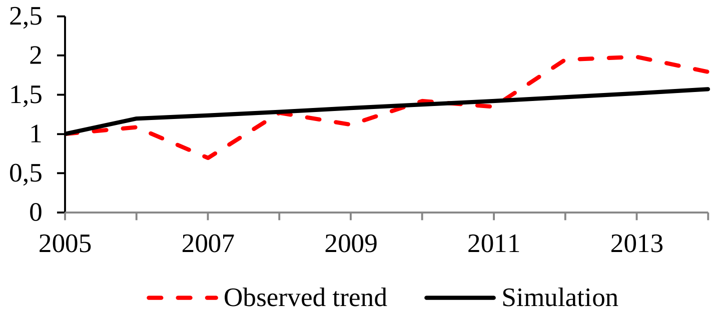


Source: Simulation & Word Development Indicators
Figure 4. Simulated and Observed services GDP



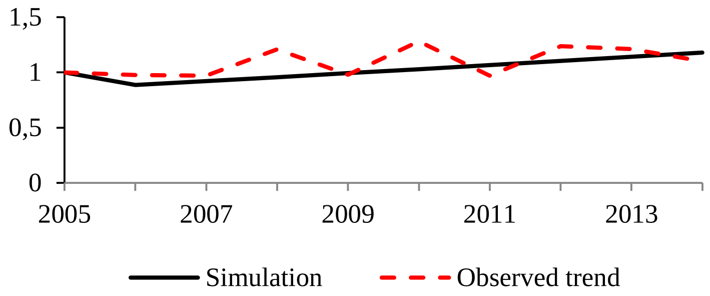
Source: simulation & FAOSTAT

Figure 5. Simulated and Observed Rice Production



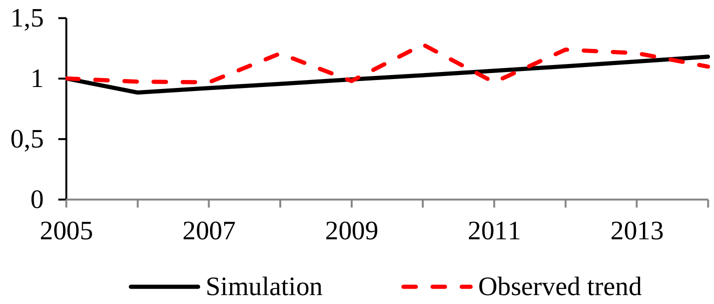
Source: simulation & FAOSTAT

Figure 6. Simulated and Observed Corn Production



Source: simulation & FAOSTAT

Figure 7. Simulated and Observed other Grains Production



Source: simulation & Word Development Indicators

Figure 8. Simulated and Observed Income Per Capita

4. Simulations and Results

In the baseline scenario, agricultural yields and world prices for agricultural commodities are assumed to vary within a range of ± 20%. This means that from one season to another, one can observe a decrease or an increase of 20% in the national agricultural production and/or in world agricultural prices. As we pointed out in section 3.2, these stochastic trends are technically caused by a random parameter that we have assumed to follow a uniform distribution of probability. The values of this parameter are between 0.8 and 1.2 in the baseline scenario.

Three alternative scenarios are then simulated. The first assumes an increase in the volatility of world food prices. Instead of baseline fluctuation between 0.8 and 1.2, we consider a fluctuation ranging from 0.5 to 1.5. The random parameter is thus assumed to follow a uniform law of probability (min=0.5, max=1.5). The second scenario is similar to the first except that the random parameter now applies to domestic agricultural yields. This means that the supply of agricultural products and world food prices may decrease or increase by 50% from one season to another. The third scenario combines the previous two, involving more volatile yields and world food prices.

The food security analysis is based on changes in the grain consumption (corn, rice, millet, sorghum, fonio, etc.). Our option to retain only the grains is justified by the fact that they are by far the main source of energy (70% of energy intake) for the population (Permanent Interstate Committee for Drought Control in the Sahel, 2004). The percentage of food consumption deviations from the baseline scenario are computed for all groups of households. We then consider that a food crisis occurs when food intake of at least one household group decreases by 10% or more compared to the baseline. This food crisis is moderate if the drop is between 10% and 15%, severe when the drop is between 15% and 20%, and extremely severe in case of a drop of 20% or more. In this context, the more unstable yields and international prices are, the greater the likelihood of a food crisis.

We performed some simulations over 20 years and computed the number and severity of food crises that emerge during the same period. Table 1 and table 2 present the number and severity of food crises and the number of food crises by household group respectively. The results suggest that climate change increases the number and severity of food crises. In the baseline scenario, we identified three food crises of which only one was severe over the period of 20 years. These crises mainly affected rural poor populations. The poor in urban areas only experienced one food crisis. In scenario 1, there were four food crises of which one was considered severe. Contrary to the baseline, the food crises affected other groups of households in a direr way, in particular the urban poor and rural non-poor. The urban poor are affected by two of the four food crises, against one for non-rural poor. Urban non-poor meanwhile are unaffected by any of the four food crises. Scenario 2 shows six food crises including two severe and one extremely severe. Two crises affected both urban poor and rural non-poor. The Scenario 3 which is a combination of the two previous scenarios shows eight food crises over the 20 years of which four are assumed to be severe and one is extremely severe. The most affected households by climate change are poor both in rural and urban areas and, to a lesser extent, rural non-poor. The urban non-poor in contrast have more resilient consumption.

Table 1. Number and **Severity of Food Crises**

Scenarios	Number of food crisis (10% and more)	Including severe crisis (between 15% and 20%)	Including extremely severe crisis (more than 20%)
S0 (Business as usual)	3	1	0
S1 (world food prices volatility)	4	1	0
S2 (crops yields instability)	6	2	1
S3 (S1+S2)	8	4	1

Source: Simulation

Several transmission channels can be explored in order to understand how climate change affects households' food consumption. The direct effects are distinguished from indirect effects. The most direct channels through which climate change affects households' food security are domestic and world food production as well as domestic and world food prices. The occurrence of a climatic shock (drought or flood) leads to a decline in domestic and/or global production which causes higher food prices both on domestic and international markets. The effect on a given household group depends on the structure of its consumption and revenue. The severity of a food crisis depends on the magnitude of the climatic shocks.

Table 2 Number of Food Crisis by Households Group

Households	S0	S1	S2	S3
Poor rural	3	4	6	7
Poor urban	1	2	2	4
Non poor rural	0	1	2	4
Non poor urban	0	0	0	0

Source: Simulation

The indirect effect occurs through agricultural value-added. Climatic shocks imply a fall in overall agricultural output, causing a decline in the remuneration of the factors of production employed in agriculture and owned by households (agricultural labor and capital). Given that the agricultural sector is connected to the rest of the economy, these climatic shocks also affect non-agricultural sectors depending on the degree of their connection with the agricultural sector. Consequently, the distribution of factors' income in the rest of the economy may be modified following a climatic shock. For the sake of clarity, we will illustrate the transmission channels by which climate change may affect households' food consumption exclusively with the results of the third scenario (S1 + S2). Of course the same logic applies to other scenarios.

Rainfall fluctuations induce a production decline for agricultural sectors exposed to the rainfall vagaries during years of drought or flood, and an increase in production during years of good rainfall. The simulation of the CGE model shows eight food crises (2012, 2013, 2016, 2020, 2022, 2023, 2024, and 2025). Figure 9 shows that the 2012 and 2013 food crises do not seem to be caused by a decline in domestic production. Indeed, while the productions of corn, rice and other grains are in an ascent phase, there are two consecutive severe crises which affect rural poor in particular. As illustrated in Figure 10, these crises are caused by a sharp rise in domestic prices for corn and other grains. The price of corn increased by 48% in 2012 from its 2011 level, and by 8% in 2013 compared to its 2012 level. For rice, these changes have been +8% and +32% respectively.

One might ask why such increases in domestic prices for corn and other grains while the corresponding domestic productions are increasing. The reason lies in the evolution of world food prices (figure 11). 2012 and 2013 are indeed characterized by an average increase of 30% and 34% of world prices for corn and other grains respectively as the result of the effect of climatic shocks on the world food market. There is therefore a transmission of global food prices onto domestic market. The growth of real income (Figure 12) due to the increase in the production and domestic prices does not seem robust enough to prevent these food crises. While domestic prices increased by over 30%, real incomes rose by only 4% and 3% for the rural poor and the urban poor respectively.

The 2016 crisis which is a moderate one is the result of increased domestic and international prices of maize and other grains; a rise that began in 2014 where prices were relatively low after the crises of 2012 and 2013.

The forecasted 2020 crisis is attributable to an excessive rise in domestic prices of corn and other grains (+ 122% and 52% respectively) and corresponding international prices (+ 26% and + 39% respectively). Urban poor are impacted by this crisis in spite of higher revenues (+ 11%) because of the sharp rise of corn price.

The most drastic decline of domestic grains production observed in 2022 (the productions of corn and other grains dropped respectively by 48% and 40% compared to their level of the previous year) resulted in a most severe food crisis. The rural poor who largely consume other grains (millet, sorghum, and fonio) experienced a consumption decline of 23%. This decline is about 13% for the urban poor and 12% for the rural non-poor.

The rise of production for other grains in 2023 allows the rural poor and rural non-poor to regain a normal consumption (i.e. a decrease of less than 10% in grains consumption) while urban poor still experience a 11% decrease in consumption. This is the result of both higher domestic corn price (+ 22%) and a decline in urban poor’s income (-3.4%).

The new fall in production of other grain in 2024 causes a new food crisis among the rural poor (-12%), while the positive shock on production of 2025 did not improve their situation because of a decline of their income.

The simulations also show the existence of abundant years characterized by an increase in food consumption, often by more than 30%. It’s the case of 2008, 2017, 2019, and 2021. The abundance results both from rises in production, sharp decline in domestic and international prices and/or increases in real household income. Plentiful years of 2008 and 2021 also demonstrate that a decline in income can take place without a food crisis. If the price decline is stronger than the decline in income, there may be an important increase in consumption. Meanwhile, years of income rises may be those of food crisis if there is a significant increase in food prices (year 2024 for example).

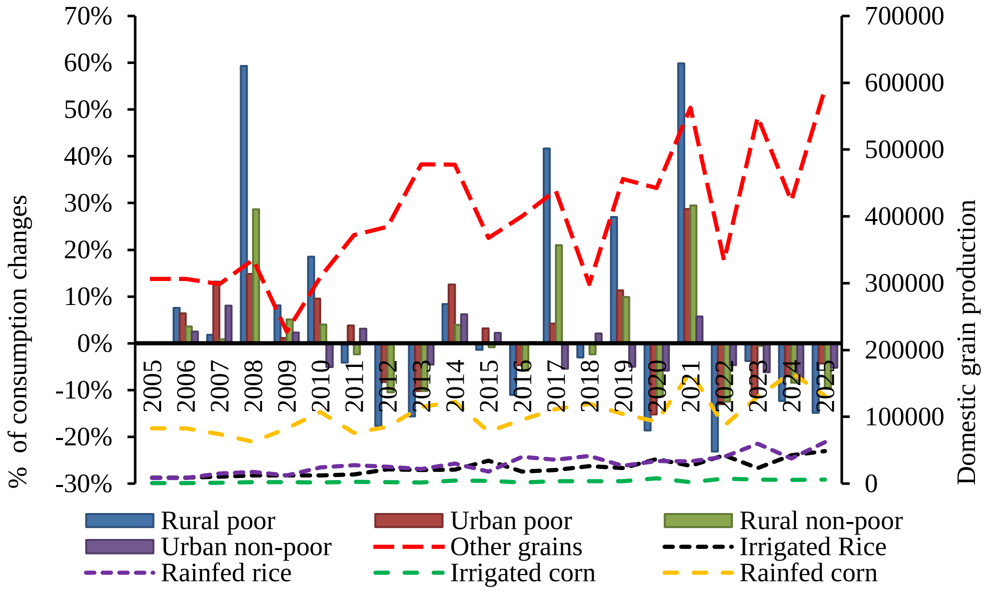
The analysis of food crises allows us to identify the rural poor populations as those who are the most vulnerable to climatic shocks. Three factors explain the degree of household vulnerability to climate change: the level of income, the sources of such income, and the degree of diversification of food consumption. Households with low income levels, which gain most of their income from agriculture, and have undiversified food consumption are the most exposed to climate change. The lack of food diversification worsens the problem because the rising price of a specific grain is not easily compensated by the substitution of other grains as food habits change very slowly over time. For farmers depending primarily on agriculture for both consumption and as sources of income, yields and prices volatility can lead to large fluctuations in income and consumption. In the absence of crop insurance as it is the case in most developing countries and because of the weakness of their savings, this category of the population is highly exposed to climate hazards.

Table 3. Structure of Income and Grains' Consumption

Households	Income Per Capita	Maize Consumption	Rice Consumption	Other Grain Consumption	Income From Agriculture	Non-Agricultural Incomes
Rural poor	63054	25 (18%)	8 (6%)	104 (76%)	72%	28%
Urban poor	72283	55 (45%)	18 (15%)	49 (40%)	32%	68%
Rural non-poor	202514	52 (20%)	26 (10%)	191 (71%)	53%	47%
Urban non-poor	378756	107 (40%)	83 (31%)	77 (29%)	07%	93%

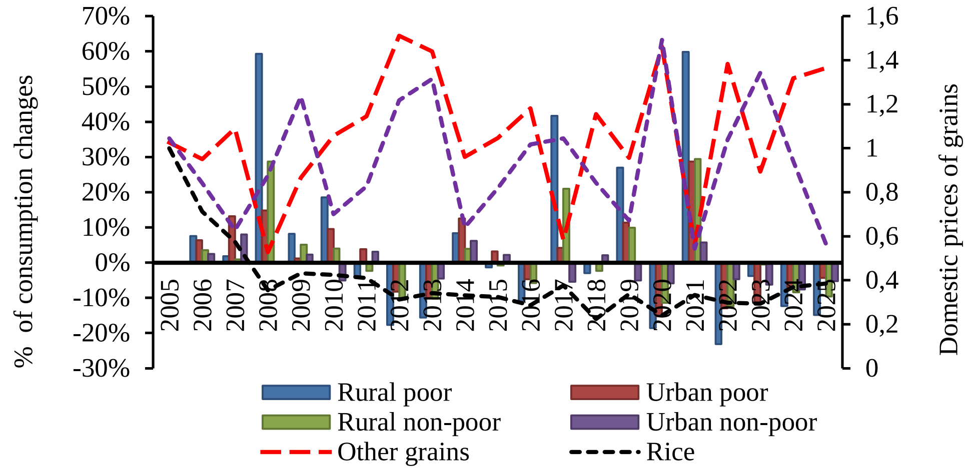
Source: Computed from SAM (2005)

In contrast, households with large income - which derives greatly these income from non-agricultural activities, and have much diversified food consumption, are less exposed to the food crises. As illustrated in the table 3, the rural poor's income is very low (25% below poverty line), over 75% of their consumption of grains consists essentially of traditional grains (millet, sorghum, and fonio), and their revenue essentially comes from agricultural activities (72%). The urban non-poor households in contrast, have higher income (more than 4 times above poverty line). They derive their income primarily from non-agricultural activities (93%) and have more diversified grains consumption.



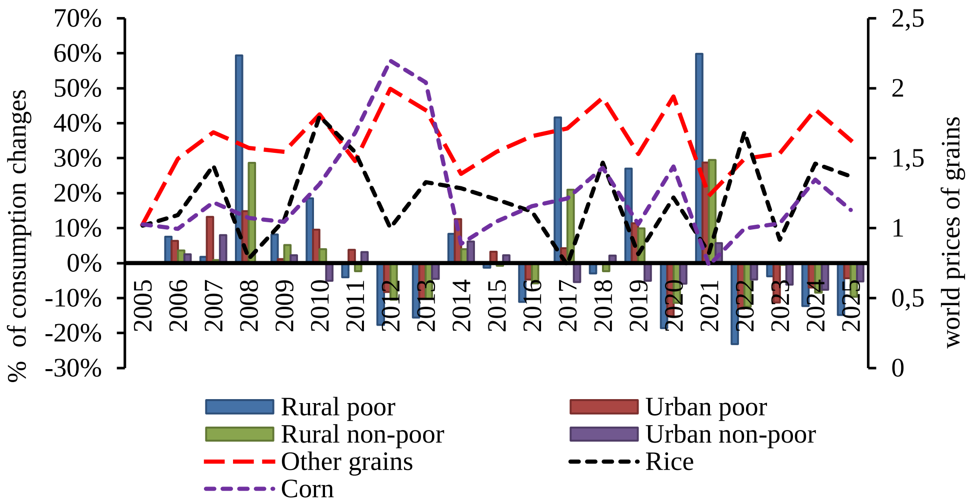
Source: Simulation

Figure 9 Percentage Deviations of Grain Consumptiona Grains Domestic Production



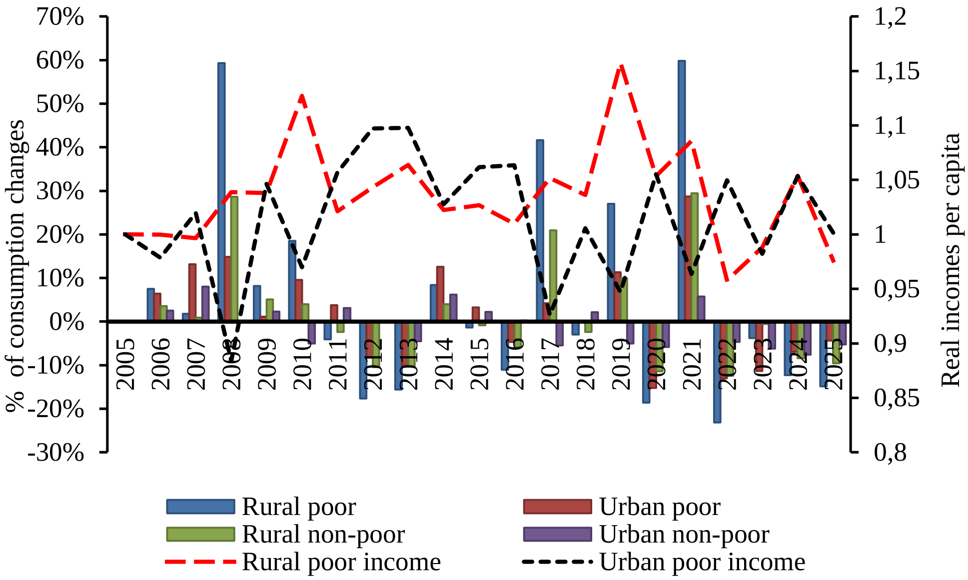
Source: Simulation

Figure 10. Percentage Deviationso Grain Consumption and Grains Domestic Prices



Source: Simulation

Figure 11. Percentage Deviations of Grain Consumption and Grains World Prices



Source: Simulation

Figure 12. Percentage Deviations of Grain Consumption and Poor Households' Income

5. Conclusion and Final Remarks

This study concludes that the impact of climate change on food security for poor households in Burkina Faso is significant: climate change is likely to increase the frequency and severity of food crisis. It points out the complexity of the mechanisms at work to explain food crises, which is only possible in a general equilibrium framework. Several factors, including domestic production, domestic and international prices, and income are combined to determine a state of food crisis or abundance. It also underlines the role of income level as well as the structure of consumption and revenue in households' vulnerability to climate change. Low income, high dependency on agriculture, and lack of diversification in food consumption increase household vulnerability to climate change. Poverty limits the ability of households to save and invest, what keeps them in a poverty trap and makes them highly vulnerable to climate change. However, a major limitation of this study is that it does not take into account the household coping capacity by modeling storage habits that could allow consumption smoothing. Public policy should assist the poorest households, especially rural ones, to increase and diversify their revenue through public investment in natural, physical, human, and financial capital.

References

Arndt, C., Asante, F., & Thurlow, J. (2015). Implications of climate change for Ghana's economy. Sustainability, 7(6), 7214-7231.

Arndt, C., Robinson, S., & Tarp, F. (2002). Parameter estimation for a computable general equilibrium model: a maximum entropy approach. Economic Modelling, 19(3), 375-398. doi: http://dx.doi.org/10.1016/S0264-9993(01)00068-2

Bezabih, M., Chambwera, M., & Stage, J. (2011). Climate change and total factor productivity in the Tanzanian economy. Climate Policy, 11(6), 1289-1302. doi: 10.1080/14693062.2011.579300

Borges, A. M. (1986). Applied general equilibrium models: an assessment of their usefulness for policy analysis: OECD.

Bosello, F., Roson, R., & Tol, R. S. (2006). Economy-wide estimates of the implications of climate change: Human health. Ecological Economics, 58(3), 579-591.

Bosello, F., Roson, R., & Tol, R. S. (2007). Economy-wide estimates of the implications of climate change: Sea level rise. Environmental and Resource Economics, 37(3), 549-571.

Breisinger, C., Diao, X., & Thurlow, J. (2009). Modeling growth options and structural change to reach middle income country status: The case of Ghana. Economic Modelling, 26(2), 514-525. doi: http://dx.doi.org/10.1016/j.econmod.2008.10.007

Butt, T. A., McCarl, B. A., Angerer, J., Dyke, P. T., & Stuth, J. W. (2005). The economic and food security implications of climate change in mali. Climatic Change, 68(3), 355-378. doi: 10.1007/s10584-005-6014-0

Cook, L. H. (1980). Validation of a Johansen-type multisectoral model : Norway, 1949-1961. PhD Thesis, Monash University, Clayton.

Dinar, A., & Mendelsohn, R. (2011). Handbook on climate change and agriculture. Cheltenham: Edward Elgar.

Dixon, P. B., & Rimmer, M. T. (2013). Chapter 19 - Validation in Computable General Equilibrium Modeling. In B. D. Peter & W. J. Dale (Eds.), Handbook of Computable General Equilibrium Modeling (Vol. Volume 1, pp. 1271-1330): Elsevier.

FAO. (2008). Climate change and food security: a framework document. Rome: Food and Agriculture Organization of the United Nations.

Fischer, G., Frohberg, K., Parry, M. L., & Rosenzweig, C. (1995). Climate Change and World Food Supply, Demand, and Trade (Vol. asaspecialpubli).

Fischer, G., Shah, M., N. Tubiello, F., & van Velhuizen, H. (2005). Socio-economic and climate change impacts on agriculture: an integrated assessment, 1990–2080. Philosophical Transactions of the Royal Society B: Biological Sciences, 360(1463), 2067-2083. doi: 10.1098/rstb.2005.1744

Gérard, F. (2010). Dynamique de l'offre, incertitude et régulation des marchés agricoles Mémoire pour l’Habilitation à diriger des recherches en Sciences économiques (pp. 71): Paris I, Université Panthéon-Sorbonne.

Gérard, F., Dury, S., Bélières, J.-F., Keita, M. S., & Benoit-Cattin, M. (2012). Comparaison de plusieurs scénarios de lutte contre l’insécurité alimentaire au Mali. Cahiers Agricultures, 21(5), 356-365.

Hamilton, J. M. (2004). Climate and the destination choice of German tourists FEEM Working Paper No. 21.2004 Centre for Marine and Climate Research, Hamburg University

Institut National de la Statistique et de la Démographie (INSD). (2008). Tableau de bord social du Burkina Faso (pp. 1-74). Ouagadougou: Institut National de la Statistique et de la Démographie.

Johansen, L. (1960). A Multi-Sectoral Study of Economic Growth. Amsterdam.: North-Holland Publishing Co.

Jorgenson, D. (1984). Econometric Methods for Applied General Equilibrium Analysis. In H. Scarf & J. Shoven (Eds.), Applied General Equilibrium Analysis (pp. 139-203). Cambridge: Cambridge University Press.

Jorgenson, D. W., Goettle, R. J., Hurd, B. H., Smith, J. B., Chestnut, L., & Mills, D. (2004). US market consequences of global climate change. Pew Center on Global Climate Change, Washington, DC.

Kehoe, T. J. (2005). An Evaluation of the Performance of Applied General Equilibrium Models on the Impact of NAFTA. In T. J. Kehoe, T. N. Srinivasan & J. Whalley (Eds.), Frontiers in Applied General Equilibrium Modeling: Essays in Honor of Herbert Scarf (pp. 341- 377). Cambridge: Cambridge University Press.

Ministère de l'Agriculture et de la Sécurité Alimentaire (MASA). (2010). Etude sur la dynamique de la consomation alimentaire au Burkina Faso. Ouagadougou.

Nelson, G. C. (2009). Climate change : impact on agriculture and costs of adaptation Food Policy Report;21. Washington: IFPRI.

OECD-FAO. (2011). OECD-FAO agricultural outlook 2011-2020. Paris: OECD Publishing and FAO.

Parry, M., Rosenzweig, C., Iglesias, A., Fischer, G., & Livermore, M. (1999). Climate change and world food security: a new assessment. Global Environmental Change, 9, Supplement 1(0), S51-S67. doi: http://dx.doi.org/10.1016/S0959-3780(99)00018-7

Permanent Interstate Committee for Drought Control in the Sahel. (2004). Normes de consommation des principaux produits alimentaires dans les pays du CILSS (pp. 1-67). Ouagadougou: CILLS/AGRHYMET et INSAH.

Reid, H., Sahl, n, L., Stage, J., & MacGregor, J. (2008). Climate change impacts on Namibias natural resources and economy. Climate Policy, 8(5), 452-466. doi: 10.3763/cpol.2008.0521

Schar, C., Vidale, P. L., Luthi, D., Frei, C., Haberli, C., Liniger, M. A., & Appenzeller, C. (2004). The role of increasing temperature variability in European summer heatwaves. [10.1038/nature02300]. Nature, 427(6972), 332-336.

Schlenker, W., & Lobell, D. B. (2010). Robust negative impacts of climate change on African agriculture. Environmental Research Letters, 5(1), 014010.

Schlenker, W., & Roberts, M. J. (2009). Nonlinear temperature effects indicate severe damages to U.S. crop yields under climate change. Proceedings of the National Academy of Sciences, 106(37), 15594-15598. doi: 10.1073/pnas.0906865106

Schubert, K. (1993). Les modèles d'équilibre général calculable : une revue de la littérature. Revue d'économie politique, 103(6), 775-825.

Srivastava, A. K., Gaiser, T., Paeth, H., & Ewert, F. (2012). The impact of climate change on Yam (Dioscorea alata) yield in the savanna zone of West Africa. Agriculture, Ecosystems & Environment, 153(0), 57-64. doi: http://dx.doi.org/10.1016/j.agee.2012.03.004

Taylor, L., Bacha, E. L., Cardoso, E. A., & Lysy, F. J. (1980). Models of growth and distribution for Brazil A World Bank research publication. New York: World Bank.

Thurlow, J., Zhu, T., & Diao, X. (2008). The impact of climate variability and change on economic growth and poverty in Zambia.

Wheeler, T. R., Craufurd, P. Q., Ellis, R. H., Porter, J. R., & Vara Prasad, P. V. (2000). Temperature variability and the yield of annual crops. Agriculture, Ecosystems & Environment, 82(1–3), 159-167. doi: http://dx.doi.org/10.1016/S0167-8809(00)00224-3

Zhai, F., Lin, T., & Byambadorj, E. (2009). A general equilibrium analysis of the impact of climate change on agriculture in the People's Republic of China. Asian Development Review, 26(1), 206-225.

Zidouemba, P. (2014). Sécurité alimentaire, productivité agricole et investissements publics au Burkina Faso : une analyse à l'aide d'un modèle d'Équilibre Général Calculable dynamique et stochastique. PhD, CIRAD - Montpellier SupAgro, UMR 1110 MOISA, Montpellier, France. Retrieved from http://prodinra.inra.fr/record/286982

Zidouemba, P., & Gérard, F. (2015). Investissement public et sécurité alimentaire au Burkina Faso : une analyse en Équilibre Général Calculable dynamique. Revue d'Etudes en Agriculture et Environnement, 96(03), 411-437. doi: doi:10.4074/S1966960715003021

APPENDIX

Table A. Income Elasticities		Income elasticities			Trade elasticities			Production
	Urban Poor	Urban Non-Poor	Rural Poor	Rural Non-Poor	Armington (o_i)	CET (φ_i)	CES (ϕ_i)	CES (μ_i)
Corn	0.91	0.33	0.91	0.33	17.5	12	0.3	0.75
Rice	1.35	0.77	1.35	0.77	5.25	3.6	0.3	0.75
Other Cereal	0.94	0.56	0.94	0.56	17.5	12	0.3	0.75
Vegetables	0.89	0.78	0.89	0.78	5.25	3.6	0.3	0.75
Groundnuts	0.92	0.82	0.92	0.82	17.5	12	0.3	0.75
Cotton					17.5	12	0.3	0.75
Fruit	0.44	0.39	0.44	0.39	5.25	3.6	0.3	0.75
Livestock	1.46	0.97	1.46	0.97	17.5	12	0.3	0.75
Other agr. products	0.92	1.24	0.92	1.24	5.25	3.6	0.3	0.75
Minerals	0.92	1.24	0.92	1.24	1.2	2	0.3	0.75
Meat_Fish	1.46	0.97	1.46	0.97	17.5	12	0.3	0.75
Textile	0.92	1.24	0.92	1.24	1.2	2	0.3	0.75
Fertilizer	0.92	1.24	0.92	1.24	1.2	2	0.3	0.75
Other industrial products	1.02	1.34	1.02	1.34	1.2	2	0.3	0.75
Restoration	1.05	0.63	1.05	0.63	0.5	0.5	0.3	0.75
Transport	0.92	1.24	0.92	1.24	0.5	0.5	0.3	0.75
Other market services	0.46	0.62	0.46	0.62	0.5	0.5	0.3	0.75
Education	0.92	1.24	0.92	1.24	0.5	0.5	0.3	0.75
Health	0.92	1.24	0.92	1.24	0.5	0.5	0.3	0.75
Other non-market services	0.46	0.62	0.46	0.62	0.5	0.5	0.3	0.75